Department of Transportation

Final Regulatory Impact Analysis

FMVSS 216, UPGRADE ROOF CRUSH RESISTANCE

Office of Regulatory Analysis and Evaluation

National Center for Statistics and Analysis

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EXECUTIVE SUMMARY

This Final Regulatory Impact Analysis examines the potential impacts of new performance requirements for passenger car and light truck roof strength. The intent of this rule is to improve occupant protection in rollover crashes that involve roof crush.

Test Requirements

The Final Rule will modify the test procedures in FMVSS No. 216 to require that vehicles less than or equal to 6,000 lbs. gross vehicle weight rating (GVWR) meet test requirements with the application of a force loading device up to 3.0 times the vehicle's unloaded weight prior to head contact with the representation of a 50th percentile male head position or 5 inches (127mm) of platen travel, whichever comes first. The test is conducted sequentially on both the driver and passenger sides of the roof. This represents a change from the current requirement, which specifies a test load of only 1.5 times the vehicle's unloaded weight without the device moving more than 127 millimeters (5 inches) conducted on one side of the roof. In addition, the rule requires that vehicles with a GVWR over 6,000 lbs. but less than or equal to 10,000 lbs. meet the same testing requirements but at a level 1.5 times the vehicle's unloaded weight. These vehicles were previously not subject to roof strength requirements. The agency examined alternative proposals that would require a 2.5, 3.0, or a 3.5 load requirement for vehicles under 6,000 lbs. GVWR, and a 1.5, 2.0, 2.5, 3.0, and 3.5 load requirement for vehicles over 6,000 lbs. GVWR. The agency examined both single-sided and 2-sided test requirements for both categories of vehicles.

Countermeasures

The agency believes that manufacturers will meet this standard by strengthening reinforcements in roof pillars, by increasing the gauge of steel used in roofs, or by using higher strength materials. The agency believes that pressure to improve fuel economy in vehicles, driven by more stringent CAFE standards as well as by market forces, together with safety considerations, will provide a strong incentive for manufacturers to achieve increased roof strength through use of light weight materials and stronger roof designs initiated during the redesign cycle. The agency believes that the lead time and phase-in schedule provided in this rule will allow manufacturers to establish such designs in an efficient manner. The agency estimates that about 82 percent of all current passenger car and light truck models with GVWRs less than 6,000 lbs. will require changes to meet the 3.0 vehicle load requirement, and that 40% percent of vehicles over 6,000 lbs. GVWR will require changes to meet the 1.5 vehicle load alternative.

Benefits

The agency estimates that the changes in FMVSS No. 216 will prevent 135 fatalities and 1,065 nonfatal injuries annually after all vehicles in the on-road fleet meet the new requirements.

Costs

The design changes made to comply with higher test load requirements will add both cost and weight to the vehicle. This will increase the initial purchase price and reduce fuel efficiency, which will increase lifetime fuel usage costs. The agency estimates that compliance with the upgraded roof strength standard will increase lifetime consumer costs by $69-$114 (2007$) per affected vehicle. Redesign costs are expected to increase affected vehicle prices by an average of about $54. Added weight is estimated to increase the lifetime cost of fuel usage by $15 to $62 for an average affected vehicle. The range in fuel costs reflects different discount rate assumptions of 7% and 3%, as well as a range of assumptions regarding the ability of manufacturers to incorporate advanced weight saving technology into their redesigned fleet. Total consumer costs are expected to range from $875 million to $1.4 billion annually.

Cost Effectiveness and Net Benefits

Cost effectiveness is a measure of the economic investment that is required to prevent a fatality. The cost effectiveness of this rule was estimated under both 3% and 7% discount rate assumptions for each alternative. Nonfatal injuries were translated into fatality equivalents based on comprehensive valuations that included both economic impacts and valuations of lost quality of life. To reflect the present value of benefits that would be experienced over the vehicle's useful life, the resulting equivalent fatalities were discounted over the vehicle's life based on annual exposure to crash involvement as measured by annual miles traveled. The 135 fatalities and 1,065 nonfatal injuries that would be prevented translate into 190 equivalent fatalities, which are valued at 156 equivalent fatalities under a 3% discount rate, and 125 equivalent fatalities under a 7% discount rate. When compared to total costs, the results indicate that the new standard will cost from $6.1 million to $9.8 million per equivalent life saved.

Net benefits represent the difference between total costs and the total monetary value of benefits. The monetary value of benefits was estimated by assigning a value of $6.1 million to each equivalent fatality prevented. This consists of a value per statistical life saved (VSL) of $5.8 million plus $300,000 in economic costs prevented. For the 3.0/1.5 load requirements of the final rule, the net impact would range from a net benefit of $6 million to a net loss of $458 million. Using an alternate comprehensive value of $8.7 million (which consists of a VSL of $8.4 million plus $300,000 in economic savings), the standard could result in a net benefit of $388 million to a net loss of $151 million. Using an alternate comprehensive value of $3.5 million (which consists of a VSL of $3.2 million plus $300,000 in economic savings), the standard could result in a net loss ranging from $376 million to $824 million. These impacts are disproportionately influenced by the relatively large contributions to costs and small contributions to benefits from vehicles over 6,000 lbs. GVWR. Nearly all alternatives covering vehicles from 6,001 to 10,000 lbs. GVWR yield net losses rather than net savings to society.

I. INTRODUCTION AND BACKGROUND

A. Current Requirements

FMVSS 216, “Roof crush resistance,” became effective on September 1, 1973. This standard established strength requirements for the roof structure over the front occupants of passenger cars with a Gross Vehicle Weight Rating (GVWR) of 6,000 pounds or less. The purpose of the standard is to reduce deaths and injuries due to crushing of the roof into the passenger compartment area in rollover crashes. Since its inception, the roof crush standard has been amended, extending its requirements to passenger cars, trucks, buses, and multipurpose passenger vehicles (MPVs) with a GVWR of 2,722 kilograms (6,000 pounds) or less (55 FR 15510, April 17, 1991). The standard was also amended to modify the test device placement procedure to accommodate vehicles with raised and highly sloped (aerodynamic) roof structures (64 FR 22567, April 27, 1999).

The test procedure currently used to evaluate compliance with the standard involves securing a vehicle on a rigid horizontal surface, placing a flat steel rectangular plate on the vehicle’s roof, and using the plate to apply a force of 1.5 times the unloaded weight of the vehicle (up to a maximum of 22,240 N, or 5,000 pounds, for passenger cars) onto the roof structure. Throughout this analysis, specific levels of unloaded vehicle weight that will be examined are referred to as the strength to weight ratio (SWR).

During the test, the plate is angled and positioned to simulate vehicle-to-ground contact on the roof over the front seat area.[1] To achieve this contact, the plate is tilted forward at a 5-degree angle, along its longitudinal axis, and tilted outward at a 25-degree angle, along it’s lateral axis, so that the plate’s outboard side is lower than its inboard side. The test plate's edges are also positioned with respect to fixed locations on the vehicle's roof, (10 inches forward of the rear edge of the windshield), to ensure that the plate stresses the roof over the front seat area. Compliance with the standard is achieved if the vehicle's roof prevents the test plate from moving downward more than 127 mm (5 inches).

B. Previous Agency Rulemaking

1. Rollovers

In 1991, Congress mandated NHTSA to assess rulemaking on rollover occupant protection as a part of the Intermodal Surface Transportation Efficiency Act (ISTEA). ISTEA required the agency to initiate rulemaking to address the problems of rollover crashes. In response to that mandate, NHTSA published an advance notice of proposed rulemaking (ANPRM) (57 FR 242, January 3, 1991) that summarized the statistics and research in rollover crashes, sought answers to several questions about vehicle stability and rollover crashes, and outlined possible regulatory and other approaches to reduce rollover fatalities. NHTSA also published a report to Congress that detailed the agency's effort in these areas (NHTSA 1999-5572-35).

The agency released a document entitled, "Planning Document for Rollover Prevention and Injury Mitigation," at a Society of Automotive Engineers (SAE) meeting on rollover on September 23, 1992. The planning document gave an overview of the rollover problem and a list of alternative actions that NHTSA was examining to address the problem. Activities described in the document included: crash avoidance research on vehicle measures for rollover resistance, research on antilock brake effectiveness, rulemaking on upper interior padding to prevent head injury, research on improved roof crush resistance to prevent head and spinal injury, research on improved side window glazing and door latches to prevent occupant ejection, and consumer information to alert people to the severity of rollover crashes and the benefits of

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[1] The roof over the front seat area means the portion of the roof, including windshield trim, forward of a transverse plane

seat belt use in this type of crash. NHTSA published a notice announcing the availability of the planning document and requesting comments (57 FR 44721, September 29, 1992).

In May 1996, NHTSA issued the "Status Report for Rollover Prevention and Injury Mitigation" (NHTSA 1996-1811-2). This document updated the progress of the programs discussed in the planning document. Under section 12 of the Transportation Recall, Enhancement, Accountability and Documentation (TREAD) Act of November 2000, NHTSA was mandated to develop a dynamic rollover test for the purposes of consumer information, to carry out a program of conducting such tests, and to conduct rulemaking to determine how best to disseminate test results to the public, as these tests are being developed. On July 3, 2001, the agency published a Request For Comment notice (66 FR 35179) discussing potential advantages and disadvantages of a variety of dynamic rollover tests that were selected to be evaluated in the agency's research program. After a subsequent comment period, NHTSA published a NPRM on October 7, 2002, discussing the results of NHTSA's evaluation of numerous driving maneuver tests for the dynamic rollover consumer information program. The NPRM also proposed several alternative methods for using the dynamic rollover test results in the agency's consumer information for vehicle rollover resistance. NHTSA is now using the dynamic rollover testing to supplement the existing static ratings in the 2004 model year.

2. Roof Crush

On April 17, 1991, NHTSA published a final rule amending FMVSS 216 to extend its requirements to MPVs, trucks, and buses with a GVWR of 2,722 kilograms (6,000 pounds) or less (56 FR 15510). NHTSA justified the extension to light trucks by the increased use of light trucks[2] as passenger vehicles and the need to ensure that those vehicles offer safety protection comparable to that offered to passenger cars. The final rule adopted the same test requirement and procedure as those for passenger cars, except for the absence of the 22,240 Newton limit on the applied force. This amendment became effective on September 1, 1994.

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passing through a point 162 mm rearward of the seating reference point of the rearmost front outboard seating position.

On May 6, 1996, the agency received a petition for rulemaking from R. Ben Hogan, Smith and Alspaugh, P.C. (Hogan). Hogan commented that the current static requirements in FMVSS 216 bear no relationship to real world rollover crash conditions and therefore should be replaced with a more realistic test such as the inverted vehicle drop test defined in the SAE Standard J996. This request coincided with agency research testing that was being conducted using the inverted drop test procedure. The petitioner also requested that NHTSA require “roll cages” to be standard in all cars as requested by some commenters responding to the January 3, 1992, ANPRM on rollover occupant protection. NHTSA granted this petition on January 8, 1997, believing that the inverted drop test had merit for further agency consideration.

On April 27, 1999, NHTSA published a final rule regarding the test procedure in FMVSS 216 (64 FR 22567). Prior to the amendments made by the final rule, the existing procedure resulted in certain vehicles with rounded roofs (e.g., the Ford Taurus) being tested with the test plate positioned too far rearward on the vehicle roof. In this position, the plate did not test the roof over the front occupants. In addition, this position created the potential for contact between the front edge of the test plate and the roof, allowing the plate to penetrate the roof along the leading edge of the plate. Similarly, in following this procedure for vehicles with raised, irregularly-shaped roofs (such as some vans with roof conversions), the initial contact point on the roof may not be above the front occupants, but on the raised rear portion of the roof, behind those occupants. In both of these cases, the positioning of the plate relative to the initial contact point on the roof, instead of relative to a fixed location on the roof, resulted in too much variability in the plate positioning and reduced test repeatability.

The April 27, 1999 final rule addressed the problem of rounded roofs by specifying a new primary test procedure for all vehicles except those with certain modified roof configurations. Under the new procedure,

[2] For purposes of this notice, the term “light truck” includes MPVs, trucks, and buses.

the test plate is positioned so that the front edge of the plate is 254 mm (10 inches) in front of the most rearward point of the windshield. Positioned in this way, the front edge of the plate is always projected slightly forward of the roof instead of contacting it. The rule addressed the problem for vehicles with raised or modified roofs by specifying a secondary test procedure if the initial point of contact is rearward of the front seat area. Under the secondary test procedure, the plate is moved forward such that its rearward edge is positioned at the rear of the roof over the front seat area.

In June 1999, RVIA and Ford submitted a petition for reconsideration regarding the rear edge plate contact on certain aerodynamically shaped roof vehicles with the secondary test procedure. To provide temporary relief, vehicle manufacturers, until October 25, 2000, had the option of using the standard's original test plate placement procedure (1973) for light trucks that have a raised or altered roof, in place of the primary or secondary procedures defined above (65 FR 4579, January 31, 2000). The original procedure positioned the plate with respect to its initial point of contact with the roof. The initial point of contact was established by angling and lowering the plate as required, following the primary test procedure until the plate contacts the roof. After establishing the initial contact point on the vehicle, the test plate was moved upwards, and the forward edge was positioned 254 mm (10 inches) forward of the initial point of contact with the vehicle. This position was allowed to make testing possible for raised roof vehicles that experience contact with the plate's rearward edge when testing to the secondary test procedure.

On October 22, 2001, NHTSA published a Request for Comment notice (66 FR 53376) to assist in the upgrade of FMVSS 216. In the Request for Comment, the agency discussed issues regarding the current standard and posed eight questions grouped according to the following areas: (1) current test procedures; (2) alternative dynamic tests; and (3) limiting headroom reduction.

<u>August 2005 NPRM</u>

On August 23, 2005, NHTSA published in the Federal Register (70 FR 49223) a notice of proposed rulemaking (NPRM) to upgrade Federal Motor Vehicle Safety Standard (FMVSS) No. 216, Roof Crush Resistance[3]. FMVSS No. 216 seeks to reduce deaths and serious injuries resulting from the roof being crushed and pushed into the occupant compartment when the roof strikes the ground during rollover crashes. FMVSS No. 216 currently applies to passenger cars, and to multipurpose passenger vehicles, trucks and buses with a GVWR of 2,722 kilograms (6,000 pounds) or less. The standard requires that when a large steel test plate (sometimes referred to as a platen) is placed in contact with the roof of a vehicle and then pressed downward, simulating contact of the roof with the ground during a rollover crash, with steadily increasing force until a force equivalent to 1.5 times the unloaded weight of the vehicle is reached, the distance that the test plate has moved from the point of contact must not exceed 127 mm (5 inches). The criterion of the test plate not being permitted to move more than a specified amount is sometimes referred to as the "platen travel" criterion. Under S5 of the standard, the application of force is limited to 22,240 Newtons (5,000 pounds) for passenger cars, even if the unloaded weight of the car times 1.5 is greater than that amount.

Proposed upgrade.

As discussed in the August 2005 NPRM, we developed our proposal to upgrade roof crush resistance requirements after considerable analysis and research, including considering comments received in response to a Request for Comments (RFC) published in the Federal Register (66 FR 53376) on October 22, 2001. Prior to publishing the RFC, the agency conducted a research program to examine potential methods for improving the roof crush resistance requirements. The agency testing program included full vehicle dynamic rollover testing, inverted vehicle drop testing, and comparing inverted drop testing to a modified FMVSS No. 216 test. After considering the results of the testing and other available information, the agency concluded that the quasi-static procedure provides a suitable representation of the real-world

[3] Docket No. NHTSA-2005-22143.

dynamic loading conditions, and the most appropriate one on which to focus our upgrade efforts. In our August 2005 NPRM, to better address fatalities and injuries occurring in roof-involved rollover crashes, we proposed to extend the application of the standard to vehicles with a GVWR of up to 4,536 kilograms (10,000 pounds), and to strengthen the requirements of FMVSS No. 216 by mandating that the vehicle roof structures withstand a force equivalent to 2.5 times the unloaded vehicle weight, and eliminating the 22,240 Newtons (5,000 pounds) force limit for passenger cars.

Further, in recognition of the fact that the pre-test distance between the interior surface of the roof and a given occupant's head varies from vehicle model to vehicle model, we proposed to regulate roof strength by requiring that the crush not exceed the available headroom. Under the proposal, this requirement would replace the current limit on test plate movement.

The proposed new limit would prohibit any roof component from contacting the head of a seated 50th percentile male dummy when the roof is subjected to a force equivalent to 2.5 times the unloaded vehicle weight. We note that this value is sometimes referred to as the strength-to-weight ratio (SWR), e.g., a SWR of 1.5, 2.5, and so forth.

We also proposed to:

- Allow vehicles manufactured in two or more stages, other than chassis-cabs, to be certified to the roof crush requirements of FMVSS No. 220, instead of FMVSS No. 216.
- Clarify the definition and scope of exclusion for convertibles.
- Revise the vehicle tie-down procedure to minimize variability in testing.

To accompany our proposal, we prepared a Preliminary Regulatory Impact Analysis (PRIA) describing the costs and benefits. We estimated that, if adopted, the proposal would result in 13-44 fewer fatalities and 498-793 fewer non-fatal injuries each year. The total estimated recurring fleet cost was $88 to $95 million. We estimated that approximately 32 percent of the current vehicle fleet would need improvements to meet the proposed upgraded requirements.

January 2008 SNPRM

On January 30, 2008, NHTSA published in the Federal Register (70 FR 5484) an SNPRM for our ongoing roof crush resistance rulemaking.[4] In that document, we asked for public comment on a number of issues that might affect the content of the final rule, including possible variations in the proposed requirements. We also announced the release of the results of various vehicle tests conducted since the proposal.

In the SNPRM, we noted that we had been carefully analyzing the numerous comments we had received on the NPRM, as well as the various additional vehicle tests, including both single-side tests and two-sided tests, conducted since the NPRM. We invited comments on how the agency should factor the new information into its decision. We noted that while the NPRM focused on a specified force equivalent to 2.5 times the unloaded vehicle weight, the agency could adopt a higher or lower value for the final rule. We explained, with respect to two-sided vehicle testing, that we believed there was now sufficient available information for the agency to consider a two-sided requirement as an alternative to the single-sided procedure described in the NPRM. We stated that we planned to evaluate both the single-sided and two-sided testing alternatives for the final rule and requested comments that would help us reach a decision on that issue.

We also noted in the SNPRM that the agency had conducted additional analysis concerning the role of vertical roof intrusion and post-crash headroom in predicting roof contact injuries to the head, neck or face during FMVSS No. 216 rollovers. At the time of the NPRM, the agency estimated benefits based on post-

[4] Docket No. NHTSA-2008-0015.

crash headroom, the only basis for which a statistical relationship with injury reduction had been established. After the NPRM, with additional years of data available, a statistically significant relationship between intrusion and injury for belted occupants was established.

<u>Congressional mandate</u>

Section 10301 of SAFETEA-LU generally required the Secretary to issue a final rule upgrading roof crush resistance by July 1, 2008, while providing for a later date under certain circumstances. That section provides:

> Sec. 10301. VEHICLE ROLLOVER PREVENTION AND CRASH MITIGATION.
>
> (a) In General.—Subchapter II of chapter 301 is amended by adding at the end the following:
>
> §30128. Vehicle rollover prevention and crash mitigation
>
> ‘‘(a) IN GENERAL.—The Secretary shall initiate rulemaking proceedings, for the purpose of establishing rules or standards that will reduce vehicle rollover crashes and mitigate deaths and injuries associated with such crashes for motor vehicles with a gross vehicle weight rating of not more than 10,000 pounds.
>
> * * * * *
>
> (d) Protection of Occupants.--One of the rulemaking proceedings initiated under subsection (a) shall be to establish performance criteria to upgrade Federal Motor Vehicle Safety Standard No. 216 relating to roof strength for driver and passenger sides. The Secretary may consider industry and independent dynamic tests that realistically duplicate the actual forces transmitted during a rollover crash. The Secretary shall issue a proposed rule by December 31, 2005, and a final rule by July 1, 2008.

The statute provides that if the Secretary determines that the July 1, 2008 deadline for the final rule cannot be met, the Secretary is to notify Congress and explain why that deadline cannot be met, and establish a new date. The Secretary provided such notification to Congress, establishing a new date of October 1, 2008. This was subsequently moved to December 15th, 2008, and then to April 30th 2009.

II. AGENCY RESEARCH AND TEST RESULTS

In response to comments received in the October 2001 FMVSS 216 Request for Comments, NHTSA initiated a review of National Accident Sampling System – Crashworthiness Data System (NASS-CDS) investigated crashes The study was intended to evaluate if there were significant changes observed in the patterns of roof damage in the current fleet and to compare real-world roof damage to both compliance and extended FMVSS 216 tests.[5] This study examined rollover cases with greater than 15.2 cm (6 inches) of vertical intrusion contained in the most recent five years of NASS-CDS (1997 to 2001). The agency evaluated the damage to the A and B pillars, roof rails and roof plane of the vehicles. All the examined vehicles had considerably greater damage than FMVSS 216 compliance tests. The NASS-CDS case review revealed that lateral roof deformation that was limited to one side of the vehicle's roof happened frequently.

After the NASS-CDS case review, a finite element study was initiated to examine the effect of using alternative roll and pitch angles for the current FMVSS 216 test procedure. A finite element model of a 1997 Dodge Caravan was used to simulate extended FMVSS 216 tests for approximately five inches of plate motion using a variety of roll and pitch angles. The simulations indicated that the Caravan roof would attain similar amounts of deformation at a lower force level using 10-degree pitch and 45-degree (10-45) roll angles compared to the current 5-degree pitch and 25-degree (5-25) roll angles. A 1997 Chevrolet S10 pickup model was also studied, but the results were less conclusive.

The results of the finite element study were encouraging enough to conduct a series of modified FMVSS 216 tests. Two tests were conducted on the Dodge Caravan and Chevrolet S10 vehicles using both the current 5-25 roll angles as well as using modified 10-45 roll angles. A third vehicle, a 2002 Ford Explorer,

[5] Extended FMVSS No. 216 tests continue to crush the roof beyond the requirements of the standard.

was also tested using the same test configurations. Each test was conducted until 254 mm (10 inches) of load plate displacement was achieved.

The roof damage between the two test configurations was generally similar. The tests using 10-45 roll angles had some additional lateral damage, but the damage was localized near the roof side rail and did not extend laterally to the midline of the vehicle. The force distribution applied to the front and back of the load plate changed considerably between the two test configurations. The test configuration using the 10-45 roll angles applied almost all of the force to the forward ram located near the front of the load plate. The 5-25 configuration applied only two-thirds of the force to the front ram. Based on the similarity of the post-test damage patterns and general force levels, there was not sufficient evidence to justify changing the load plate configuration. Thus, the agency proposed to keep using the 5-25 roll angles in future FMVSS 216 upgrade testing.

Table II-1
Proposed FMVSS 216 Roof Crush Testing @% of Vehicle Weight

Vehicle	Ram Travel @150%		Cos 25^o	Test% Weight	Ram Travel @250%		Cos 25^o	Test % Weight	Ram Travel @300%		Cos 25^o
2002 Toyota Camry	25 mm	1.0 in	0.9 in	250	50 mm	2.0 in	1.8 in	300	60 mm	2.3 in	2.1 in
2002 Honda CRV	33 mm	1.3 in	1.2 in	250	112 mm	4.4 in	4.0 in	300	140 mm	5.5 in	5.0 in
1997 Dodge Grand Caravan	38 mm	1.5 in	1.4 in	250	85 mm	3.3 in	2.9 in	265			
2001 Chevy Tahoe	40 mm	1.6 in	1.4 in	250	65 mm	2.6 in	2.3 in	290			
1998 Chevy S-10 PU	42 mm	1.6 in	1.5 in	250	65 mm	2.6 in	2.3 in	276			
2002 Ford Mustang	39 mm	1.5in	1.4 in	250	115 mm	4.5 in	4.1 in	265			
2002 Ford Crown Vic	49 mm	1.9 in	1.7 in	250	190 mm	7.5 in	6.8 in	300	245 mm	9.6 in	8.6 in
2002 Ford Explorer	43 mm	1.6 in	1.5 in	250	215 mm	8.5 in	7.7 in	300	255 mm	10.0 in	9.0 in
2002 Dodge Ram 1500 PU	45 mm	1.7 in	1.6 in	249 - Fail	100 mm	3.9 in	3.5 in				
1999 Ford E150 Van	50 mm	2.0 in	1.8 in	188 - Fail							

Indicates Pass at 300%		Indicates Failure at 300 %		Indicates Failure at 250%

A set of ten recent model vehicles, were tested using an extended FMVSS 216 procedure to gather further roof strength data. These vehicles were tested to 25.4 cm (10 inches) of load plate displacement. These vehicles included the following: 2002 Dodge Ram 1500 Pickup, 2002 Toyota Camry, 2002 Ford Mustang, 2002 Honda CRV, 2002 Ford Explorer, 2002 Ford Crown Victoria, 2001 Chevy Tahoe, 1999 Ford E-150, 1998 Chevy S-10 Pickup, and 1997 Dodge Grand Caravan. The test results are shown in Table II-1.

Additional instrumentation was included in all of the extended tests to measure the motion of the roof directly above the head of the 50th percentile dummy. Three string potentiometers were connected from the roof to known locations near the floor of the vehicle. These displacement measurements enabled the tracking of the motion of a single point on the roof during the test. These measurements were intended to provide some measure of the relationship between external plate displacement and available occupant headroom throughout the test. All of the extended FMVSS 216 tests used the seating procedure from the FMVSS 208 test procedure.

All ten vehicles in Table II-1 attained the FMVSS 216 required applied force of 1.5 times the unloaded vehicle weight within 5.1 cm (2 inches) of plate displacement. Nine of the ten vehicles exceeded an applied force of 2.0 times the unloaded vehicle weight within 7.6 cm (3 inches) of plate displacement. The Ford E-150 van never exceeded an applied force of 2.0 times the unloaded vehicle weight during the test. Six of the ten vehicles tested (1998 Chevy S10 Pickup, 2002 Toyota Camry, 2002 Honda CRV, 1997 Dodge Grand Caravan, 2002 Ford Mustang, and 2001 Chevy Tahoe) exceeded an applied force of 2.5 times the unloaded vehicle weight within the 127 mm (5 inches) of plate displacement allowed in the current standard.

The roof displacement measurements were combined with the initial occupant seating position to determine the initial occupant headroom. For the 10 vehicles tested in the research program, the initial headroom from the occupant’s head to the hard roof, ranged from 98 mm (3.9 inches) for the Ford Mustang to 254 mm (10 inches) for the Ford E-150. The depth of the roof liner varied considerably among the vehicles tested. The Ford Mustang had the smallest distance from the roof liner to the hard roof of 8 mm (0.3 inches), and the Ford E-150 van had the largest distance of 61 mm (2.4 inches).

String potentiometer measurements were used to track the 3-dimensional motion of the roof location directly above the occupant’s head. The post-test location of the roof attachment point was unlikely to be directly above the occupants head, however the downward displacement of this roof point is expected to provide an indication of the occupant headroom throughout the roof crush test. At an applied force of 1.5

times the vehicle weight, the occupant head-to-hard roof clearance ranged from 95 mm (3.7 inches) to 252 mm (9.9 inches). All of the test vehicles had greater than 100 mm of head-to-hard roof clearance except for the Ford Mustang. At 2.0 times the vehicle weight, the head-to-hard roof clearance ranged from 68 mm (2.7 inches) to 181 mm (7.1 inches) for the 9 vehicles that reached this force level. At 2.5 times the vehicle weight, the head-to-hard roof clearance ranged from 14 mm (0.5 inches) to 176 mm (6.9 inches) for the eight vehicles that reached this force level during the extended testing. If the liner depths did not change as the roof crushed, then at an applied force of 2.5 times the vehicle weight, six vehicles still had over 25 mm (1 inch) of head to roof liner clearance and 5 vehicles had over 75 mm (3 inches) of head-to-roof liner clearance. Even at 3.0 times the vehicle weight, two of the vehicles (Toyota Camry and Honda CRV) still had over 75 mm (3 inches) of head-to-roof liner clearance. While the string potentiometers were not an exact measurement of occupant headroom, they did provide useful insights into the performance tradeoffs that can exist between roof strength and occupant headroom.

After completing the initial research program, NHTSA conducted ten additional extended FMVSS 216 tests with a 50th percentile Hybrid III dummy to better assess occupant headroom as a function of applied force, by determining when the roof contacted the dummy's head. The following vehicles were tested to 25.4 cm (10 inches) of load plate displacement: 2003 Ford Focus, 2003 Chevy Cavalier, 2003 Subaru Forester, 2002 Toyota Tacoma, 2001 Ford Taurus, 2003 Chevy Impala, 2002 Nissan Xterra, 2003 Ford F-150, 2003 Ford Expedition, and 2003 Chevy Express 15-passenger van. The test results are shown in Table II-2.

These ten additional tests used the FMVSS 208 seating procedure to place the 50th percentile Hybrid III dummy in the occupant seat. The dummy was seated throughout the duration of the 25.4 cm (10 inch) displacement of the load plate. Video cameras tracked the interior roof as it approached the dummy's head. For each vehicle, the agency tracked the force level and the load plate displacement, and recorded the point where the roof contacted the dummy's head.

Table II-2
Proposed FMVSS 216 Roof Crush Testing @% of Vehicle Weight

Vehicle	Ram Travel @150%		Cos 25^o	Test % Weight	Ram Travel @250%		Cos 25^o	Test % Weight	Ram Travel @300%		Cos 25^o
2003 Subaru Forester	21 mm	0.8 in	0.7 in	250	40 mm	1.6 in	1.5 in	300	45 mm	1.8in	1.6 in
2003 Chevy Impala	32 mm	1.3 in	1.1 in	250	53 mm	2.1 in	1.9 in	300	63 mm	2.5 in	2.2 in
2002 Nissan Xterra	33 mm	1.3 in	1.2 in	250	45 mm	1.8 in	1.6 in	300	57 mm	2.2 in	2.0 in
2003 Ford Focus	30 mm	1.2 in	1.1 in	250	60 mm	2.4 in	2.2 in	275			
2003 Chevy Cavalier	32 mm	1.3 in	1.1 in	250	68 mm	2.7 in	2.4 in	263			
2002 Toyota Tacoma	38 mm	1.5in	1.4 in	250	66 mm	2.6 in	2.4 in	266			
2003 Ford F-150	37 mm	1.5 in	1.3 in	250	77 mm	3.0 in	2.7 in	285			
2001 Ford Taurus	48 mm	1.9 in	1.7 in	250 – Fail Head Touch	90 mm	3.5 in	3.2 in				
2003 Ford Expedition	56mm	2.2in	2.0 in	235 - Fail	115 mm	4.5 in	4.1 in				
2003 Chevy Express Van	68 mm	2.7 in	2.4 in	205 - Fail	110 mm	4.3 in	3.9 in				

Indicates Pass at 300%		Indicates Failure at 300 %		Indicates Failure at 250%

All ten vehicles attained the FMVSS 216 required applied force of 1.5 times the unloaded vehicle weight prior to roof contact with the dummy's head as shown in Table II-2. Seven vehicles exceeded an applied force of 2.5 times the unloaded vehicle weight, prior to roof contact with the dummy's head, and three of the vehicles exceeded 3.0 times the unloaded weight of the vehicle.

The Subaru Forester even exceeded an applied force of 4.0 times the unloaded vehicle weight without roof contact with the dummy's head. Among the ten vehicles tested, the roof contacted the dummy's head between 82 mm (3.2 inches) and 185 mm (7.3 inches) of plate displacement.

NHTSA issued an SNPRM to address the comments received from the NPRM relevant to the appropriateness of a Final Rule SWR. During the comment period the agency continued to collect data on the more recent production vehicles (above and below 6,000 lbs GVWR) shown below in Table II-3. There appear to be many more vehicles in the less than 6,000 lbs GVWR classification that have achieved SWR's in excess of 3.0.

Table II-3
Results of Single-Sided Test (5º x 25º Platen Angle)

Vehicle	Unloaded Vehicle Weight (kg)	Peak Strength within 127 mm		Peak Strength Prior to Head Contact		Platen Displacement at Head Contact (mm)
		N	SWR	N	SWR	
2006 VW Jetta	1,443	72,613	5.1	72,613	5.1	158
2007 Scion tC	1,326	59,749	4.6	59,749	4.6	113
2006 Volvo XC90	2,020	90,188	4.6	N/A	N/A	N/A
2006 Honda Civic	1,251	55,207	4.5	55,207	4.5	177
2007 Toyota Tacoma	1,489	64,441	4.4	64,441	4.4	123
2006 Mazda 5	1,535	66,621	4.4	66,621	4.4	155
2007 Toyota Camry	1,468	62,097	4.3	62,097	4.3	N/A
2007 Toyota Yaris	1,038	41,073	4	41,073	4	115
2006 Ford 500	1,657	63,181	3.9	63,181	3.9	150
2007 Nissan Frontier	1,615	62,828	3.9	62,828	3.9	167
2006 Subaru Tribeca	1,907	72,306	3.9	72,306	3.9	112
2006 Mitsubishi Eclipse	1,485	51,711	3.6	51,711	3.6	127
2006 Hummer H3	2,128	70,264	3.4	70,264	3.4	185
2006 Hyundai Sonata	1,505	46,662	3.2	46,662	3.2	131
2007 Dodge Caravan	1,759	52,436	3	52,436	3	N/A
2006 Chrysler Crossfire	1,357	38,179	2.9	38,179	2.9	107
2004 Honda Accord	1,413	38,281	2.8	38,281	2.8	140
2007 Saturn Outlook*	2,133	57,222	2.7	57,222	2.7	N/A
2006 Ford Mustang	1,527	40,101	2.7	41,822	2.8	132
2005 Buick Lacrosse	1,590	40,345	2.6	40,345	2.6	126

2006 Sprinter Van*	1,946	49,073	2.6	N/A	N/A	N/A
2004 Cadillac SRX	1,961	50,346	2.6	50,346	2.6	138
2007 Honda CRV	1,529	38,637	2.6	38,637	2.6	N/A
2007 Chrysler 300	1,684	41,257	2.5	41,257	2.5	N/A
2005 Buick Lacrosse	1,588	37,196	2.4	37,196	2.4	123
2006 Honda Ridgeline	2,036	47,334	2.4	47,334	2.4	172
2007 Ford F-150*	2,413	54,829	2.3	54,829	2.3	N/A
2007 Buick Lucerne	1,690	38,268	2.3	38,268	2.3	N/A
2004 Chevrolet 2500 HD*	2,450	55,934	2.3	56,294	2.3	171
2007 Pontiac G6	1,497	33,393	2.3	33,393	2.3	124
2007 Chevrolet Express*	2,471	55,038	2.3	55,038	2.3	N/A
2007 Jeep Grand Cherokee	1,941	41,582	2.2	41,582	2.2	117
2007 Chevrolet Tahoe*	2,462	49,878	2.1	49,878	2.1	N/A
2006 Dodge Ram*	2,287	37,596	1.7	42,578	1.9	158
2003 Ford F-250*	2,658	44,776	1.7	44,776	1.7	205
2008 Honda Accord	1478	57,578	4.0	57,578	4.0	123
2007 Ford Edge	1917	80,032	4.3	80,032	4.3	145
2007 Toyota Tundra*	2344	71,229	3.1	71,229	3.1	131
2007 Toyota Tacoma	1751	63,547	3.7	63,547	3.7	124
2007 Chevrolet Colorado	1561	28,602	1.9	28,602	1.9	105
2008 Smart ForTwo	824	42,752	5.3	42,752	5.3	119

- GVWR greater than 6,000 pound

In response to public interest groups concerns that more roof damage occurred on the far side (trailing edge, second roof contact) than on the near sided, the agency initiated two-sided roof crush tests. Commenters suggested that the two-sided tests represented a more realistic simulation of real-world intrusion. It was further argued that when the near side roof and windshield was damaged in the rollover, that the far side would not be able to withstand the subsequent forces and would deform further than the near side. The two-sided data collected by the agency on vehicles above and below 6,000 lbs GVWR shown below in Table II-4.

Table II-4

Results of 2-sided Testing (5º x 25º Platen Angle)

Vehicle	Peak SWR Prior to 127 mm of Platen Travel or Head Contact		Peak Force Change
	1st Side	2nd Side	
2007 Chevrolet Express [6]	2.3	1.7	-27.3%
2007 Jeep Grand Cherokee	2.2	1.6	-27.1%
2007 Pontiac G6	2.3	1.7	-23.8%
2005 Lincoln LS *	2.6	2.0	-21.3%
2007 Saturn Outlook	2.7	2.2	-20.8%
2003 Ford Crown Victoria *	2.0	1.7	-19.5%
2007 Ford F-150	2.3	1.9	-19.0%
2007 Chevrolet Tahoe	2.1	1.7	-16.4%
2007 Toyota Yaris	4.0	3.4	-15.8%
2005 Buick LaCrosse	2.6	2.2	-13.5%
2007 Toyota Tacoma	3.3	3.7	-12.4%
2007 Buick Lucerne	2.3	2.1	-10.8%
2003 Chevrolet Impala *	2.9	2.5	-9.9%
2004 Lincoln LS *	2.5	2.2	-8.7%
2006 Subaru Tribeca	3.9	3.5	-8.3%
2007 Scion tC	4.6	4.3	-6.7%
2006 Chrysler Crossfire	2.9	2.7	-5.6%
2007 Dodge Caravan	3.0	2.9	-5.3%
2007 Honda CRV	2.6	2.5	-4.9%
2005 Buick LaCrosse	2.4	2.3	-3.4%
2004 Nissan Quest *	2.8	2.7	-3.0%
2001 GMC Sierra *	1.9	1.9	-1.3%
2007 Chrysler 300	2.5	2.5	1.6%
2004 Chrysler Pacifica *	2.2	2.4	7.0%
2007 Toyota Camry	4.3	4.7	9.0%
2004 Land Rover Freelander *	1.7	2.0	19.2%
2008 Honda Accord	3.5	4.0	NA**

[6] Between first and second side tests, the front door on the tested side was opened. Damage to the vehicle during the first side test, caused the door to not properly latch close. The door was clamped until the latched engaged, locking the door in place. This may have reduced the measured peak load on the second side.

2007 Ford Edge	3.3	3.32	-3.6%
2007 Toyota Tundra	3.1	3.3	17.4%
2007 Toyota Tacoma	3.7	3.3	-12.5%
2007 Chevrolet Colorado	2.2	1.7	-21.5%
2008 Smart ForTwo	3.5	5.3	NA**

* Crush of first side stopped at windshield cracking.

* * Test stopped when 3.5 SWR reached – not carried out to 5 inches.

The two-sided test results showed the first side test generally produces a weakening of the structure. This was shown by the fact that the recorded SWR for the second side is generally lower than for the first side. On average, the peak strength for the second side was reduced by 8.4 percent. When considering different vehicle weight categories, the two-sided testing indicated an average difference of approximately 7.1 percent lower peak force for the second side in vehicles with a GVWR equal to or less than 2,722 kilograms (6,000 pounds) and 14.9 percent lower peak force for the second side in vehicles over 2,722 kilograms (6,000 pounds) GVWR. However, for several of the vehicles, we observed considerably higher reductions in peak strength. Of the 31 vehicles tested, excluding the Chevrolet Express,[7] six experienced reductions in strength of 19 percent or greater.

[7] Between the first and second side tests, the front door on the tested side was opened. Because of damage to the vehicle during the first side test, the door would not properly close. The door was clamped until the latch engaged, locking the door in place. This may have compromised the structural integrity of the roof and reduced the measured peak load on the second side.

Pass/Fail Rate of the Vehicle Fleet

In the NPRM, the agency estimated that 32 percent of the vehicle fleet would have to be changed to meet the 1-sided test 2.5 SWR proposal. In response to the NPRM, manufacturers commented that NHTSA's estimates underestimated the portion of the vehicle fleet that would require changes. The manufacturers noted that NHTSA's estimates were based on individual vehicles' actual weights, but that manufacturers would have to design roof structures to meet the maximum weight that each body design would be required to carry. Thus, for example, test results from a vehicle with a four-cylinder engine and manual transmission might not be indicative of the same vehicle with a six-cylinder engine and automatic transmission option, even though they share the same body design and roof structure. The agency agrees with this comment and will make appropriate adjustments for this concern in its current analysis. The agency notes that, in addition to increasing the portion of the fleet that will be modified, this will effectively increase the fleet average roof strength to a level above the minimum requirements of the standard because lighter weight versions of each body shell will still meet the higher standard based on the maximum weight for vehicles that share the same body shell.

Based on the agency's testing, the more recent vehicle designs appear to have stronger roofs. To adjust for maximum vehicle weight, an 8% adjustment was applied to the required SWR. The 8% adjustment was derived by examining the lightest and heaviest weight models available for the common body forms in a sample of vehicles. This produced an average difference of 16%. The 8% midpoint was used because it was uncertain where any given vehicle fell in this range. Some would be higher, some lower.

We have conducted an analysis to examine the relative impact of each alternative SWR and two-sided testing vs. single-sided testing, based primarily on the results of the agency's own FMVSS No. 216 testing program. Since the publication of the October 2001 request for comment (66 Fed. Reg. 53376), the agency has conducted roof strength testing on 76 vehicles. Although these tests were conducted on specific vehicles, for this exercise, the results were adjusted to reflect the maximum weight configuration for each make/model. The agency tested 26 vehicles with GVWRs less than 6,000 pounds (2,722 kilograms) under the proposed two-sided testing regime. Fourteen of these vehicles passed the proposed 2.5 SWR on both the first and second side tested. Only nine vehicles passed a 3.0 SWR on both sides and only six passed a 3.5 SWR. The agency also conducted two-sided tests on six vehicles with GVWRs over 6,000 pounds (2,722 kilograms). Only one of these vehicles passed a 2.5 or greater SWR on both sides.

The agency also has single-sided testing data on 33 vehicles with GVWRs less than 6,000 pounds (2,722 kilograms) and 11 vehicles with GVWRs over 6,000 pounds (2,722 kilograms). For these vehicles, we calculated a two-sided test average equivalent requirement based on the difference between first- and second-sided peaks SWRs found in the two-sided tests.

Using this requirement as a proxy for two-sided tests, an estimate was made of the impact of two-sided test on this population of tested vehicles. The results for this sample of 76 vehicles were then sales weighted to estimate the relative pass/fail rates that might result for each testing procedure. The results for vehicles with high GVWRs (over 6,000 lbs. GVWR) were quite different from those for vehicles with low GVWRs. As shown in Table II-5, 90-100 percent of vehicles over 6,000 pounds (2,722 kilograms) GVWR failed under the 2.0, 2.5, 3.0, and 3.5 SWR scenarios[8]. The vehicles with GVWR under 6,000 pounds (2,722 kilograms) had failure rates of 62% for 1-sided testing and 63% for 2-sided testing for the 2.5 SWR alternative.[9] For

[8] In addition to the 2.5, 3.0, and 3.5 SWRs considered for vehicles under 6,000 lbs. GVWR, lower SWRs of 1.5 and 2.0 are considered for vehicles over 6,000 lbs., which are considerably heavier and which are being regulated for the first time. See discussion under Alternatives in Chapter III.

[9] This assumes that the sample of vehicles tested only on one side will achieve proportionately the same second side results as the average result from the smaller sample of 2-sided tests (within each respective weight category above and

the 3.0 SWR, failure rates were 75% for the 1-sided testing and 82% for 2-sided testing. For the 3.5 alternative failure rates were 88% for 1-sided testing and 96% for 2-sided testing. For all three SWR alternatives, failure rates were higher for the two-sided tests, but the difference was significant only under the 2.5 SWR requirement, with failure rates for both testing conditions approaching 80% for the 3.0 SWR alternative and exceeding 80% for the 3.5 SWR alternative. This reflects the relatively large concentration of vehicles with SWRs near the 2.5 threshold.

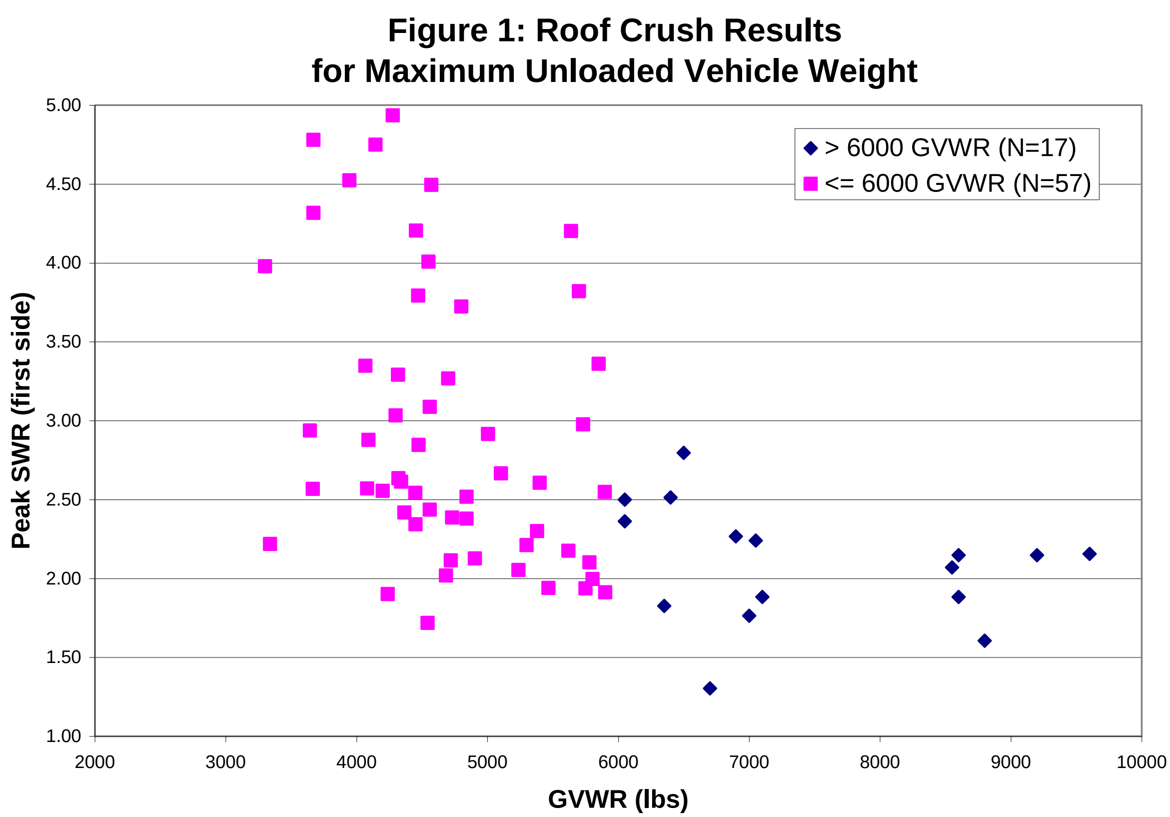
Table II-5

Failure Rates Based on Maximum GVWR

2-Sided Testing					
GVWR:	1.5 SWR	2.0 SWR	2.5 SWR	3.0 SWR	3.5 SWR
< 6,000lbs. GVWR			62.93%	82.04%	95.52%
> 6,000lbs. GVWR	40%	93%	100.00%	100.00%	100.00%
Total			72.14%	86.50%	96.63%
1-Sided Testing					
GVWR:		2.0 SWR	2.5 SWR	3.0 SWR	3.5 SWR
< 6,000lbs. GVWR			61.55%	75.32%	88.45%
> 6,000lbs. GVWR	13%	90%	91.50%	100.00%	100.00%
Total			68.99%	81.45%	91.32%

below 6,000 lbs. GVWR). This method is adopted because the relatively small sample of second sided tests had average SWRs that were significantly lower than the larger sample of single-sided tests, and it was considered important to include some estimate for the larger sample to prevent this downward bias. The median first side test result for passenger vehicles below 6,000 lbs. GVWR in 1-sided tests was 2.76 compared to 2.60 for vehicles in 2-sided tests. The median maximum SWR for passenger vehicles below 6,000 lbs. GVWR in 1-sided test was 2.63 compared to an estimated 2.41 for vehicles in 2-sided tests. For vehicles over 6,000 lbs. GVWR, the median first side test result in 1-

Figures 1 and 2 illustrate the first and second side test results for the respective samples of vehicles that were tested on each side. Figure 1 contains the first side test results for vehicles tested under both 1-sided and 2-sided tests. Figure 2 shows the second side test results for vehicles that were tested on both sides. Figure 3 illustrates the shift caused by second sided testing in the vehicles tested on 2 sides. Figure 4 shows the estimated impact of second sided tests on vehicles that were only tested on one side. All of the results illustrated in the above figures have been adjusted for each vehicle's maximum weight configuration.



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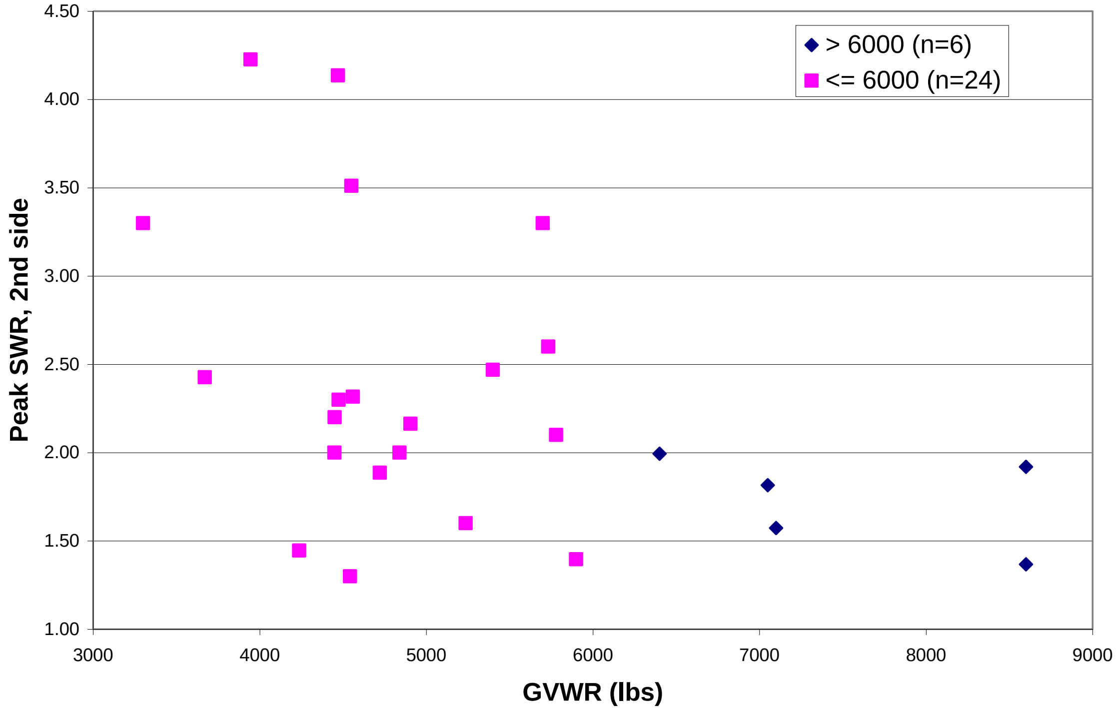
sided tests was 2.37 compared to 2.30 for vehicles in 2-sided tests. The median <u>maximum</u> SWR for these larger sides in

Figure 2
2nd Side Peak SWR for Maximum Vehicle Weight



1-sided tests was 2.15 compared to an estimated 1.57 for vehicles in 2-sided tests.

Figure 3

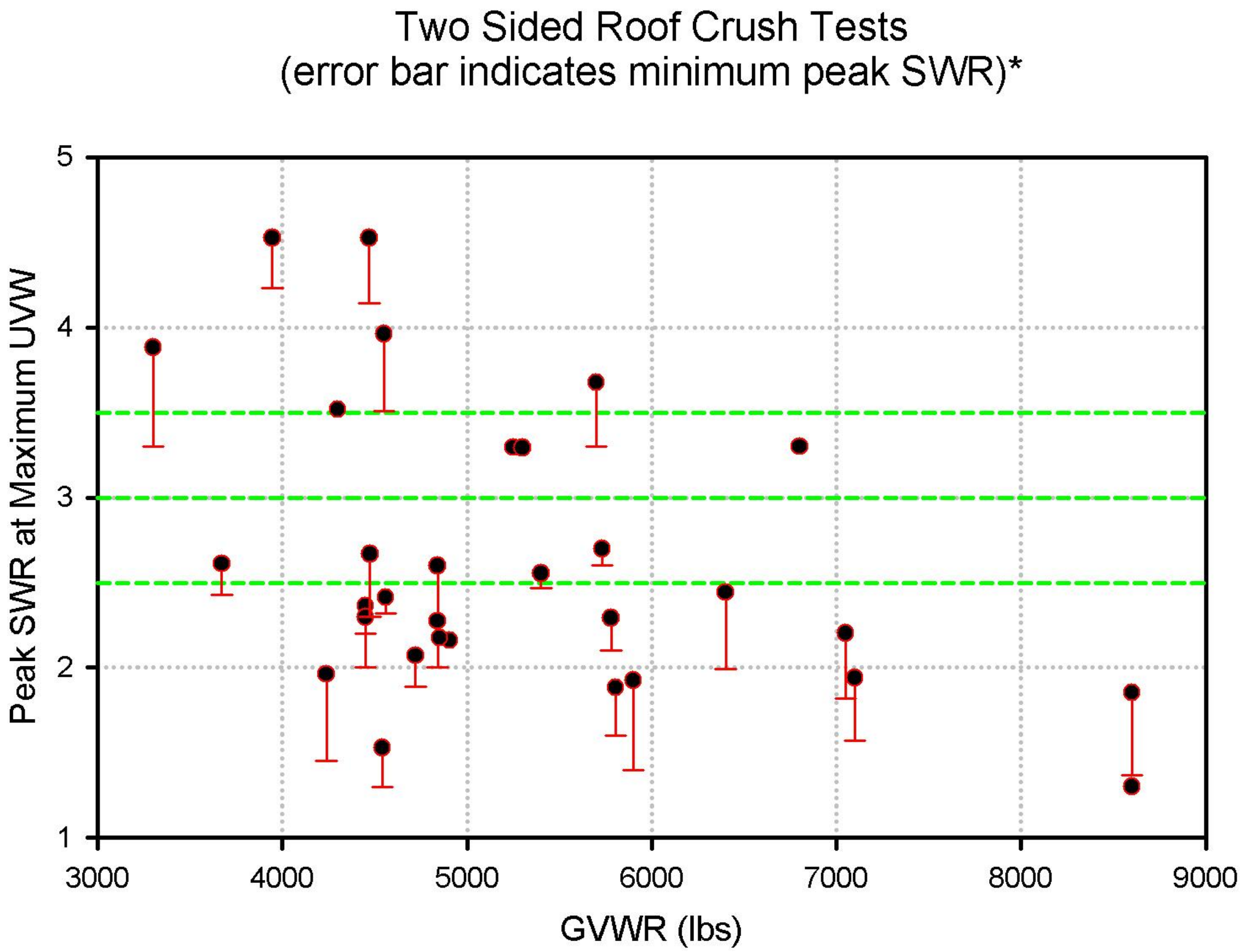
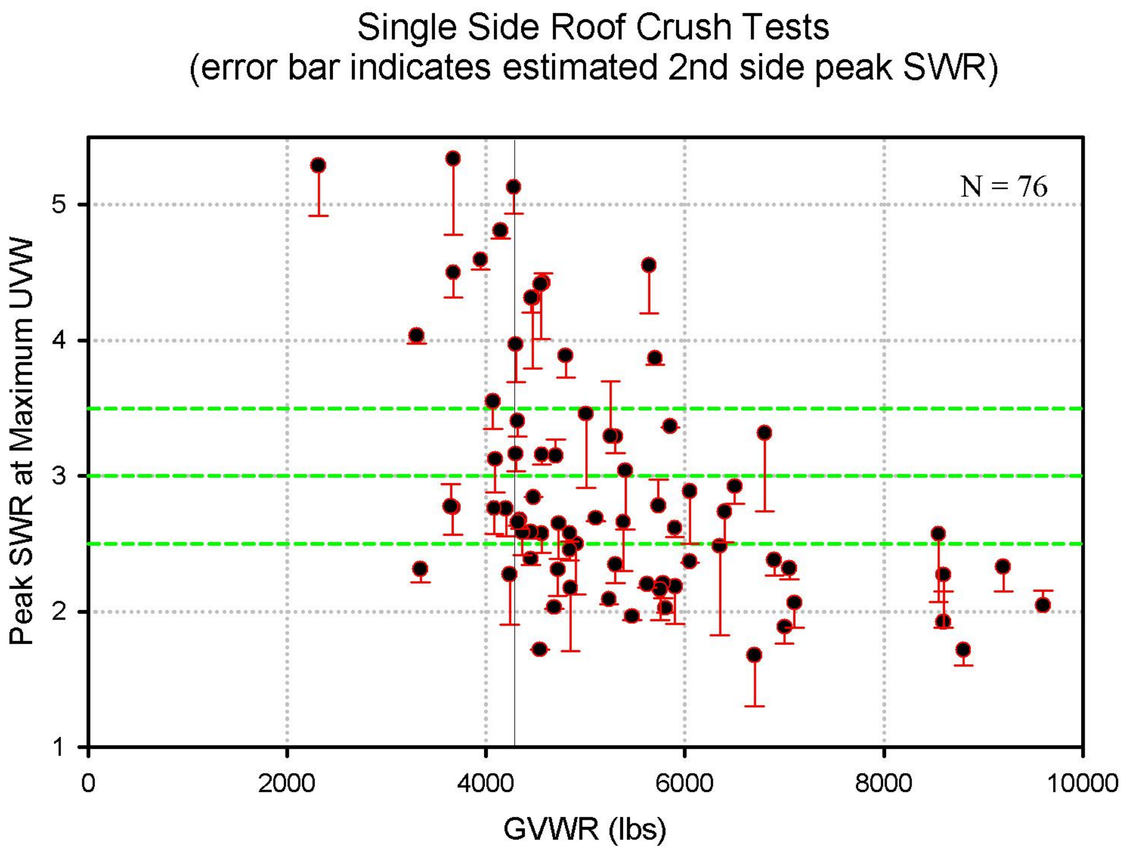

Two Sided Roof Crush Tests
(error bar indicates minimum peak SWR)*
Peak SWR at Maximum UVW
GVWR (lbs)
5
4
3
2
1
3000
4000
5000
6000
7000
8000
9000

Figure 4


Single Side Roof Crush Tests
(error bar indicates estimated 2nd side peak SWR)
N = 76
Peak SWR at Maximum UVW
GVWR (lbs)
1
2
3
4
5
0
2000
4000
6000
8000
10000

III. ALTERNATIVES

A. Alternatives

The agency considered upgrading the present roof crush resistance requirement in FMVSS 216 of 1.5 times the vehicle's unloaded weight to a higher level of 2.5, 3.0, or 3.5 times the vehicle weight. In addition, the agency considered establishing a new standard for vehicles > 6,000 lbs. GVWR at levels of 1.5, 2.0, 2.5, 3.0, and 3.5. All alternatives include the additional requirement that no roof component can touch the head of a 50th percentile Hybrid III dummy when seated in the driver or front passenger seat. In addition, the agency examined both single sided and two sided testing requirements. The five SWR alternatives and testing requirements are discussed below:

B. 1.5 and 2.0 Times Vehicle Weight Alternatives

As observed in Tables II 1-4 there are very few vehicles that would not pass a roof crush resistance of 2.0 times the vehicle's weight when tested using an extended FMVSS 216 procedure. The agency believes only increasing the roof crush resistance to a factor of 2.0 times the vehicle's weight or lower for vehicles under 6,000 lbs. GVWR would accomplish very little, and the corresponding benefits would be equally inconsequential. Thus, the agency is not pursuing a 1.5 or 2.0 times the vehicle's weight requirement for vehicles under 6,000 lbs. GVWR, but will examine and consider the higher 2.5, 3.0, and 3.5 alternatives. For vehicles over 6,000 lbs. GVWR, Table II-5 indicates that there are a number of vehicles that do not pass 2.0 or 1.5 SWRs. These vehicles are currently not covered by FMVSS 216 and their added weight makes compliance more costly. Moreover, they have a relatively small target population from which to draw safety benefits (see Chapter IV). Thus, the agency will consider both 2.0 and 1.5 SWRs for vehicles >6,000 lbs. GVWR.

C. 2.5 Times Vehicle Weight Alternative

From Table II-5, an estimated 69- 72% of tested vehicles would not pass a roof crush resistance of 2.5 times the vehicle's weight when tested using an extended FMVSS 216 procedure. The resulting benefits and costs that correspond to these test results relative to a roof crush resistance requirement of 2.5 times the vehicle's weight are discussed in Chapters IV and V, respectively.

D. 3.0 Times Vehicle Weight Alternative

From Table II-5, an estimated 81- 87% of tested vehicles would not pass a roof crush resistance of 3.0 times the vehicle's weight when tested using an extended FMVSS 216 procedure. The resulting benefits and costs that correspond to these test results relative to a roof crush resistance requirement of 3.0 times the vehicle's weight are discussed in Chapters IV and V respectively.

E. 3.5 Times Vehicle Weight Alternative

From Table II-5, an estimated 91-97% of tested vehicles would not pass a roof crush resistance of 3.5 times the vehicle's weight when tested using an extended FMVSS 216 procedure. The resulting benefits and costs that correspond to these test results relative to a roof crush resistance requirement of 3.5 times the vehicle's weight are discussed in Chapters IV and V respectively.

F. Single Sided and 2-Sided Tests

Under the current version of FMVSS No. 216, vehicles must meet the standard's requirements for both the driver and passenger sides of the vehicle. Thus, roof crush resistance protection is required for both the driver and passenger sides of the vehicle. The standard specifies a single-sided test. While a vehicle must meet the standard's test requirements regardless of whether it is tested on the driver or passenger side, a particular vehicle is tested on only one side.

As discussed in the NPRM, a number of commenters on our 2001 RFC suggested that the agency specify a two-sided test requirement, i.e., a requirement that vehicles must meet the standard's test requirements when tested sequentially on each side of the vehicle, one side after the other. Commenters making this recommendation included Public Citizen and the Center for Injury Research. The commenters stated that vehicle occupants on the far side of the rollover have a much greater risk of serious injury than occupants on the near side,[10] and argued that a two-sided requirement is needed to protect far side occupants.

In the NPRM, the agency summarized six two-sided tests it had conducted in light of those comments. The testing sought to evaluate the strength of the second side of the roof of vehicles whose first side had already been tested. In this testing, after the force was applied to one side of the roof over the front seat area of a vehicle, the vehicle was repositioned and force was then applied on the opposite side of the roof over the front seat area. In performing these tests on both sides of a vehicle, the agency used the platen angle currently specified in FMVSS No. 216 (5 degree pitch forward and 25 degree rotation outward, along its lateral axis). We concluded that the strength of the roof on the second side of some vehicles may have been increased or decreased as a result of the deformation of the first side of the roof. The agency indicated that it planned to conduct further research before proposing rulemaking in this area.

In commenting on the NPRM, a number of consumer advocacy organizations and other commenters strongly supported a two-sided test requirement. These commenters included, among others, Public Citizen, the Center for Injury Research, the Center for Auto Safety, and Advocates. Supporters of a two-sided requirement argued that more damage occurs to the far (or trailing) side of the vehicle in a rollover crash, and a two-sided test would better reflect this real-world intrusion. They further argued that when the near side roof and windshield are compromised in a rollover, the far side will not be able to withstand the forces of the event, and, consequently, facilitate roof collapse. ARCCA, Consumers Union, and SAFE suggested a two-sided test would simulate the impact that occurs in the majority of rollover incidents.

In light of the substantial interest in a two-sided test requirement, NHTSA expanded the series of two-sided roof crush tests discussed in the NPRM. In our January 2008 SNPRM, we explained that we had, by that time, conducted a total of 26 sequential two-sided tests, and that we were releasing these data to the public in conjunction with the SNPRM.

In the SNPRM it was noted that that the two-sided test results showed the first side test generally produces a weakening of the structure. This was shown by the fact that the recorded SWR for the second side was generally lower than for the first side. On average, the peak strength for the second side was reduced by 8.7 percent. However, for several of the vehicles, we observed considerably higher reductions in peak strength. Of the 25 vehicles tested, excluding the Chevrolet Express,[11] six experienced reductions in strength of 19 percent or greater.

With respect to two-sided vehicle testing, we stated that we believed that the post-NPRM tests provided the agency with sufficient additional information for the agency to consider a two-sided test requirement for the final rule. We stated that we would evaluate both the single-sided and two-sided testing alternatives for the final rule, and requested comments to help us reach a decision on that issue.

Comments

In commenting on the SNPRM, a number of consumer advocacy organizations continued to strongly support a two-sided test requirement. Public Citizen stated that in a vast majority of rollover cases, the injured party was typically seated on the far side, that is, the side of the second impact. It argued that it is

[10] Near side is the side toward which the vehicle begins to roll and far side is the trailing side of the roll.

[11] Between the first and second side tests, the front door on the tested side was opened. Because of damage to the vehicle during the first side test, the door would not properly close. The door was clamped until the latch engaged, locking the door in place. This may have compromised the structural integrity of the roof and reduced the measured peak load on the second side.

not possible to upgrade FMVSS No. 216 without a two-sided test requirement. Some commenters argued, as they had in commenting on the NPRM, that they believe SAFETEA-LU requires a two-sided test.

IIHS stated that while it supports any changes that would increase the level of roof strength of the vehicle fleet, it has no real-world data to address the potential benefits of two-sided testing. It stated that a single-sided test with a higher SWR may be more effective at promoting robust roof designs than a two-sided test with a lower SWR requirement.

The Alliance stated that it believes the agency has provided insufficient justification for two-sided testing. It stated that the agency has not provided analysis demonstrating that two-sided testing relates to real-world safety. The Alliance also expressed concern that two-sided testing would amplify variability and repeatability problems. That organization argued that the agency's limited repeatability testing for a potential two-sided requirement indicates poor repeatability in SWR between the first and second side tests for the same vehicle. The Alliance cited tests of the Lincoln LS and Buick LaCrosse.

According to the Alliance, these differences may be due solely to lack of test procedure repeatability and test lab reproducibility, rather than any real weakening or strengthening of the roof structure due to the first side test. That commenter stated that in a two-sided scenario, the deformed shape of a vehicle tested for roof strength on one side between any two tests is not identical. The starting point for the roof-strength testing on the second is therefore, according to the Alliance, inherently different and results in substantial variability in measured roof strength.

AIAM stated that based on the information and analysis provided by the agency regarding the two-sided test, it believes that the test shows enough potential to merit further consideration by the agency. AIAM argued that additional analysis would be needed before it could provide a preferred regulatory approach, but indicated that the two-sided approach would more directly address the multiple roof contact weakening phenomenon.

Agency Response

To help evaluate the merits of a two-sided test requirement, the agency analyzed 1997 through 2006 NASS-CDS rollover crash data, involving restrained occupants.[12] Only vehicles that overturned and experienced 2 or more quarter turns were included. This study excluded convertibles and vehicles that had a fixed object collision between a pole or tree and the roof. This study included 4,030 NASS-CDS investigated vehicles.

The data were analyzed for differences in injury risk for the near and far side occupants and also to ascertain any disparity in the amount of roof intrusion. For all rollovers involving two or more quarter turns, the data showed that there are a similar number of near and far side occupants involved in the event. A further review of the injury outcomes showed that the number of far side injured occupants occurs at a slightly higher frequency when compared to the near side.

The occupant injury data were further analyzed to determine whether the relative proportion of near and far side injured occupants varied with the amount of roof intrusion. The injury outcomes for occupants in vehicles with less than 12 cm (5 inches) of near side roof intrusion show higher frequency of injury for the far side occupant at the various injury levels. The outcomes for injured occupants in vehicles with 13 cm (5 inches) or greater near side intrusion have similar percentages of severe injuries between near and far occupants. Based on this analysis, the data indicate there may be some higher risk for far side occupants at lower levels of intrusion; however none of the results were statistically significant.

The analysis investigated the difference in roof intrusion between the near and far side of the vehicle that experienced two quarter turns or more. For the 4,030 NASS-CDS vehicles, there was a weighted average maximum vertical intrusion of 7.9 cm (3.1 inches) on the near side and 10.9 cm (4.3 inches) on the far side of the rollover-involved vehicle. The far side of the vehicle averaged 3 cm (1.2 inches) more vertical intrusion than the near side.

The analysis also investigated the intrusion difference between the near and far side grouped by the severity of the rollover. (Severity of the rollover was defined by single or multiple roof-to-ground exposures). The data showed a 3 cm (1.2 inch) bias toward the far side intrusion, independent of the severity of the rollover. For example, vehicles experiencing five or more quarter turns had 9.2 cm (3.6 inches) of near-side intrusion compared to 12.2 cm (4.8 inches) of far-side intrusion. The analysis concluded for crashes with multiple roof-to-ground exposures (or severe rollovers), there is a more intrusion on the far side.

Since the publication of the SNPRM, the agency has conducted an additional six tests for a total of 32 two-sided tests. On average, the peak strength for the second side was reduced by 8.4 percent. This reduction in strength is consistent with our NASS-CDS analysis, showing a slight increase of intrusion on the second side. This also may explain the increased risk to injury for far side occupants. In all the tests, the windshield fractured during the first side test and there was not a catastrophic collapse of the roof on the second side.

In general, there was a good correlation in peak strength between the first and second side. The agency did test five vehicles that resulted in increased strength on the second side. However, for several of the vehicles, we observed considerably higher reductions in peak strength. Of the 32 vehicles tested, excluding the Chevrolet Express, six experienced reductions in strength of 19 percent or greater. The two-sided testing conducted by NHTSA indicated an average difference of approximately 7 percent lower peak force for the second side in vehicles under 2,722 kilograms (6,000 pounds) GVWR and 15 percent lower peak

[12] "Evaluation of 2 Side Roof Crush Testing"

force for the second side in vehicles over 2,722 kilograms (6,000 pounds) GVWR. Both single- sided and 2-sided test requirements are analyzed in this analysis.

IV. BENEFITS

A. Effectiveness of Increased Roof Strength

Although a significant level of roof crush frequently occurs in rollover crashes, previous efforts to link roof crush to occupant injury have yielded mixed results. Bahling[13] compared dummy neck loadings in production vehicles to rollcaged vehicles and found that neck loads resulted from “diving” impacts where the torso momentum compresses the neck against the vehicle interior. They also concluded that the reduction in roof deformation in the rollcaged vehicle had no effect in reducing neck loads in the area of ground impact. In an early study, Huelke[14] concluded that no statistical relationship exists between the Abbreviated Injury Scale (AIS) and roof crush for restrained occupants in rollovers. Likewise, MacKay[15] used field accident investigations to conclude that seat belts did not reduce head injuries in rollovers. By contrast, Huelke[16] concluded that fatality rates were lower for belted occupants, but primarily due to ejection mitigation. In another early study Partyka[17], found that data in the National Crash Severity Study (NCSS) were too sparse to draw conclusions. In a more recent study of NASS-CDS data, Partyka[18] was unable to ascertain the significance of roof intrusion on injuries in rollover crashes because of concerns that roof intrusion might be a surrogate for crash severity rather than a single cause of injury, and that data was not available for non-injury contacts. Rains and Kanianthra[19] analyzed NASS-CDS data and found indications that head injury increases with reductions in head room, but also found trends indicating higher risk of head injury with headroom reduction.

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[13] Bahling G.S., R.T. Bunford, G.S. Kaspzyk, E.A. Moffat, K.F. Orlowaki, and J.E. Stocke, “Rollover and Drop Tests – The Influence of Roof Strength on Injury Mechanics Using Belted Dummies,” SAE Paper 902314, Society of Automotive Engineers, Warrendale, PA, 1990.
[14] Huelke, D.F., J.C. Marsh, and H.W. Sherman, “Analysis of Rollover Accident Factors and Injury Causation,” 16th Conference of the American Association of Automotive Medicine, 1972.
[15] MacKay, G.M. and I.D. Tampan, “Field Studies of Rollover Performance”, SAE 700417, 1970 International Automobile Safety Conference Compendium, P-30, Society of Automotive Engineers, 1970.
[16] Huelke, D.F., T.E. Lawson, R. Scott, J.C. Marsh, “The Effectiveness of Belt Systems in Frontal and Rollover Crashes.” SAE 770148, 1977.
[17] Partyka, S. “Rollovers and Injury on the NCSS File.” NHTSA, 1978
[18] Partyka, S.C. “Roof Intrusion and Occupant Injury in Light Passenger Vehicle Towaway Crashes.” Office of Vehicle Safety Standards, National Highway Traffic Safety Administration, Washington D.C., 1992.
[19] Rains, G.C. and J.M. Kanianthra, “Determination of the Significance of Roof Crush on Head and Neck Injury to Passenger Vehicle Occupants in Rollover Crashes, SAE 950655, Detroit Michigan, 1995.

These previous efforts compared injury rates to factors such as roof strength and pre-crash headroom. However, a 2003 NHTSA analysis, which examined the relationship between injury and post crash headroom (Austin et al)[20] found a statistically significant relationship between injury rates and roof crush based on roof contact with the occupant's head. The injury pattern was noticeably different (less serious) in cases where roof intrusion did not exceed the pre-crash headroom of the occupant – in other words, when the deformed structure did not intrude below the occupant's head. The initial Austin et al study examined all rollover non-ejected, belted cases of head injury regardless of other injuries that the occupant incurred, whether they were caused by intrusion or not. However, the changes required by the proposal in NHTSA's August 2005 NPRM were limited to specific test loads. Many crashes are essentially catastrophic in nature – they impart stress loads on the vehicle's roof that would overwhelm even the increased strength required by an upgraded test procedure.

In the PRIA, to accommodate this approach, the Austin analysis was re-run with a more specific set of restrictions – i.e., belted non-ejected[21] rollover fatalities or injuries <u>with vertical intrusion over the injured occupant's seat</u>, <u>where the injury was caused by roof contact</u> and <u>the injury is the single maximum level injury experienced by the occupant</u>.[22] Unbelted occupants were not considered because in a rollover without restraints they will essentially become moving objects within the vehicle and tying their injuries to vehicle crush (as opposed to their own movement) is problematic. The restriction to vertical intrusion over the occupant's seat was necessary to establish cause and effect. The restriction to sole maximum injury level was made because if an occupant has multiple injuries at the same maximum level, they would still be injured at that level even if the intrusion-caused injury were eliminated. However, NHTSA recognizes that this might still improve the injured occupant's outcome, and thus this approach gives a conservative

[20] Austin, Rory, Hicks, Maurice, Summers, Stephen, "The Role of Post-Crash Headroom in Predicting Roof Contact Injuries to the Head, Neck, or Face During FMVSS 216 Rollovers", NHTSA, 2003, Docket No. 2005-22143-52.
[21] Complete ejections were excluded. Partial ejections were included.

estimate of safety benefits.

In the PRIA, the agency estimated benefits based on post-crash headroom, the only basis for which a statistical relationship with injury reduction had been established at that time. In that analysis, the agency estimated that the proposed 2.5 SWR requirement would prevent 13 to 44 fatalities.[23]

More recently, the agency has estimated benefits based on the relationship between intrusion and the probability of injury. This relationship was not established when the NPRM was published, but with additional years of data available, a statistically significant relationship between intrusion and injury for belted occupants has since been established. A study regarding this relationship has been peer reviewed and was placed in the docket concurrent with the publication of the SNPRM.[24] The agency also examined unbelted occupants but there was no statistically significant relationship between intrusion and injury for these occupants. This broader relationship will be used in this analysis to estimate benefits from increased roof strength.

B. Target Population

The stated purpose of FMVSS 216 is to "reduce deaths and injuries due to the crushing of the roof into the occupant compartment." This rationale, as well as the test procedure itself, suggest that the standard does not apply to all injured occupants of rollover crashes. Rather, it covers a more narrow set of injuries. Therefore, the target population, defined as occupants who are likely to benefit from a stronger roof due to an upgrade of FMVSS 216, is a subset of all occupants injured during a rollover. This section first explains the procedure for determining the target population. The section then describes the calculation of the

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[22] For fatalities the restriction was only that the fatal injury be at the maximum level, but not necessarily the single injury at the level. See more detailed discussion under "Target Populations".

[23] This range reflects 2 different methodologies that were examined.

[24] Strashny, Alexander, "The Role of Vertical Roof Intrusion and Post-Crash Headroom in Predicting Roof Contact Injuries to the Head, Neck, or Face during FMVSS 216 Rollovers: An Updated Analysis, October 2007, DOT HS 810847.

population that may benefit from one of the two proposed upgrades.

The target population estimates are based on results from NASS-CDS from 1997 through 2006. The beginning year, 1997, is when NASS-CDS first recorded the exact magnitude of intrusion. At the time of this analysis, 2006 is the most recent year available. The vehicles considered for the benefit calculations are non-convertible light duty vehicles (NASS-CDS body type 2 through 49) with a roof-involved rollover that might be mitigated by the requirements of this rulemaking Vehicles that rolled only one-quarter turn to the side were excluded because they did not experience a roof-to-ground contact consistent with the test procedure. Any damage to roof components from such crashes would be due to lateral rather than vertical intrusion. Vehicles that experienced a collision with a fixed object (other than a bush, embankment, ditch, culvert, or the ground) to the top of the vehicle were also excluded. These vehicles, which typically struck trees, poles, or bridge abutments, experienced a more concentrated force than would occur solely with a ground contact and are unlikely to benefit from the levels of roof strength anticipated in this rulemaking. Most of these cases involve catastrophic intrusion. However, the Agency examined all cases excluded due to collision with a fixed object and found 2 cases where damage was minimal and the occupants might have benefited from stronger roofs. These 2 cases were included in the target population.

The occupants counted for benefits calculations were not fully ejected, belted, and seated in an outboard seat of the vehicles described above. Based on data from 1997-2001 NASS-CDS we determined that an estimated 77 percent of the seriously and fatally injured with known serious injuries who were fully ejected in roof-involved rollovers received their most severe injury from outside of the vehicle and another estimated 3 percent received injuries of equal severity from both outside and inside the vehicle. Consequently, it appears that preventing ejection is the most important means for reducing injury to fully ejected rollover occupants.

A number of commenters argued that ejections should be included in the target population. The Center for

Auto Safety (CAS) and Advocates for Highway and Auto Safety (AHAS) argued that improving roof strength would impact ejection and that mitigated ejections should therefore be included in the agencies benefit calculations. AHAS also argued that rear seat occupants should be covered by the revised standard. SAFE argued that roof crush increases the likelihood of glass fracture and deforms vehicle structure, thereby increasing the possibility of ejection. They also argue that roof crush reduces the effectiveness of restraint systems, decreases the effectiveness of rollover air curtains, and decreases the ability of occupants to be extricated from the vehicle. Xprts,LLC (XPRTS) disagreed with several of NHTSA's target population restrictions. They stated that ejected occupants, rear seat occupants, and children under 12 should be included. They also argue that roof crush can cause thoracic and spinal injuries, and that upper extremity injuries from ejection through side windows should also be included. Many of these points were repeated in a separate submission by the Center for Injury Research (CIR) signed by one of the XPRT authors. Consumers Union (CU) and Public Citizen (PC) also argued that stronger roofs would reduce ejections and better maintain the performance of other safety features such as safety belts, air bags, and door locks. PC also argued that unbelted occupants would benefit from stronger roofs.

In response, the agency has conducted several analyses of ejections in rollovers. The first study was a statistical analysis examining the relationship between intrusion and ejection. In this study,[25] Strashny examined 36 different probit models examining belted cases, unbelted cases, complete ejections, all ejections (including both complete and partial ejection), continuous models, dichotomous models, adjusted models based on both quarter turns and roof exposures, as well as unadjusted models. In all, there were 18 models for complete ejections and 18 for all ejections. Strashny found that there was no statistically significant relationship between the amount of intrusion and the probability of complete ejection in any of the 18 full ejection models. For all ejections, which include partial ejections, he found some level of statistical significance for 8 of the 18 models, indicating that a minority of the models found a possibility that some

[25] Strashny, Alexander, "The Role of Vertical Roof Intrusion in Predicting Occupant Ejection", National Center for Statistics and Analysis.

partial ejections might be influenced by stronger roofs. However, 10 of the models found no statistically significant relationship between intrusion and all ejections. We note that partial ejections that meet the other inclusion criteria are a part of the target population for this rulemaking. We also note that no cases of full ejection meet the other criteria.

The Agency then conducted a detailed examination of all fatal complete ejection cases that were excluded from the target population. A panel of 3 safety engineers independently examined each case to determine whether a) for ejections through open doors there was deformation in the door latch area where the root cause could be directly attributed to roof crush, and b) for ejections through windows the broken glass through which the occupant was ejected was directly related to deformation of the roof rather than dynamic crash impulse or roof to ground contact. The panel concluded that there were no cases that met either of these criteria. Therefore, based on these findings and Strashny's finding of no correlation between intrusion and ejection probability, all cases of total ejection were excluded from the target population.

For occupants who were unbelted but not fully ejected, we could not establish a relationship between roof crush injuries and the magnitude of roof crush. Strashny analyzed the relationship between intrusion and injuries to unbelted occupants and found no significant correlation. This is not unexpected because unbelted occupants essentially become flying objects inside vehicles as they roll over and head injuries can occur at multiple interior locations. Therefore, only belted occupants are included in the target population.

The test itself measures roof strength over front outboard seats. However, most of the design changes to meet higher SWRs that were submitted by manufacturers or estimated in NHTSA's finite element models involve changes to the B-pillars, which would increase protection for rear seat occupants as well. Therefore, rear seat occupants will be included in the target population.

Occupants for whom injury severity was unknown and fatalities without injury information were excluded from the analysis, but the sample weights were adjusted to reflect the estimated total number of occupants at each injury level. Also, fatalities were adjusted to reflect the average number of non-convertible light vehicle rollover fatalities in Fatality Analysis Reporting System (FARS) from 1997 through 2006. Finally, the occupants in the target population had vertical intrusion of a roof component over their seating position, where a roof component includes the roof itself, roof side rails, front (windshield) and back (backlight) headers, A and B pillars, the sun visor, as well as any roof console, sunroof components, or roll-bar. This criterion ensures that affected occupants were exposed to roof crush. Finally, the occupant had to experience a relevant injury, which is defined as a head, face, or neck injury from a vertically intruding roof component into the occupant's seating position. We also explored intrusion that was over the front middle seating position and lateral and longitudinal intrusion, but relaxing these assumptions did not change the results.

Table IV-1 demonstrates how each of the above restrictions reduces the injured population affected by roof crush relevant to FMVSS 216. The restrictions that matter the most appear to differ by the severity of injury. For serious injuries and fatalities, large drops occur when excluding fully ejected occupants. A second large drop occurs when excluding the unbelted who were not fully ejected. For minor and moderate injuries, large drops occur when excluding the unbelted. All four of the injury categories also experienced significant drops when excluding vehicles with no vertical intrusion of a roof component and when requiring that the occupant have a relevant injury. Finally, not all occupants with a relevant injury are applicable for benefits purposes. For survivors, only injured occupants where the relevant roof crush injury was the sole maximum severity (AIS) injury are included in the calculation of safety benefits lives saved. For fatalities, only those occupants for whom the relevant roof crush injury was either the sole maximum severity injury or one of the most severe injuries are counted for lives saved. This approach reflects the fact that eliminating one of two or more injuries of identical severity would not change the status of the occupant – they would still be injured at the same severity level. However, an analysis of head-injured fatality cases indicated that when 2 or more injuries of the same MAIS level occur to different body regions, the cause of death is the head injury in 2/3 of the cases. Therefore, for fatalities, both sole MAIS injury cases and 2/3 of those cases with a head injury at MAIS that were not the sole MAIS were considered to be relevant injuries.

Table IV-1

Defining the Population Affected by FMVSS 216 Relevant Roof Crush

All vehicles	AIS 1	AIS 2	AIS 3-5	Fatalities
Non-Convertible Light Vehicles in Rollovers	199,822	37,305	21,673	10,150
Roof-Involved Rollover	164,213	32,959	19,262	8,645
Some Fixed Object Collision on Top	153,520	29,419	17,766	7,559
Not Totally Ejected	149,850	26,033	12,355	3,654
Using Safety Restraints	116,670	14,327	8,970	2,096
Outboard seats	115,018	14,241	8,781	2,096
Roof Component Intrusion	68,730	10,922	6,842	1,444
Head, Neck, or Face Injury from Intruding Roof Component	24,035	6,580	2,993	957
Injury - Not MAIS	0	-1,900	-1,252	-237
Injury at MAIS - Not Sole Injury	-17,818	-292	-253	-53
Sole MAIS Injury	**6,216**	**4,388**	**1,487**	**667**

PC & LT < 6,000 lbs	AIS 1	AIS 2	AIS 3-5	Fatalities
Non-Convertible Light Vehicles in Rollovers	172,846	33,170	18,929	8,719
Roof-Involved Rollover	144,410	29,098	17,360	7,536
Some Fixed Object Collision on Top	136,080	26,270	16,122	6,484
Not Totally Ejected	133,241	23,400	11,406	3,142
Using Safety Restraints	104,571	12,421	8,379	1,936
Outboard seats	103,249	12,373	8,190	1,936
Roof Component Intrusion	60,061	9,370	6,372	1,304
Head, Neck, or Face Injury from Intruding Roof Component	20,687	5,868	2,615	842
Injury - Not MAIS	0	-1,771	-1,119	-157
Injury at MAIS - Not Sole Injury	-16,082	-262	-212	-50
Sole MAIS Injury	**4,605**	**3,835**	**1,283**	**635**

LT > 6,000 lbs	AIS 1	AIS 2	AIS 3-5	Fatalities
Non-Convertible Light Vehicles in Rollovers	26,975	4,135	2,744	1,431
Roof-Involved Rollover	19,803	3,861	1,902	1,110
Some Fixed Object Collision on Top	17,440	3,149	1,644	1,075
Not Totally Ejected	16,608	2,634	949	511
Using Safety Restraints	12,099	1,906	591	160
Outboard seats	11,770	1,868	591	160
Roof Component Intrusion	8,669	1,552	471	140
Head, Neck, or Face Injury from Intruding Roof Component	3,348	712	378	116

Injury - Not MAIS	0	-128	-133	-80
Injury at MAIS - Not Sole Injury	-1,736	-31	-40	-3
Sole MAIS Injury	**1,611**	**553**	**205**	**33**

Note: The relevant target population is in **bold**.

The target population relevant to FMVSS 216 (the bold numbers in Table IV-2 is thus a relatively small subset of the occupants injured in rollovers. For fatalities, the estimated total for the target population is 7 percent of all non-convertible light vehicle rollover fatalities (667/10,150). For minor injuries, the estimated total is closer to 1 percent and for serious injuries (MAIS 3-5) it is about 7 percent. There is an apparent jump in the moderate injury category (MAIS2) where the target population is an estimated 12 percent of the total population, but this estimate is due in large part to two NASS-CDS cases with a combined annual weight of over 3,200.

The difference between the target population for vehicles over 6,000 lbs. GVWR and those under 6,000 lbs. GVWR is significant. Only 5% of fatalities in the overall target population occur in vehicles over 6,000 lbs. GVWR. Ninety-five percent of fatalities occur in vehicles under 6,000 lbs. GVWR. For serious nonfatal injuries, the larger vehicles make up roughly 12%, and for minor injuries, they make up about 20% of the target population. These discrepancies reflect fewer vehicles in this category in the on-road fleet, and may also reflect the vehicles size as well as their frequency of use as working vehicles. Heavier vehicles are less likely to roll over and vehicles in use at job sites may be less likely to be driven at high speeds or under the influence of alcohol.

C. Approach and Methodology

There are two basic pass/fail criteria in the proposal. Vehicles will be tested using a standard plate mounted at an angle that simulates vehicle-to-ground contact over the front seat area. The plate will be pushed into the roof until a force equal to the specified SWR multiplied by the vehicle's weight is attained. One side of the roof is tested, then the process is repeated on the other side. During this procedure, the SWR must be attained prior to the roof making head contact with a headform positioned to represent a 50th percentile male occupant, or have a maximum of 50 inches of plate travel, whichever comes first.

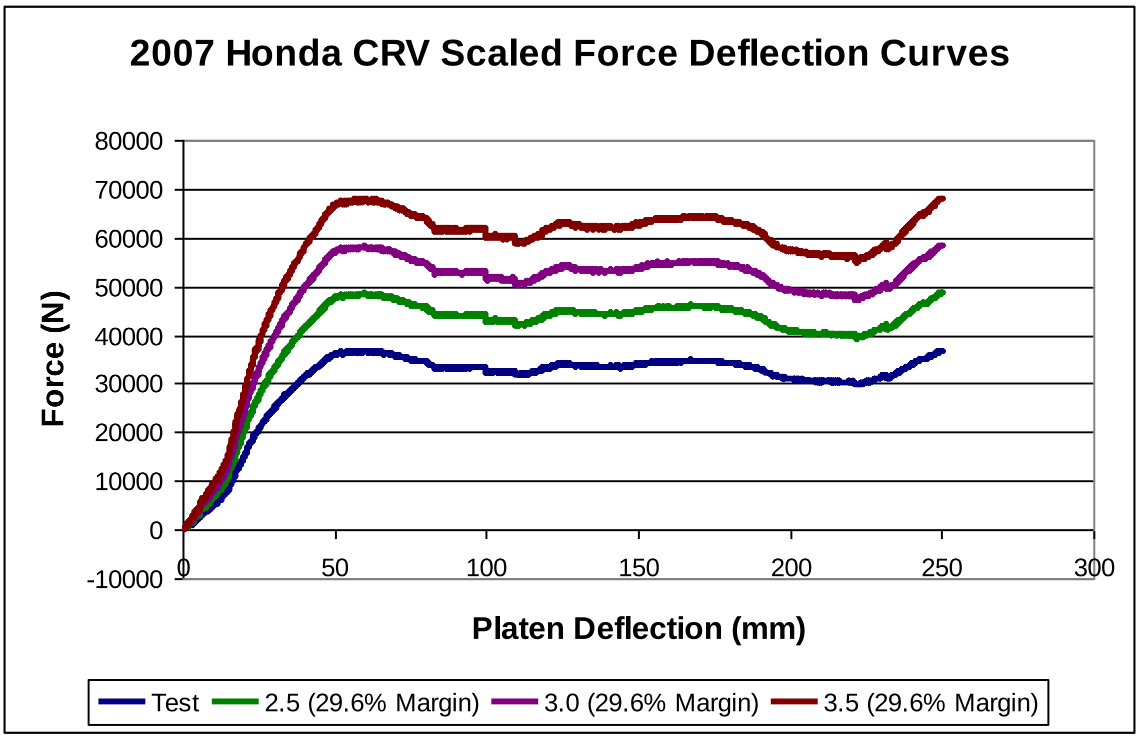
SWR Impact Models

To estimate the impact that the proposed test requirements would have on roof intrusion, NHTSA examined the force deflection curves from a series of 76 quasi-static vehicle tests conducted to determine their performance under conditions that lead to roof crush. These tests were conducted over several minutes and produced about 900 separate data points to define the base deflection curves. The tests are further described in Chapter II, Agency Research and Test Results. An example of these curves (based on the 2007 Honda CRV), which plot the displacement of the roof plate used in the test to the force applied (measured as a percent of vehicle weight), is shown for the second side test (labeled "test") in Figure IV-A. The vehicles tested were designed to meet current testing standards, which specify a force of 1.5 times the vehicles' weight, although they typically exceed that level. In order to estimate vehicle behavior at the higher levels being proposed, NHTSA derived an adjustment factor by comparing the peak vehicle load experienced prior to estimated head contact or 5 inches platen travel[26] with the load that would be required under the proposal. This was done for the 17 vehicles below 6,000 lbs. GVWR that failed to achieve the proposed 3.0 force level and the 19 vehicles that failed to achieve the 3.5 force level. For example, the Honda CRV experienced a peak load of 2.45 times its weight, which fails the 2.5, 3.0 and the 3.5

[26] Head contact was estimated using string pot measurements in the first series of vehicles, but dummy contact measurements with the second set of tests. See Chapter II for further discussion.

alternatives. Under the 3.0 alternative, the adjustment factor would be 1.58 (3.89/2.45)[27]. These factors were used to scale the original force deflection curves for each vehicle to levels consistent with the alternative requirements of 2.5, 3.0, and 3.5 with 20% compliance margins at maximum vehicle weight.

Figure IV-A



Manufacturers normally build a margin of safety into their vehicle designs to ensure that vehicles can pass test requirements. Table IV-2 illustrates these margins for our test vehicles. Within the 59 regulated vehicles tested on the first side, the margin by which vehicle roof strength exceeds the current standard averaged about 100 percent, and the minimum margin was 15 percent. This represents both compliance

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[27] The numerator reflects adjustments for both compliance margin (20%) and maximum vehicle weight (8%). Thus: 3.0x1.296=3.89. See discussion of compliance margin following in this section. Discussion of maximum vehicle weight adjustment can be found in Chapter II and Chapter V.

margins and voluntary strength levels in excess of the standard. Under more difficult test requirements, manufacturers may not be able or willing to maintain the high average safety margins they experience under the current standard. However, NHTSA believes it is likely that manufacturers will maintain a minimum safety margin equal to at least 20 percent. NHTSA used this assumption in its calculations for the PRIA. In comments to the docket, Safety Research & Strategies, Inc. (SRS) stated that the strength to weight ratio (SWR) need only increase an average of less than 10 percent because manufacturers already have built-in compliance margins of 20-25%. SAFE argued that in their experience the typical safety margin is 10%-15%, and in some cases is less than 5%. Public Citizen (PC) argued that NHTSA must provide evidence for its assertion that vehicles will generally over-comply with the standard.

As noted in both the PRIA and elsewhere in this FRIA, the sample of vehicles tested by NHTSA had SWRs that exceeded the requirements of FMVSS 216 by considerable margins, averaging well in excess of the 20% margin assumed by the Agency. In the course of subsequent industry meetings and docket comments, the Agency has not received any factual information contradicting this assumption. A number of manufacturers provided confidential cost and weight estimates on this basis. In at least one case, manufacturers argued that the margin might exceed 20% if 2-sided testing were required. Moreover, we note that whatever assumption NHTSA uses will affect both costs and benefits since costs will be estimated to the same level that benefits will be calculated to. We therefore examined scenarios that assume a 20 percent safety margin as well as the basic requirements.

Separate curves were thus developed for 2.5, 3.0 and 3.5 scenarios with this 20 percent safety margin. The 2.5, 3.0, and 3.5 curves in Figure IV-A were thus derived as a simple proportional relationship between the current standard and the proposed standard. For example, the peak force for the second side of the Honda CRV occurred at about 2.45x its curb weight (Table II-4) at about 36,750 N of force. Assuming manufacturers will maintain a compliance margin of 20 percent for whatever changes they make, for the 3.0 requirements, this implies they will actually strengthen it to 3.89 (3.0x1.296). We estimated that the peak force to failure at 3.0 would be proportional to the ratio of the strength requirements - in this case 1.59 (3.89/2.45). Therefore we assume that the peak force at 3.0 would be about 58,432 N. (1.59 x 36,750 N). The same proportion is applied to each point on the curve to produce the estimated scaled force deflection curve for a 3.0 requirement. The resulting curves are shown together with the baseline curve for the Honda CRV in Figure IV-A.

Table IV-2

Compliance Margin for Sample of Regulated Tested Vehicles (One-sided Tests)

Year	***Make***	***Model***	***Peak SWR in 127 mm***	***Compliance Margin***
2004	CADILLAC	SRX	2.62	1.74
2006	HUMMER	H3	3.37	2.25
2003	FORD	CROWN VICTORIA	2.02	1.35
2004	CHRYSLER	PACIFICA	2.21	1.47
2003	CHEVROLET	TRAILBLAZER	2.16	1.44
2004	NISSAN	QUEST	2.78	1.85
2006	SUBARU	TRIBECA	3.86	2.58
2006	VOLVO	XC90	4.55	3.03
2003	FORD	WINDSTAR	2.20	1.47
2003	KIA	SORENTO	1.96	1.31
2007	DODGE	CARAVAN	3.04	2.03
1997	DODGE	GRAND CARAVAN	2.66	1.77
2007	FORD	EDGE	3.29	2.19
2002	FORD	EXPLORER	2.35	1.57
2007	TOYOTA	TACOMA	3.29	2.20
2001	FORD	CROWN VICTORIA	2.09	1.39
2003	TOYOTA	TACOMA	2.69	1.79
2002	NISSAN	XTERRA	3.46	2.30
2007	CHRYSLER	300	2.50	1.66
2007	CHEVROLET	COLORADO	2.17	1.45
2004	LINCOLN	LS	2.58	1.72
2004	LINCOLN	LS	2.45	1.64
2006	FORD	FIVE HUNDRED	3.88	2.59
2001	MITSUBISHI	MONTERO	2.65	1.76
2007	BUICK	LUCERNE	2.35	1.57
2005	NISSAN	FRONTIER	3.96	2.64
2001	FORD	TAURUS	2.03	1.35
2006	MAZDA	MAZDA5	4.42	2.95
2007	HONDA	CRV	2.58	1.72

2003	CHEVROLET	IMPALA	3.15	2.10
2007	TOYOTA	TACOMA	4.41	2.94
2004	LAND ROVER	FREELANDER	1.72	1.15
2003	CHEVROLET	IMPALA	2.84	1.89
2007	TOYOTA	CAMRY	4.31	2.87
2004	HONDA	ELEMENT	4.31	2.87
2005	BUICK	LACROSSE	2.39	1.59
2005	BUICK	LACROSSE	2.59	1.72
2002	FORD	MUSTANG	2.58	1.72
2006	FORD	MUSTANG	2.68	1.78
2002	HONDA	CRV	2.66	1.77
2003	MAZDA	MAZDA6	3.40	2.27
2008	HONDA	ACCORD	3.52	2.34
2006	HYUNDAI	SONATA	3.16	2.11
2006	VOLKSWAGEN	JETTA	5.13	3.42
2007	PONTIAC	G6	2.27	1.52
1998	CHEVROLET	S-10	2.76	1.84
2003	SUBARU	FORESTER	4.81	3.20
2002	TOYOTA	CAMRY	3.12	2.08
2004	HONDA	ACCORD	2.76	1.84
2006	MITSUBISHI	ECLIPSE	3.55	2.36
2007	SCION	TC	4.62	3.08
2006	HONDA	CIVIC	4.50	3.00
2006	CHRYSLER	CROSSFIRE	2.87	1.91
2003	FORD	FOCUS	2.76	1.84
2003	CHEVROLET	CAVALIER	2.77	1.85
2003	MINI	COOPER	2.31	1.54
2007	TOYOTA	YARIS	4.03	2.69
		Average	**3.05**	**2.04**

The benefits for the alternative load requirements will be evaluated using the crush measured in NASS-CDS reported crash cases. For each crush measurement the change in static deflection between the baseline and alternative requirements, for equivalent energy absorption, will be used to estimate the change in vertical crush. Following development of these individual force deflection curves for the 17 vehicles that did not meet the 3.0 load requirement for the second side test, each curve was integrated over its full test duration to estimate the total energy experienced at each point during the test. Using these data, energy was plotted as a function of deflection. The resulting curves are shown for the example vehicle in Figure IV-B. These curves were then analyzed to produce a set of reconfigured curves that plotted the change in deflection as a function of baseline deflection. These measurements were taken from Figure IV-B relative to the baseline curve, i.e., the deflection at each point on the baseline curve in Figure IV-B was compared to the deflection on each of the alternative load requirement curves to produce a difference that is reflected on the y-axis. The resulting curves are shown for the Honda CRV in Figure IV-C. These curves describe the change that would be expected in intrusion levels for each level of base intrusion under the alternative roof strength levels. For example, for the CRV, a rollover that would cause 200 mm of intrusion with its existing roof would cause about 45 mm less intrusion if the roof were strengthened to meet a 2.5 standard, about 65 mm less intrusion in a roof that was strengthened to meet a 3.0 requirement, and about 85 mm less intrusion in a roof that was strengthened to meet a 3.5 SWR requirement.

Figure IV-B

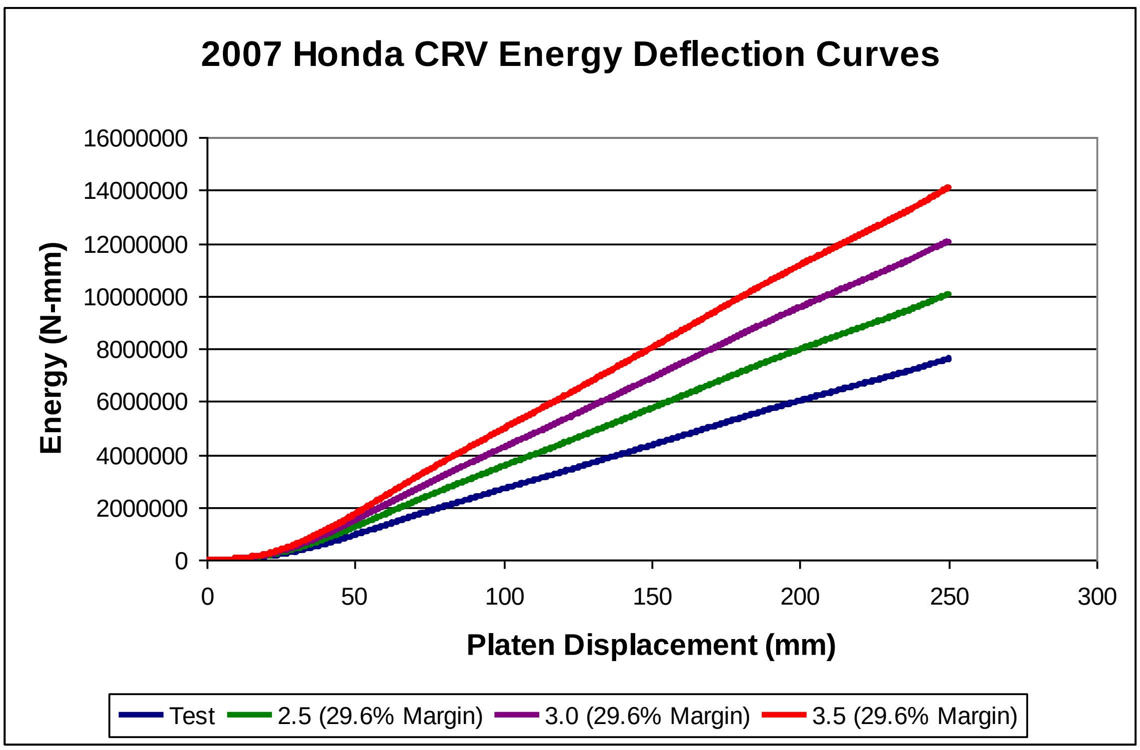


Figure IV-C

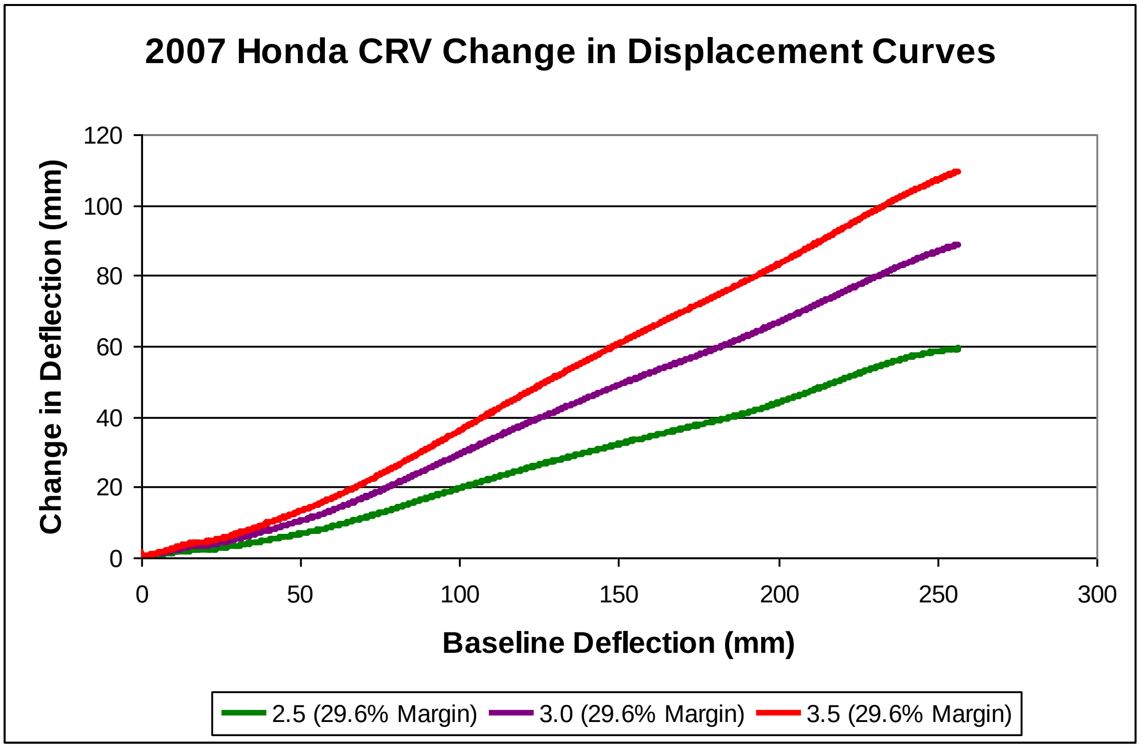
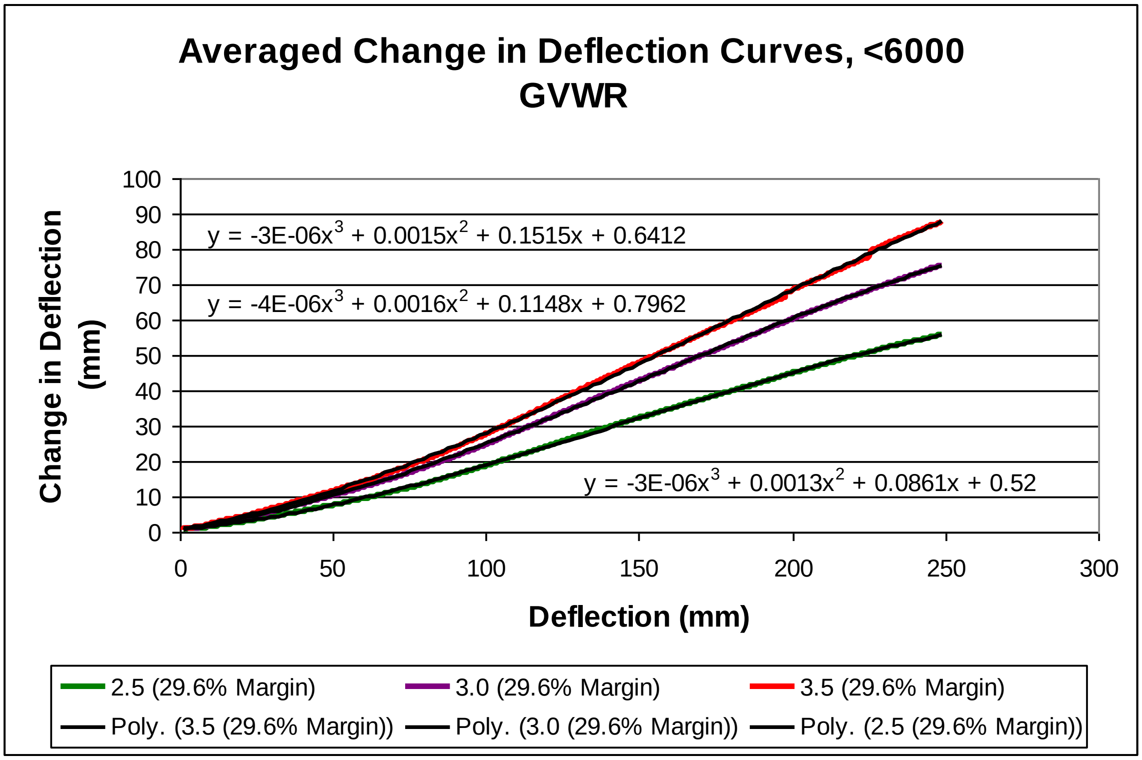

2007 Honda CRV Change in Displacement Curves
Change in Deflection (mm)
120
100
80
60
40
20
0
0
50
100
150
200
250
300
Baseline Deflection (mm)
2.5 (29.6% Margin)
3.0 (29.6% Margin)
3.5 (29.6% Margin)

Figure IV-D


Averaged Change in Deflection Curves, <6000 GVWR
y = -3E-06x3 + 0.0015x2 + 0.1515x + 0.6412
y = -4E-06x3 + 0.0016x2 + 0.1148x + 0.7962
y = -3E-06x3 + 0.0013x2 + 0.0861x + 0.52
Change in Deflection (mm)
Deflection (mm)
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
2.5 (29.6% Margin)
3.0 (29.6% Margin)
3.5 (29.6% Margin)
Poly. (3.5 (29.6% Margin))
Poly. (3.0 (29.6% Margin))
Poly. (2.5 (29.6% Margin))

The force displacement curves for all vehicles that failed a specific SWR requirement were averaged to produce a representative curve for each SWR level[28]. In order to include the widest range of vehicles, all of the roof crush tests that were conducted for 250 mm of platen displacement were included in the averages. Test results from first side tests were linearly scaled down by 7 percent for vehicles below 6,000 GVWR and 15 percent for vehicles above 6,000 GVWR. These reductions represent the average change in peak SWR for the 2 side roof crush tests for vehicles in the same weight range. For vehicles under 6,000 lbs. GVWR, twenty nine vehicles were averaged to produce the deflection curve for the 2.5 alternative and the force displacement curves for 34 vehicles were averaged to produce the curve for the 3.0 alternatives. For the 3.5 SWR, a total of 41 vehicles were averaged. These average curves are shown in Figure IV-D. A third order polynomial regression was then run for each curve in Figure IV-D to produce a model of expected displacement impact from higher force levels. The resulting models for the three alternatives were as follows:

For 2.5 times vehicle weight $y = -0.000003\,x^3 + 0.0013\,x^2 + 0.0861\,x + 0.52$

For 3 times vehicle weight $y = -0.000004\,x^3 + 0.0016\,x^2 + 0.1148\,x + 0.7692$

For 3.5 times vehicle weight $y = -0.000003\,x^3 + 0.0015\,x^2 + 0.1515x + 0.6412$

Where:

y = intrusion prevented (in mm)

x = baseline intrusion (in mm)

For vehicles over 6,000 lbs. GVWR, a total of 6 vehicles were averaged for the 1.5 SWR, 13 vehicles were averaged for the 2.0 SWR, and 15 vehicles were averaged for the 2.5, 3.0, and 3.5 SWRs. The models for the over 6,000 lbs. alternatives were:

[28] Vehicles were included if they failed to pass the specific SWR plus the previously mentioned 8% allowance for maximum vehicle weight plus a 10% safety margin. This reflects our assumption that manufacturers would choose to

For 1.5 times vehicle weight $y = -5.0e{-6}x^3 + 0.0020x^2 - 0.0435x + 1.813$

For 2.0 times vehicle weight $y = -5.0e{-6}x^3 + 0.0021x^2 + 0.0066x + 1.9122$

For 2.5 times vehicle weight $y = -5.0e{-6}x^3 + 0.0023x^2 + 0.0535x + 2.1431$

For 3 times vehicle weight $y = -5.0e{-6}x^3 + 0.0023x^2 + 0.1161x + 2.1445$

For 3.5 times vehicle weight $y = -4.0e{-6}x^3 + 0.0023x^2 + 0.1663x + 2.1473$

These models were applied to baseline intrusion levels for each case that meets the definition of a relevant injury in our target population to estimate the hypothetical intrusion prevented by the increased force requirement.

Due to the nature of the third order equation, there is an inflection point at which the curve begins to slope downward. This inflection point is realized after 254 mm, and therefore cannot be visualized on our curve fit. With very large baseline intrusions, represented by "x" in the equations, the intrusion prevented ("y") might decrease or even become a negative value. Since the upgrade would never increase overall intrusion, we calculated the largest "y" value, and with the intrusion corresponding "x" value assumed that any baseline intrusion greater than "x" would have an intrusion prevented value of the maximum "y." This assumption only affected a relatively small number of severe cases and thus had only minor impact on the estimated benefits.

Safety Analysis and Forensic Engineering (SAFE) stated that the ability of a roof to resist roof crush is directly related to the energy the roof can resist, not necessarily the peak force. They further stated that the NHTSA benefit estimates were flawed because of their assumption that the shape of the force vs. displacement curves would be the same regardless of roof strength. SAFE argued that in their experience force vs. deflection curves for stronger roofs almost always reach peak force much faster and tend to remain at a fairly high level of force throughout the test, unlike weak designs, which may drop off

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redesign their vehicles at some point prior to exceeding their full compliance margin of 20%.

dramatically after reaching peak force. They also noted that they had conducted inverted drop tests in which incremental increases in roof strength result in exponential reductions in roof crush.

In the vehicle modifications study, the finite element analysis (change in energy deflection) the profile curves were coarsely estimated by using a linear scaling approach. While this approach is clearly not a real-world representation, it provided a uniform methodology that the agency could use to compare all the NHTSA vehicle test data points in a similar format. The agency used this approach to estimate the incremental shift that might occur due to added strength requirements. A change in deformation modes could either increase or decrease the predicted impact of higher strength requirement on any specific vehicle, but lacking comprehensive modeling and exact product plans for the vehicle fleet, predicting changes in deformation modes is problematic. Moreover, linear scaling is not intrinsically biased in either direction, so to the extent that deformation modes do change on specific vehicles, the overall impacts should be minimized. The agency recognizes that there may be specific vehicle designs that, when coupled with specific design changes, would experience reductions in roof crush that would either exceed or be less than those that occur under an assumption of linear scaling. Without specific design schematics for every model vehicle, the agency believes that the assumption of linear scaling is a reasonable method to estimate the relative performance of vehicles under different roof strength scenarios.

Benefit Calculation

As previously mentioned, the basis for benefit calculations is a statistical analysis conducted by NHTSA to assess the relationship between intrusion and injury probability. This research was peer reviewed and published in October 2007[29] In that report, Strashny established probability relationships for each AIS injury severity category based on intrusion levels using a series of both binary and ordered probit models. He

[29] Strashny, Alexander, The Role of Vertical Roof Intrusion and Post-Crash Headroom in Predicting Roof Contact Injuries to the Head, Neck, or Face During FMVSS 216 Rollovers; An Updated Analysis, October 2007, U.S. Department of Transportation, National Highway Traffic Safety Administration, Washington, D.C . DOT 810 847

examined both continuous and dichotomous models, as well as both unadjusted and adjusted models. The unadjusted continuous intrusion ordered probit model was selected for use in this analysis. The aggregated results from the unadjusted model are essentially the same as the aggregated results from an adjusted model, though the unadjusted model is somewhat easier to use. According to the model, the probability of injury at each severity level is as follows:

$$p(AIS0) = \Phi(1.20 + y)$$

$$p(AIS1) = \Phi(2.21 + y) - \Phi(1.20 + y)$$

$$p(AIS2) = \Phi(2.81 + y) - \Phi(2.21 + y)$$

$$p(AIS3) = \Phi(3.06 + y) - \Phi(2.81 + y)$$

$$p(AIS4) = \Phi(3.18 + y) - \Phi(3.06 + y)$$

$$p(AIS5) = \Phi(3.24 + y) - \Phi(3.18 + y)$$

$$p(AIS6) = 1 - \Phi(3.24 + y)$$

Where $\Phi(\ )$ is the standard normal cumulative distribution function, $y = -0.075 * i$, and i is the intrusion, measured in inches. Values of $\Phi(\ )$ can be determined in Excel using the NORMDIST function: $\Phi(x) = NORMDIST(x,0,1,1)$.

Using these relationships, benefits were calculated as follows. For each case in the target population, intrusion levels were calculated under each alternative SWR using the combined displacement impact curve. These intrusion levels were used in the above formulas to calculate the probabilities of each specific MAIS level injury.

The effectiveness of each SWR level was derived as follows:

The effectiveness of each SWR level was derived as follows:

$$e_{in} = 1 - \frac{p_{in}}{p_{bn}}.$$

Where e_{in} = the effectiveness of SWR requirement i against injury level n

p_{in} = the probability of an injury of severity n for SWR requirement i.

p_{bn} = the probability of an injury of severity n for the base SWR of the case vehicle. Note that p_{bn} is the probability of injury as calculated by the model.

The effectiveness for each case was then weighted according to its relative case weight and the aggregate of all cases was summed to produce the average effectiveness rate against each specific injury level for each SWR alternative. The effectiveness rates were then applied to the appropriate injury target population to estimate the reduction in injury that would occur from stronger roofs.

A number of commenters including GM, Ford, Nissan, and Safety Analysis Inc (SAI) stated that the statistical correlation Strashny found between roof intrusion and injury does not establish a causal relationship between roof deformation and injury. SAI noted that the studies by both Rains and Strashny merely suggest that there is a relationship. SAI stated that "….when you compare rollover accidents that have significant roof/pillar deformation with other rollover accidents that have very little or no roof/pillar deformation, you are not comparing similar accidents with respect to roof-to-ground impact severity. Just the fact that two vehicles are in a rollover with greater than 2 quarter turns does not mean they are in the same or even similar impact severities". SAI also notes an earlier study (matched pair comparison project) in which production and roll bar equipped vehicles were tested where the comprehensive forces measured on test dummies were similar regardless of the vehicle roof crush. Ford stated that "The amount of roof deformation is only an indication of the severity of the impact between the roof and the ground…." GM stated that "Observations of injury occurrence at the end of a rollover collision reveal nothing regarding the relationship of roof deformation, roof strength, or roof strength-to-weight ratio injury causation." Nissan stated that deformation and injury severity are both independently associated with roof impact severity.

The agency agrees that as a general principle, a statistical correlation does not in itself prove beyond a doubt that a causal relationship exists. However, the Strashny study was designed with a strict focus to only include injury scenarios where the intruding roof was the injury source. The study compared cases where there was intrusion to cases where there was no intrusion and found that as intrusion increases, the probability of, and severity of injury also increases. The study controlled for crash severity using quarter turns, which is the best available metric for rollover severity. Contrary to SAIs contention, the study does not compare crashes over 2 quarter turns as a group. Rather, it compares only crashes of similar severity as defined by each iterative quarter turn exposure. Thus, a vehicle that experienced 3 quarter turns would only be compared to other vehicles that experienced 3 quarter turns. SAI's and Ford's argument seems to imply that any difference in roof intrusion must be due to a difference in impact severity rather than roof strength or design, whereas the Strashny study, by controlling for quarter turns, attempts to minimize differences due to impact severity. Further, the study included only belted cases which minimized the impact of "diving" as an injury cause.

There are logical reasons to believe that a collapsing roof that strikes an occupant's head at the nearly instantaneous impact velocity experienced when structures deform might cause serious injury. These types of injuries were documented by Rechnitzer and Lane in a detailed investigation of 43 rollover crashes[30]. The agency believes that the statistically significant relationship between roof intrusion and injury found in the Strashny study indicates a probability that roof crush causes injuries.

Regarding the SAI matched pair comparison project, the agency notes that the dummy necks used in the tests are not biofidelic. They are rigid structures that do not allow for the normal bending that occurs in the

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[30] Rechnutzer, George and Lane, John, "Rollover Crash Study, Vehicle Design and Occupant Injuries", Monash University, 1994.

human spine. The agency believes that lateral bending plays an important role in determining the degree of injury sustained by humans in rollovers, and does not view these results as an adequate measure of injury in humans during rollover crashes.

The Insurance Institute for Highway Safety (IIHS) released the report "Roof Strength and Injury Risk in Rollover Crashes" in March 2008. The main conclusion of the report was that "increased measures of roof strength resulted in significantly reduced rates of fatal or incapacitating driver injury after accounting for vehicle stability, driver age, and state differences" in single-vehicle rollover crashes. The study was based upon all single-vehicle rollovers involving eleven midsize sport utility vehicles and their corporate twins in twelve States. The vehicles selected were all four-door models without electronic stability control (ESC) or side curtain air bags. Police-reported injury outcomes were defined by a dichotomous variable: incapacitating/fatal (KA on the KABCO injury severity scale) or non-incapacitating/complaint/no injury (BCO on the KABCO scale). The study included all drivers regardless of belt use or ejection status. The main explanatory variable was roof strength, for which twelve different measures were used. The control variables in the statistical model included driver age, static stability factor (SSF), which was used as a proxy for rollover severity, and indicator variables for the State to control for any reporting differences. The report also contained additional statistical models to address secondary questions. The researchers reported that the conclusions held for belted drivers, but the relationship between roof strength and injury outcome did not hold for unbelted drivers. The researchers also reported that the results generally held using an injury outcome of fatal versus non-fatal.

On March 27, 2008, JP Research and Biomech submitted an evaluation of the IIHS study to the FMVSS 216 SNPRM docket. The JP Research evaluation focused on the claim that "there is no relationship between roof strength-to-weight ratio (SWR) and serious injury/fatality" when additional control variables were added to the statistical model. JP Research used the same data and approach as the IIHS study with the addition of the following control variables: aspect ratio, alcohol involvement, vehicle weight, vehicle age, driver gender, belt use, vehicle drive type, and whether the driver was completely ejected. Upon re-estimating the statistical model with the additional variables, JP Research found that the strength to weight ratio (at five inches of displacement) was no longer a statistically significant predictor of KA injuries and that most of the additional control variables were statistically significant. JP Research reported the results of several other statistical models, including one for belted non-ejected drivers, and roof strength was not a statistically significant predictor of the likelihood of KA injuries in any of their statistical models with the additional control variables. JP research also pointed out that four of the models, and their corresponding measures of roof strength, accounted for about 75 percent of the IIHS data. Therefore, a handful of models may be driving the results rather than the full set of twelve models.

On May 13, 2008, IIHS responded to the JP Research evaluation in the FMVSS 216 SNPRM docket. IIHS contended that the additional control variables do not belong in the statistical model predicting KA injuries, and they focused their criticism on the belt use, alcohol involvement, and ejection status variables. IIHS claimed that belt use and alcohol involvement should not be included in the statistical model because these two variables have a large degree of measurement error and because the error may be correlated with injury outcome. For example, they argue that an officer may accurately determine that a serious or fatally injured driver was not wearing a belt, but an uninjured driver who was unbelted may be able to lie to the police and claim they were belted. A similar argument was made for alcohol where a serious or fatal injury is likely to result in a blood test, but the determination of alcohol involvement in a crash without an injury may depend only upon the officer’s observation. The measurement error suggested by IIHS could overestimate the effects of belt use and alcohol involvement and underestimate the effect of other variables such as roof strength.

IIHS presented a different argument for why they did not include ejection status in their statistical model. According to IIHS, roof strength is related to ejection status. Therefore, since ejection status also is related to injury severity, IIHS claimed that including ejection status as a causal factor would lead to an underestimate of the true effect of roof strength. To demonstrate the validity of their argument, IIHS presented a statistical model of ejection status (either full or partially ejected) as a function of roof strength (SWR at five inches), driver age, and SSF. Roof strength was a statistically significant predictor of ejection status in their statistical model. The researchers did not include belt use in their statistical model of ejection status -- it is likely that they would cite their measurement error argument as the reason.

On May 30, 2008, JP Research responded to the IIHS comments in the FMVSS 216 SNPRM docket. JP Research noted that because of the extremely low proportion of totally and partially ejected belted drivers in the State data files (102 out of 13913 observations, or 0.7%), police-reported belt use almost perfectly predicts no ejection. JP Research presented a statistical model of the relationship between roof strength and ejection status for unbelted drivers with additional control variables such as alcohol involvement, rural/urban, driver gender, and the vehicle aspect ratio. Many of the additional control variables were statistically significant predictors of ejection status, but the measure of roof strength was not. JP Research also argued that belt use and alcohol involvement variables are important enough predictors of injury severity that they cannot be excluded from the statistical model and that methods used to control for the possible overestimation of the effect of belt use due to measurement error do not significantly change their results. Finally, JP Research demonstrated that roof strength (SWR) was no longer a statistically significant predictor of KA injuries for belted drivers when only the additional control variable of urban/rural was included.

Overall, JP Research raised some very important criticisms of the validity of the IIHS findings. The decision by IIHS to exclude belt use from both the model predicting KA injuries and the model predicting ejection status is particularly worrisome given its importance in reducing injuries and preventing ejection. IIHS also reports that models for drivers without reported belt use did not produce a statistically significant relationship between roof strength and injury risk, and they claim that a small sample size may be to blame. However, they do not sufficiently explain their arguments about the low statistical power of their sample with over 2000 unbelted cases. JP Research also demonstrated that the IIHS results for belted drivers are not robust to model specification since the inclusion of a rural indicator is enough for roof strength to lose statistical significance. The reason may be that the roof strength is almost the same for every model, which means that roof strength may be measuring roof strength as well as any excluded factors related to the particular model. If any of the excluded control variables related to driver factors, such as alcohol involvement or the rural/urban indicator, are also related to the vehicle model then it is difficult to separate out the effects of roof strength versus the driver characteristics related to the specific vehicle model. Excluding driver factors that are related to injury severity as well as the specific vehicle model could lead to an overestimation of the effect of roof strength. Furthermore, there are a relatively small number of models, and four models make up almost three-quarters of the cases. Therefore, unexplained factors related to one or two models could be driving the results. Finally, one issue that was not a major topic addressed in the docket discussion was whether these results based upon a very specific body type, midsize four-door SUVs, applies to other types of vehicles. In fact, IIHS suggested that the results may be different for other body types, which means that their reported relationship between roof strength and KA injuries may not apply to other types of light duty vehicles.

On February 5, 2009, IIHS presented results of their forthcoming Enhanced Safety of Vehicles (ESV) conference paper at the SAE Government/Industry meeting. The study is a continuation of research that IIHS previously submitted to the FMVSS 216 SNPRM docket in March and May of 2008. While the 2008 research focused on 11 midsize SUVs, the 2009 study also includes 12 small cars. Overall, IIHS reports a statistically significant relationship between greater roof strength and a lower risk of fatal and incapacitating injuries for drivers of both the small cars and the midsize SUVs. IIHS also responded to some previous concerns raised by JP Research in the 216 SNPRM docket by demonstrating that the statistically significant relationship held for both the subpopulations of non-ejected drivers and of belted drivers. IIHS also reported that the inclusion of a rural/urban indicator did not change the results. Previously, JP Research demonstrated that roof strength was no longer a statistically significant predictor of injury for the belted SUV drivers when the statistical model included a rural/urban indicator.

While the new IIHS study addresses many of the criticisms of their 2008 research, there are several issues that remain. In reviewing the graph of roof strength by injury rate, it appears that three car models are driving the results. Factors not captured by the statistical model's control variables that are related to one or more of these three models could account for the results. A similar criticism was previously raised in the critical review of SUV study.

The fact that the new IIHS study reports a statistically significant strong relationship between roof strength and ejection suggests that their result is due to something other than intrusion. Similarly, the fact that the statistical relationship between roof strength and injury risk reported by IIHS decreases in magnitude when restricted to the non-ejected or the belted subpopulations suggests that there are unmeasured factors since these relationships would be expected to increase in magnitude when restricted to the relevant target populations. These unmeasured factors that do not appear to be related to intrusion could be responsible for the strong result reported by IIHS.

NHTSA used a significantly different statistical approach in its research related to roof crush resistance. Rather than measure roof strength, NHTSA used the amount of vertical roof intrusion. NHTSA also used the severity of any injuries to the head, neck, or face from an intruding roof component instead of police-reported severity from the KABCO scale. Therefore, NHTSA was able to focus on a specific injury mechanism related to FMVSS No. 216, and we were able to separate roof injuries from other rollover injuries such as those that occur in one-quarter turn rollovers or when the vehicle does not experience roof damage. The variables needed to make these determinations are not available in the State data files used by IIHS and JP Research, so NHTSA used the National Automotive Sampling System – Crashworthiness Data System. These cases contain detailed coding performed by NHTSA trained crash investigators based upon vehicle inspections and relevant medical records. Injury severity is measured using the Abbreviated

Injury Scale (AIS) rather than police reported severity (KABCO).

Even though the ability to focus on a specific injury mechanism increases the internal validity of the results, NHTSA's research recognizes that other factors such as belt use, rollover severity, occupant age, and occupant gender should be included in the statistical modeling. The research used investigator determined belt use instead of police reported belt use. While there is no standard measure for rollover severity, previous NHTSA research has demonstrated that both, the number of quarter-turns to the side and the number of roof-to-ground exposures, are severity proxies related to injury outcome. NHTSA research includes almost all non-convertible light duty vehicles in its analysis although the statistical models generally control for passenger cars versus other vehicles (pickups, sports utility vehicles, and vans).

NHTSA's recent research on roof crush has excluded totally ejected occupants based upon the assumption that roof intrusion is unrelated to the risk of total ejection. Given the debate between IIHS and JP Research regarding the hypothesized relationship between roof strength and the risk of being totally ejected, NHTSA conducted a statistical study of the relationship between vertical roof intrusion and total ejection. The research demonstrated that the magnitude of vertical roof intrusion is not related to the probability of a total ejection. Therefore, NHTSA stands by its decision to exclude totally ejected occupants from the FMVSS No. 216 target population of those who could benefit from increased roof resistance.

Among the occupants who were not totally ejected, NHTSA examined the relationship between vertical roof intrusion and injury outcomes separately for the unbelted and belted populations. The models included control variables for the number of quarter turns to the side, gender, age, and an indicator variable for a passenger car. The relationship between roof intrusion and injury outcomes was statistically significant for the belted population, but it was not statistically significant for the unbelted population. Furthermore, we believe that the sample size for the unbelted occupants was sufficient to determine whether a statistical significant relationship exists between the intrusion and injury.

In the end, NHTSA stands by its conclusion that roof intrusion during rollovers is related to increased injuries to the head, neck, and face among the belted population. However, we do not find evidence of a statistically significant relationship between roof intrusion and head, neck, and face injuries to unbelted occupants or between roof intrusion and total ejection.

Adjustment for Failure Rate

The initial results described above represent benefits if roof strength were increased in 100% of the vehicle fleet. However, many vehicles already meet the strength requirements of alternative SWRs. Therefore, an adjustment must be made to reflect benefits only from those vehicles that do not meet the specific requirements of each alternative. Previously, in Chapter II, failure rates were derived for each alternative SWR under both 2 and 1 sided tests. These rates, which are summarized in Table II-5, were applied to the initial benefit estimate to adjust for the portion of the vehicle fleet that already meets the requirements under each alternative.

Adjustment for Electronic Stability Control

The PRIA for the August 2005 NPRM to amend FMVSS No. 216 examined the model year (MY) 2005 fleet. During MY 2005, Electronic Stability Control (ESC) was voluntarily installed on roughly 18% of the new light vehicle fleet. Because both ESC, and FMVSS No. 216 address rollover injuries, the PRIA took into account the impact of the 18% penetration of ESC. However, NHTSA published a proposal in September 2006 and a final rule in April 2007 requiring ESC on 100% of passenger cars and of light trucks, multipurpose passenger vehicles, and vans (LTVs), effective September 1, 2011.[31] Therefore, the FRIA for the final rule upgrading FMVSS No. 216 will adjust the target population for this rulemaking to reflect the ESC mandate. Since ESC is a highly effective countermeasure, preventing roughly half of all rollovers in passenger cars

[31] See the Final Rule published April 6, 2007 (72 FR 17236) and the Final Regulatory Impact Analysis, FMVSS 126, Electronic Stability Control Systems", March 2007, Docket No. 2007-27662-2

and LTVs, this adjustment will significantly reduce the target population and thus the safety benefits associated with FMVSS No. 216.

The adjustment is a function of the 100% ESC penetration that will be required in all new vehicles compared to the on-road fleet that is reflected in 1997-2006 NASS and FARS databases, the effectiveness of ESC in reducing single vehicle crashes, and the portion of rollover crashes that occur in single vehicle crashes. The formula is as follows:

ESCf = $(P_n - P_b)$*e

Where ESCf = ESC adjustment factor

Pn = Required ESC penetration all new vehicles (100%)

Pb = ESC penetration in the MY fleets that were on road during 1997-2006 (1.15%).

e = Weighted effectiveness of ESC against rollover crashes

The inputs and results of this estimate are shown in Table IV-3. Base penetration rates are NHTSA estimates based on an examination of ESC installation rates by model year. Effectiveness rates were derived from an evaluation of ESC effectiveness conducted by NHTSA.[32] Effectiveness rates for single vehicle rollovers and multi-vehicle crash rollovers were combined by weighting each effectiveness rate by the relative prevalence of single or multi-vehicle crashes in the target population. Calculations were made separately for passenger cars and light trucks, and for fatal and nonfatal crashes to reflect variation in the available inputs. The vehicle types were combined based on the incidence of occupant injuries in the target population (roughly 54% passenger cars and 46% LTVs). The resulting separate adjustment factors for fatalities and nonfatal injuries will be applied to the appropriate target population injury categories, with the

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[32] 2007 Statistical Analysis of the Effectiveness of Electronic Stability Control (ESC) Systems – Final Report (NHTSA Report No. DOT HS 810 794, Author: Jennifer N. Dang)
Summary in HTML format:
http://www.nhtsa.dot.gov/portal/site/nhtsa/menuitem.73d943432bd16dd24ec86e10dba046a0/, and click on the title of this report (1st item in the "2005 to Present" section)

combined PC&LTV number being used for the <6,000 lbs. GVWR category and the LTV factor being used for the > 6,000 lbs. category. Thus, roughly half of all 216 target population fatalities and injuries to occupants of vehicles under 6,000 lbs. GVWR, and roughly 60% of all fatalities and injuries to occupants of vehicle over 6,000 lbs. GVWR, will be prevented by ESC.

Table IV-3

ESC Adjustment Factor

	Fatalities		Nonfatal Injuries	
	PC	LTV	PC	LTV
Required ESC Installation	100%	100%	100%	100%
97-06 On-road Fleet % Installation	1.15%	1.15%	1.15%	1.15%
Effectiveness	41.42%	59.05%	48.18%	58.42%
Factor	0.4094	0.5837	0.4762	0.5775
Factor PC+LTV		0.4896		0.5228

Adjustment for Increased Safety Belt Use

Safety belt use has increased significantly over the past 11 years. According to NHTSA's National Occupant Protection User Survey (NOPUS), belt use increased steadily from 62% in 1997 to 83% in 2008. As discussed previously in this chapter, the target population for improved roof strength is strictly defined to include only belted occupants. Unbelted occupants who meet all other criteria are excluded. When compared to the rate of belt use reflected in the 1997-2006 databases, current high levels of safety belt use

Report in pdf format:
http://www.nhtsa.dot.gov/staticfiles/DOT/NHTSA/NCSA/Regulatory%20Evaluation/static%20-%20PDF%20file/DOT%20HS%20810%20794.pdf

would increase the number of rollover cases that would potentially benefit from higher roof strength. An adjustment will be made to the 1997-2006 target population to reflect the impact of higher belt use rates that will be experienced by the newer vehicle fleets that will meet the higher roof strength requirements.

Table IV-4 shows the history of safety belt use rates over the past 11 years. Belt use has risen steadily since 1997 to a level that is 21 points higher in 2008 than in 1997. The average usage rate during the 1997-2006 period, which comprised the base years data for our target population, was 73.5%. Current (2008) usage is at 83%, which means there are 12.9 percent more vehicle occupants wearing their belts now than in the 1997-2006 period.

Table IV-4
NOPUS Nationwide Safety Belt Usage Rates

Year	NOPUS (%)	1997-2006 Avg
1997	62	
1998	65	
1999	67	
2000	71	
2001	73	
2002	75	73.5
2003	79	
2004	80	
2005	82	
2006	81	
2007	82	
2008	83	
Increase % Belt Use = >>>>		1.1293

Observed usage is a reasonable indicator for use by persons involved in most nonfatal crashes. However, research has shown that usage in fatal crashes is lower than usage in the general driving population. This reflects the fact that occupants who don't wear belts are more likely to die in a crash than belt wearers, and thus represent a higher relative portion of fatalities in crashes. The relationship between observed use and use in fatal crashes has been derived in a series of NHTSA analyses.[33] The formula that establishes this relationship is:

$U_p = .43751U_o + .47249U_o^2$

Where U_p = use in potentially fatal crashes

U_o = Observed usage in the driving population

The above formula predicts the usage rate of all persons involved in potentially fatal crashes (both those saved by belts and those who die) as a function of observed use in the general population. It predicts a curvilinear relationship that reflects a greater increase in usage by those involved in potentially fatal crashes as observed usage approaches 100%. This occurs because the drivers who are most likely to be involved in fatal crashes are risk takers who are also the least likely to use safety belts. As overall belt use increases, they represent an ever-growing portion of the remaining unbelted occupant pool from which new belted riders are drawn. At current usage levels, unit increases in observed belt use result in greater increases in usage in potentially fatal crashes. To determine the usage rate by persons who are actually killed, an adjustment must be made to reflect the effectiveness of safety belts in preventing fatalities. The formula for this adjustment is:

$U_f = [U_p-(e*U_f)]/[1-(e*U_f)]$

Where U_f = Usage by fatals

U_p = use in potentially fatal crashes

e = effectiveness of safety belts against fatalities (50% for passenger cars and LTVs)

Table IV-5 lists the results of the calculations for the 1997-2006 base data and the current calendar year fleet:

[33] Wang, J.S. and Blincoe, L.J., BELTUSE Regression Model Update, U.S.DOT, NHTSA, Washington D.C., June 2001. and Wang, J.S. and Blincoe, L.J., Belt Use Regression Model – 2003 Update, USDOT, NHTSA, Washington

Table IV-5

Metrics Relating Belt Use Rates

	1997-2006 Avg	2008	Percent Change
Observed Use (Uo)	73.50	83.00	1.1293
UPFC from Uo	57.68	68.86	1.1938
Use in Fatals (Uf)	40.53	51.11	1.2756

The above formulas and table show the predicted relationship between belt use changes at different levels. However, changes in belt use rates are not identical to changes in belted occupants in the target population. To determine the change in belted occupants, data from Table IV-1 were used to estimate the net impact of higher belt use on the target population. To accomplish this, it was assumed that belt use in potentially fatal crashes would increase by the rate predicted in Table IV-5, or 19.4%. This increase was used to impute the total added belted cases in PFC. These added cases were assumed to be drawn proportionally from the unbelted populations of ejected and non-ejected occupants. Safety belts are estimated to be about 50% effective in reducing fatalities in passenger vehicles. For non-ejected occupants, it was assumed that belts would save 50% of the newly belted, leaving the remaining 50% as additions to the belted population. For ejected occupants, based on a study by Kahane[34], it was assumed that belts would prevent 91% of ejections for the newly belted. Based on a study by Winnicki,[35] preventing ejection eliminates 70 percent of fatalities. This implies that 63.7% of previously ejected fatalities that buckle up will be prevented. The remainder of the newly belted ejected fatalities would become additions

D.C., DOT-HS-809-639, May, 2003

[34] Kahane, Charles J. , *Fatality Reduction by Safety Belts for Front-Seat Occupants of Cars and Light Trucks*, NHTSA, U.S. DOT, Washington, D.C., DOT HS 809 199, December 2000.

to the belted population. The new belted population was then compared to the original belted population to determine the net increase in belted cases. The resulting factor, 1.2145, will be applied to the fatality target population to reflect current higher belt use rates. The rate of increase in observed belt use (1.1938) will be applied to nonfatal injuries.

Adjustment for Consistency with Sales Projections

The target population for safety benefits was based on the average injury experience over the 1997-2006 period. It is thus a function of the amount of driving exposure that occurred over this period. The number of vehicles on the road is to some extent, a measure of this exposure. During this time frame, the on-road vehicle fleet was made up of model year vehicles stretching back 30 years or more. Annual sales of vehicles over this period ranged from as few as 8 million to over 17 million, with an average of roughly 15 million. However, for this analysis the agency is estimating costs based on a projected annual sales rate of 17 million vehicles per year. This has implications for the level of safety benefits that would be expected in future fleets of this size. To compare costs and benefits under a common exposure basis, an adjustment will be made to the benefit estimate to make it consistent with the estimated size of the future vehicle fleet.

The basis for this adjustment is an analysis of sales, VMT, and survival rates for vehicles that were in the on-road fleet over the course of the 10 years that were included in the target population. Survival rates and VMT were taken from the fuel economy schedule discussed elsewhere in this analysis. Sales were derived from Wards Automotive Reports tables for each calendar year.

For each calendar year, an exposure adjusted average annual sales rate basis was estimated for passenger cars as follows:

[35] Winnicki, John, *Estimating the Injury Reducing Benefits of Ejection-Mitigating Glazing*, NHTSA, USDOT, DOT HS 808 369, February 1996.

$$R = \sum_{i=1}^{26} \frac{p_i * v_i}{\sum_{j=1}^{26} p_j * v_j} * s_i$$

Where: R = exposure adjusted annual sales rate

p = survival probability of vehicles of age i

v = vehicle miles traveled by vehicles of age i

s = vehicle sales during year i

For light trucks, the same formula was used except that vehicle lifetime survival rates and VMT were estimated over a 36 year period, reflecting the longer useful lifetime typically experienced with light trucks. The process was repeated for both cars and light trucks for each year from 1997-2006. The results were averaged over the ten year period, indicating an average exposure adjusted sales rate of 15,030,608 vehicles produced the initial target population. The adjustment factor is thus 17,000,000/15,030,608 or 1.131.

The results of applying the ESC, safety belt, and fleet size adjustment factors are summarized in Table IV-6 for 2-sided tests and in Table IV-7 for 1-sided tests. Two sided tests prevent roughly 10-20% more fatalities than one sided tests. This is a function of a somewhat higher failure rate and a slightly more stringent test procedure for two-sided tests.

Table IV-6
Final Safety Benefits (Injuries Prevented) for 2-Sided Tests

Injury Severity Level	Strength to Weight Ratio				
<6000 lbs.	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**
MAIS1			192	338	464
MAIS2			282	482	649
MAIS3			71	121	161
MAIS4			39	65	87
MAIS5			8	13	18
Total Nonfatal			592	1,019	1,378
Fatal			80	133	175
>6000 lbs.	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**
MAIS1	23	94	148	196	231
MAIS2	15	60	91	115	131
MAIS3	5	21	30	38	43
MAIS4	2	7	10	12	14
MAIS5	0	1	1	1	1
Total Nonfatal	46	183	280	363	420
Fatal	2	6	8	10	11

Table IV-7
Final Safety Benefits (Injuries Prevented) for 1-Sided Tests

Injury Severity Level	Strength to Weight Ratio				
<6000 lbs. GVWR	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**
MAIS1			168	275	396
MAIS2			249	397	559
MAIS3			63	100	139
MAIS4			34	54	75
MAIS5			7	11	16
Total Nonfatal			522	838	1,184
Fatal			71	111	153
>6000 lbs. GVWR	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**
MAIS1	7	83	102	156	197
MAIS2	5	54	65	95	116
MAIS3	2	18	22	32	38
MAIS4	1	6	7	11	13
MAIS5	0	1	1	1	1
Total Nonfatal	13	162	197	295	365
Fatal	0	5	6	9	10

The results indicate that for vehicles < 6,000 lbs. GVWR under 2-sided test requirements, about 13% of the 635 fatalities in the target population would be prevented by a 2.5 SWR. A 3.0 SWR would prevent about

21% of all fatalities. A 3.5 SWR would prevent 28% of all fatalities. For a 1-sided test requirement in vehicles <6,000 lbs. GVWR, about 11% of fatalities would be prevented by a 2.5 SWR for all vehicles. A 3.0 SWR would prevent about 17% of all fatalities. A 3.5 SWR would prevent 24% of all fatalities. Proportional savings are slightly higher in heavier vehicles, reflecting the added strength needed to achieve equivalent SWR levels, but the low target population in these vehicles limits the savings that can result.

V . COSTS

In the PRIA, NHTSA based its cost estimates on 4 vehicles: the 1997 Plymouth Neon, the 1999 Ford E-150 Van, the 1997 Dodge Caravan, and the 1998 Chevrolet S-10 pickup. These vehicles were used because they were the only vehicles for which the agency had finite element models which could be used to simulate the impact of roof design changes on roof strength. The agency used these vehicles to impute costs for the overall fleet based on the relative roof strength of a sample of tested vehicles. A similar procedure was used for vehicle weight changes. The PRIA estimated that the average cost per affected vehicle would be approximately $11 to meet the 2.5 SWR alternative and $51 for the 3.0 SWR alternative, with individual model costs as high as $16 for the 2.5 alternative and $84 for the 3.0 alternative. The PRIA also estimated average weight increases ranging from 2 to 14 kilograms (4 to 30 pounds). Weight is a factor in the analysis because it influences both fuel economy and potentially the vehicle's center of gravity, which can influence the vehicle's tendency to roll over.

In response, the Alliance of Automobile Manufacturers (Alliance) submitted an analysis of costs and weights for 2 vehicle types – a large SUV and a large pickup truck.[36] The Alliance estimates were based on engineering studies from a variety of manufacturers and represented a range of results for each vehicle type. The Alliance estimated that variable unit costs for a large SUV would range from $38 to $58 to meet a 2.5 SWR alternative, $60 to $90 to meet a 3.0 SWR alternative and $110 to $130 to meet a 3.5 SWR alternative. Based on NHTSA cost studies, total consumer costs including overhead, profit, and dealer markup could be 50 percent higher than these variable costs. The Alliance estimated the corresponding weight increases for these scenarios to be 27 to 30 kilograms (60 to 67 pounds) for the 2.5 SWR, 68 to 122 kilograms (150 to 270 pounds) for the 3.0 SWR, and 113 to 245 kilograms (250 to 540 pounds) for the 3.5 SWR. For the large pickup truck the Alliance estimated that variable unit costs would range from $55 to $185 to meet a 2.5 SWR alternative, $100 to $200 to meet a 3.0 SWR alternative and $165 to $525 to meet a 3.5 SWR alternative. The Alliance estimates for corresponding weight increases for these scenarios were 17 to 31 kilograms (38 to 68 pounds) for the 2.5 SWR, 39 to 118 kilograms (85 to 260 pounds) for the 3.0 SWR, and 54 to 236 kilograms (120 to 520 pound) for the 3.5 SWR.

The Alliance also contracted an independent study by Magna Steyr on the feasibility of modifying a crew cab pickup for compliance with the NPRM proposal (2.5 SWR). The study concluded that meeting the proposal in a 3 year lead-time was feasible, but would add 33 kilograms (73 pounds) and $76 to $98 in variable costs. It also found that if enough leadtime were provided to allow implementation during a new production cycle, higher strength materials were feasible in conjunction with new tooling and this could result in a 5 kilogram (11 pound) savings in weight relative to the base vehicle.

The Alliance data represent industry estimates of costs and weight impacts for the two types of vehicles – large SUVs and large pickup trucks – for which higher SWRs are likely to pose the most difficult challenges and result in the largest cost and weight penalties. However, these types of vehicles represent only a small portion of new vehicle sales (approximately 9 percent) and their design challenges are unlikely to be representative of the bulk of the vehicle fleet. The Alliance did not provide estimates for other vehicle types – passenger cars, light pickups, crossover SUVs, etc. Based on our test results, the agency believes that meeting a higher SWR may be significantly easier for the vehicle types not submitted by the Alliance.

The agency has also conducted additional tear down studies. A study conducted by The Ohio State University examined the Volvo XC-90 and the Ford Explorer. The study found that the XC-90 roof had roughly 1/3 more structural parts than the Explorer, and that implementing some of the XC-90 design concepts in the Ford Explorer would increase material and tooling costs by $81 and weight by 15 kilograms (33 pounds). Additional work based on finite element models and cost teardown studies conducted by Ludtke Associates and the National Crash Analysis Center found that strengthening the 2003 Ford Explorer

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[36] *See* Docket No. NHTSA-2005-22143-249.

to 3.0 SWR would raise the vehicle's price by $33 to $35 and increase its weight by 5 to 10 kilograms (10 to 23 pounds). They also examined a 2000 Ford Taurus. The study indicated that raising the Taurus to a 3.0 SWR would increase its price by $175 to $204, and increase its weight by 7 to 12 kilograms (15 to 27 pounds). However, this vehicle design has been discontinued.

Ford, GM, and Chrysler provided a variety of estimates for specific vehicles. A summary of these estimates is included on Table V-1. Most of these data are confidential and will not be shown in the public version of this document.

Public Citizen in their comments of March, 27 2008, noted the Ohio State Study showed that a Ford Explorer could be modified to have a roof performance of the Volvo XC90 for about $81.

The Center for Auto Safety on March 27, 2008 commented that some manufacturers – including Toyota, General Motors, Ford, and Subaru – are already producing cars and light trucks with substantially stronger occupant compartments in recognition of the occupant protection principals put forth by DeHaven. These manufacturers are using high strength steel in key parts of the occupant compartment structure primarily to improve occupant protection in offset frontal and side impacts. The cost of increased roof strength – which can be engineered into the vehicle only by improving the overall occupant compartment strength, must be apportioned among all crash modes. Thus, no more than one-third the cost of the improved roof strength should be allocated to improved rollover occupant protection.

Advocates for Highway and Auto Safety on March 27,2008 commented that NHTSA should not base their benefits in any final rule on the exaggerated figures provided by the Alliance of Automobile Manufacturers, for the weight and cost of complying with 2.5X, 3.0X, or 3.5X roof crush resistance. The Alliance estimated that it will cost an additional $130 for a large SUV to comply with the 3.5X alternative.

Safety Analysis and Forensic Engineering (SAFE), disputed the weight claims made by the Alliance in their docket submission. SAFE stated that they had reinforced a number of heavy vehicles including the Ford F-series Superduty pickup trucks, Ford Econoline vans, and Chevy Suburbans to meet or exceed an SWR of 3.5. They stated that they have never added more than 187 lbs. and typically add between 75 and 125 lbs. They stated that they have modified a Ford-350 Superduty Supercab with a GVWR of nearly 10,000 lbs. to exceed a 3.5 SWR by adding only 152 lbs.

Estimated Weight Impacts

The agency thus has a limited sample of cost and weight estimates covering different vehicles, strength requirements, and test requirements. An examination of these estimates indicates that the results vary considerably based on specific vehicle characteristics, as well as the design approaches that were assumed by the commenters or contractors who conducted the analyses. Moreover, some estimates from different sources conflict with others. Table V-1 summarizes the results of estimates from all sources including NHTSA’s finite element model studies, publicly available docket submissions, and confidential docket submissions from manufacturers (not shown in the public version of this analysis).

Table V-1

Summary of Cost and Weight Estimates to Increase Roof Strength from Commenters and NHTSA Research

		Base SWR	Weight (lbs.)				Cost ($)		
Source	Vehicle		2.5	3	3.5		2.5	3	3.5
	CONFIDENTIAL								
	CONFIDENTIAL								
	CONFIDENTIAL								
	CONFIDENTIAL								
	CONFIDENTIAL								
	CONFIDENTIAL								
	CONFIDENTIAL								
GW	2000 Ford Taurus	2	26.5	15.0 - 27.0				175 - 204	
	2000 Ford Taurus	2	16.1						
GW	2003 Ford Explorer	2.25	11.9	10.0 - 23.0				33 - 35	
Ohio State	2003 Ford Explorer				33				$81.00
GW	1997 NEON	1.88	5.2				$3.00		
GW	1997 Caravan	2.65		20				$42.00	

GW	1998 Chevy S-10	2.75		30				$50.00	
	CONFIDENTIAL								
	CONFIDENTIAL								
	CONFIDENTIAL								
	CONFIDENTIAL								
	CONFIDENTIAL								
	CONFIDENTIAL								
	CONFIDENTIAL								
	CONFIDENTIAL								
GW	1999 Ford E150	1.88	10				$30.00		
Alliance	Generic Large PU		38-68	85-260	120-520		$83.05-279.35	$151-302	$249.15-792.75
	Generic Large SUV		60-67	150-270	250-540		$57.38 -87.58	$90.60-135.90	$166.10-196.30
Magna Steyr	Generic Large Pickup	1.6	72				$76-$98		
	Generic Large Pickup	1.6	-11				$60-$75		
* 2-Sided Tests	Shaded rows contain Confidential data and are not shown in Public version of this analysis								

There are a total of 20 estimates of weights to meet a 2.5 SWR, 8 estimates for a 3.0 SWR, and 6 estimates for 3.5 SWR. For costs, there were 10 estimates for a 2.5 SWR, 10 for a 3.0 SWR, and 7 for a 3.5 SWR. Of the vehicles in Table V-1, 7 are passenger cars, 6 are SUVs, 10 are pickups, and 3 are vans. Only 4 of the passenger cars included usable information because weight impacts were bunched with other weight offsets such that the added weight due to roof strength was obscured. 16 of the cases provide base SWRs for the subject vehicles.

Although the specific estimates were often contradictory as to the exact impact of raising the SWR, there was a reasonably consistent trend indicating that the weight and cost needed to meet any specific standard would increase as vehicle size increased. Other things being equal, this is to be expected since the absolute strength needed to meet a specific SWR is a function of the vehicle's weight. To meet a 2.0 SWR, a vehicle that weighs 3000 lbs. must have a roof structure capable of withstanding 6,000 lbs. of force, whereas a vehicle that weighs 5,000 lbs. must have a roof structure capable of withstanding 10,000 lbs. of force. To illustrate the impact of changes in SWR on the vehicle fleet, a model was developed based on this concept.

To derive this model, the agency selected from Table V-1 all vehicles that had identifiable base SWRs, base weights, SWRs achieved by redesign, and added weight to meet these redesign levels. This left 15 vehicle redesigns, each with a unique set of these factors. These vehicles were then normalized to a common basis using 2 assumptions – that for each vehicle, the change in weight needed to meet a specific SWR is proportional to the change in strength required by that SWR, and that the change in strength to meet a 2-sided test (over a 1-sided test) was equal to the average change in strength observed in NHTSA's 2-sided test program (roughly 7% for vehicles under 6,000 lbs. GVWR and roughly 15% for vehicles over 6,000 lbs. GVWR). The agency realizes that there are instances where these assumptions may not hold. For example, at some marginal strength requirement threshold, a manufacturer may choose to shift to a grade of steel that is stronger but lighter than steel that would have been used for changes to meet a slightly weaker requirement. However, this upgraded steel would have a higher cost/lb. and possibly higher assembly costs as well. Moreover, determining the thresholds where this could occur for each vehicle is not possible.

Under these assumptions, a 2-sided test equivalent weight increase was derived for each vehicle[37] for the 2.5 SWR alternative assuming a 20% compliance margin. These values were then regressed using a variety of different statistical models to explore functions that could be used to estimate the added weight required to meet a 2-sided, 2.5 SWR requirement for any specific vehicle.

The 4 models examined were:

1) A simple linear relationship between vehicle weight and added weight (Linear Model).
2) A multivariate model with both vehicle weight and base SWR as independent variables (Multivariate Model).
3) A quadratic model based on vehicle weight (Quadratic Model).
4) A third order polynomial based on vehicle weight (Polynomial Model).

The 4 models are shown graphically in Figures V-1, V-2, V-3, and V-4. All had reasonably good fits to the data, but the 2 power models (models 3 and 4) had the best fits with nearly identical r squares of roughly .84. The multivariate model had an r square of .81 while the linear model had an r square of .78.

The 2 linear models generally predict higher weight impacts across most vehicle weight categories. This is a function of the relative steepness of the slopes required to reach the high weights associated with heavier

[37] Calculations were based on the vehicle's weight plus an upward adjustment to reflect the maximum weight that might occur for its body style. NHTSA examined the range of weights available for a sample of vehicles and found an average 16% difference between the lightest version and the heaviest version. Since it is uncertain where any particular vehicle would fall in this range, an average impact of 8% was applied to each case.

vehicles. Accompanying this trend are relatively low predictions of weight increases for the lightest categories of vehicles. In fact, both linear form models potentially predict weight <u>reductions</u> for vehicles below 2,500 lbs., with the simple linear model predicting reductions below 2,700 lbs. Generally, the simple linear model matches up poorly with the data at levels below 3,000 lbs. The multivariate model performs better in this range, but under certain combinations of SWR and vehicle weight, it also can produce negative or understated results. Both linear forms tend to predict values well above the majority of data points that bunch between 3,500-5,000 lbs. The multivariate model most closely tracks the higher estimates within any given range.

By contrast, the 2 power functions closely track the preponderance of data points. These models predict a slow but increasing rise in weight impacts up through about 5,000 lbs., after which their slopes turn steeper than the linear models, and they predict even higher weight changes than the linear models for the heaviest vehicles.

Of the 4 models, the simple linear model provides the weakest fit. More importantly, it is unusable for vehicles within a substantial portion of the possible weight ranges. The simple linear model was therefore discarded. Likewise, the multivariate model produces potentially inaccurate (negative) results at lower vehicle weights for certain SWR/weight combinations. Thus, both linear models were discarded.

Given the limited sample of data available to the agency, and the variety of possible design outcomes associated with hundreds of vehicle designs, the agency acknowledges that there is a great degree of uncertainty in making predictions based on this small set of data. Each of the models has its own functional bias (characteristics) but, although judgments can be made regarding how well they fit the data, it is much more difficult to determine how representative the data are of the vehicle fleet. Both of the power functions produce similar results overall. Visually, the quadratic polynomial seems to better fit the bulk of the data points and produces a rapid rise in weight that, based on an examination of the data, is expected for heavier vehicles. It also provides average weight measures that are roughly midway between the multivariate and polynomial models. Note that, while there is variation at specific weight levels across all the models, the average weight impact for all vehicle weights across the 3 best models (highest to lowest estimate) differs by only about 6 percent for vehicles under 6,000 lbs. GVWR. For vehicles over 6,000 lbs. GVWR, the average weight impact differs by 33 percent. In both cases the quadratic model gives an estimate between the polynomial and multivariate models, which makes it neither the most conservative nor most liberal choice. The potential variation produced by selecting the quadratic model is roughly + - 3% for vehicles under 6,000 lbs. For vehicles over 6,000 lbs. GVWR, the variation is more skewed, varying from +24% to – 9%, but using either of the other models would increase this variation. For these reasons, the quadratic model will be adopted to estimate vehicle weight increases.

(NOTE: Figures V-1 through V-4 contain Confidential data and are removed from the public version of this document)

FIGURE V-1

CONFIDENTIAL

FIGURE V-2

CONFIDENTIAL

FIGURE V-3

CONFIDENTIAL

FIGURE V-4

CONFIDENTIAL

To estimate the average weight impact across the vehicle fleet, the agency used results from the 76 vehicles that were part of the roof crush test program (see Chapter II). Vehicles were divided into over 6,000 lbs. GVWR and under 6,000 lbs. GVWR categories for separate analysis. In cases where vehicles were tested across several model years, only the most recent model year results were used.

For the > 6,000 lbs. GVWR category, each vehicle that failed the 2.5 standard plus a 20% compliance margin, plus an 8% adjustment for maximum vehicle weight was included. The 8% adjustment was derived by examining the lightest and heaviest weight models available for the common body forms in a sample of vehicles. This produced an average difference of 16%. The 8% midpoint was used because it was uncertain where any given vehicle fell in this range. Some would be higher, some lower. Each vehicle's maximum weight was used as the independent variable for the three models. The resulting estimated weight increases for each vehicle were then weighted using relative sales volumes to produce an average weight.

For the <6,000 lbs category, a similar process was used. However, vehicles within this weight category were divided into 6 discreet categories for small, medium, and large passenger cars, SUVs, vans, and pickups. A separate average weight increase was estimated for each vehicle category from the sample of tested vehicles and these weights were then combined based on the relative sales of each vehicle type during the most recent time period for which sales data were available (January through May 2008). This was done because the size profile of the sample of vehicles that were included in NHTSA's test program was not well matched with the makeup of current vehicle sales. Sustained high fuel prices have caused a dramatic shift in buyer preferences towards smaller, more fuel efficient vehicles, and manufacturers have switched production or announced plans to switch production away from the less fuel efficient SUVs and pickups and into smaller passenger cars or downsized LTVs.

The resulting average weight estimates for the 2.5 SWR, as well as the other SWRs, are summarized in Table V-2. The derivation of SWRs other than 2.5 is discussed below.

TABLE V-2

Initial Estimates of Average Weight Increases to Modify Existing Models to Meet Improved SWRs for 2-Sided Tests

SWR	<6,000 lbs. GVWR	>6,000 lbs. GVWR
2.5	18.6	42.1
3.0	37.3	84.2
3.5	55.9	126.3
2.0	NA	21.1
1.5	NA	8.4

<u>Weight Impacts for Alternative SWRs</u>

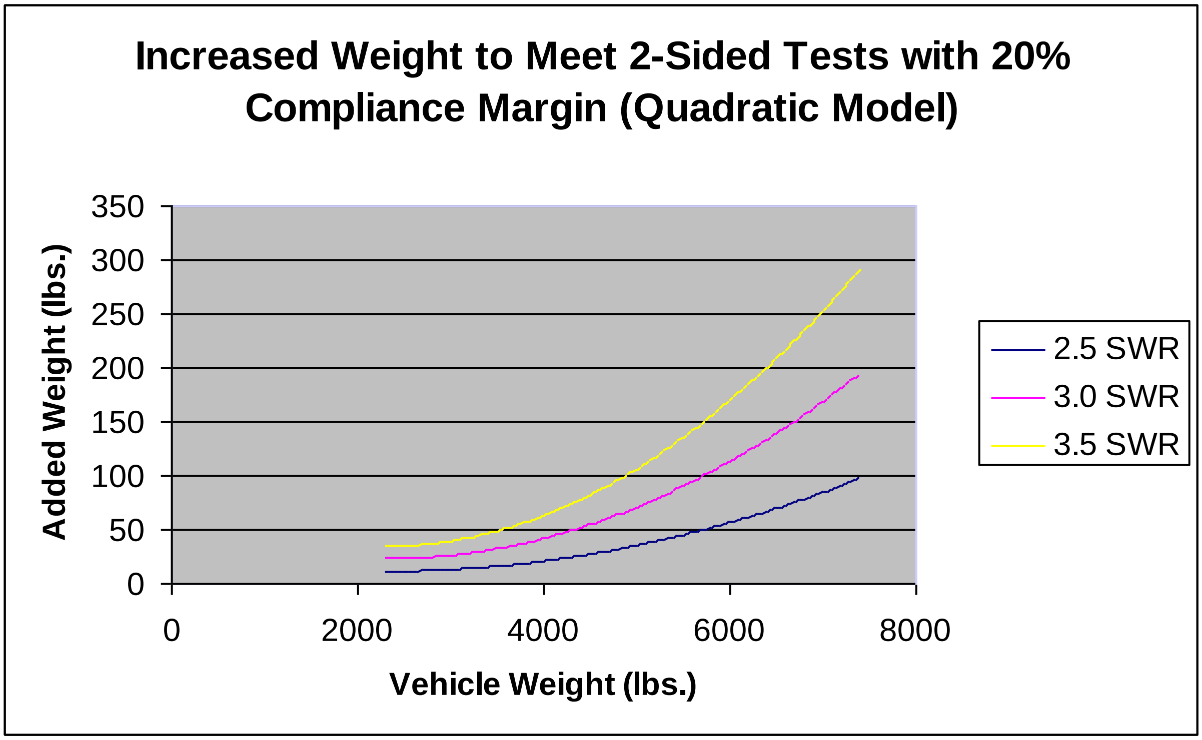
Initial estimates of added weight needed to meet the alternative SWR requirements were derived by shifting the curves for the three 2-sided 2.5 SWR models to reflect the higher strength requirements. The factors used to shift these curves were derived using the same assumptions noted above, i.e., that for each vehicle, the change in weight needed to meet a specific SWR is proportional to the change in strength required by that SWR, and that the change in strength to meet a 2-sided test (over a 1-sided test) was equal to the average change in strength observed in NHTSA's 2-sided test program. These assumptions were applied to the original 15 vehicle redesigns that were used to derive the 2.5 models. The same process was repeated normalizing to the alternative SWRs. The results indicate an average ratio for the 3.0/2.5 SWR of

1.96, and an average ratio for the 3.5/2.5 SWR of 2.91[38]. The same process was then repeated for the larger sample of tested vehicles that fail the 2.5 SWR to produce sales weighted average factors of 1.98 and 2.95 for 3.0 and 3.5 SWRs respectively. Based on these relationships, the 3.0 SWR weights were estimated by shifting the 2.5 SWR curve up by a factor of 2.0, and the 3.5 SWR weights were estimated by shifting the 2.5 SWR curve up by a factor of 3.0. The same process produced estimates of 0.5 for the 2.0 SWR and 0.2 for the 1.5 SWR.

Figure V-5 illustrates the resulting curves for the 3 SWRs applicable to vehicles < 6,000 lbs. GVWR for the Quadratic model. The resulting base estimates are shown for all SWRs in Table V-2. The results indicate an increasing weight impact at any given SWR for heavier vehicles. This occurs because the greater stress placed on heavier vehicles requires more strength, and thus more material to counteract than for lighter vehicles. It also reflects the fact that lighter vehicles generally are already at higher SWRs, and thus have a smaller marginal increase in SWR to attain.

[38] As with the original process, a 20% compliance margin was assumed for each alternative SWR.

Figure V-5



It is apparent from both docket submissions and NHTSAs own studies that the approach used to meet design changes is dependent on the point in the design cycle that changes are made. Manufacturers typically redesign vehicles every 4-7 years. Changes forced into the middle of the normal design cycle will typically be of an add-on nature, involving welded in reinforcements within the existing vehicle shape and structure. By contrast, when manufacturers initiate new vehicle designs, they can integrate the added strength requirements into the vehicles shape and structure, and plan the manufacturing process around the need for stronger and lighter reinforcements. When changes can be accomplished during the normal redesign cycle, many tooling and equipment costs are essentially sunk costs that would be expended during redesign regardless of the design specifics. It is thus far more efficient to accomplish structural redesigns at this time, and this is largely a function of leadtime.

Among the fairly limited sample of design analysis that were submitted in response to the NPRM and SNPRM, the agency found one to be of particular interest because of its approach and the level of detail that it provided. Magna Steyr was commissioned by the Alliance of Automobile Manufacturers to analyze changes to a vehicle to meet a 2.5 1-sided test requirement under both short term and long term (7-10 years) leadtime assumptions. The vehicle was a representative crew cab pickup truck chosen to represent "….the segment of vehicles not currently regulated by FMVSS 216, with the greatest range of UVWs with a common roof support structure and with the greatest challenge because of their large UVW". The vehicle weighed 7357 pounds and had a base SWR of 1.6.

Magna Steyr developed a finite element model for this vehicle consisting of 350,000 elements. According to their submission, they then "…..correlated the force deflection characteristics of the finite element model by replicating the gages and materials of the physically tested vehicle in the model. This served as a starting point for subsequent material substitutions and design iterations……All material substitutions and additional reinforcements had to satisfy the design and manufacturing constraints developed by Magna Steyr with input from Alliance members on issues such as maximum material thickness, minimum bend radii, thickness ratios for spot welding adjacent parts, welding compatibility of adjacent parts etc."

The resulting analysis by Magna Steyr found that improving the subject vehicle from its 1.6 SWR to a 2.5 SWR with a 20% compliance margin (effectively a 3.0 SWR) using current technology would require both upgrading current components and adding additional reinforcements. Magna Steyr estimated that the net impact of these changes was a weight increase of 72 pounds and an incremental piece cost of between $76 (high volume) and $98 (low volume) per vehicle.

The second part of the Magna Steyr study analyzed a long leadtime scenario which allowed for the use of more advanced technologies. This analysis was predicated on material strength upgrades for all base parts as well stronger, but fewer reinforcements. Under these design parameters, the overall weight of the roof structure actually decreased by 11 pounds and variable costs increased from $60 (high volume) to $75 (low volume) per vehicle. This analysis thus indicates the possibility of redesigns that, while increasing prices due to advanced materials, do not add significant weight to the vehicle.

The agency anticipates that this rule will be issued with enough leadtime to provide manufacturers the opportunity to establish stronger roof designs within the majority of vehicles normal redesign cycles. There are several reasons why this is important for this rule in particular: 1) the nature of the changes required to strengthen the roof are structural in nature. Unlike some safety standards like Electronic Stability Control, Air Bags, Safety Belts, etc., these changes are not basic add-ons of technology, but rather involve the overall design of the vehicle’s body structure. For changes of this nature, the efficiencies available through redesign are much more cost effective than add-on reinforcements. 2) As noted in Appendix A, normal add-on reinforcements will increase the center of gravity of vehicles and potentially create an increased probability of rollover. This would offset the benefits achieved by stronger roofs. To prevent this, manufacturers must minimize the weight added above the center of gravity or offset CG impacts through other redesigned features such as increasing the track width or designing in a lower CG from the start. These types of changes can best be accomplished during the initial vehicle design process.

The agency thus believes that, given adequate leadtime, manufacturers will ultimately employ roof designs that minimize added weight by maximizing the inherent strength of roofs through efficient designs that, within the confines of stylistic and other functional requirements, provide for the strongest interactive design parameters for roofs and pillars. This will involve the use of advanced materials.

In their docket submission, Magna Steyr provided a detailed list of the materials, weights, and costs involved in the base design as well as the 2 different upgrade scenarios they designed. These data are summarized in Table V-3.

Table V-3
MAGNA STEYR COST ANALYSIS

		BASELINE				CURRENT TECHNOLOGY				ADVANCED TECHNOLOGY			
	No. parts	Weight/ Part	$/lb	Total Cost	Total Weight	Weight/ Part	$/lb	Total Cost	Total Weight	Weight/ Part	$/lb	Total Cost	Total Weight
A-Pillar Hinge Pillar Outer	2	14.76	$0.80	$23.62	29.52	16.16	$0.80	$25.86	32.32	7.03	$1.40	$19.68	14.06
A-Pillar Inner	2	2.96	$0.80	$4.74	5.92	3.14	$0.80	$5.02	6.28	2.84	$1.15	$6.53	5.68
B-Pillar Outer	2	20.56	$0.80	$32.90	41.12	22.52	$0.80	$36.03	45.04	12.73	$1.40	$35.64	25.46
B-Pillar Inner	2	2.90	$0.80	$4.64	5.80	3.37	$1.10	$7.41	6.74	3.79	$1.40	$10.61	7.58
B-Pilar Reinforcement Upper	2	2.10	$0.80	$3.36	4.20	1.68	$1.10	$3.70	3.36	2.30	$1.40	$6.44	4.60
C-Pillar Outer	2	11.48	$0.80	$18.37	22.96	12.02	$0.80	$19.23	24.04	7.97	$1.40	$22.32	15.94
C-Pillar Body Side Outer	2	4.79	$0.80	$7.66	9.58	4.79	$1.10	$10.54	9.58	6.36	$1.40	$17.81	12.72
C-Pillar Reinforcement Upper	2	3.45	$0.80	$5.52	6.90	3.45	$1.40	$9.66	6.90	2.76	$1.40	$7.73	5.52
C-Pillar Inner	2	3.53	$0.80	$5.65	7.06	3.53	$1.10	$7.77	7.06	3.13	$1.40	$8.76	6.26
Side Header Outer	2	1.08	$0.80	$1.73	2.16	1.08	$0.80	$1.73	2.16	1.54	$1.40	$4.31	3.08
Side Header Inner	2	2.99	$0.80	$4.78	5.98	2.99	$1.10	$6.58	5.98	2.23	$1.40	$6.24	4.46
Frt Header Upper	1	3.26	$1.10	$3.59	3.26	3.26	$1.10	$3.59	3.26	2.44	$1.40	$3.42	2.44
Frt Header Lower	1	3.73	$1.10	$4.10	3.73	3.73	$1.10	$4.10	3.73	2.78	$1.40	$3.89	2.78
Roof Bow	1	4.18	$0.80	$3.34	4.18	8.78	$1.10	$9.66	8.78	2.93	$1.40	$4.10	2.93
Rear Header	1	2.98	$0.80	$2.38	2.98	2.98	$0.80	$2.38	2.98	4.58	$1.40	$6.41	4.58
Roof Panel	1	41.60	$0.80	$33.28	41.60	41.60	$1.10	$45.76	41.60	30.38	$1.40	$42.53	30.38
Sill Outer	2	3.53	$0.80	$5.65	7.06	3.53	$0.80	$5.65	7.06	3.53	$1.40	$9.88	7.06
Door ring Outer	2	21.54	$0.80	$34.46	43.08	21.54	$0.80	$34.46	43.08	20.10	$0.80	$32.16	40.20
A-Pilar Tube Reinf Part 1	2					4.24	$1.10	$9.33	8.48	3.92	$1.10	$8.62	7.84
A-Pilar Tube Reinf Part 2	2					3.10	$1.10	$6.82	6.20	2.88	$1.10	$6.34	5.76
Hinge Reinf	2					1.04	$1.10	$2.29	2.08	1.04	$1.10	$2.29	2.08
A Pillar Inner Reinf	2					0.46	$0.80	$0.74	0.92				
B Pillar Outer Reinf	2					3.12	$0.80	$4.99	6.24	2.86	$0.80	$4.58	5.72
B Pillar Tube Reinf Part 1	2					2.65	$1.00	$5.30	5.30	2.65	$1.00	$5.30	5.30
B Pillar Tube Reinf Part 2	2					1.65	$1.00	$3.30	3.30	1.65	$1.00	$3.30	3.30
B Pillar Inner Reinf Part 1	2					2.93	$1.10	$6.45	5.86	2.04	$1.10	$4.49	4.08
B Pillar Inner Reinf Part 2	2					2.39	$0.80	$3.82	4.78	1.78	$0.80	$2.85	3.56

MAGNA STEYR COST ANALYSIS

	No. parts	BASELINE Weight/ Part	$/lb	Total Cost	Total Weight	CURRENT TECHNOLOGY Weight/ Part	$/lb	Total Cost	Total Weight	ADVANCED TECHNOLOGY Weight/ Part	$/lb	Total Cost	Total Weight
B Pillar Inner Reinf Part 3	2					1.49	$0.80	$2.38	2.98	1.49	$0.80	$2.38	2.98
Rocker Reinforcement	2					5.69	$1.40	$15.93	11.38				
Retractor Cover Plate	2					0.58	$1.40	$1.62	1.16				
Total				$199.77	247.09			$302.10	318.63			$288.63	236.35
Added Weight Over Baseline (lbs.)									72				-11
		Price/ pound =		$0.81		Price/ pound =		$0.95		Price/ pound =		$1.22	

Cost Methodology

Although the agency received a variety of cost and weight estimates, only the Magna Steyr submission addressed the issue of integrating design changes through material substitution in enough detail to provide a basis for further analysis. This submission will thus be used as a model to generate cost estimates for the vehicle fleet.

The Magna Steyr analysis depicts changes to a 7,357 lb. Crew Cab pickup that increases its SWR from 1.6 to 3.0 in a single sided test. When compared to the entire new vehicle fleet, this is clearly not a representative vehicle in terms of weight, body form, or base SWR. This is especially true for the <6,000 lb. GVWR category where most vehicles are either passenger cars or light SUVS, where the average base SWR is about 2.2, and where the average vehicle weight is roughly 3,700 lbs. The Magna Steyr analysis tracks new reinforcements that are added to existing roof structures as well as changes in gauge or materials to existing roof and body structures. To create a model that is representative of the new vehicle fleet based on the Magna Steyr analysis, a series of adjustments will be necessary. These adjustments will be required to:

1) Adjust the Magna Steyr vehicle results to reflect the higher SWRs that are consistent with the alternatives examined in this analysis.
2) Estimate the average base weight of existing roof structures that might be modified in the fleet.
3) Estimate the amount of weight that will be added to the base roof structure through strengthening add-ons such as added reinforcements or material gauge increases.
4) Adjust the Magna Steyr vehicle models for each alternative to reflect the lower weight of vehicles in the fleet.

5) Normalize the cost and weight estimates of the average fleet to reflect the higher SWR of vehicles in the new car fleet.

Adjustments to Magna Steyr Results to Reflect Examined Alternatives

The Magna Steyr vehicle was modified to meet a one sided SWR requirement of 2.5 x vehicle weight plus a 20% compliance margin. The alternatives examined in this analysis involve both single and 2 sided testing under a variety of SWRs (2.5, 3.0, 3.5). To adopt the Magna Steyr model to these alternatives, its results must be normalized to their higher levels.

To accomplish this, the relative strength of the Magna Steyr roof structure designs was determined. Magna Steyr provided analyses of 2 different technology scenarios – the first uses current technology that could be accomplished with short leadtime, the second utilizes advanced technology that requires changes to be made during the vehicles redesign cycle. Each scenario results in a different roof structure with a different specific weight that can withstand the same force limits (a 3.0 SWR measured in a 1 sided test.) The force/lb. for each roof component design mix was derived by dividing the total force achieved for the Magna Steyr vehicle by the weight of the respective roof structures. The results were then divided into the total force required for the Magna Steyr vehicle to meet each of the alternatives.

Previously we noted that within NHTSA's test fleet, vehicles < 6,000 lbs. GVWR that were subjected to 2 sided tests experienced a change in required SWR of roughly 7% above the single sided results for the same vehicle (15% for vehicles > 6,000 lbs. GVWR). To adjust the Magna Steyr results to each alternative SWR and sides tested option, the following formula was used:

$$[(7357*SWR(n)*1.2*(1+sn))/((7357*2.5*1.2)/W(t))] - 247.09$$

Where:

7357 = Magna Steyr vehicle weight

SWR(n) = Strength to Weight ratio required for alternative n

1.2 = compliance margin

S(n) = adjustment factor for number of sides testing required for alternative n. This equals .07 for 2 sided tests for vehicles < 6,000 lbs. GVWR, .15 for vehicles >6,000 lbs. GVWR, and 0.0 for single sided test alternatives

2.5 = SWR goal in Magna Steyr vehicle analyses

W(t) = original Magna Steyr weight of roof components (either 318.63 for current technology or 236.35 for advanced technology).

247.09 = Base weight of Magna Steyr vehicle roof components

So, for example, for the 3.0 SWR alternative with a 2 sided test requirement, the equivalent weight requirement for the Magna Steyr vehicle under the high technology option would be:

[((7357*3.0*1.2*1.07))/((7357*2.5*1.2)/236.35)]-247.09 = 56.38 lbs.

This process gives a range of weight results that vary across each alternative. Table V-4 summarizes the equivalent weight impacts estimated for the Magna Steyr vehicle under each alternative. These are essentially proxy starting points for estimating impacts to the lighter vehicles in the overall fleet. Results for two sided tests are different for vehicles over and under 6,000 lbs. GVWR because the impact of two sided testing is greater on heavy vehicles than on lighter vehicles (15% vs. 7%).

Table V-4

Magna Steyr Vehicle Derived Results for Alternative SWRs and Test Requirements				
	< 6,000 lbs. GVWR		> 6,000 lbs. GVWR	
	1-Sided Tests	2-Sided Tests	1-Sided Tests	2-Sided Tests
1.5 SWR				
Current Technology	NA	NA	39	46
Advanced Technology	NA	NA	-11	-11
2.0 SWR				
Current Technology	NA	NA	55	65
Advanced Technology	NA	NA	-11	-11
2.5 SWR				
Current Technology	72	94	72	119
Advanced Technology	-11	6	-11	25
3.0 SWR				
Current Technology	135	162	135	193
Advanced Technology	37	56	37	79
3.5 SWR				
Current Technology	199	230	199	266
Advanced Technology	84	107	84	133

Thus, for example, while the Magna Steyr vehicle was estimated to achieve a 2.5 SWR with a 20% compliance margin with weight impacts of 72 pounds using current technology, or a weight savings of 11 pounds using advanced technology, requiring the same vehicle to meet a 2 sided test with the same 2.5 SWR level would require weight increases of 94 pounds using current technology or 6 pounds using advanced technology. More stringent requirements require thicker gauges of either the current mix of steels used in the current technology scenario, or of the advanced high strength steels used in the advanced technology scenario. In either case, total weight increases relative to the 2.5 one sided SWR. Conversely, the more lax requirements require less total weight. Note, however, that the weaker requirements all share the same high technology impact of a savings of 11 pounds. This represents the need to retain a basic level of structural integrity regardless of how low the formal requirement for roof strength might be. The agency does not have information to determine this level, so it is assumed that manufacturers would not further diminish the weight of the roof structure beyond the level that results from the original advanced technology scenario.

Base Roof Component Weight

The Magna Steyr analysis included a detailed breakdown of the existing roof components in the 7,357 lb. GVWR crew cab pickup that they analyzed. A list of those components, which weighed a total of 247 lbs., is included in Table V-3. They include inner and outer structural components of the A, B, and C pillars, the front, side, and rear headers, as well as the roof panel, outer sill, and outer door ring. For their current technology fix, which resulted in a 72 lb. weight increase, Magna Steyr modified many of these components by increasing the components' gauge, by substituting a higher strength steel, or both in combination. For the Advanced Technology scenario, which allowed for an eleven pound weight decrease, they substituted more exotic steels which attained high strength but allowed for significant weight reductions. Modifications to the base existing roof structure are thus integral to the cost of complying with increased roof strength requirements.

The weight of base roof structures varies across the hundreds of vehicle models offered in the U.S. market. Vehicles vary stylistically, as well as in practical requirements for interior space, headroom, and structural challenges to meet existing standards. Larger vehicles require more roof structure to cover wider and deeper interiors, and may require taller A, B, and C-pillars to provide more headroom as well. Larger vehicles also weigh more, increasing the relative need for component strength to meet any given SWR. Vehicles in the < 6,000 lbs. GVWR category are primarily passenger cars and small SUVs, and their weight and roof structure differs significantly from the Magna Steyr crew cab pickup. The agency does not have detailed information regarding the weight of roof components for these vehicles. Therefore, an estimate of the weight of base roof structure components in this fleet that could be changed will be made assuming that roof component weight is roughly proportional to the load it must be designed to bear. This is a function of the average vehicle weight and the relative roof strength achieved in the < 6,000 lbs. GVWR fleet.

The weight and SWR of the < 6,000 lbs. GVWR fleet was estimated by examining the 56 test vehicles in that weight category for which NHTSA has specific weight and SWR information. The vehicles that failed each examined SWR alternative were used for estimates for that alternative. Failed vehicles' weights and SWRs were averaged based on relative vehicle sales rates. Seventeen passenger cars failed the 2.5 SWR requirements, and these vehicles had an average weight of 3,257 lbs. and an average SWR of 2.25. Seventeen LTVs also failed the 2.5 SWR alternative, and these vehicles had an average weight of 4,094 lbs. and an average SWR of 2.20.

The estimated average weight of this fleet's base roof components was thus derived as follows:

R(f) = (W(f)*SWR(f)/W(ms)*SWR(ms)*R(ms)

Where R(f) = average base roof component weight of the vehicle fleet (calculated separately for < 6,000 lbs. GVWR and > 6,000 lbs. GVWR fleets)

W(f) = average weight of < 6,000 lbs. GVWR fleet vehicles

SWR(f) = average SWR attained by the vehicle fleet (calculated separately for < 6,000 lbs. GVWR and > 6,000 lbs. GVWR fleets)

W(ms) = weight of Magna Steyr vehicle

SWR(ms) = SWR of Magna Steyr vehicle

R(ms)= base roof component weight of Magna Steyr vehicle (247.09 lbs.)

For passenger cars < 6,000 lbs. GVWR, the estimated weight of roof components is therefore (3257x2.25)/(7357x1.6)x247 = 154 lbs.

For LTVs < 6,000 lbs. GVWR, the estimated weight of roof components is (4094x2.20)/(7357x1.6)x247 = 189 lbs.

Several points should be noted here. The first is that different body styles can result in significantly different shapes and weight proportions for roof components. A- and B-pillars can vary in thickness or height, but are fundamentally similar in shape in most vehicles. B-pillars are typically vertical members viewed from a side perspective with slight angular tilt viewed from a frontal perspective. A-pillars are typically tilted at varying angles depending on the vehicles styling profile. The component with the most variation is the C-pillar. The sheet metal proportions of C-pillars show significant variation across body styles because they often incorporate large portions of the rear body panels within the same stamping. Thus, C-pillars may represent a different proportion of total roof component weight in passenger cars and LTVs than they do in pickups, where they are basically abridged vertical members. The importance of C-pillars in achieving increased roof strength is thus likely to be variable across vehicle designs.

NHTSA examined documents from manufacturers submitted in response to the NPRM and SNPRM detailing design changes to meet higher SWR requirements and found no involvement of C-pillars in any cases except for the Magna Steyr analysis, and in one case for a 3.5 SWR alternative in one vehicle. This would seem to indicate that C-pillars may not be involved in most vehicle design changes. The Magna Steyr vehicle also appears to have a narrow B pillar to accommodate centrally opening doors, which with its pickup body style, forces it to rely on C pillars for structural integrity. This would have two offsetting impacts on the estimates of base roof weight. First, to whatever extent manufacturers did modify C pillars in passenger cars or SUVs, the assumption of proportionality to roof strength requirements might understate the full weight of components equivalent to those fully utilized in Magna Steyr. This would understate design cost changes because C-pillars are significantly heavier in these types of vehicles. Secondly, to whatever extent the design costs were underestimated, it would also underestimate the potential structural area that is available for weight reduction. This would decrease the potential for reduced fuel expenditures, and overstate the cost of added fuel. The two impacts are directionally offsetting, but their net impact is unknown. However, the agency believes that for most vehicles, C pillars are unlikely to be changed, and the basic assumption used is actually that the weight of roof components that will likely be changed, wherever they are located, is proportional to the relative load the roof must bear. Overall, we believe that the assumption of proportionality provides a reasonable, but not precise, basis for estimating the weight of basic roof components that might be changed in these vehicles.

To gain perspective on the results of this method we examined the 4 finite element models that were developed for the agency by George Washington University to simulate the cost of meeting specific FMVSS as well as a more recent one developed for the S-10 pickup. Using these models the weight of roof components that would be changed was estimated. The results were as follows:

Taurus:

Including full C-pillar stampings: 229.45 lbs.

Excluding C-pillars: 133.55 lbs.

Neon:

Including full C-pillar stampings: 100.23 lbs.

Excluding C-pillars: 88.08 lbs.

Explorer:

Including full C-pillar stampings: 204.8 lbs.

Excluding C-pillars: 115.5 lbs.

Caravan:

Including full C-pillar stampings: 358.3 lbs.

Excluding C-pillars: 122.7 lbs.

S-10 Pickup:

No C-pillars: 63.6 lbs.

These 5 vehicles are the only ones for which NHTSA has finite element models that can be used to break out roof component weight. They are not a representative sample of vehicles offered today. Both the Taurus and Neon are currently out of production and the Explorer and Caravan have since undergone redesign. The S-10 is a small pickup with a much smaller roof than most vehicles. They are shown here to give perspective to the issue of roof design and weight. The range of roof component weights across the 2 design choices generally spans the predicted weights derived for each category of vehicle (154 lbs. for passenger cars and 189 lbs. for LTVs). The Neon, being a smaller vehicle, has components that are lighter than the estimate for average passenger cars while the heavier Taurus has components that are potentially nearly 50% above the estimate. Both the Explorer and Caravan exceed the estimate for LTVs when C-pillars are included, but are below the estimate when C-pillars are excluded. The S-10 has no C-pillar, and its roof covers a small area.

It is apparent that there are significant weight differences attributable to C-pillar stampings that will present manufacturers with considerable design choice when determining how best to meet this standard. Spreading the design changes across C-pillars through the use of high strength light weight materials would increase production costs, but would also open up opportunities for significant weight savings and their associated fuel efficiency advantages.

Added Weight from New Reinforcements or Material Gauge Increases

In addition to material and gauge changes to existing roof components, higher roof strength requirements will be achieved through added structural reinforcements. In Table V-3, these added reinforcements are listed in the lower part of the table in bold typeface. They primarily include reinforcements to the inner, outer, and tube areas of the A, B, and C pillars. Magna Steyr's current technology scenario adds a dozen reinforcements using a variety of both basic and exotic steels. For the advanced technology scenario, only nine of these reinforcements are retained since incorporating high strength steel into the basic roof structure reduces the need for add-on reinforcements.

Previously it was established that there is a general relationship between vehicle weight and the added weight necessary to comply with a given standard. This relationship was a function of 2 factors:

1) The higher force levels that are imparted on heavier vehicles to meet any given SWR requirement.
2) The higher SWRs typically already achieved by lighter vehicles

To adjust the Magna Steyr model to reflect vehicle characteristics of the < 6,000 lbs. GVWR fleet, these 2 factors will be separately estimated so that they can be applied to the specific characteristics of this fleet. This section discusses the adjustment for point 1) above. The adjustment for point 2) will be discussed in a later section.

As previously noted, the basis for establishing this relationship is data collected by the agency in response to its NPRM and SNPRM. These data were summarized in Table V-1. There are a total of 20 estimates of weights to meet a 2.5 SWR, 8 estimates for a 3.0 SWR, and 6 estimates for 3.5 SWR. For costs, there were 10 estimates for a 2.5 SWR, 10 for a 3.0 SWR, and 7 for a 3.5 SWR. Of the vehicles in Table V-1, 7 are passenger cars, 6 are SUVs, 10 are pickups, and 3 are vans. Only 4 of the passenger cars included usable information because weight impacts were bunched with other weight offsets such that the added weight due to roof strength was obscured. 16 of the cases provide base SWRs for the subject vehicles.

Although the specific estimates were often contradictory as to the exact impact of raising the SWR, there was a reasonably consistent trend indicating that the weight and cost needed to meet any specific standard would increase as vehicle size increased. Other things being equal, this is to be expected since the absolute strength needed to meet a specific SWR is a function of the vehicle's weight. To meet a 2.0 SWR, a vehicle that weighs 3,000 lbs. must have a roof structure capable of withstanding 6,000 lbs. of force, whereas a vehicle that weighs 5,000 lbs. must have a roof structure capable of withstanding 10,000 lbs. of force. To estimate the impact of changes in SWR on the vehicle fleet, a model was developed based on this concept.

To derive this model, the agency selected from Table V-1 all vehicles that had identifiable base SWRs, base weights, SWRs achieved by redesign, and added weight to meet these redesign levels. This left 15 vehicle redesigns, each with a unique set of these factors. These vehicles were then normalized to a common basis using 2 assumptions – that for each vehicle, the change in weight needed to meet a specific SWR is proportional to the change in strength required by that SWR, and that the change in strength to meet a 2-sided test (over a 1-sided test) was equal to the average change in strength observed in NHTSA's 2-sided test program (roughly 7% for vehicles under 6,000 lbs. GVWR and roughly 15% for vehicles over 6,000 lbs. GVWR). The agency realizes that there are instances where these assumptions may not hold. For example, at some marginal strength requirement threshold, a manufacturer may choose to shift to a grade of steel that is stronger but lighter than steel that would have been used for changes to meet a slightly weaker requirement. However, this upgraded steel would have a higher cost/lb. and possibly higher assembly costs as well. Moreover, determining the thresholds where this could occur for each vehicle is not possible.

Under these assumptions, a 2-ided test equivalent weight increase was derived for each vehicle[39] for the 2.5 SWR alternative assuming a 20% compliance margin. Then, a similar calculation was made to estimate the weight increase that would be required to meet a 1.6 SWR, the level attained by the Magna Steyr vehicle. The difference in these values were then regressed using a variety of different statistical models to explore functions that could be used to estimate the added weight required to meet a 2-sided, 2.5 SWR requirement for any specific vehicle. A quadratic function was chosen with the following parameters:

$-8.86\ E07x^2+0.0228658x-33.13481$

Where x = vehicle weight

Using this function, an estimate of the weight change that would be required to change an average vehicle in the < 6,000 lbs. GVWR category was established using the average weight of these vehicles (3,257 lbs. for passenger cars and 4094 lbs. for LTVs). A similar calculation was made based on the Magna Steyr vehicle's weight (7,257 lbs.) and a ratio of the resulting estimates was derived to adjust the Magna Steyr added weight data to the average < 6,000 lbs. GVWR passenger car and LTV levels. The results indicate that an average < 6,000 lbs. GVWR passenger car would only have to add 37% as much weight to change from a 1.6 SWR to a 2.5 SWR as would the Magna Steyr vehicle. LTVs < 6,000 lbs. GVWR would only have to add 52% as much weight.

We should note here that, while this function expresses the best fit through the data, it does not imply that the fit is good. In fact, the R^2 for this model is only 0.39. This reflects the fact that there is a great deal of variation in roof structures among models with similar weights due both to different body styles and different

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Calculations were based on the vehicle's weight plus an upward adjustment to reflect the maximum weight that might occur for its body style. NHTSA examined the range of weights available for a sample of vehicles and found an design parameters within common body styles. This variation would be significantly diminished if only common body styles were analyzed separately, but there are too few data points for some body styles to allow for separate calculations (6 passenger cars, 4 SUVs, 3 pickup trucks, 2 vans).

Adjustment to Reflect the Higher SWR of Vehicles in the New Vehicle Fleet

The Magna Steyr vehicle was modified from its base 1.6 SWR to an SWR equivalent to 2.5 plus a 20% compliance margin or 3.0. However, the fleet of vehicles in the < 6,000 lbs. GVWR category that fail the 2.5 SWR alternative have an average base SWR of 2.25 for passenger cars and 2.20 for LTVs, roughly 40% higher than the Magna Steyr vehicle. There is thus a smaller gap between these vehicles' current roof strength levels and the levels that must be obtained for the new standards. These vehicles would thus require a smaller increase in their strength to attain any nominal higher SWR level.

To adjust for this, a factor was derived from the ratio of the estimated SWR required to meet each alternative to the base SWRs of the Magna Steyr and average < 6,000 lbs. GVWR vehicles.

$F_{swr} = (1-SWR_a/SWR_f)/(1-SWR_a/SWR_{ms})$

Where: F_{swr} = Factor to adjust for higher fleet SWR

SWR_a = Nominal SWR of specific alternative x 1.20 x1.08 x$(1+t_n)$

t_n = Factor representing increase in strength required to meet 2 sided test over 1 sided test (7% for vehicles < 6,000 lbs. GVWR; 15% for vehicles > 6,000 lbs. GVWR, 0% for single sided test scenarios)

SWR_f = Average SWR of specific vehicle fleet that will be modified (calculated separately for passenger cars, LTVs < 6,000 lbs. GVWR, and vehicle > 6,000 lbs. GVWR)

SWR_{ms} = SWR of Magna Steyr vehicle (1.6)

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average 16% difference between the lightest version and the heaviest version. Since it is uncertain where any particular vehicle would fall in this range, an average impact of 8% was applied to each case.

For Passenger cars meeting a 1 sided 2.5 SWR standard this gives:

(1-3.24/2.25)/(1-3.24/1.6) = .4293

For LTVs < 6,000 lbs. GVWR meeting a single sided 2.5 SWR standard this gives:

(1-3.24/2.20)/(1.3.24/1.6) = .4612

For vehicles > 6,000 lbs. GVWR meeting a single sided 2.5 SWR standard this gives:

(1-3.24/1.72)/(1.3.24/1.6) = .8622

Table V-5 summarizes the resulting adjustment factors for each alternative and vehicle type. As would be expected, the factors are generally higher for heavier vehicles. Factors increase as SWRs increase across common base SWRs and they also increase for a given SWR when moving from 1-sided to 2-sided tests. These factors would not necessarily increase as SWRs increase if the base SWR of the affected vehicle fleet changes, since this would reset the basis for the calculation.

Table V-5

Adjustment Factors for Base SWRs of Failing Fleet			
Passenger Cars	Base SWR	1 Sided	2 Sided
2.5	2.25	0.4293	0.4635
3.0	2.70	0.3077	0.3380
3.5	2.70	0.3706	0.3922
LTVs <6,000 lbs. GVWR			
2.5	2.20	0.4612	0.4935
3.0	2.26	0.5037	0.5255
3.5	2.26	0.5488	0.5643
LTVs >6,000 lbs. GVWR			
1.5	1.66	0.7957	0.8729
2.0	1.66	0.9056	0.9219
2.5	1.72	0.8622	0.8777
3.0	1.72	0.8814	0.8914
3.5	1.72	0.8922	0.8994

Cost and Weight Model

Using the parameters derived from the above adjustments, high cost and low weight anchor points were established separately for each of the 3 vehicle categories (passenger cars < 6,000 lbs. GVWR, LTVs <6,000 lbs. GVWR, LTVs> 6,000 lbs. GVWR) for each alternative scenario. These points correspond to the high and low weight impacts noted in Table V-4. These points essentially represent a worst case result based on current technology under relatively short leadtime and a best case result which assumes adequate leadtime allowing for application of advanced materials during the normal design cycle. Between these points is a continuum of possible impacts representing, from the highest weight to lowest weight case, iteratively more advanced technology, increasing cost/lb., and less vehicle weight. Each of these points represents a hypothetical solution that is neither as weight-costly as the current technology scenario, nor as weight-saving as the advanced technology scenario.

Table V-6 illustrates this continuum for the Magna Steyr vehicle meeting a single sided test and a 2.5 SWR with a 20% compliance margin (3.0 SWR). The adjustments described previously would be applied to each row of this model to estimate the cost and weight impacts for each vehicle category. As vehicle weight declines, the mix of advanced materials increases and the average cost/lb. increases as well. Note, however, that although the cost/lb steadily increases, the number of pounds of weight required declines by a slightly faster rate. This results in a steady but gradual decrease in the total cost of achieving compliance. This would be a desirable result for manufacturers, provided they are able to accomplish the advanced technology changes envisioned by Magna Steyr. However, Magna Steyr noted that this is predicated upon achieving significant improvements in material availability and manufacturing processes. The interaction of costs and weights is illustrated in Figure V-6. However, we note that the application of the adjustment factors discussed above decreases the rate of increase for unit costs relative to the change in weight. This occurs because the adjustments are applied to 100% of the weight change, but they only affect the increased portion of unit materials costs. This can affect the relative rates of change for weight and unit costs, and can result in a gradual overall increase in unit costs as weight declines.

In reality, of course, for any given vehicle, both cost and weight impacts would occur in a more stepwise manner as manufacturers decide to replace specific components with specific material grades or add specific reinforcements. A decision to replace the B-pillars with high strength steel would potentially reduce weight substantially. A subsequent decision to apply the same treatment to the A-pillars would cause another drop in weight, etc. Nonetheless, for purposes of estimating cost and weight impacts, a continuous model is appropriate because it represents the entire fleet of vehicles. The step points for different vehicles could lie at different places along the continuum. The stepwise nature of implementing design decisions is illustrated in Figure V-7

Table V-6

Model Results for Magna Steyr Vehicle Meeting 1-sided 2.5 SWR w/20% Compliance Margin

Weight Change	Unit $/lb.	Total Roof Weight	Total Roof Piece Cost	Added Piece Cost	Consumer Cost
-11	$1.221	236.09	$288.308	$88.54	$101.23
-10	$1.218	237.09	$288.74	$88.97	$101.72
-9	$1.215	238.09	$289.17	$89.40	$102.21
-8	$1.211	239.09	$289.59	$89.82	$102.69
-7	$1.208	240.09	$290.01	$90.24	$103.17
-6	$1.205	241.09	$290.41	$90.64	$103.63
-5	$1.201	242.09	$290.82	$91.05	$104.09
-4	$1.198	243.09	$291.21	$91.44	$104.54
-3	$1.195	244.09	$291.60	$91.83	$104.99
-2	$1.191	245.09	$291.98	$92.21	$105.42
-1	$1.188	246.09	$292.35	$92.58	$105.85
0	$1.185	247.09	$292.72	$92.95	$106.27
1	$1.181	248.09	$293.08	$93.31	$106.69
2	$1.178	249.09	$293.44	$93.67	$107.09
3	$1.175	250.09	$293.79	$94.02	$107.49
4	$1.171	251.09	$294.13	$94.36	$107.88
5	$1.168	252.09	$294.46	$94.69	$108.26
6	$1.165	253.09	$294.79	$95.02	$108.64
7	$1.161	254.09	$295.11	$95.34	$109.01
8	$1.158	255.09	$295.43	$95.66	$109.37
9	$1.155	256.09	$295.73	$95.97	$109.72
10	$1.151	257.09	$296.04	$96.27	$110.06

11	$1.148	258.09	$296.33	$96.56	$110.40
12	$1.145	259.09	$296.62	$96.85	$110.73
13	$1.142	260.09	$296.90	$97.13	$111.05
14	$1.138	261.09	$297.18	$97.41	$111.37
15	$1.135	262.09	$297.45	$97.68	$111.67
16	$1.132	263.09	$297.71	$97.94	$111.97
17	$1.128	264.09	$297.96	$98.19	$112.26
18	$1.125	265.09	$298.21	$98.44	$112.55
19	$1.122	266.09	$298.45	$98.68	$112.82
20	$1.118	267.09	$298.69	$98.92	$113.09
21	$1.115	268.09	$298.92	$99.15	$113.36
22	$1.112	269.09	$299.14	$99.37	$113.61
23	$1.108	270.09	$299.35	$99.58	$113.86
24	$1.105	271.09	$299.56	$99.79	$114.09
25	$1.102	272.09	$299.76	$100.00	$114.32
26	$1.098	273.09	$299.96	$100.19	$114.55
27	$1.095	274.09	$300.15	$100.38	$114.76
28	$1.092	275.09	$300.33	$100.56	$114.97
29	$1.088	276.09	$300.51	$100.74	$115.17
30	$1.085	277.09	$300.68	$100.91	$115.37
31	$1.082	278.09	$300.84	$101.07	$115.55
32	$1.078	279.09	$300.99	$101.22	$115.73
33	$1.075	280.09	$301.14	$101.37	$115.90
34	$1.072	281.09	$301.28	$101.52	$116.06
35	$1.069	282.09	$301.42	$101.65	$116.22
36	$1.065	283.09	$301.55	$101.78	$116.37
37	$1.062	284.09	$301.67	$101.90	$116.51
38	$1.059	285.09	$301.79	$102.02	$116.64
39	$1.055	286.09	$301.90	$102.13	$116.76
40	$1.052	287.09	$302.00	$102.23	$116.88
41	$1.049	288.09	$302.09	$102.33	$116.99
42	$1.045	289.09	$302.18	$102.41	$117.09
43	$1.042	290.09	$302.27	$102.50	$117.19
44	$1.039	291.09	$302.34	$102.57	$117.27
45	$1.035	292.09	$302.41	$102.64	$117.35
46	$1.032	293.09	$302.47	$102.71	$117.42
47	$1.029	294.09	$302.53	$102.76	$117.49
48	$1.025	295.09	$302.58	$102.81	$117.54
49	$1.022	296.09	$302.62	$102.85	$117.59
50	$1.019	297.09	$302.66	$102.89	$117.63
51	$1.015	298.09	$302.69	$102.92	$117.67
52	$1.012	299.09	$302.71	$102.94	$117.69
53	$1.009	300.09	$302.73	$102.96	$117.71
54	$1.005	301.09	$302.74	$102.97	$117.72
55	$1.002	302.09	$302.74	$102.97	$117.73
56	$0.999	303.09	$302.74	$102.97	$117.72
57	$0.996	304.09	$302.73	$102.96	$117.71
58	$0.992	305.09	$302.71	$102.94	$117.69
59	$0.989	306.09	$302.69	$102.92	$117.66

60	$0.986	307.09	$302.66	$102.89	$117.63
61	$0.982	308.09	$302.62	$102.85	$117.59
62	$0.979	309.09	$302.57	$102.81	$117.54
63	$0.976	310.09	$302.52	$102.76	$117.48
64	$0.972	311.09	$302.47	$102.70	$117.42
65	$0.969	312.09	$302.40	$102.64	$117.34
66	$0.966	313.09	$302.33	$102.57	$117.26
67	$0.962	314.09	$302.26	$102.49	$117.18
68	$0.959	315.09	$302.17	$102.41	$117.08
69	$0.956	316.09	$302.08	$102.32	$116.98
70	$0.952	317.09	$301.99	$102.22	$116.87
71	$0.949	318.09	$301.88	$102.12	$116.75
72	$0.946	319.09	$301.77	$102.01	$116.62

Figure V-6

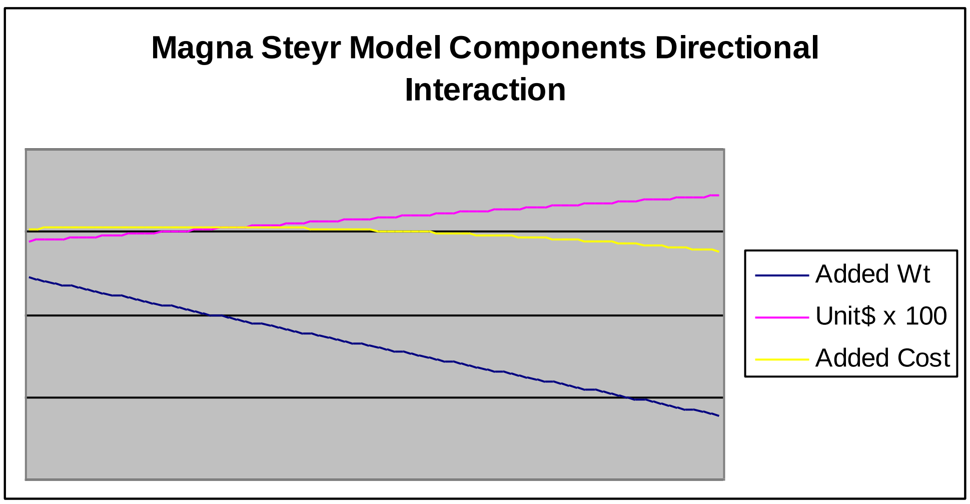
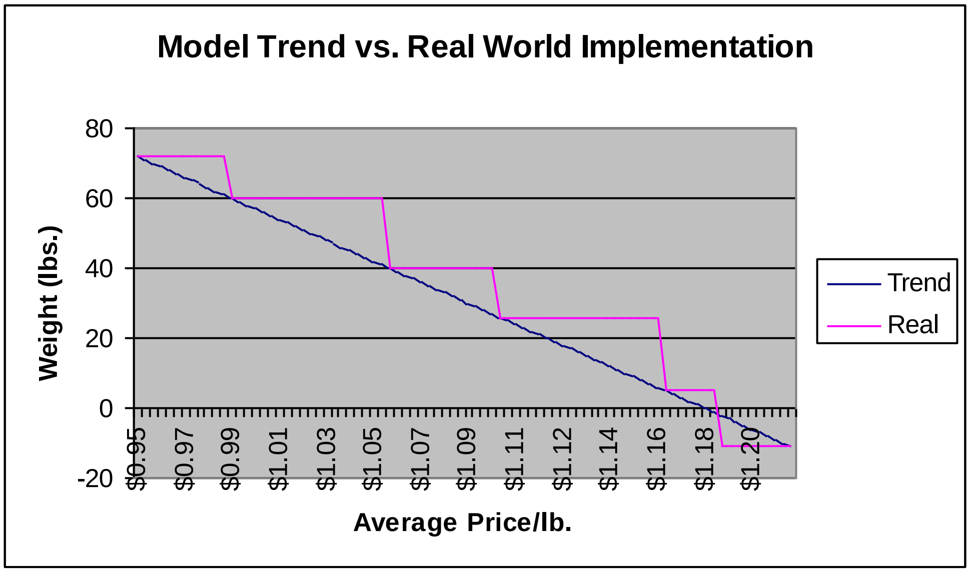


Figure V-7



Cost and Weight Range

Most of the redesign efforts illustrated in both NHTSA's finite element models and analysis submitted by manufacturers involve the use of current technology to modify existing vehicle designs that were not originally designed with higher roof strength in mind. As noted previously, the agency anticipates that this rule will be issued with enough leadtime to provide manufacturers the opportunity to establish stronger roof designs within the majority of vehicles normal redesign cycles.

The agency believes that manufacturers will strive to minimize the weight impacts of added roof strength. Several factors provide strong incentives for strategies that favor the use of light weight solutions. These include:

1) CAFE standards. On December 19, 2008, the Energy Independence and Security Act was signed into law requiring that manufacturers achieve a fleet-wide average fuel economy level of 35 mpg by

2020. NHTSA has already issued an NPRM proposing to require a fairly aggressive path to achieve this level and additional pressure is being asserted by those who favor even higher standards to combat greenhouse gas emissions. The manufacturers face a difficult challenge to achieve these levels of fuel efficiency and they will strive to minimize any weight impacts throughout their vehicle designs.

2) Fuel Prices. Rising fuel prices have already caused a shift in both buyer preferences and manufacturer product plans towards more fuel efficient vehicles. While CAFE standards will set minimum required levels of efficiency, competition among manufacturers to produce the most fuel efficient vehicles to meet consumer demand will provide an additional incentive to minimize weight.
3) Rollover Propensity. Adding weight to the roof area of vehicles causes an increase in the center of gravity, which increases the risk of rollover crashes. NHTSA monitors the rollover propensity of all vehicles through its NCAP ratings program where a Static Stability Factor (SSF) is published. Changes in a vehicle's center of gravity can cause a shift in the SSF. This would put that vehicle at a competitive disadvantage in the marketplace among safety conscious consumers.

For these reasons, the agency believes that the add-on redesign approaches found in most submitted analyses will exaggerate the weight impacts that will ultimately occur when vehicles are redesigned with roof strength, fuel economy, and rollover propensity in mind. The "current technology" solution in the Magna Steyr analysis is thus likely to overstate solutions that would actually be implemented given enough leadtime. The agency believes that manufacturers will strive to achieve results consistent with minimizing weight increases, or even, in some cases, reducing vehicle weight. To reflect this, the minimum weight impact estimate derived from each model will be considered the low end of the cost and weight range.

Technically, a hypothetical lower bound in weight impacts is reflected in the Magna Steyr analysis, which demonstrated that higher roof strength could be achieved in a manner that is weight neutral or even a savings beyond the base vehicle weight. However, it is uncertain whether this type of design would be practical across all vehicles. Magna Steyr noted in its analysis that this type of solution is "…predicated upon achieving significant improvements in material availability and manufacturing processes." Moreover, their analysis assumed a single sided test with a 2.5 SWR. Most of the scenarios examined here require higher strength levels. Thus, while we expect manufacturers will make every effort to accomplish this, we are reluctant to assume it as a certainty. Overall, the agency believes that manufacturers will comply with roof strength standards using designs that are reflected in the most weight efficient half of each alternative's model – that is, the range of impacts bounded by the lowest weight impact and the median weight impact. Thus, we estimate a range of possible costs defined at the lower end by the model's most weight efficient scenario, representing the natural goal that manufacturers would strive for, and at the upper end by the median or midpoint scenario, which recognizes that while manufacturers will strive to reduce weight as much as possible, for some vehicle designs the most weight-efficient scenario might not be practical. We believe this is a reasonable assumption in light of the conflicting data presented in response to the NPRM and SNPRM, and in light of the pressure manufacturers will be under to minimize vehicle weight.

<u>Results</u>

Tables V-7 – V-9 summarize the resulting weight impacts estimated by this process for passenger cars, LTVs < 6,000 lbs. GVWR, and LTVs > 6,000 lbs. GVWR. Weight impacts increase dramatically as vehicles increase in size, reflecting the need for more structure to withstand the higher loads needed to meet any given standard for heavier vehicles. All scenarios anticipate lower weight increases than those needed for the Magna Steyr vehicle since that vehicle was significantly heavier than the average vehicles in each category, and because the vehicle fleet already has a higher SWR than the Magna Steyr vehicle, and thus a smaller gap to close to meet any given standard. These weight estimates are represented graphically in Figures V-8 and V-9.

Table V-7a

Derived Results for Alternative SWRs and Test Requirements Net Weight Impact (lbs.) Passenger Cars		
	1-Sided Tests	2-Sided Tests
1.5 SWR		
Current Technology	NA	NA
Advanced Technology	NA	NA
2.0 SWR		
Current Technology	NA	NA
Advanced Technology	NA	NA
2.5 SWR		
Current Technology	5.2	9.1
Advanced Technology	-1.6	1.1
3.0 SWR		
Current Technology	10.4	14.6
Advanced Technology	4.4	7.5
3.5 SWR		
Current Technology	21.4	27.9
Advanced Technology	12.2	17.7

Note: The term "Current Technology" in Table V-7indicates the midpoint of the model range. Advanced Technology indicates the bottom of the range of weight impacts.

Table V-7b

Derived Results for Alternative SWRs and Test Requirements Net Weight Impact (lbs.) LTVs < 6,000 lbs. GVWR		
	1-Sided Tests	2-Sided Tests
1.5 SWR		
Current Technology	NA	NA
Advanced Technology	NA	NA
2.0 SWR		
Current Technology	NA	NA
Advanced Technology	NA	NA
2.5 SWR		
Current Technology	8.0	13.8
Advanced Technology	-2.4	1.6
3.0 SWR		
Current Technology	24.2	32.2
Advanced Technology	10.3	16.6

3.5 SWR		
Current Technology	43.7	53.5
Advanced Technology	25.8	33.9

Note: The term "Current Technology" in Table V-8 indicates the midpoint of the model range. Advanced Technology indicates the bottom of the range of weight impacts.

Table V-8

Derived Results for Alternative SWRs and Test Requirements Net Weight Impact (lbs.) All Vehicles < 6,000 lbs. GVWR		
	1-Sided Tests	2-Sided Tests
1.5 SWR		
Current Technology	NA	NA
Advanced Technology	NA	NA
2.0 SWR		
Current Technology	NA	NA
Advanced Technology	NA	NA
2.5 SWR		
Current Technology	5.9	10.2
Advanced Technology	-1.8	1.2
3.0 SWR		
Current Technology	13.7	18.8
Advanced Technology	5.8	9.7
3.5 SWR		
Current Technology	26.2	34.0
Advanced Technology	15.5	21.5

Note: The term "Current Technology" in Table V-8 indicates the midpoint of the model range. Advanced Technology indicates the bottom of the range of weight impacts.

Table V-9

Derived Results for Alternative SWRs and Test Requirements Net Weight Impact (lbs.) LTVs > 6,000 lbs. GVWR		
	1-Sided Tests	2-Sided Tests
1.5 SWR		
Current Technology	9.4	12.5
Advanced Technology	-6.5	-7.1
2.0 SWR		
Current Technology	15.8	19.7
Advanced Technology	-6.5	-7.2

2.5 SWR		
Current Technology	21.0	49.5
Advanced Technology	-6.4	17.1
3.0 SWR		
Current Technology	59.3	95.3
Advanced Technology	25.3	55.4
3.5 SWR		
Current Technology	99.4	141.7
Advanced Technology	58.8	94.3

Note: The term "Current Technology" in Table V-9 indicates the midpoint of the model range. Advanced Technology indicates the bottom of the range of weight impacts.

Figure V-8

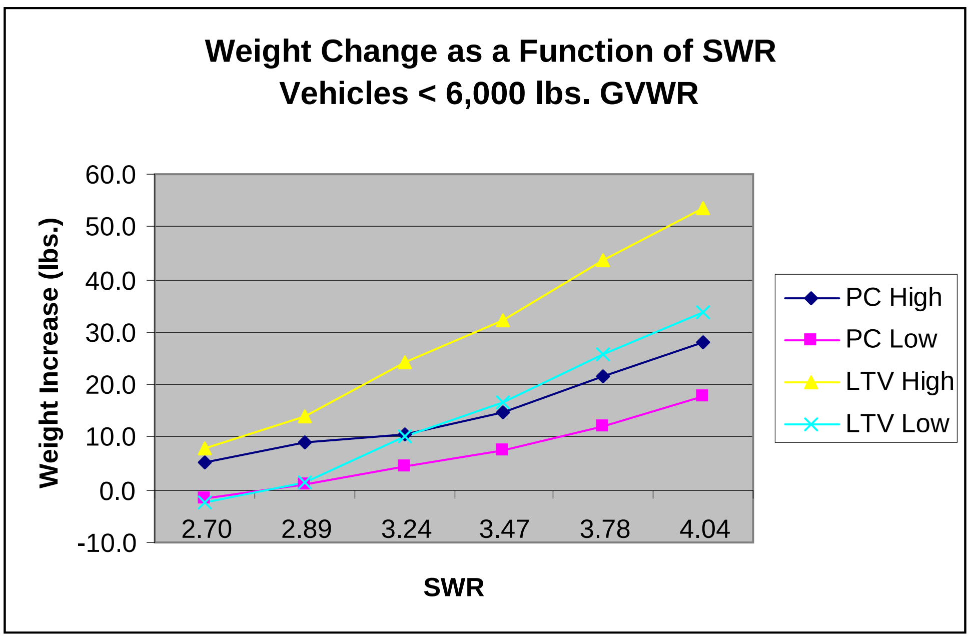


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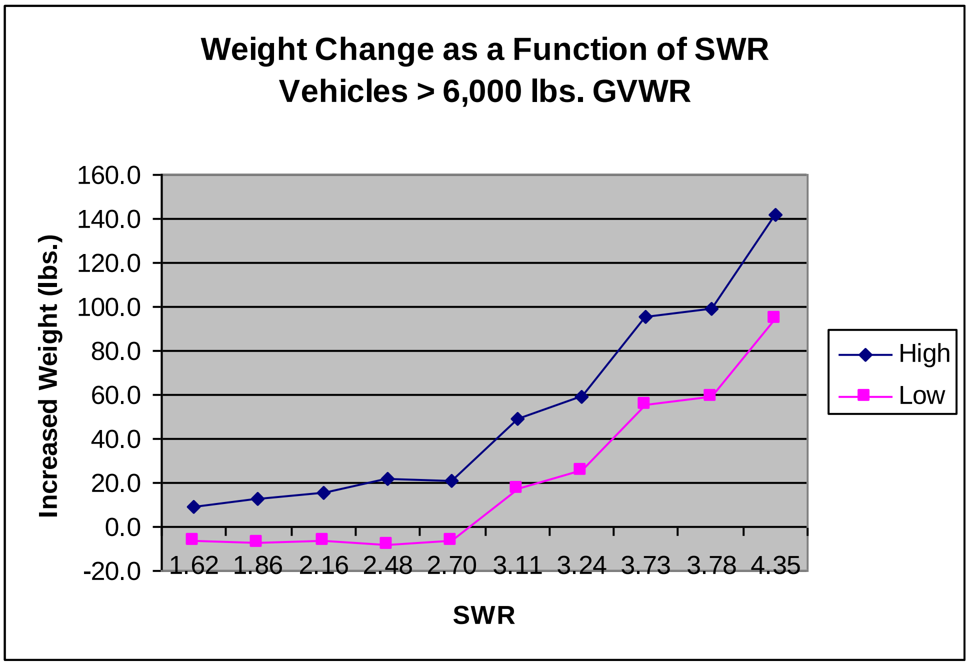
Figure V-9


Weight Change as a Function of SWR
Vehicles > 6,000 lbs. GVWR
Increased Weight (lbs.)
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
-20.0
1.62
1.86
2.16
2.48
2.70
3.11
3.24
3.73
3.78
4.35
SWR
High
Low

Note that the general trend in weight increases derived from this method appears more linear than the simple weight/SWR curves derived previously in this chapter. The reason for this is that these curves represent changes to the specific vehicles that fail at each rate, and take into account the higher SWRs of those vehicles. They thus represent the gap between vehicles that fail at each level and the weight needed for those specific vehicles to pass rather than relative changes to meet ever increasing SWRs for a common vehicle. The narrowing gap between the base SWR of vehicles that fail at each level and the higher SWR requirement directionally offsets the tendency for higher SWRs to become disproportionately more weight expensive and produces a more linear relationship.

We also note that there is a stair-step shape to the >6,000 lbs. GVWR vehicle chart. This is a function of alternating weight impacts on the x-axis from functions of SWR severity to functions of sides tested. For vehicles >6,000 lbs., the impact of second sided testing is almost as great as for shifting up a half point in SWR, especially at the higher SWR alternatives. The impact of moving up by just an SWR basis, or by sides tested for a common SWR, can be seen by tracing every other data point, which produces a more linear form among the higher alternatives.

Vehicle Price Impacts

As with weight changes, the impact on vehicle prices of design changes required to meet higher SWR requirements was estimated for a variety of specific vehicles as well as some more generic vehicle types. However, the cost trend is more complex because achieving weight savings is typically accomplished by using more expensive material components.

As noted previously, the approach taken in this analysis is to link design costs to the weight changes derived from each specific alternative's model. This entails deriving a cost/pound that is representative of the full cost of variable materials, labor, and manufacturing costs, as well as changes in fixed costs and normal markups to retail price levels that would be associated with design changes. Most of the estimates available from NHTSA's finite element models or provided by manufacturers represented short term fixes to existing vehicle designs. These estimates involved a variety of materials including both routine and exotic steels, but, in most cases, design modifications involved using mostly conventional materials and add-on reinforcements. Only a few submissions provided enough information to establish an estimate of the variable cost/lb. of materials.

As noted above, the agency believes that the long- term solution to added roof strength lies in the use of advanced light weight materials and designs. The agency recognizes that the exact mix of these materials will vary significantly across vehicle designs. For this analysis, we have calculated the average cost per pound of the mix of materials used in the Magna Steyr advanced technology design. From Table V-3, the total cost of the modified roof parts for the advanced technology scenario, including the upgraded materials cost of baseline parts plus the cost of added reinforcements, was $289 for parts weighing a total of 236 lbs., or $1.22 per pound. By contrast, the average price/lb. for component materials in the base case was $0.81, and in the current technology scenario it was $0.95. The $1.22 estimate represents the variable piece cost from redesign to a higher SWR. As noted previously, the exact mix of components estimated across each model varied as the possible design solutions moved from the current technology scenario to the advanced technology scenario covering the iterative range from $0.95 to $1.22.

Costs that are initiated midstream during the 4-7 year model life of a vehicle would entail significant capital investment to retool and modify assembly line procedures for the added installation costs. Modifications of this nature involve the basic style and design of a vehicles body structure. As such, they are done most efficiently when integrated into the normal redesign cycle of the vehicle. Under these circumstances, much of the added capital investment that would have been needed during the vehicle's normal life cycle essentially become sunk costs that would be routinely incurred in the normal course of developing and producing a new model vehicle. The agency intends to grant enough leadtime for this rulemaking to allow compliance within the normal course of vehicle redesign. This should minimize the need for additional tooling or other capital investment to accomplish these changes. To reflect this, the costs derived from the Magna Steyr analysis will be expressed as consumer costs by increasing them by factors representing both manufacturer and dealer markup (1.03 and 1.11 respectively), but not for variable manufacturing, tooling, or infrastructure costs. We recognize that it is possible that there would be some level of such costs, most likely associated with possible shifts in the assembly process. However, we do not have data that would enable us to isolate these costs for the specific changes this rule will trigger. We will explore the possible impacts of this issue in both a sensitivity analysis at the end of this chapter and the Uncertainty Analysis in Chapter IX.

A final adjustment is made to express these costs in 2007$ to make them compatible with the rest of the analysis. This was done using the GDP implicit price deflator to mark costs up from 2006 economics.[40] The consumer level cost/lb. for the advanced technology scenario roof strength upgrade is thus $1.44 ($1.22x1.11x1.03x (119.8/116.7)).

Table V-10 summarizes the weight impact and design cost estimates for each SWR under each advanced technology weight adjustment factor (ATF) for 2-sided tests. Table V-11 summarizes the same information for 1-sided tests.

Table V-10
Summary of Weight Impacts and Design Change Costs/ Affected Vehicle, 2-Sided Tests

Summary of Weight Impacts (lbs.)				**Design Cost Summary ($/vehicle)**		
Vehicles < 6,000 lbs. GVWR				Vehicles < 6,000 lbs. GVWR		
SWR	Low	High		SWR	Low	High
2.5	1.19	10.22		2.5	$38.80	$37.84
3.0	9.68	18.78		3.0	$48.68	$47.16
3.5	21.52	34.00		3.5	$70.23	$69.53
Vehicles > 6,000 lbs. GVWR				Vehicles > 6,000 lbs. GVWR		
SWR	Low	High		SWR	Low	High
1.5	-7.13	12.46		1.5	$68.63	$69.02
2.0	-7.15	19.74		2.0	$73.04	$80.75
2.5	17.05	49.47		2.5	$106.39	$118.07
3.0	55.39	95.33		3.0	$162.64	$176.91
3.5	94.32	141.68		3.5	$219.20	$236.02

Table V-11
Summary of Weight Impacts and Design Change Costs/ Affected Vehicle, 1-Sided Tests

Summary of Weight Impacts (lbs.)				**Design Cost Summary ($/vehicle)**		
Vehicles < 6,000 lbs. GVWR				Vehicles < 6,000 lbs. GVWR		
SWR	Low	High		SWR	Low	High
2.5	-1.79	5.91		2.5	$31.88	$30.31
3.0	5.83	13.66		3.0	$40.62	$39.08
3.5	15.47	26.18		3.5	$59.73	$58.92
Vehicles > 6,000 lbs. GVWR				Vehicles > 6,000 lbs. GVWR		
SWR	Low	High		SWR	Low	High
1.5	-6.50	9.39		1.5	$62.56	$59.74
2.0	-6.51	15.83		2.0	$72.48	$74.82
2.5	-6.35	21.01		2.5	$71.39	$79.99
3.0	25.31	59.25		3.0	$118.58	$130.80

[40] The Magna Steyr report did not specify a year's economics, but it was dated December 2006.

3.5	58.76	99.43		3.5	$167.55	$182.06

In Tables V-12 and V-13, total fleet design costs are summarized reflecting both failure rates and aggregate fleet volume of 17 million vehicles, with roughly 75% being vehicles under 6,000 lbs. GVWR.

Table V-12
Summary of Design Change Costs, 2-Sided Tests

Cost/Affected Vehicle (2007$)				**Total Design Cost (M2007$)**		
Vehicles < 6,000 lbs. GVWR				Vehicles < 6,000 lbs. GVWR		
SWR	Low Weight	High Weight		SWR	Low Weight	High Weight
2.5	$38.80	$37.84		2.5	$311.9	$304.2
3.0	$48.68	$47.16		3.0	$510.2	$494.3
3.5	$70.23	$69.53		3.5	$857.0	$848.5
Vehicles > 6,000 lbs. GVWR				Vehicles > 6,000 lbs. GVWR		
SWR	Low Weight	High Weight		SWR	Low Weight	High Weight
1.5	$68.63	$69.02		1.5	$116.0	$116.6
2.0	$73.04	$80.75		2.0	$287.0	$317.2
2.5	$106.39	$118.07		2.5	$449.4	$498.8
3.0	$162.64	$176.91		3.0	$687.1	$747.4
3.5	$219.20	$236.02		3.5	$926.0	$997.1

Table V-13
Summary of Design Change Costs, 1-Sided Tests

Cost/Affected Vehicle (2007$)				**Total Design Cost (M2007$)**		
Vehicles < 6,000 lbs. GVWR				Vehicles < 6,000 lbs. GVWR		
SWR	Low Weight	High Weight		SWR	Low Weight	High Weight
2.5	$31.88	$30.31		2.5	$250.68	$238.34
3.0	$40.62	$39.08		3.0	$390.87	$376.05
3.5	$59.73	$58.92		3.5	$674.97	$665.81
Vehicles > 6,000 lbs. GVWR				Vehicles > 6,000 lbs. GVWR		
SWR	Low Weight	High Weight		SWR	Low Weight	High Weight
1.5	$62.56	$59.74		1.5	$34.36	$32.81
2.0	$72.48	$74.82		2.0	$275.57	$284.47

2.5	$71.39	$79.99		2.5	$275.95	$309.19
3.0	$118.58	$130.80		3.0	$500.94	$552.56
3.5	$167.55	$182.06		3.5	$707.81	$769.11

Several commenters asserted that the cost of strengthening roofs should be partitioned to other safety countermeasures. The Center for Injury Research (CIR), suggested that the costs of FMVSS 216 should be allocated to side impact, frontal offset, and rollover crashes. The Center for Auto Safety (CAS) stated that "Some manufacturers are already using substantially stronger occupant compartments to improve their performance in frontal offset tests and side impact tests. The cost of increased roof crush – which can be successfully engineered into a vehicle only by improving occupant compartment strength generally – must be apportioned among all crash modes. No more than one-third of the cost of the improved roof strength should be allocated to improve rollover occupant protection."

The agency agrees that structural changes can potentially have consequences in crash modes other than those for which they were intended. In the case of roof crush, CIR and CAS apparently anticipate that reinforcements added to roof structures will also contribute to added protection in side impact or offset crashes. However, determining these impacts is highly problematic, and the suggestion that costs should be equally divided between 3 crash modes assumes that all three modes would benefit equally from the changes and that all structural changes specifically required to meet the roof crush standard will also contribute to safety in those modes. Neither of the commenters provided any information to support such a contention. CIR did cite several examples of cases where manufacturers had made changes to the IIHS frontal offset crash test which also increased roof strength for those vehicles, but this does not suggest an equal apportionment of costs. The agency believes that most of the reinforcement/redesign involved to increase roof strength would not produce significant results in other modes. For example, side impact crashes might benefit from B-pillar reinforcements that extend below the window sill, but these represent only a small portion of the design changes anticipated to meet FMVSS 216 upgrades, and in some or many cases they would not be used at all.

Also, the concept of cross-allocating design costs would, in theory, work both ways. If the agency were to allocate costs required to achieve higher roof strength to other crash modes, then shouldn't the agency partially allocate costs to improve safety to other crash modes to roof crush? Failure to properly account for all such interactions would result in a gross undercounting of the full costs of improving safety. Even if the agency had the data needed to properly allocate such costs, the only way such a scheme would work would be if all regulations were promulgated simultaneously, a practical impossibility.

The only practical way to address this issue would be to measure the safety impacts in other modes. The agency has noted, for example, that adding weight above the center of gravity could result in an increased propensity to roll over (although, for reasons discussed elsewhere in this analysis, the agency does not expect manufacturers to do this). Also, several commenters have asserted that added weight will aggravate cases of size-safety mismatch. There are a number of hypothetical safety impacts that the agency is unable to evaluate because they depend on the mix of specific design changes that manufacturers eventually choose to adopt. The agency acknowledges that these impacts could occur to some extent, but also notes that some would improve safety and some would make it worse. These secondary impacts are thus to some extent offsetting, which would mitigate their overall impact.

<u>Fuel Economy Impacts</u>

To the extent that vehicles designed with stronger roofs become heavier, they will become less fuel efficient and consume more fuel. The cost to consumers of increased roof strength is thus the sum of the increase in the vehicle purchase price and the value of added lifetime fuel costs. Fuel costs consist of the price of the additional gallons of fuel consumed, as well as a number of “externalities” which pose costs to society at large as well as the individual consumer. Externalities include damages from green house gas emissions such as CO_2 which contributes to global warming, The value of these pollutants is subject to debate and a variety of estimates are available in the literature These values are discussed in NHTSA’s FRIA for MY 2011 CAFE standards.[41] Following procedures used in the PRIA for CAFE, greenhouse gas values will increase 2.4% annually. Another externality results from higher fuel prices from increased demand or “monopsony.” Monopsony impacts are valued at $0.27/gallon. In its 2011 CAFE FRIA, the agency discusses a variety of valuations for both greenhouse gases and monopsony. The agency notes that the value chosen for greenhouse gases depends to some extent on whether the values represent only domestic impacts or international impacts and that if international impacts are chosen, then monopsony costs become largely a transfer payment which would not be added into the net externalities. The sum of these 2 externalities is thus similar regardless of whether a national or an international valuation is chosen for greenhouse gases. Because of this, the agency did not definitively establish one approach in the 2011 CAFE FRIA. For this analysis, we have used a combined valuation for greenhouse gases and monopsony costs of $0.29 to illustrate theses impacts. Readers are refereed to the Final Rule for MY 2011 CAFE standards for a more detailed discussion of this issue. An additional value of $0.12/gallon was also included to reflect the impact of price shock from added consumption. This is also discussed further in the 2011 CAFE Final Rule

For significant impacts on fuel consumption, other impacts such as decreased driving and the cost of maintaining military security to promote stability in oil supplies might theoretically be affected as well, but the overall impact on fuel consumption from this standard is so minute (roughly 1 gallon/year for each affected vehicle) that it is unlikely to affect either of these behaviors. Likewise environmental impacts from added

[41] Final Regulatory Impact Analysis, Corporate Average Fuel Economy for Model Year 2011 Passenger Cars and Light Trucks, Office of Regulatory Analysis and Evaluation, National Center for Statistics and Analysis, U.S. DOT,

fuel production for criteria pollutants such as carbon monoxide (CO), volatile organic compounds (VOC), nitrous oxide compounds (NOx), particulate matter (PM2.5), and sulfur oxide (SOx) are unlikely to be significantly affected by this rulemaking.

The impact of added weight on lifetime fuel economy is a function of mileage, survival probability, the price of gasoline, the change in vehicle fuel economy due to the added weight, and the discount rate chosen to express lifetime impacts in their present value. The projected price of gasoline was taken from the Department of Energy's Annual Energy Outlook 2008 High fuel price scenario. Fuel taxes averaging about $0.38 per gallon are excluded since these are a transfer payment and not a cost to society. Gasoline prices are projected to increase steadily through 2030.

Table V-14
Components of Social Cost of Changes in Fuel Consumption

Year	AE0 2008Fuel Price Forecast (1) (2007$gallon)	Total Federal and State Taxes (2) (2007$/gallon)	Fuel Price Excluding Taxes (2007$/gallon)	Value of Externalities (2007$ gallon)	Social Value of Fuel Savings (2007$/gallon)
2011	$2.949	$0.420	$2.529	$0.403	$2.93
2012	$2.974	$0.416	$2.56	$0.404	$2.96
2013	$3.023	$0.412	$2.61	$0.404	$3.02
2014	$3.077	$0.409	$2.67	$0.405	$3.07
2015	$3.093	$0.405	$2.69	$0.405	$3.09
2016	$3.138	$0.402	$2.74	$0.406	$3.14
2017	$3.200	$0.399	$2.80	$0.407	$3.21
2018	$3.241	$0.395	$2.85	$0.407	$3.25
2019	$3.301	$0.392	$2.91	$0.408	$3.32
2020	$3.363	$0.388	$2.98	$0.409	$3.38
2021	$3.451	$0.385	$3.07	$0.409	$3.48
2022	$3.491	$0.381	$3.11	$0.410	$3.52
2023	$3.492	$0.378	$3.11	$0.411	$3.52
2024	$3.510	$0.374	$3.14	$0.411	$3.55
2025	$3.485	$0.371	$3.11	$0.412	$3.53
2026	$3.494	$0.371	$3.12	$0.413	$3.54
2027	$3.518	$0.371	$3.15	$0.413	$3.56
2028	$3.545	$0.371	$3.17	$0.414	$3.59
2029	$3.576	$0.371	$3.20	$0.415	$3.62
2030	$3.618	$0.371	$3.25	$0.416	$3.66
2031	$3.618	$0.371	$3.25	$0.417	$3.66

(1) Average retail price for all grades of motor gasoline. Source: Energy Information Administration, Annual Energy Outlook 2008 High Fuel Cost Case Forecast, Table 12, http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_12.xls

(2) Sum of Federal and sales-weighted average of state taxes on motor gasoline during 2007. Source: Federal Highway Administration, Highway Statistics 2002, Table MF-121T, http://www.fhwa.dot.gov/policy/ohim/hs02/xls/mf121t.xls

Table V-15
Present Discounted Value @7% of Lifetime Impact of 13.27 lbs Weight Increase in an Average Passenger Car (2007 Dollars)

Vehicle Age (years)	Vehicle Miles Traveled	Survival Probability	Weighted Vehicle Miles Traveled	Social Value Fuel Price per Gallon (2007 dollars)	Fuel Consumption with Base Fuel Economy (gallons)	Fuel Consumption with New Fuel Economy (gallons)	Present Value of Fuel Consumption (Base FE)	Present Value of Fuel Consumption (New FE)
1	12,885	0.995	12,821	$2.93	502	504	$1,424.39	$1,428.93
2	12,641	0.99	12,515	$2.96	490	492	$1,312.13	$1,316.32
3	12,377	0.9831	12,167	$3.02	477	478	$1,214.03	$1,217.90
4	12,094	0.9731	11,769	$3.07	461	463	$1,118.30	$1,121.87
5	11,796	0.9593	11,316	$3.09	443	445	$1,011.67	$1,014.90
6	11,484	0.9413	10,810	$3.14	424	425	$917.35	$920.27
7	11,160	0.9188	10,253	$3.21	402	403	$830.17	$832.82
8	10,825	0.8918	9,654	$3.25	378	379	$740.98	$743.34
9	10,483	0.5604	5,875	$3.32	230	231	$429.67	$431.04
10	10,135	0.8252	8,363	$3.38	328	329	$583.15	$585.01
11	9,783	0.7866	7,695	$3.48	302	302	$514.95	$516.60
12	9,429	0.717	6,760	$3.52	265	266	$428.22	$429.59
13	9,075	0.6125	5,558	$3.52	218	218	$329.54	$330.59
14	8,722	0.5094	4,443	$3.55	174	175	$247.79	$248.58
15	8,374	0.4142	3,469	$3.53	136	136	$179.69	$180.26
16	8,032	0.3308	2,657	$3.54	104	104	$128.99	$129.40
17	7,698	0.2604	2,005	$3.56	79	79	$91.59	$91.88
18	7,374	0.2028	1,495	$3.59	59	59	$64.35	$64.55
19	7,061	0.1565	1,105	$3.62	43	43	$44.83	$44.98
20	6,763	0.12	812	$3.66	32	32	$31.13	$31.23
21	6,481	0.0916	594	$3.66	23	23	$21.29	$21.36
22	6,217	0.0696	433	$3.66	17	17	$14.50	$14.55
23	5,972	0.0527	315	$3.66	12	12	$9.86	$9.89
24	5,750	0.0399	229	$3.67	9	9	$6.72	$6.74
25	5,551	0.0301	167	$3.67	7	7	$4.58	$4.59
26	5,379	0.0227	122	$3.67	5	5	$3.13	$3.14
Total			143,402		5,619	5,637	$11,702.98	$11,740.33

The baseline miles-per-gallon figure for passenger cars is 31.9 mpg, and for light trucks under 6,000 lbs. GVWR the baseline mpg is 28.4 mpg. For vehicles over 6,000 lbs. GVWR, the base fuel economy is 22.4. These estimates reflect a weighted average based on manufacturer's product plans submitted to the agency prior to its NPRM on MY 2011-2015 CAFE standards. Average vehicle weights for these same categories are 3,325 lbs., 4,323 lbs., and 5,183 lbs. respectively. A sample calculation for passenger cars for the proposal is:

$$\sum_{n=1}^{20} [(V_n * S_n)/(w/(w+i))^{.8} * fe * .80 - (V_n * S_n)/fe * .80] * p_n * d_n$$

Where:

V = Vehicle miles traveled

S = Survival probability

w = Baseline vehicle weight

i = Incremental weight from redesigned roof structure

fe = Baseline EPA fuel economy

.80 = Factor to derive on-road fuel economy from EPA fuel economy

p = Fuel price

d = Mid-year discount factor

This process is shown in Table V-15 where each year's variables are combined to produce estimates of the impact on fuel consumption under both baseline and revised vehicle weights. Table V-15 reflects a 7 percent discount rate and a 13.27 lb. increase in the weight of an average 3,325 lb. passenger car. Over the vehicle's life, this increases fuel consumption by 18 gallons (5,637 – 5,619), with a present value of $37 ($11,740- $11,703).

In Table V-16 the results of this process are summarized for 2-sided tests for each Alternative and vehicle type under both a 3 percent and a 7 percent discount rate. In Table IV-17, the total costs under each scenario are estimated, reflecting the total vehicle fleet and the pass/fail rates under each alternative (See Chapter II). The results indicate that for vehicles under 6,000 lbs., a 2.5 SWR 2 sided standard would add from 1-9 lbs, resulting in lifetime cost increases of from $3-$34 per affected vehicle totaling from $25-$272 million in added fuel expenditures across the affected fleet annually. A 3.0 SWR standard would add from 9-17 lbs, resulting in lifetime cost increases of from $25-$62 per affected vehicle totaling from $263-$653 million in added fuel expenditures across the affected fleet annually. The remaining results for 2 sided tests are summarized in Tables V-16 and V-17. Results for single-sided test alternatives are summarized in Tables V-18 and V-19.

Table V-16

Summary of Weight and Fuel Economy Impacts/ Affected Vehicle, 2-Sided Tests

Estimated Weight (lbs.)			Fuel Cost 3% Discount Rate		Fuel Cost 7% Discount Rate	
PCs and LTVs < 6,000 lbs. GVWR						
SWR	**Low**	**High**	**Low**	**High**	**Low**	**High**
2.5	1.19	10.22	$4.25	$36.43	$3.33	$28.58
3.0	9.68	18.78	$34.53	$66.98	$27.03	$52.43
3.5	21.52	34.00	$76.69	$121.15	$60.09	$94.92
Vehicles > 6,000 lbs. GVWR						
SWR	**Low**	**High**	**Low**	**High**	**Low**	**High**
1.5	-7.13	12.46	-$26.56	$46.40	-$20.65	$36.08
2.0	-7.15	19.74	-$26.63	$73.46	-$20.70	$57.12
2.5	17.05	49.47	$63.41	$184.01	$49.30	$143.07
3.0	55.39	95.33	$205.85	$354.24	$160.05	$275.42
3.5	94.32	141.68	$350.07	$525.85	$272.19	$408.86

Table V-17

Summary of Weight and Total Fuel Economy Impacts (Millions 2007$), 2- Sided Tests

Estimated Weight (lbs.)			Total Fuel Cost 3% Discount Rate		Total Fuel Cost 7% Discount Rate	
PCs and LTVs < 6,000 lbs. GVWR						
SWR	**Low**	**High**	**Low**	**High**	**Low**	**High**
2.5	1.19	10.22	$34.2	$292.9	$26.8	$229.8
3.0	9.68	18.78	$361.9	$702.0	$283.3	$549.5
3.5	21.52	34.00	$935.9	$1,478.4	$733.3	$1,158.3
Vehicles > 6,000 lbs. GVWR						
SWR	**Low**	**High**	**Low**	**High**	**Low**	**High**
1.5	-7.13	12.46	-$44.9	$78.4	-$34.9	$61.0
2.0	-7.15	19.74	-$104.6	$288.6	-$81.3	$224.4
2.5	17.05	49.47	$267.9	$777.4	$208.3	$604.4
3.0	55.39	95.33	$869.6	$1,496.5	$676.1	$1,163.5
3.5	94.32	141.68	$1,478.9	$2,221.5	$1,149.9	$1,727.2

Table V-18

Summary of Weight and Fuel Economy Impacts/ Affected Vehicle, 1-Sided Tests

Estimated Weight (lbs.)			Fuel Cost 3% Discount Rate		Fuel Cost 7% Discount Rate	
PCs and LTVs < 6,000 lbs. GVWR						
SWR	**Low**	**High**	**Low**	**High**	**Low**	**High**
2.5	-1.79	5.91	-$6.51	$21.53	-$5.10	$16.89
3.0	5.83	13.66	$20.82	$48.74	$16.29	$38.14
3.5	15.47	26.18	$55.45	$93.83	$42.69	$72.24
Vehicles > 6,000 lbs. GVWR						
SWR	**Low**	**High**	**Low**	**High**	**Low**	**High**
1.5	-6.50	9.39	-$24.22	$34.95	-$18.83	$27.17
2.0	-6.51	15.83	-$24.22	$58.92	-$18.83	$45.81
2.5	-6.35	21.01	-$23.63	$78.19	-$18.38	$60.79
3.0	25.31	59.25	$94.12	$220.36	$73.18	$171.33
3.5	58.76	99.43	$218.34	$369.45	$169.76	$287.25

Table V-19

Summary of Weight and Total Fuel Economy Impacts (Millions 2007$), 1-Sided Tests

Estimated Weight (lbs.)			Total Fuel Cost 3% Discount Rate		Total Fuel Cost 7% Discount Rate	
PCs and LTVs < 6,000 lbs. GVWR						
SWR	**Low**	**High**	**Low**	**High**	**Low**	**High**
2.5	-1.79	5.91	-$51.19	$169.30	-$40.10	$132.81
3.0	5.83	13.66	$200.34	$469.00	$156.75	$367.00
3.5	15.47	26.18	$626.60	$1,060.31	$482.41	$816.33
Vehicles > 6,000 lbs. GVWR						
SWR	**Low**	**High**	**Low**	**High**	**Low**	**High**
1.5	-6.50	9.39	-$13.30	$19.19	-$10.34	$14.92
2.0	-6.51	15.83	-$92.09	$224.02	-$71.59	$174.17
2.5	-6.35	21.01	-$91.34	$302.24	-$71.05	$234.98
3.0	25.31	59.25	$397.61	$930.91	$309.15	$723.78
3.5	58.76	99.43	$922.38	$1,560.74	$717.15	$1,213.49

Sensitivity Analysis – Manufacturing Costs

As noted above, it is possible that the there may be some level of added manufacturing burden above the added material costs derived from the Magna Steyr analysis.   For example, variable labor and manufacturing costs might increase because the use of advanced materials may require more difficult welding techniques or entail more energy expenditure, or possibly more assembly steps. Thus, the assembly of a vehicle with advanced materials may entail more than just bolting on a different reinforcement. It could involve both increasing the complexity of assembly and increasing the number of pieces that will be assembled.

To estimate the value of these changes, ratios were derived from a study of possible design upgrades to improve roof strength.[42] Data from this report indicate that, on average, variable labor and manufacturing costs add roughly 25% above materials costs. In our base case, we assumed that these costs would essentially be sunk costs that would be incurred during scheduled redesign and would essentially not be different from the costs that would be incurred for the newly redesigned vehicle. For example, a newly designed B-pillar made of a lighter grade of steel would still require the same basic assembly process. Or, that manufacturers would, in the course of setting up their plants for the new vehicle designs, incorporate the most efficient methods to assemble the vehicle in such a way that these costs would not increase. The substitution of one material for another would thus not necessarily require an increase in assembly labor or energy usage.

However, the impact on the assembly process of stronger roofs during a complete vehicle redesign is uncertain. Moreover, even if the assembly process does become more complex or costly, it is not clear which part of the process would be affected, or by how much. Some portions of the vehicle assembly process may change while others would not. The range of possible redesigns covered by the models used in this analysis involves numerous combinations of design changes and material substitutions. To examine the potential impact of this issue, additional markups of 10% and 25% will be applied to the full design cost of each alternative. The 25% markup assumes a full proportional increase in variable manufacturing costs across the entire roof assembly process despite the opportunity presented by incorporating these changes into the redesign. The 10% markup examines an alternative assumption that such changes are limited to only a portion of the assembly process. For the chosen alternative of the final rule, the results are summarized in Table V-20 below.

[42] Ludtke & Associates, "Final Report, Cost, Weight, and Lead Time Analysis, Roof Crush Upgrade", National Highway Traffic Safety Administration, Washington, D.C., December 31, 2006

Table V-20

Sensitivity Analysis, Impact of Different Assumptions Regarding Variable Manufacturing Costs 3.5/2.0 SWR, Two-Sided Tests (Millions$)						
Markup Factor	1.0		1.1		1.25	
	Low	High	Low	High	Low	High
Total Cost	$875	$1,391	$937	$1,452	$1,031	$1,544
Cost/Equivalent Fatality	$6.1	$9.8	$6.5	$10.2	$7.1	$11.0
Net Benefits@$5.8M VSL	$6	-$458	-$56	-$519	-$150	-$611
Net Benefits@$8.4M VSL	$388	-$151	$325	-$212	$231	-$303
Net Benefits@$3.2M VSL	-$376	-$824	-$438	-$885	-$532	-$977

The results indicate that a 25% increase in variable manufacturing costs across the entire redesign would increase total costs of the rule by from 11%-18%. This would increase the cost/equivalent fatality to $7.1 million -$11.0million. A more likely scenario in which variable assembly costs increase for some, but not all assembly procedures (proxied by a 10% increase), would increase total costs by from 4%-7%, and would result in cost/equivalent fatality of $6.5 million -$10.2 million. Thus, these alternate assumptions would make the standard marginally less cost effective, but would not radically alter the predicted impacts.
This issue is examined further in the probability uncertainty analysis in Chapter IX

Certification and Compliance Test Costs

The agency believes the compliance test costs for the proposed alternatives will be about $10,000 per test, which is about 3 times the cost of the current test. The increased cost is the result of a new tie down procedure, the increased test load, the placement of a head form to represent a 50th percentile male head position in the front occupant seat to evaluate pass/fail headroom criteria, and the requirement for second side testing. These changes increase the preparation time by approximately one day as compared to the present compliance test.

VI. LEADTIME AND PHASE-IN

NHTSA proposed that manufacturers be required to comply with the new requirements three years after the issuance of the final rule. At that time, based upon vehicle testing, we estimated that 68 percent of the current fleet already complied with the proposed roof strength criteria. We anticipated the proposal would not require fleet-wide roof structural changes and believed the manufacturers had engineering and manufacturing resources to meet the new requirements within that timeframe.

In commenting on the NPRM, vehicle manufacturers and their associations argued that additional leadtime was needed, and that a significantly greater portion of the fleet would require redesign than estimated by the agency. The Alliance, Ford and GM stated that approximately 60 percent of their fleets would need to be redesigned, and Hyundai commented that 75 percent of its vehicles would need changes to comply with the requirements.

Toyota, Ford, GM, Hyundai, Nissan and DaimlerChrysler stated that the agency underestimated the necessary modifications to vehicle design and manufacturing challenges that must be overcome to comply with the proposal. Ford, GM, DaimlerChrysler, and Toyota stated that the challenges are especially true for heavier vehicle over 2,722 kg (6,000 pounds) GVWR which have not been required to meet FMVSS No. 216. GM and Ford stated that they rely on outside suppliers for advanced high strength material and currently there is an insufficient supply base for high strength steel. They also cited significant manufacturing challenges that must be overcome to adapt ultra-high strength steel to the mass production environment. They argued that leadtime with a phase-in is necessary to permit growth in the supply base and allow the manufacturers to resolve manufacturability issues for high volume production requirements.

The vehicle manufacturers generally requested a three-year leadtime followed by a multi-year phase-in. Most supported a minimum three year phase-in. GM requested a 4-year phase-in period, and DaimlerChrysler requested a 5-year phase-in only for vehicles over 3,855 kg (8,500 pounds). The AIAM requested compliance credits for an early phase in, while the Alliance, Ford and Mitsubishi requested carryforward credits. The AIAM and Ferrari requested that small volume manufacturers be permitted to comply at the end of the phase-in due to compliance difficulties, long product cycles and cost penalties associated with running structural changes to vehicle programs.

In commenting on the SNPRM, the Alliance reiterated points made in its comment on the NPRM, stating that the final rule needs to provide at least three years initial leadtime followed by a multi-year phase-in with carryforward credits. It stated that additional time is need if the agency adopted the proposed head contact criterion, a two-side test requirement, or an SWR higher than 2.5. Ford suggested that if the agency adopted a more stringent requirement than the one it focused on in the NPRM, that vehicles meeting a 2.5 SWR/one-sided test requirement earn compliance credits before and during the phase-in.

Agency Decision/Response

After carefully considering the comments and available information, and for the reasons discussed below, we have decided to adopt different implementation schedules for vehicles with a GVWR of 2,722 kilograms (6,000 pounds) or less, i.e., the vehicles currently covered by FMVSS No. 216, and those with a higher GVWR. The implementation schedules we are adopting are as follows:

Passenger cars, multipurpose passenger vehicles, trucks and buses with a GVWR of 2,722 kilograms (6,000 pounds) or less. We are adopting a phase-in of the upgraded roof crush resistance requirements for these vehicles. The phase-in requirement for manufacturers of these vehicles (with certain exceptions) is as follows:

--25 percent of the vehicles manufactured during the period from September 1, 2012 to August 31, 2013;

--50 percent of the vehicles manufactured during the period from September 1, 2013 to August 31, 2014;

--75 percent of the vehicles manufactured during the period from September 1, 2014 to August 31, 2015;

--100 percent of light vehicles manufactured on or after September 1, 2015.

Credits may be earned during the phase-in, i.e., beginning September 1, 2012, and carried forward through August 31, 2015.

Small volume manufacturers are not subject to the phase-in but must meet the requirements beginning on September 1, 2015. Vehicles produced in more than one stage and altered vehicles must meet the upgraded requirements beginning September 1, 2016.

<u>Multipurpose passenger vehicles, trucks and buses with a GVWR greater than 2,722 kilograms (6,000 pounds) and less than or equal to 4,536 kilograms (10,000 pounds)</u>. All of these vehicles must meet the requirements beginning September 1, 2016,[43] with the following exception. Vehicles produced in more than one stage and altered vehicles must meet the requirements beginning September 1, 2017.

Our rationale for this implementation schedule is as follows.

As discussed in the FRIA, a significantly larger proportion of the vehicle fleet will require changes than estimated at the time of the NPRM. This would be true even for a 2.5 SWR/one-sided test requirement, and the proportion is higher for the 3.0 SWR/two-sided requirement. We therefore agree that a combination of approximately three years leadtime plus a multi-year phase is appropriate.

In developing the implementation schedule, we have considered costs and benefits. The vast majority of the benefits of the rule come from vehicles with a GVWR of 2,722 kilograms (6,000 pounds) and less. Of the 139 fatalities that will be prevented each year, 133 will come from these lighter vehicles. Moreover, the lighter vehicles are generally redesigned more often than the heavier vehicles. Also, manufacturers are familiar with designing and testing the lighter vehicles to meet the current FMVSS No. 216 requirements.

In order to implement the upgraded requirements in a cost effective manner, we believe it is appropriate to provide approximately three years of leadtime coupled with a 25 percent/50 percent/75 percent/100 percent phase-in for the lighter vehicles, and longer leadtime for the heavier vehicles. The benefits for the heavier vehicles are relatively small, and approximately seven years leadtime will generally permit manufacturers to improve roof strength at the same time they redesign these vehicles for other purposes.

While vehicle manufacturers made varying recommendations for the specific provisions of a phase-in, the phase-in we are adopting for lighter vehicles is within the general range of those recommendations. We recognize that manufacturers argued that longer leadtime should be provided for requirements more stringent than a 2.5 SWR/one-sided test requirement. However, while the 3.0 SWR/two-sided test requirement will increase the number of vehicles requiring redesign and the specific countermeasures that are needed, we believe that approximately three years of leadtime coupled with a 25 percent/50 percent/75 percent/100 percent phase-in provides sufficient time for manufacturers to make these changes. We note that the vehicles likely to present the greatest design challenges under our proposal were the ones with a GVWR above 2,722 kilograms (6,000 pounds), for which we are providing longer leadtime and a lower SWR. Vehicle manufacturers have not provided persuasive evidence that longer leadtime is needed, or that a less stringent requirement should be established for an initial period.

We believe that providing for carry forward credits during the phase-in, but not advance credits, balances encouraging early compliance and manufacturer flexibility with also encouraging manufacturers to continue

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[43] If heavier vehicles are designed to meet the new requirements early, their production volumes are not to be included when calculating the light vehicle fleet phase-in percent compliance. The phase-in schedule for the two fleets are

to improve roof strength during the years of the phase-in.

As with a number of other rulemakings, we are establishing special requirements for small volume manufacturers and for vehicles produced in more than one stage and altered vehicles.

Given the leadtime needed for manufacturers to redesign their vehicles to meet the upgraded roof crush requirements, we find good cause for the compliance dates included in this document.

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separate.

VII. COST-EFFECTIVENESS AND BENEFIT-COST ANALYSES

A. Cost–Effectiveness Analysis

The cost of saving a life is one measure of the relative impact of a proposed regulation. When compared with similar cost measures for alternative approaches or existing regulations, it provides a perspective on the relative merits of the regulation being considered. However, safety countermeasures usually mitigate nonfatal injury as well as death, and all of these impacts must also be accounted for. NHTSA addresses this issue in its safety standards by measuring the cost per equivalent life saved. In order to calculate a cost per equivalent life saved, nonfatal injuries must be expressed in terms of fatalities. This is done by comparing the value of preventing nonfatal injuries to the value of preventing a fatality. Comprehensive values, which include both economic impacts and lost quality (or value) of life considerations will be used to determine the relative value of fatalities and nonfatal injuries. These values were taken from the most recent study on the cost of crashes published by NHTSA,[44] updated to reflect the recent revision in the value of a statistical life specified in guidance from the Office of the Secretary of Transportation. This guidance, which was released on February 5th, 2008, changed the value of a statistical life (VSL) to $5.8 million, with recommendations that values of $3.2 million and $8.4 million also be considered to account for uncertainty.

When accounting for the benefits of safety measures, cost savings not included in value of life measurements must also be accounted for. 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 addition to these factors, preventing a motor vehicle fatality will reduce costs for medical care, emergency services, insurance administrative costs, workplace costs, and legal costs. If the countermeasure is one that also prevents a crash from occurring, property damage and travel delay would

[44] L. Blincoe, A. Seay, E. Zaloshnja, T. Miller, E. Romano, S. Luchter, R. Spicer, (May 2002) "The Economic Impact of Motor Vehicle Crashes, 2000". Washington D.C.: National Highway Traffic Safety Administration, DOT HS 809 446.

be prevented as well. The sum of both value of life and economic cost impacts is referred to as the comprehensive cost savings from reducing fatalities.

The countermeasures that result from FMVSS 216 affect vehicle crashworthiness and would thus not involve property damage or travel delay. The non-VSL factors estimated in the 2002 NHTSA report cited above were updated to 2007 price levels and combined with the revised VSL to produce estimates of total comprehensive values for each injury severity level. The resulting factors used to translate nonfatal injuries into fatal equivalents were as follows:

MAIS1 .0028

MAIS2 .0436

MAIS3 .0804

MAIS4 .1998

MAIS5 .6656

Fatality 1.000

Thus, for example, each MAIS 4 injury prevented is counted as roughly 20% of a fatality, meaning that roughly five MAIS 4 injuries are counted as being equal to one fatality. MAIS 5 injuries, which include the most serious types of nonfatal injuries such as severe brain injury and quadriplegia, are valued at two-thirds a fatality. The more numerous but less serious MAIS 1-3 injuries are valued at small fractions of a fatality. A more complete discussion of the calculations behind these costs is presented in Appendix C of this document.

Table VII-1 summarizes the safety benefits for each alternative under consideration for 2-sided testing. The alternatives shaded in gray are the combined alternatives that include all vehicles under 10,000 lbs. GVWR.

Unshaded alternatives represent either the over 6,000 lbs. GVWR or under 6,000 lbs. GVWR weight group. The table lists fatalities prevented, nonfatal injuries prevented, and equivalent fatalities prevented undiscounted, discounted at 3%, and discounted at 7%. Discounting is required because some impacts of this standard such as safety benefits and added fuel consumption will occur over the vehicle's life, whereas design improvements will be paid for when the vehicle is purchased. The discounting process expresses both costs and benefits in terms of their present value.

In their comments to the NPRM, Public Citizen objected to the concept of discounting future lives saved, arguing that it is an ethically challenged approach that skews the cost-benefit comparison in favor of less stringent standards. They also argue against the use of cost-benefit analysis in making policy decisions, arguing that it ignores the idea that not all costs have the same moral or ethical value. They argue that regulatory costs represent the cost to industry of what it should have done as a good corporate citizen in the absence of regulation, and are thus merely the appropriate price for participation in society.

Discounting of future costs and benefits is a standard analytical practice widely accepted by economists, courts, and academia as a necessary adjustment to reflect the basic concept of time preference. Rather than skewing the cost-benefit in favor of less stringent standards, it properly adjusts future impacts so that the results are not improperly skewed to favor delayed impacts over immediate impacts. In a world of limited resources, society would choose programs that provide benefits immediately or in the near future over programs that provide the same nominal benefits in the far future. The agency will continue to discount future cost and benefit impacts as properly required by OMB guidelines.

PC 's argument that the costs of regulation represent the cost to industry of being a good corporate citizen fails to consider that cost-benefits analysis is conducted at the consumer level. Although the initial investment needed to modify vehicles to meet new safety standards is borne by the industry, ultimately these costs are passed on to consumers in the form of higher vehicle prices. Moreover, in the case of roof crush standards, there is potentially a significant weight penalty that will affect the vehicle's fuel efficiency and increase lifetime fuel costs for consumers. The price that consumers must pay for incremental reductions in risk is a legitimate consideration for policy makers in determining the advisability and/or extent of safety regulations.

Table VII-2 summarizes total costs under each 2-sided testing alternative. Total costs consist of design costs, which are incurred through higher vehicle prices at the time of purchase, and lifetime fuel costs that occur due to added vehicle weight. Fuel costs, which occur over the vehicle's life, are already expressed in present value terms. Costs are shown across the range of weight estimates under each discount rate examined in Chapter V. Table VII-3 summarizes the cost per equivalent fatality (CEF) for each 2-sided testing alternative. For each category, total costs are divided by equivalent fatalities to produce an estimate of the cost per equivalent fatality. It is apparent from Table VII-3 that this rule is much more cost effective for vehicles under 6,000 lbs. GVWR than for vehicles over 6,000 lbs. GVWR. The cost/equivalent fatality for vehicles over 6,000 lbs. GVWR is roughly 12-16 times that for the lighter vehicles at any given SWR. For vehicles< 6,000 lbs. GVWR, the low range of 2.5 SWR scenarios fall within the current DOT guidance for the value of a statistical life ($6.1 million – the comprehensive cost equivalent of a $5.8 million VSL), while the high range results still fall within the upper limit established in DOT's VSL guidance to reflect uncertainty ($8.7 million – the comprehensive cost equivalent of the $8.4 million VSL). However, for vehicles > 6,000 lbs. GVWR, the CEFs exceed the $6.1 million VSL by factors ranging from 700%-1500%. For the 3.0 SWR, vehicles under 6,000 lbs. GVWR fall within the DOT guidance value under the low weight, 3% discount rate scenario, but exceed it under the high weight and 7% scenarios by relatively small margins ranging from 5%-40%. But for vehicles > 6,000 lbs., the CEFs exceed the guidance by factors ranging from 1300%-2100%. Clearly, requiring stronger roofs for the larger vehicles, which are required to be covered by this rule by SAFETEA-LU, will not produce a cost/beneficial result under any scenario. This is primarily a result of the low target population found among these vehicles, which limits the scope of benefits that can be experienced from stronger roofs. It is also a function of higher weight penalties and costs required to strengthen roofs for heavier vehicles to higher absolute strength levels.

Because of this disproportionate impact from large vehicles, the agency considered bi-lateral standards for the 2 groups and examined lower SWRs of 1.5 and of 2.0 for vehicles > 6,000 lbs. GVWR. Among the full fleet alternatives (shaded) in Table VII-3, the most cost-effective results occur for the alternatives that incorporate a 1.5 SWR for vehicles >6,000 lbs. These alternatives combine the higher benefits from lighter vehicles at a each specific SWR with the lower costs for the heavier vehicles at a 1.5 SWR and 2.0 SWR for vehicles > 6,000 lbs. GVWR . Both alternatives produce results that are far less costly than those with higher SWRs.

B. Benefit-Cost Analysis

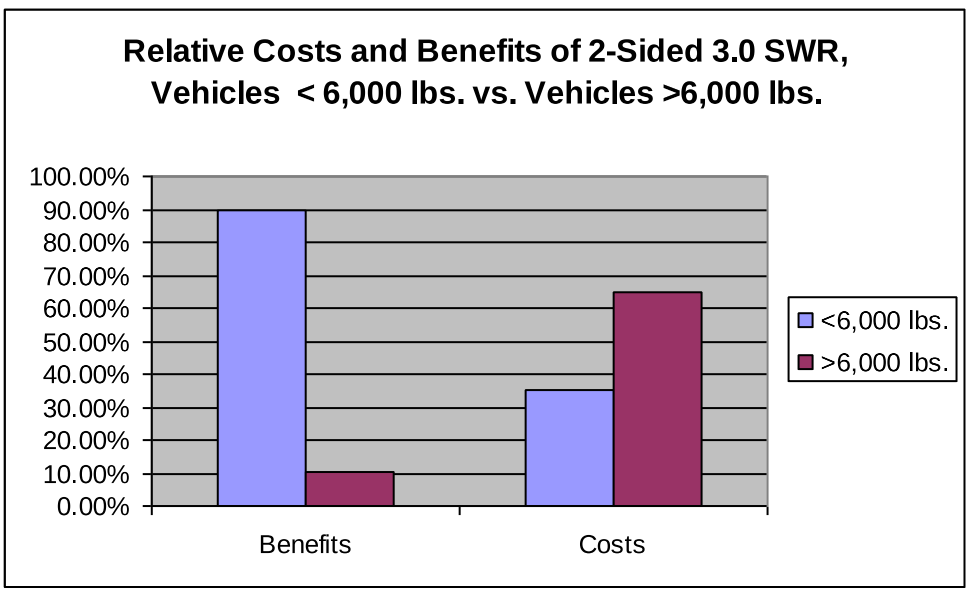
Effective January 1, 2004, OMB Circular A-4 requires that analyses performed in support of proposed rules must include both cost effectiveness and benefit-cost analysis. Benefit-cost analysis differs from cost effectiveness analysis in that it requires that benefits be assigned a monetary value, and that this value be compared to the monetary value of costs to derive a net benefit. Total benefits are derived by multiplying the VSL by the equivalent lives saved. The net benefits are derived by subtracting total costs from the total benefits. In the 2005 PRIA, NHTSA used a value of $3.5 million per life saved to calculate net benefits. In response, Advocates for Highway and Auto Safety (AHAS) stated that the $3.5 million value of a statistical life used by the agency is too low. They cited several studies that mention values significantly higher than the $3.5 million value. They conclude that the agency's valuation is at the lower end of values used by other departments and agencies of the Federal government. PC also stated that $3.5 million is below what many juries award and that some nonfatal injuries can also exceed this value.

On February 5th, 2008, the U.S. Department of Transportation officially increased the value of statistical life that should be used by various DOT modes to $5.8 million. This value was based on an extensive review of current literature. The official DOT guidance also recommends that a range of values, $3.2 million and $8.4 million, be analyzed in recognition of the uncertainty that exists surrounding this issue.

Preventing death and injury yields savings to society not fully encompassed by VSL measures. There are numerous economic impacts from traffic crashes that aren't reflected in standard willingness-to-pay studies that must also be accounted for. These include savings from lower medical care costs, emergency services costs, workplace costs, legal costs, insurance administrative costs, and portions of lost productivity. Based on previous NHTSA studies[45] updated for inflation, the agency estimates that preventing a fatality results in roughly $300,000 in societal benefits that are not accounted for in VSL estimates. To reflect this, net benefit calculations will be based on an equivalent fatality value of $6.1 million. After adjusting for these costs, nearly all alternative scenarios covering vehicles up to 10,000 lbs. GVWR yield net losses rather than net savings to society. From Table VII-4 covering 2-sided tests, for the 2.5/1.5 SWR alternative, the low weight scenarios yield net benefits of $42-$157 million, but the high weight estimates produce net losses of $218-$250 million. For the 3.0/1.5 alternative, the full range across all weight and discount rate scenarios is a savings of $6 million to a loss of $458 million. The 3.5/1.5 scenario produces a range of losses between $612 million and $1.3 billion. For the scenarios with 2.0 SWR for the heavier vehicles, savings shrink and losses increase. The range of impacts for the 2.5/2.0 SWR scenario is a savings of $90 million to a loss of $585 million. A 3.0/2.0 SWR alternative produces losses ranging from $61 million to $809 million. A 3.5/2.0 SWR alternative produces losses ranging from $680 million to $1.6 billion.

Again, this is mostly driven by the large contributions to costs and small contributions to benefits from vehicles over 6,000 lbs. GVWR. Figure VII-1 illustrates this discrepancy.

Figure VII-1



[45] Blincoe et al, 2002

As mentioned previously, DOT VSL guidance also recommends considering VSLs of $8.4 million and $3.2 million in order to acknowledge uncertainty regarding the VSL. A sensitivity analysis based on $8.7 million ($8.4 million VSL plus the $300,000 economic savings adjustment discussed above) was also examined to determine whether any of the alternatives could produce positive benefits under the high end estimate of VSL. The results are shown in Table VII-5. Under this alternate VSL assumption, vehicles < 6,000 lbs. GVWR produce positive net benefits under all four 2.5 scenarios instead of under only two using a $5.8 million VSL. All four 3.0 SWR scenarios also produce positive net benefits compared to only one under a $5.8 million VSL. None of the 3.5 SWR scenarios produces positive net benefits. None of these higher level alternatives are positive for vehicles > 6,000 lbs. GVWR even with this higher VSL. Under the combined (shaded) alternatives, 3 of the 4 scenarios under 2.5/1.5 SWR and two scenarios under 3.0/1.5 SWR are positive compared to only two and one respectively under $5.8 million. Two of the 4 scenarios under 2.5/2.0 SWR and two scenarios under 3.0/2.0 SWR are positive compared to only one and none respectively under $5.8 million. Results based on $3.2 million are shown in Table VII-6. All results under this low VSL are negative.

Tables VII-7 through VII-12 summarize the same information as Tables VII-1 through VII-6 for one sided tests. They generally show similar trends as 2-sided tests, but produce somewhat lower costs and benefits, and, in some cases, slightly better cost-effectiveness and net benefit results.

Tables VII-13through VII-24 summarize the net impact of each individual alternative in ascending severity. Results in these tables are derived from their corresponding summary in Tables VII-1 through VII-12 using the previous less severe alternative as a base level.

Table VII-1

Summary of Benefits, 2-Sided Tests

SWR Alternative	Fatalities	Nonfatal Injuries	Undiscounted Fatal Equivalents	Discounted Fatal Equivalents 3%	Discounted Fatal Equivalents 7%
2.5 SWR <6,000 lbs. GVWR	80	592	112	92	74
2.5 SWR >6,000 lbs. GVWR	8	280	18	14	11
2.5 SWR 0-10,000lbs. GVWR	88	871	129	106	85
2.5 SWR <6/ 2.0 SWR>6	86	774	124	101	81
2.5 SWR <6/ 1.5 SWR>6	82	637	115	94	76
3.0 SWR <6,000 lbs. GVWR	133	1,019	187	153	123
3.0 SWR >6,000 lbs. GVWR	10	363	22	18	14
3.0 SWR 0-10,000lbs. GVWR	143	1,382	209	171	137
3.0 SWR <6/ 2.5 SWR>6	141	1,299	204	167	134
3.0 SWR <6/ 2.0 SWR>6	139	1,202	199	163	131
3.0 SWR <6/ 1.5 SWR>6	135	1,065	190	156	125
3.5 SWR <6,000 lbs. GVWR	175	1,378	247	203	163
3.5 SWR >6,000 lbs. GVWR	11	420	25	20	15
3.5 SWR 0-10,000lbs. GVWR	187	1,798	272	222	178
3.5 SWR <6/ 2.0 SWR>6	181	1,561	259	212	171
3.5 SWR <6/ 1.5 SWR>6	177	1,424	250	205	165
1.5 SWR >6,000 lbs. GVWR	2	46	3	3	2
2.0 SWR >6,000 lbs. GVWR	6	183	12	10	8

Table VII-2

	Summary, Total Costs, 2-Sided Tests (Millions 2007$)			
	Low Weight Estimate		High Weight Estimate	
	Discount Rate		Discount Rate	
SWR Alternative	3%	7%	3%	7%
2.5 SWR <6,000 lbs. GVWR	$346.1	$338.7	$597.1	$534.0
2.5 SWR >6,000 lbs. GVWR	$717.3	$657.7	$1,276.1	$1,103.2
2.5 SWR 0-10,000lbs. GVWR	$1,063.4	$996.4	$1,873.2	$1,637.2
2.5 SWR <6/ 2.0 SWR>6	$528	$544	$1,203.0	$1,075.6
2.5 SWR <6/ 1.5 SWR>6	$417.0	$419.8	$792.1	$711.6
3.0 SWR <6,000 lbs. GVWR	$872.1	$793.5	$1,196.3	$1,043.8
3.0 SWR >6,000 lbs. GVWR	$1,556.7	$1,363.2	$2,243.8	$1,910.9
3.0 SWR 0-10,000lbs. GVWR	$2,428.8	$2,156.7	$3,440.2	$2,954.7
3.0 SWR <6/ 2.5 SWR>6	$1,589.5	$1,451.2	$2,472.5	$2,147.0
3.0 SWR <6/ 2.0 SWR>6	$1,054.5	$999.2	$1,802.2	$1,585.5
3.0 SWR <6/1.5 SWR>6	$943.1	$874.6	$1,391.4	$1,221.4
3.5 SWR <6,000 lbs. GVWR	$1,792.9	$1,590.3	$2,326.9	$2,006.8
3.5 SWR >6,000 lbs. GVWR	$2,404.9	$2,075.9	$3,218.5	$2,724.3
3.5 SWR 0-10,000lbs. GVWR	$4,197.8	$3,666.2	$5,545.4	$4,731.1
3.5 SWR <6/ 2.0 SWR>6	$1,975.2	$1,795.9	$2,932.7	$2,548.5
3.5 SWR <6/ 1.5 SWR>6	$1,863.8	$1,671.4	$2,521.9	$2,184.4
1.5 SWR >6,000 lbs. GVWR	$70.9	$81.1	$195.0	$177.6
2.0 SWR >6,000 lbs. GVWR	$182.3	$205.6	$605.9	$541.7

Table VII-3

	Summary, Cost/Equivalent Fatality, 2 Sided Tests (Millions 2007$)			
	Low Weight Estimate		High Weight Estimate	
	Discount Rate		Discount Rate	
SWR Alternative	3%	7%	3%	7%
2.5 SWR <6,000 lbs. GVWR	$3.8	$4.6	$6.5	$7.2
2.5 SWR >6,000 lbs. GVWR	$50.4	$59.7	$89.7	$100.1
2.5 SWR 0-10,000lbs. GVWR	$10.0	$11.8	$17.7	$19.3
2.5 SWR <6/ 2.0 SWR>6	$5.2	$6.7	$11.9	$13.2
2.5 SWR <6/ 1.5 SWR>6	$4.4	$5.5	$8.4	$9.4
3.0 SWR <6,000 lbs. GVWR	$5.7	$6.4	$7.8	$8.5
3.0 SWR >6,000 lbs. GVWR	$88.4	$99.9	$127.4	$140.0
3.0 SWR 0-10,000lbs. GVWR	$14.2	$15.8	$20.2	$21.6
3.0 SWR <6/ 2.5 SWR>6	$9.5	$10.8	$14.8	$16.0
3.0 SWR <6/ 2.0 SWR>6	$6.5	$7.6	$11.1	$12.1
3.0 SWR <6/ 1.5 SWR>6	$6.1	$7.0	$8.9	$9.8
3.5 SWR <6,000 lbs. GVWR	$8.8	$9.7	$11.5	$12.3
3.5 SWR >6,000 lbs. GVWR	$122.1	$136.0	$163.4	$178.4
3.5 SWR 0-10,000lbs. GVWR	$18.9	$20.5	$24.9	$26.5
3.5 SWR <6/ 2.0 SWR>6	$9.3	$10.5	$13.8	$14.9
3.5 SWR <6/ 1.5 SWR>6	$9.1	$10.1	$12.3	$13.2
1.5 SWR >6,000 lbs. GVWR	$27.9	$41.20	$76.8	$90.3

2.0 SWR >6,000 lbs. GVWR	$18.8	$27.34	$62.4	$72.0

Table VII-4

	Summary, Net Benefits, 2-Sided Tests , $5.8 million VSL* (Millions 2007$)			
	Low Weight Estimate		High Weight Estimate	
	Discount Rate		Discount Rate	
SWR Alternative	3%	7%	3%	7%
2.5 SWR <6,000 lbs. GVWR	$213	$111	-$38	-$84
2.5 SWR >6,000 lbs. GVWR	-$631	-$590	-$1,189	-$1,036
2.5 SWR 0-10,000lbs. GVWR	-$418	-$479	-$1,228	-$1,120
2.5 SWR <6/ 2.0 SWR>6	$90	-$49	-$585	-$580
2.5 SWR <6/ 1.5 SWR>6	$157	$42	-$218	-$250
3.0 SWR <6,000 lbs. GVWR	$62	-$42	-$262	-$292
3.0 SWR >6,000 lbs. GVWR	-$1,449	-$1,280	-$2,136	-$1,828
3.0 SWR 0-10,000lbs. GVWR	-$1,388	-$1,322	-$2,399	-$2,120
3.0 SWR <6/ 2.5 SWR>6	-$569	-$632	-$1,452	-$1,328
3.0 SWR <6/ 2.0 SWR>6	-$61	-$202	-$809	-$788
3.0 SWR <6/ 1.5 SWR>6	$6	-$111	-$442	-$458
3.5 SWR <6,000 lbs. GVWR	-$556	-$595	-$1,090	-$1,012
3.5 SWR >6,000 lbs. GVWR	-$2,285	-$1,983	-$3,098	-$2,631
3.5 SWR 0-10,000lbs. GVWR	-$2,841	-$2,578	-$4,189	-$3,643
3.5 SWR <6/ 2.0 SWR>6	-$680	-$755	-$1,637	-$1,507
3.5 SWR <6/ 1.5 SWR>6	-$612	-$664	-$1,270	-$1,177
1.5 SWR >6,000 lbs. GVWR	-$55	-$69	-$180	-$166

2.0 SWR >6,000 lbs. GVWR	-$123	-$160	-$547	-$496

* Based on $5.8 million VSL plus $300,000 economic externalities. See text.

Table VII-5

	Summary, Net Benefits, 2-Sided Tests, $8.4 Million VSL			
	Low Weight Estimate		High Weight Estimate	
	Discount Rate		Discount Rate	
SWR Alternative	3%	7%	3%	7%
2.5 SWR <6,000 lbs. GVWR	$438	$292	$187	$97
2.5 SWR >6,000 lbs. GVWR	-$598	-$565	-$1,157	-$1,010
2.5 SWR 0-10,000lbs. GVWR	-$160	-$273	-$970	-$914
2.5 SWR <6/ 2.0 SWR>6	$337	$103	-$337	-$428
2.5 SWR <6/ 1.5 SWR>6	$388	$228	$13	-$64
3.0 SWR <6,000 lbs. GVWR	$438	$261	$113	$10
3.0 SWR >6,000 lbs. GVWR	-$1,409	-$1,248	-$2,096	-$1,796
3.0 SWR 0-10,000lbs. GVWR	-$971	-$988	-$1,982	-$1,786
3.0 SWR <6/ 2.5 SWR>6	-$160	-$304	-$1,043	-$1,000
3.0 SWR <6/ 2.0 SWR>6	$337	$118	-$411	-$468
3.0 SWR <6/ 1.5 SWR>6	$388	$196	-$60	-$151
3.5 SWR <6,000 lbs. GVWR	-$59	-$195	-$593	-$611
3.5 SWR >6,000 lbs. GVWR	-$2,239	-$1,948	-$3,053	-$2,596
3.5 SWR 0-10,000lbs. GVWR	-$2,298	-$2,142	-$3,646	-$3,207
3.5 SWR <6/ 2.0 SWR>6	-$160	-$337	-$1,117	-$1,090
3.5 SWR <6/ 1.5 SWR>6	-$109	-$259	-$767	-$772
1.5 SWR >6,000 lbs. GVWR	-$50	-$65	-$174	-$161
2.0 SWR >6,000 lbs. GVWR	-$101	-$142	-$524	-$478

* Based on $8.4 million VSL plus $300,000 economic externalities. See text.

Table VII-6

	Summary, Net Benefits, 2-Sided Tests, $3.2 Million VSL			
	Low Weight Estimate		High Weight Estimate	
	Discount Rate		Discount Rate	
SWR Alternative	3%	7%	3%	7%
2.5 SWR <6,000 lbs. GVWR	-$13	-$70	-$264	-$266
2.5 SWR >6,000 lbs. GVWR	-$664	-$616	-$1,222	-$1,062
2.5 SWR 0-10,000lbs. GVWR	-$676	-$686	-$1,486	-$1,327
2.5 SWR <6/ 2.0 SWR>6	-$158	-$247	-$833	-$779
2.5 SWR <6/ 1.5 SWR>6	-$74	-$144	-$449	-$436
3.0 SWR <6,000 lbs. GVWR	-$315	-$345	-$639	-$595
3.0 SWR >6,000 lbs. GVWR	-$1,490	-$1,312	-$2,177	-$1,859
3.0 SWR 0-10,000lbs. GVWR	-$1,805	-$1,656	-$2,816	-$2,454
3.0 SWR <6/ 2.5 SWR>6	-$978	-$961	-$1,861	-$1,657
3.0 SWR <6/ 2.0 SWR>6	-$460	-$522	-$1,208	-$1,108
3.0 SWR <6/ 1.5 SWR>6	-$376	-$418	-$824	-$765
3.5 SWR <6,000 lbs. GVWR	-$1,054	-$996	-$1,588	-$1,412
3.5 SWR >6,000 lbs. GVWR	-$2,330	-$2,018	-$3,144	-$2,666
3.5 SWR 0-10,000lbs. GVWR	-$3,385	-$3,014	-$4,732	-$4,079
3.5 SWR <6/ 2.0 SWR>6	-$1,200	-$1,173	-$2,157	-$1,926
3.5 SWR <6/ 1.5 SWR>6	-$1,116	-$1,069	-$1,774	-$1,582

1.5 SWR >6,000 lbs. GVWR	-$61	-$74	-$185	-$170
2.0 SWR >6,000 lbs. GVWR	-$146	-$177	-$569	-$513

* Based on $3.2 million VSL plus $300,000 economic externalities. See text.

Table VII-7

	Summary of Benefits, 1-Sided Tests				
				Discounted Fatal Equivalents	
SWR Alternative	Fatalities	Nonfatal Injuries	Undiscounted Fatal Equivalents	3%	7%
2.5 SWR <6,000 lbs. GVWR	71	522	99	82	66
2.5 SWR >6,000 lbs. GVWR	6	197	13	10	8
2.5 SWR 0-10,000lbs. GVWR	78	718	112	92	74
2.5 SWR <6/ 2.0 SWR>6	77	684	110	90	72
2.5 SWR <6/ 1.5 SWR>6	72	535	100	82	66
3.0 SWR <6,000 lbs. GVWR	111	838	156	128	103
3.0 SWR >6,000 lbs. GVWR	9	295	19	15	12
3.0 SWR 0-10,000lbs. GVWR	120	1,133	174	142	114
3.0 SWR <6/ 2.5 SWR>6	117	1,034	168	138	111
3.0 SWR <6/ 2.0 SWR>6	116	1,000	166	136	109
3.0 SWR <6/ 1.5 SWR>6	112	851	156	128	103
3.5 SWR <6,000 lbs. GVWR	153	1,184	215	176	142
3.5 SWR >6,000 lbs. GVWR	10	365	22	18	14

3.5 SWR 0-10,000lbs. GVWR	163	1,549	237	194	155
3.5 SWR <6/ 2.0 SWR>6	158	1,346	226	185	149
3.5 SWR <6/ 1.5 SWR>6	153	1,198	216	177	142
1.5 SWR >6,000 lbs. GVWR	0	13	1	1	1
2.0 SWR >6,000 lbs. GVWR	5	162	11	9	7

Table VII-8

	Summary, Total Costs, 1-Sided Tests (Millions 2007$)			
	Low Weight Estimate		High Weight Estimate	
	Discount Rate		Discount Rate	
SWR Alternative	3%	7%	3%	7%
2.5 SWR <6,000 lbs. GVWR	$199.5	$210.5	$407.7	$371.1
2.5 SWR >6,000 lbs. GVWR	$184.6	$204.9	$611.4	$544.2
2.5 SWR 0-10,000lbs. GVWR	$384.1	$415.4	$1,019.1	$915.3
2.5 SWR <6/ 2.0 SWR>6	$383.0	$414.5	$916.1	$829.8
2.5 SWR <6/ 1.5 SWR>6	$220.6	$234.6	$459.7	$418.9
3.0 SWR <6,000 lbs. GVWR	$591.1	$547.6	$845.0	$743.0
3.0 SWR >6,000 lbs. GVWR	$898.6	$810.1	$1,483.5	$1,276.3
3.0 SWR 0-10,000lbs. GVWR	$1,489.7	$1,357.7	$2,328.5	$2,019.3
3.0 SWR <6/ 2.5 SWR>6	$775.8	$752.5	$1,456.4	$1,287.1
3.0 SWR <6/ 2.0 SWR>6	$774.6	$751.6	$1,353.5	$1,201.6
3.0 SWR <6/ 1.5 SWR>6	$612.2	$571.6	$897.0	$790.7
3.5 SWR <6,000 lbs. GVWR	$1,301.6	$1,157.4	$1,726.1	$1,482.1
3.5 SWR >6,000 lbs. GVWR	$1,630.2	$1,425.0	$2,329.9	$1,982.6
3.5 SWR 0-10,000lbs. GVWR	$2,931.8	$2,582.3	$4,056.0	$3,464.7
3.5 SWR <6/ 2.0 SWR>6	$1,485.1	$1,361.4	$2,234.6	$1,940.8
3.5 SWR <6/ 1.5 SWR>6	$1,322.6	$1,181.4	$1,778.1	$1,529.9
1.5 SWR >6,000 lbs. GVWR	$21.1	$24.0	$52.0	$47.7
2.0 SWR >6,000 lbs. GVWR	$183.5	$204.0	$508.5	$458.6

Table VII-9

	Summary, Cost/Equivalent Fatality, 1 Sided Tests (Millions 2007$)			
	Low Weight Estimate		High Weight Estimate	
	Discount Rate		Discount Rate	
SWR Alternative	3%	7%	3%	7%
2.5 SWR <6,000 lbs. GVWR	$2.4	$3.2	$5.0	$5.7
2.5 SWR >6,000 lbs. GVWR	$17.8	$25.6	$59.1	$67.9
2.5 SWR 0-10,000lbs. GVWR	$4.2	$5.6	$11.1	$12.4
2.5 SWR <6/ 2.0 SWR>6	$4.2	$5.7	$10.2	$11.5
2.5 SWR <6/ 1.5 SWR>6	$2.7	$3.5	$5.6	$6.3
3.0 SWR <6,000 lbs. GVWR	$4.6	$5.3	$6.6	$7.2
3.0 SWR >6,000 lbs. GVWR	$60.4	$70.3	$99.8	$110.8
3.0 SWR 0-10,000lbs. GVWR	$10.5	$11.9	$16.3	$17.7
3.0 SWR <6/ 2.5 SWR>6	$5.6	$6.8	$10.6	$11.6
3.0 SWR <6/ 2.0 SWR>6	$5.7	$6.9	$9.9	$11.0
3.0 SWR <6/ 1.5 SWR>6	$4.8	$5.5	$7.0	$7.7
3.5 SWR <6,000 lbs. GVWR	$7.4	$8.2	$9.8	$10.5
3.5 SWR >6,000 lbs. GVWR	$92.2	$104.0	$131.8	$144.7
3.5 SWR 0-10,000lbs. GVWR	$15.1	$16.6	$20.9	$22.3
3.5 SWR <6/ 2.0 SWR>6	$8.0	$9.2	$12.1	$13.1
3.5 SWR <6/ 1.5 SWR>6	$7.5	$8.3	$10.1	$10.7
1.5 SWR >6,000 lbs. GVWR	$27.7	$40.70	$68.3	$80.9

2.0 SWR >6,000 lbs. GVWR	$21.1	$30.33	$58.6	$68.2

Table VII-10

	Summary, Net Benefits, 1-Sided Tests , $5.8 Million VSL			
	Low Weight Estimate		High Weight Estimate	
	Discount Rate		Discount Rate	
SWR Alternative	3%	7%	3%	7%
2.5 SWR <6,000 lbs. GVWR	$298	$190	$90	$29
2.5 SWR >6,000 lbs. GVWR	-$122	-$158	-$548	-$495
2.5 SWR 0-10,000lbs. GVWR	$176	$34	-$459	-$466
2.5 SWR <6/ 2.0 SWR>6	$167	$27	-$366	-$388
2.5 SWR <6/ 1.5 SWR>6	$281	$169	$42	-$15
3.0 SWR <6,000 lbs. GVWR	$187	$79	-$67	-$117
3.0 SWR >6,000 lbs. GVWR	-$808	-$742	-$1,393	-$1,206
3.0 SWR 0-10,000lbs. GVWR	-$621	-$661	-$1,460	-$1,323
3.0 SWR <6/ 2.5 SWR>6	$65	-$77	-$615	-$612
3.0 SWR <6/ 2.0 SWR>6	$56	-$84	-$522	-$534
3.0 SWR <6/ 1.5 SWR>6	$170	$58	-$114	-$161
3.5 SWR <6,000 lbs. GVWR	-$227	-$292	-$652	-$617
3.5 SWR >6,000 lbs. GVWR	-$1,522	-$1,344	-$2,222	-$1,899
3.5 SWR 0-10,000lbs. GVWR	-$1,749	-$1,634	-$2,874	-$2,516
3.5 SWR <6/ 2.0 SWR>6	-$358	-$455	-$1,107	-$1,035
3.5 SWR <6/ 1.5 SWR>6	-$243	-$313	-$699	-$661
1.5 SWR >6,000 lbs. GVWR	-$16	-$21	-$47	-$44

2.0 SWR >6,000 lbs. GVWR	-$131	-$164	-$456	-$418

* Based on $5.8 million VSL plus $300,000 economic externalities. See text.

Table VII-11

	Summary, Net Benefits, 1-Sided Tests, $8.4 Million VSL			
	Low Weight Estimate		High Weight Estimate	
	Discount Rate		Discount Rate	
SWR Alternative	3%	7%	3%	7%
2.5 SWR <6,000 lbs. GVWR	$498	$351	$302	$200
2.5 SWR >6,000 lbs. GVWR	-$98	-$137	-$521	-$474
2.5 SWR 0-10,000lbs. GVWR	$401	$214	-$220	-$275
2.5 SWR <6/ 2.0 SWR>6	$388	$204	-$145	-$212
2.5 SWR <6/ 1.5 SWR>6	$484	$332	$244	$148
3.0 SWR <6,000 lbs. GVWR	$500	$331	$265	$150
3.0 SWR >6,000 lbs. GVWR	-$774	-$713	-$1,354	-$1,176
3.0 SWR 0-10,000lbs. GVWR	-$273	-$382	-$1,089	-$1,026
3.0 SWR <6/ 2.5 SWR>6	$403	$193	-$257	-$324
3.0 SWR <6/ 2.0 SWR>6	$390	$183	-$168	-$250
3.0 SWR <6/ 1.5 SWR>6	$485	$312	$201	$93
3.5 SWR <6,000 lbs. GVWR	$205	$56	-$193	-$249
3.5 SWR >6,000 lbs. GVWR	-$1,482	-$1,310	-$2,176	-$1,863
3.5 SWR 0-10,000lbs. GVWR	-$1,276	-$1,254	-$2,370	-$2,112
3.5 SWR <6/ 2.0 SWR>6	$95	-$92	-$626	-$649
3.5 SWR <6/ 1.5 SWR>6	$191	$37	-$265	-$312
1.5 SWR >6,000 lbs. GVWR	-$15	-$19	-$46	-$43
2.0 SWR >6,000 lbs. GVWR	-$110	-$147	-$433	-$400

* Based on $8.4 million VSL plus $300,000 economic externalities. See text.

Table VII-12

	Summary, Net Benefits, 1-Sided Tests, $3.2 Million VSL			
	Low Weight Estimate		High Weight Estimate	
	Discount Rate		Discount Rate	
SWR Alternative	3%	7%	3%	7%
2.5 SWR <6,000 lbs. GVWR	$97	$28	-$111	-$132
2.5 SWR >6,000 lbs. GVWR	-$146	-$175	-$572	-$514
2.5 SWR 0-10,000lbs. GVWR	-$48	-$146	-$683	-$646
2.5 SWR <6/ 2.0 SWR>6	$388	$204	-$587	-$565
2.5 SWR <6/ 1.5 SWR>6	$484	$332	-$160	-$178
3.0 SWR <6,000 lbs. GVWR	-$127	-$174	-$380	-$369
3.0 SWR >6,000 lbs. GVWR	-$842	-$767	-$1,427	-$1,233
3.0 SWR 0-10,000lbs. GVWR	-$969	-$940	-$1,808	-$1,602
3.0 SWR <6/ 2.5 SWR>6	-$272	-$348	-$953	-$883
3.0 SWR <6/ 2.0 SWR>6	-$277	-$352	-$856	-$802
3.0 SWR <6/ 1.5 SWR>6	-$145	-$196	-$430	-$415
3.5 SWR <6,000 lbs. GVWR	-$660	-$641	-$1,084	-$966
3.5 SWR >6,000 lbs. GVWR	-$1,563	-$1,373	-$2,263	-$1,931
3.5 SWR 0-10,000lbs. GVWR	-$2,223	-$2,014	-$3,347	-$2,896
3.5 SWR <6/ 2.0 SWR>6	-$810	-$819	-$1,560	-$1,399
3.5 SWR <6/ 1.5 SWR>6	-$678	-$663	-$1,133	-$1,011
1.5 SWR >6,000 lbs. GVWR	-$18	-$22	-$49	-$46
2.0 SWR >6,000 lbs. GVWR	-$151	-$179	-$476	-$433

* Based on $3.2 million VSL plus $300,000 economic externalities. See text.

Table VII-13

	Incremental Benefits, 2-Sided Tests				
			Undiscounted	Discounted Fatal Equivalents	
		Nonfatal	Fatal		
SWR Alternative	Fatalities	Injuries	Equivalents	3%	7%
<6,000 lbs. GVWR:					
2.5	80	592	112	92	74
3.0	53	428	75	61	49
3.5	42	359	60	50	40
>6,000 lbs. GVWR:					
1.5	2	46	3	3	2
2.0	4	137	9	7	6
2.5	3	97	6	5	3
3.0	2	83	4	3	3
3.5	1	57	3	2	2

Table VII-14

	Incremental Total Costs, 2-Sided Tests			
	Low Estimate Discount Rate		High Estimate Discount Rate	
SWR Alternative	3%	7%	3%	7%
<6,000 lbs. GVWR:				
2.5	$346.1	$338.7	$597.1	$534.0
3.0	$526.0	$454.8	$599.2	$509.8
3.5	$920.7	$796.8	$1,130.5	$963.0
>6,000 lbs. GVWR:				
1.5	$70.9	$81.1	$195.0	$177.6
2.0	$111.4	$124.6	$410.8	$364.1
2.5	$535.0	$452.1	$670.3	$561.5

3.0	$839.4	$705.5	$967.7	$807.7
3.5	$848.2	$712.7	$974.7	$813.4

Table VII-15

Incremental Cost/Equivalent Fatality, 2-Sided Tests				
	Low Estimate Discount Rate		High Estimate Discount Rate	
SWR Alternative	3%	7%	3%	7%
<6,000 lbs. GVWR:				
2.5	$3.8	$4.6	$6.5	$7.2
3.0	$8.6	$9.2	$9.7	$10.3
3.5	$18.6	$20.0	$22.8	$24.1
>6,000 lbs. GVWR:				
1.5	$27.9	$41.2	$76.8	$90.3
2.0	$15.5	$22.4	$57.3	$65.6
2.5	$118.5	$129.2	$148.4	$160.5
3.0	$247.7	$268.6	$285.5	$307.5
3.5	$405.5	$439.7	$466.0	$501.8

Table VII-16

Incremental Net Benefits, $5.8 Million VSL, 2-Sided Tests				
	Low Estimate Discount Rate		High Estimate Discount Rate	
SWR Alternative	3%	7%	3%	7%
<6,000 lbs. GVWR:				
2.5	$212.7	$111.1	-$38.3	-$84.2
3.0	-$151.0	-$153.0	-$224.2	-$208.0
3.5	-$618.1	-$553.2	-$828.0	-$719.4

>6,000 lbs. GVWR:				
1.5	-$55.4	-$69.1	-$179.5	-$165.6
2.0	-$67.7	-$90.7	-$367.1	-$330.2
2.5	-$507.4	-$430.7	-$642.7	-$540.2
3.0	-$818.7	-$689.5	-$947.0	-$791.7
3.5	-$835.4	-$702.8	-$961.9	-$803.5

Table VII-17

Incremental Net Benefits, $8.4 Million VSL, 2-Sided Tests				
	Low Estimate Discount Rate		High Estimate Discount Rate	
SWR Alternative	3%	7%	3%	7%
<6,000 lbs. GVWR:				
2.5	$437.8	$292.2	$186.8	$96.9
3.0	-$0.3	-$31.6	-$73.5	-$86.7
3.5	-$496.6	-$455.4	-$706.5	-$621.6
>6,000 lbs. GVWR:				
1.5	-$49.6	-$64.5	-$173.7	-$161.0
2.0	-$51.1	-$77.8	-$350.5	-$317.3
2.5	-$497.0	-$422.7	-$632.3	-$532.1
3.0	-$810.9	-$683.5	-$939.3	-$785.6
3.5	-$830.7	-$699.1	-$957.2	-$799.8

Table VII-18

Incremental Net Benefits, $3.2 Million VSL, 2-Sided Tests				
	Low Estimate Discount Rate		High Estimate Discount Rate	
SWR Alternative	3%	7%	3%	7%
<6,000 lbs. GVWR:				
2.5	-$12.6	-$70.3	-$263.6	-$265.5
3.0	-$301.9	-$274.5	-$375.1	-$329.5
3.5	-$739.8	-$651.1	-$949.6	-$817.3
>6,000 lbs. GVWR:				

1.5	-$61.4	-$73.7	-$185.5	-$170.2
2.0	-$84.3	-$103.6	-$383.7	-$343.1
2.5	-$517.9	-$438.8	-$653.2	-$548.3
3.0	-$826.5	-$695.5	-$954.8	-$797.7
3.5	-$840.2	-$706.5	-$966.7	-$807.3

Table VII-19

	Incremental Benefits, 1-Sided Tests				
SWR Alternative	Fatalities	Nonfatal Injuries	Undiscounted Fatal Equivalents	Discounted Fatal Equivalents 3%	Discounted Fatal Equivalents 7%
<6,000 lbs. GVWR:					
2.5	71	522	99	82	66
3.0	40	316	56	46	37
3.5	42	346	59	49	39
>6,000 lbs. GVWR:					
1.5	0	13	1	1	1
2.0	5	148	10	8	6
2.5	1	35	2	2	1
3.0	3	99	6	5	4
3.5	1	70	4	3	2

Table VII-20

	Incremental Total Costs, 1-Sided Tests			
	Low Estimate Discount Rate		High Estimate Discount Rate	
SWR Alternative	3%	7%	3%	7%
<6,000 lbs. GVWR:				
2.5	$199.5	$210.5	$407.7	$371.1
3.0	$391.6	$337.0	$437.3	$371.8
3.5	$710.4	$609.8	$881.1	$739.2

>6,000 lbs. GVWR:				
1.5	$21.1	$24.0	$52.0	$47.7
2.0	$162.4	$180.0	$456.5	$410.9
2.5	$1.1	$0.9	$103.0	$85.5
3.0	$713.9	$605.2	$872.0	$732.2
3.5	$731.6	$614.9	$846.4	$706.3

Table VII-21

Incremental Cost/Equivalent Fatality, 1-Sided Tests				
	Low Estimate Discount Rate		High Estimate Discount Rate	
SWR Alternative	3%	7%	3%	7%
<6,000 lbs. GVWR:				
2.5	$2.4	$3.2	$5.0	$5.7
3.0	$8.5	$9.1	$9.5	$10.0
3.5	$14.6	$15.6	$18.1	$18.9
>6,000 lbs. GVWR:				
1.5	$27.7	$40.7	$68.3	$80.9
2.0	$20.5	$29.3	$57.7	$67.0
2.5	$0.7	$0.7	$61.7	$66.2
3.0	$157.9	$172.8	$192.9	$209.0
3.5	$259.9	$281.8	$300.7	$323.7

Table VII-22

Incremental Net Benefits, $5.8 Million VSL, 1-Sided Tests				
	Low Estimate Discount Rate		High Estimate Discount Rate	
SWR Alternative	3%	7%	3%	7%
<6,000 lbs. GVWR:				
2.5	$297.9	$189.8	$89.7	$29.2
3.0	-$111.0	-$111.1	-$156.6	-$145.9
3.5	-$413.9	-$371.1	-$584.6	-$500.5

>6,000 lbs. GVWR:				
1.5	-$16.4	-$20.5	-$47.4	-$44.1
2.0	-$114.1	-$143.8	-$408.2	-$373.5
2.5	$9.0	$6.7	-$92.8	-$77.7
3.0	-$686.4	-$584.5	-$844.5	-$710.8
3.5	-$714.5	-$602.0	-$829.2	-$692.9

Table VII-23

Incremental Net Benefits, $8.4 Million VSL, 1-Sided Tests				
	Low Estimate Discount Rate		High Estimate Discount Rate	
SWR Alternative	3%	7%	3%	7%
<6,000 lbs. GVWR:				
2.5	$498.2	$351.0	$301.7	$199.8
3.0	$1.9	-$20.3	-$37.0	-$49.6
3.5	-$294.7	-$275.2	-$458.2	-$398.7
>6,000 lbs. GVWR:				
1.5	-$14.6	-$19.0	-$45.6	-$42.8
2.0	-$95.8	-$128.3	-$387.4	-$357.4
2.5	$12.9	$9.9	-$88.4	-$74.3
3.0	-$676.0	-$575.8	-$832.7	-$701.7
3.5	-$708.0	-$596.6	-$821.9	-$687.3

Table VII-24

Incremental Net Benefits, $3.2 Million VSL, 1-Sided Tests				
	Low Estimate Discount Rate		High Estimate Discount Rate	
SWR Alternative	3%	7%	3%	7%
<6,000 lbs. GVWR:				
2.5	$97.3	$28.3	-$110.9	-$132.3
3.0	-$223.9	-$202.1	-$269.6	-$236.9
3.5	-$533.1	-$467.1	-$703.8	-$596.5
>6,000 lbs. GVWR:				
1.5	-$18.2	-$21.8	-$49.1	-$45.5

2.0	-$132.5	-$156.8	-$426.6	-$387.7
2.5	$5.2	$4.0	-$96.6	-$80.6
3.0	-$696.8	-$591.9	-$854.9	-$718.9
3.5	-$720.9	-$606.6	-$835.7	-$698.0

VIII. REGULATORY FLEXIBILITY ACT AND UNFUNDED MANDATES REFORM ACT ANALYSIS

A. Regulatory Flexibility Act

The Regulatory Flexibility Act of 1980 (5 U.S.C. § 601 et seq.) requires agencies to evaluate the potential effects of their proposed and final rules on small businesses, small organizations, and small governmental jurisdictions. The head of the agency has certified that the final rule will not have a significant 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 (id. At § 605(b)), we discuss below many of the issues that a final regulatory flexibility analysis would address (§ 604).

1. Description of the reasons why action by the agency is being considered

NHTSA has determined that there is a safety need to upgrade the agency's roof strength standard to reduce death and injury in rollover crashes. This rulemaking action is required by section 10301 of SAFETEA-LU.

2. Objectives of, and legal basis for, the final rule

Under 49 U.S.C. 322(a), the Secretary of Transportation (the "Secretary") has authority to prescribe regulations to carry out the duties and powers of the Secretary. One of the duties of the Secretary is to administer the National Traffic and Motor Vehicle Safety Act, as amended. The Secretary has delegated the responsibility for carrying out the National Traffic and Motor Vehicle Safety Act to NHTSA .[46] The

[46] 49 U.S.C. 105 and 322; delegation of authority at 49 CFR 1.50.

agency is authorized to issue Federal motor vehicle safety regulations that meet the need for motor vehicle safety. NHTSA is issuing the final rule under 49 U.S.C. 322, 30111, 30115, 30117, 30166, and 30168; delegation of authority at 49 CFR 1.50. This rulemaking action is required by section 10301 of SAFETEA-LU.

3. Description and estimate of the number of small entities to which the final rule will apply

The final regulation appies to motor vehicle manufacturers, final stage manufacturers, and alterers.

Business entities are defined as small businesses using the North American Industry Classification System (NAICS) code, for the purposes 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. Affected business categories include: (a) To qualify as a small business in Automotive Manufacturing (NAICS 336111), the firm must have fewer than 1,000 employees., b) In the Light Truck and Utility Vehicle Manufacturing (NAICS 336112), the firm must have fewer than 1,000 employees, c) In Motor Vehicle Body Manufacturing, the firm must have fewer than 1,000 employees, d) In Motor Vehicle Seating and Interior Trim Manufacturing (NAICS 336360), the firm must have fewer than 500 employees, and e) In All Other Motor Vehicle Parts Manufacturing (NAICS 336399), the firm must have fewer than 750 employees.

Small motor vehicle manufacturers

There are 6 vehicle manufacturers that qualify as small businesses that are affected by this rule. Table VIII-1 provides information about the 6 small domestic manufacturers in MY 2007.

Table VII-1
Small Vehicle Manufacturers

Manufacturer	Employees	Estimated Sales	Sale Price Range	Est. Revenues*
Fisker Automotive**	N/A	15,000 projected	$80,000	N/A
Mosler Automotive	25	20	$189,000	$2,000,000
Panoz Auto Development Company	50	150	$90,000 to $125,000	$16,125,000
Saleen Inc.	170	1,000[#]	$39,000 to $59,000	$49,000,000
Saleen Inc.	170	16[##]	$585,000	$9,000,000
Standard Taxi***	35	N/A	$25,000	$2,000,000
Tesla Motors, Inc.	250	2,000	$65,000 to $100,000	N/A

* Assuming an average sales price from the sales price range.
** Fisker Automotive is a joint venture of Quantum Fuel Systems Technologies Worldwide, Inc. and Fisker Coachbuild, LLC.
*** Standard Taxi is a subsidiary of the Vehicle Production Group LLC. 35 employees is the total for VPG LLC.
[#] Ford Mustang Conversions
S7 modell

The average price increase per affected vehicle <6,000 lbs. GVWR is estimated to be about $55. For the least expensive vehicle in Table VII-1, the cost increase is no more than two tenths of one percent ($55/$25,000 = .002). For other manufacturers, the impact would be even less.

We believe that the market for the products of these small manufacturers is highly inelastic. Purchasers of these products are enticed by the desire to have an unusual vehicle. Thus, we do not believe that raising the price by this small amount will have any effect on vehicle sales. We suspect these price increases will be passed on to the final customers. Based on this analysis, the agency believes that the final rule will not have a significant economic impact on these six small vehicle manufacturers.

There are several hundred final stage manufacturers and alterers, only a portion of which modify roof structures. Many of these manufacturers will have the option to certify compliance with FMVSS 220 or FMVSS 216. FMVSS 220 requires a 1.5 SWR when the vehicle is loaded with an evenly distributed vertical force, thus these vehicles will have an easier test to certify compliance to than that required in the upgraded FMVSS 216. This lower requirement is consistent with the lower rollover involvement of these vehicles, which, in the rare instances when they do roll over, tend to roll only ¼ turn.

There are several other reasons why impacts on small manufacturers are expected to be limited. Small businesses using chassis cabs will be in a position to take advantage of "pass-through certification", and therefore are not expected to incur any additional expenditures. We are also excluding a narrow category of multi-stage vehicles from FMVSS No. 216 altogether, multi-stage trucks built on incomplete vehicles other than chassis cabs. Final stage manufacturers and alterers can wait until one year after the end of phase-in to meet the new requirements. Finally, some of the vehicles manufactured by these small businesses are convertibles, which are not affected by the rule.

4. <u>Description of the projected reporting, record keeping and other compliance requirements for small entities</u>

The agency is amending the test procedures in FMVSS 216 to require that vehicles < 6,000 lbs. GVWR meet test requirements with the application of a force loading device up to 3.0 times the vehicle's weight without the roof crushing 127 millimeters (5 inches) or to a level where it touches the head of a seated 50th

percentile male dummy. This represents a change from the current requirement, which specifies a test load of only 1.5 times the vehicle's weight without the device moving more than 127 millimeters (5 inches). The agency is also requiring that vehicles > 6,000 lbs. GVWR will have to meet FMVSS 216 for the first time, specifying a 2.0 SWR for these products.

5. Duplication with other Federal rules

There are no relevant Federal rules that may duplicate, overlap or conflict with the rule.

6. Description of any significant alternatives to the final rule

The agency is modifying the test procedures in FMVSS 216 to require that vehicles < 6,000 lbs. GVWR be tested with the application of a force loading device up to 3.0 times the vehicle's weight without the roof crushing to a level of 5 inches or where it touches the head of a seated 50^{th} percentile male dummy. Vehicles > 6,000 lbs. GVWR will be required to meet an SWR of 1.5. NHTSA also examined an alternative to increase roof strength to 2.5 and 3.5 times the vehicles weight for vehicles < 6,000 lbs. GVWR, and additional alternative SWRs of 2.0, 2.5, 3.0, and 3.5 for vehicles > 6,000 lbs. GVWR. The agency also examined single sided test alternatives for all SWR levels.

In summary, the agency is modifying the test procedures in FMVSS 216 to require that vehicles be tested with the application of a force loading device up to 3.0 times the vehicle's weight without the roof crushing to a level where it touches the head of a seated 50^{th} percentile male dummy or 5 inches. Vehicles > 6,000 lbs. GVWR will be required to meet an SWR of 1.5. There are 6 vehicle manufacturers affected by this rule that are considered to be small businesses. Most of the intermediate and final stage manufacturers of vehicles built in two or more stages and alterers have 1,000 or fewer employees. However, there would be no significant economic impact on small business, small organizations, or small governmental units from this rule.

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 State, 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 2007 results in $130 million (119.846/92.106 = 1.30). The assessment may be included in conjunction with other assessments, as it is here.

This final rule is not estimated to result in expenditures by State, local or tribal governments of more than $130 million annually. However, it will result in the expenditure by the automobile manufacturers and/or their suppliers of more than $130 million annually. The estimated annual consumer cost, including added fuel usage,are $875 million-$1.4 billion. These effects have been discussed previously in this Final Regulatory Impact Analysis (see Chapter V, Costs).

IX. PROBABILISTIC UNCERTAINTY ANALYSIS

This chapter identifies and quantifies the major uncertainties in the cost-effectiveness and net benefit (benefit-cost) analyses and examines the impacts of these uncertainties. Throughout the course of these analyses, many assumptions were made, diverse data sources were used, and different statistical processes were applied. The variability of these assumptions, data sources, and statistical processes potentially would influence the estimated regulatory outcomes. Thus, all these assumptions, data sources, and derived statistics can be considered as uncertainty factors for the regulatory analysis. The purpose of this uncertainty analysis is to identify the uncertainty factors with appreciable variability, quantify these uncertainty factors by appropriate probability distributions, and induce the probabilistic outcomes accompanied with degrees of probability or plausibility. This facilitates a more informed decision-making process.

A Monte Carlo statistical simulation technique[47] is used to accomplish the process. The technique is to first randomly select values for those uncertainty factors from their pre-established probability distributions. The selected values then are fed back to the cost-effectiveness and net benefit analysis process to generate all possible outcomes. The process is run repeatedly. Each complete run is a trial. Crystal Ball®[48], a spreadsheet-based risk analysis and forecasting software package which includes the Monte Carlo simulation technique tool, was chosen to automate the process. In addition to simulation results, Crystal Ball® also provides the degree of certainty (or confidence, or credibility) that is associated with the simulated results. The degree of certainty provides the decision-makers an additional piece of important information to evaluate the outcomes.

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[47] a: Robert, C.P. & Casella, G., *Monte Carlo Statistical Methods*, Springer-Verlag New York, Inc., 1999

b: Liu, J.S., *Monte Carlo Strategies in Scientific Computing*, Springer-Verlag New York, Inc., 2001
(Or any statistics books describing the Monte Carlo simulation theory are good references for understanding the technique).

[48] A registered trademark of Decisioneering, Inc.

The analysis starts by establishing mathematical models that imitate the actual processes in deriving cost-effectiveness and net benefits, as shown in previous chapters. The formulation of the models also allows analysts to conveniently identify and categorize uncertainty factors. In the mathematical model, each variable (e.g., cost of technology) represents an uncertainty factor that would potentially alter the model outcomes if its value were changed. Variations of these uncertainty factors are described by appropriate probability distribution functions. These probability distributions are established based on available data. If data are not sufficient or not available, professional judgments are used to estimate the distribution of these uncertainty factors.

After defining and quantifying the uncertainty factors, the next step is to simulate the model to obtain probabilistic results rather than single-value estimates. The simulation repeats the trials until certain pre-defined criteria[49] are met and a probability distribution of results is generated.

A. Simulation Models

Mathematical models were built to imitate the process used in deriving cost-effectiveness and net benefits as developed in previous chapters. Both the cost-effectiveness and net benefit models comprise two principal components: benefits and total cost. In cost-effectiveness, benefits were represented by fatal equivalents (FEs). In net benefit analysis, benefits were represented in dollar value, which is the product of cost per live saved and fatal equivalents. Since benefits (fatalities and injuries reduced) were already expressed as fatal equivalents in the cost-effectiveness model, the net benefit model is just one step removed from the cost-effectiveness model. The total net cost of the rule includes the cost of the vehicle technology/countermeasures (in short, technology cost) and the added fuel economy cost. The following sections discuss the benefit and the total net cost components. Note that it is unfeasible to describe all the statistical processes, assumptions, and parameters that were used to derive the benefit and net cost components. Therefore, simplified mathematical formulas were used to describe these two components and to convey the uncertainty analysis process. The simplified formulas are those comprised with primary factors (or functions) with each of the factors representing a consolidated result from a series of statistical processes.

A.1 Benefit Component

As described in the benefit chapter, the initial injury benefits (i.e., fatalities, MAIS 1-5 injuries) were derived first. Then the initial benefits were gone though a series adjustments to derive the benefits of the rule. These adjustment factors are: (a) vehicle sales factor, which equalizes the vehicle fleet size used for both benefit and cost estimates to 17 million, (b) failure rate factor, which reflects the percent of vehicles that would actually fail the rule, (c) ESC factor, which accounts for the impact of a full implementation of ESC, (d) belt use factor which prorates the initial benefits to account for the projected belt use increase, and (e) multiple cause factor which identifies the applicable portion among fatal cases that were caused by multiple body region injuries. Therefore, if a_i represents the overall adjustment factor, i.e., a multiplication of vehicle-sales factor, failure-rate factor, ESC factor, belt-use-rate factor, and multiple-cause factor, the injury benefit process thus can be simplified as follows:

$$\mathbf{B_i = IB_i * a_i}, \; 1 \le i \le 6$$

Where,

i = MAIS severity level with 1 for MAIS 1 injuries and i=6 for fatalities

B_i = MAIS i injury benefit

IB_i = Initial MAIS i benefit

a_i = Overall adjustment factor for MAIS i injury

[49] The pre-defined criteria may change with each uncertainty analysis. In this case, we require a 99 percent precision in

As described, FEs is the basic benefit measurement for estimating cost-effectiveness. To prepare for cost-effectiveness analysis, the derived injury benefits were then translated into fatal equivalents (FEs) through the following steps:

(1) multiplying the injury benefits by their corresponding injury-to-fatality ratios, and

(2) discounting FEs to derive the discounted net benefits over the vehicle's life.

Therefore, the total FEs can be represented by the following mathematical formula:

$$FEs = (\sum_{i=1}^{6} B_i * r_i) * d$$

$$= (\sum_{i=1}^{6} IB_i * a_i * r_i) * d$$

Where,

i	= MAIS severity level with 1 for MAIS 1 injuries and 6 for fatalities
FEs	= Fatal equivalents
B_i	= MAIS i injury benefit
IB_i	= Initial MAIS i benefit
a_i	= Overall adjustment factor for MAIS i injury
r_i	= Injury-to-fatality ratios
d	= Cumulative lifetime discount factor, either at 3 or 7 percent discount rate.

For net benefits, benefits are expressed in monetary value. Therefore, FEs is further translated into monetary value. If G denotes the cost per fatality (or cost per equivalent life saved), benefit in the net benefit calculation is equal to G*FEs. Hence, the benefit component for net benefits is:

$$G * FEs = G * (\sum_{i=1}^{6} IB_i * a_i * r_i) * d$$

---

mean for each simulated outcome such as total costs, cost-effectiveness, and net benefits as described later.

A.2 Net Cost Component

The net cost of the rule comprises two portions: vehicle technology cost and lifetime fuel economy cost. Both portions of costs vary with averaged added weights and the number of affected vehicles. The affected vehicles are vehicles that would fail the roof strength requirements of the rule.

A.2.1 Vehicle Technology Cost

Vehicle technology cost is the product of vehicle technology cost per affected vehicle (unit technology cost) and the total number of affected vehicles as describe in the cost chapter. However, the manufacturing assembly cost that was discussed in the sensitivity analysis but not included in the main cost estimating process is considered an important factor since it would impact the total cost of the rule and subsequently the cost-effectiveness and net benefit of the rule. Therefore, the analysis also examines its impact by including its variation in the cost model. Eventually, unit technology costs as estimated in the cost chapter were further inflated by an assembly cost factor to account for possible variation in assembly cost. Consequently, the mean technology costs produced in the uncertainty analysis are expected to be higher than those estimated in the cost chapter.

For this rule, the unit technology cost is a function of projected average added weights, i.e., its value varies with weight change. Similarly, the assembly cost factor is also a function of added weights. The number of affected vehicles is derived from estimated failure rate and the total projected new vehicles sales. The total technology cost can be represented as:

$$C_V = \sum_{i=1}^{2} [1 + a_s(w_i)] * c_i(w_i) * v_i * F_i$$

Where,

C_V = Total vehicle technology cost

w_i = Average added weights per affected vehicle

a_s = Assembly cost adjustment factor

c_i = Technology cost per vehicle, i=1 for vehicles GVWR <= 6000 lbs and i=2 for GVWR > 6000 lbs

v_i = Projected new vehicle sales

F_i = Failure rate

A.2.2 Lifetime Fuel Economy Cost

Fuel economy cost is the difference in the total lifetime fuel economy cost before and after the implementation of the rule. The unit lifetime fuel economy cost is also measured on a per affected vehicle basis. Thus, the total lifetime fuel economic cost (C_F) of the rule is the product of unit lifetime fuel economy cost and total affected vehicles. The model can be represented by the following formula:

$$C_F = \sum_{i=1}^{2} cfe_i(w_i) * v_i * F_i$$

Where,

C_F = Total lifetime fuel economy cost at 3 or 7 percent discount, with i=1 for GVWR $\leq$ 6000 pounds and i=2 for GVWR > 6000 pounds

cfe_i = Unit lifetime fuel economy per vehicle at 3 or 7 percent discount

w_i = Average added weights per affected vehicle

v_i = Projected new vehicle sales

F_i = Failure rate

A.4 Cost-Effectiveness Model and Net Benefit Model

The cost-effectiveness measures the net cost per equivalent live saved, i.e., it is net costs (C_N) divided by fatal equivalents (FEs). Fatal equivalent, vehicle technology cost, and fuel economy cost models described in previous sections are used to establish the cost-effectiveness model. Net cost is defined as the sum of vehicle technology cost (C_V) and lifetime fuel economy cost (C_F). The cost-effectiveness model (CE) has the format:

$$
\begin{aligned}
CE &= \frac{C_N}{FEs} \\
&= \frac{C_V + C_F}{FEs} \\
&= \frac{\sum_{i=1}^{2}[1 + a_s(w_i)] * c_i(w_i) * v_i \ * F_i + \sum_{i=1}^{2} cfe_i(w_i) * v_i * F_i}{(\sum_{i=1}^{6} IB_i * a_i * r_i) * d}
\end{aligned}
$$

The net benefit is the difference between benefits expressed in monetary value and the net cost. The net benefit model (NB) has the format:

$$
\begin{aligned}
NB &= G * FEs - C_N \\
&= G * FEs - C_V \text{ - } C_F \\
&= G * (\sum_{i=1}^{6} IB_i * a_i * r_i) * d - \sum_{i=1}^{2}[1 + a_s(w_i)] * c_i(w_i) * v_i \ * F_i - \sum_{i=1}^{2} cfe_i(w_i) * v_i * F_i
\end{aligned}
$$

Where, G is the cost per fatality.

B. Uncertainty Factors

Each parameter shown in the above cost-effectiveness and net benefit models represents a major category of uncertainty factors. Therefore, there are ten categories of uncertainty factors that would impact the cost-effectiveness: (1) initial injury benefit, IB_i, (2) the overall adjustment factor a_i, (3) injury-to-fatality ratios, r_i, (4) cumulative lifetime discount factors, d, (5) unit technology cost per vehicle, c_i, (6) assembly cost adjustment factor, (7) unit lifetime fuel economy cost per vehicle, cfe_i, (8) average added weights per affected vehicle, w_i,(9) number of new vehicles, v_i, and (10) vehicle failure rate F_i. The net benefit model has one additional uncertainty factor (11) cost per fatality, G, in addition to those eight for the cost-effectiveness model.

Initial injury benefits, IB_i, which corresponds to a benefit level where 100 percent of vehicles would fail the rule. The factor IB_i was derived from the baseline population and the corresponding injury risk reduction rate. Uncertainty for this factor included that from baseline population and that from injury risk reduction rate. The sources of uncertainty include sources such as demographic projections, driver/occupant behavioral changes (e.g., shifts in safety belt use), increased roadway travel, new Government safety regulations, and survey errors in NHTSA's data sampling system NASS-CDS. All these sources of uncertainty should be used to estimate the variation of IB_i. However, the population sample of the rule is small and thus is associated with relatively large survey errors. On average, about 12,812 injuries would be impacted by this rule. The one standard error is estimated to be 8,682, which is 68 percent of the mean. The agency believes that the survey errors are sufficient to account for the majority of the uncertainties associated with baseline population and risk probability. Therefore, only the survey errors are considered and they are used as the proxy for establishing a variation for IB_i. The analysis treats one standard error as 100 percent bounds for IB_i, and IB_i is normally distributed (i.e., even distribution around the mean) within this range. In other words, the initial benefits would range from (1 -0.68) * mean to (1 + 0.68) * mean. To satisfy range and shape (normal distribution) constraints, a beta probability was chosen to describe the variations for initial injury benefits.

However, probability function for individual MAIS benefits can not be established independently due to the inter-correlation among these injuries benefits and among the risk probabilities used to derive it. To address the interdependency issue, the analysis established the variation for the overall initial benefits (i.e., all injury benefits combined) first. After establishing the variation, the overall benefits were segregated by GVWR category and it then were further distributed into individual MAIS injury and fatal benefits. The distribution was based on their mean proportions between weight categories and within a weight category. These proportions are treated as constants.

Overall adjustment factor, a_i, comprises five adjustment factors as described in the benefit model section.

The overall adjustment factor is equal to the product of vehicle-sales factor, failure-rate factor, ESC factor, safety-belt-use factor, and, multiple-cause factor. As expected, uncertainty for each of these 5 adjustments would all contribute to the variation of a_i and all associated uncertainty sources should be considered when estimating the variation. However, of these adjustments, uncertainty surrounding the ESC factor is considered the most critical because of the significance of ESC impact and the variability of that impact. ESC factor, in general concept, is equal to one minus ESC effectiveness. ESC effectiveness for MAIS injuries and fatalities ranged from 49 to 58 percent which significantly reduced the benefits of the rule by reducing the target population. Furthermore, the uncertainty for ESC impact includes the estimation errors inherited in the statistical processes, the variability of the data systems (i.e., FARS and State Data Systems), and the representativeness of the data samples (i.e., SUVs representing LTVs). Thus, the variation sounding the ESC effectiveness is believed to be sufficient to account for the majority of uncertainty generated from the other three factors.

Although, the remaining 4 factors would also contribute to the uncertainty of a_i, their impacts to the overall variation is expected to be negligible. The vehicle-sales factor places benefit and cost estimates on an equalized fleet size. It was derived from the actual vehicle sales numbers. Variation associated with this factor thus is expected to be small. The safety-belt-use factor was derived from the historical safety belt use survey data. It is a ratio of two safety belt use rates. Ratios generally have a small deviation from the mean. Thus, this factor is expected not to significantly impact the uncertainty of a_i. Similarly, the conclusion is also applicable to the multiple-cause factor which is also a ratio. Finally, since the failure-rate factor impacts both cost and benefits proportionally, its impact on the final results would be limited.

Thus, the variation sounding the ESC effectiveness is believed to be sufficient to account for the majority of uncertainty generated from the other four factors. Statistical variation for ESC effectiveness was the sole source for estimating the variation for a_i. The remaining four adjustment factors were treated as constants and did not contribute to the uncertainty for a_i.

Injury-to-fatality ratios, r_i, reflect the relative economic impact of injuries compared to fatalities based on their estimated comprehensive unit costs. They were revised from the most current 2002 crash cost assessment[50]. The crash cost assessment itself is a complex analysis with an associated degree of uncertainty. At this time, these uncertainties are unknown and thus are not quantified in the analysis. Although these ratios vary with the value of statistical life, the variation was small and did not significantly impact fatal equivalent calculation. Therefore, the analysis treats these ratios as constants.

Cumulative lifetime discount factors, d, represent the present discount factor over the vehicle's life. These factors are derived based on the agency study on vehicle miles traveled and vehicle survivability[51]. Variation of these factors comes from vehicle mileage surveys, national vehicle population, and statistical process. These uncertainties cannot be quantified at this time. Thus, the analysis treats these factors as constants.

Technology unit cost (i.e., cost per affected vehicle), c_i, is a function of added weights.. The sources of uncertainties for this factor arise from, but are not limited to, the projected average added weights, maturity of the technologies/countermeasures, potential fluctuation in labor and material costs (e.g., due to economics from production volume), and the statistical processing errors for establishing the unit cost as a function of added weights. According to professional judgments of NHTSA cost analysts and contractors, the cost generally will fall within 10 percent of the point estimate shown in the cost chapter. Any cost in this range would have equal chance to be the true cost. Thus, the analysis treats the cost as uniformly distributed for a given added weight level. The shape of the overall distribution for technology unit cost is determined by the probability distribution of the average added weights per affected vehicle.

[50] The Economic Impact of Motor Vehicle Crashes 2000, NHTSA DOT HS 809 446, May 2002

Assembly cost adjustment factor a_s, is a significant factor since it affects the technology cost estimates. For this rule, added weights are used as synonymous to material technology. Therefore, this factor also varies with added weights. Although the agency does not have data regarding the impact of using more advanced materials on assembly process, the agency speculates that assembly cost would be more likely to increase in cases that use more advanced materials than in cases that more standard materials was used. Based on this assumption, and by default that the factor is bounded by a range, at a given weight, a beta distribution is chosen to describe the factor. The overall shape of the distribution along the added weights is also influenced by the distribution of added weights.

Average added weights per affected vehicle, w_i, is a significant factor since it affects the technology cost and fuel economy cost. It is function of material strength. The uncertainty sources included the advancement of material technologies and statistical process used for deriving the projected material strength and weight-strength ratios. The agency believes that manufacturers have an incentive to achieve a better fuel economy therefore they would likely use a newer technology to limiting the weight gain. Based on this judgment, w_i is set to range between 9.68 to 18.78 pounds for vehicles with GVWR no greater than 6000 pounds and -7.13 to 12.46 pounds for vehicles with GVWR greater than 6000 pounds. And, w_i is normally distributed within the specified range. To achieve the range and uniform shape (i.e., evenly distributed around the mean) constraints, a beta probability distribution is chosen to describe the variation of wi. Note that the range for w_i is the lower end to the mid-point of the possible projected weight gains. A negative weight signifies a net vehicle weight loss.

Unit lifetime fuel economy cost per affected vehicle, cfe_i is expected to have certain level of variability. Its uncertainty comes from many sources such as projected average weight gain, fuel price projections, vehicle lifespan, annual vehicle miles traveled, survival probability, and discount rate. Other than average weight gain, variations for these sources are unknown at this time. The overall magnitude of the uncertainty

[51] Vehicle Survivability and Travel Mileage Schedules, Technical Report, DOT HS 809 952, January 2006 (Docket No.

for cfe$_i$ is difficulty to quantify. However, giving the importance of the fuel economy impacts, the analysis provides a variation for fuel price, The value of fuel price is treated as uniformly distributed and ranges between a 15 percent deviation of the mean, i.e., value between (0.85*mean, 1.15*mean). Consequently, at a given added weight, the value of cfe$_i$ also uniformly fluctuates within a 15 percent from the mean value. Since cfe$_i$ is a function of w_i (average added weights), the general shape of the probability distribution is determined by the probability of w_i.

Number of new vehicles, v_i, is an uncertainty factor that would impact the cost estimates. Although, vehicle sales have gradually increased over time, they are subject to annual variation due to changes in economic conditions, which are difficult to predict. Thus, the number of vehicles (v_i) is treated as a constant.

Vehicle failure rate, F_i was derived based on 76 vehicles the agency tested. The uncertainty source is primary from the representative of these 76 vehicles. Given that the 76 vehicles covered a very diverse vehicle body types and weight categories and they included both very popular vehicles and small market share vehicles, the agency considers the variation for the failure rates would be very small. Moreover, the variations in the failure rate impacts both cost and benefits proportionally, which would mitigate its impact on the final results. Therefore, the analysis treats this factor as constant.

The ten factors discussed above would impact the cost-effectiveness outcome. The net benefit model has an additional factor, cost per fatality, G.

Cost per fatality, G, is an uncertainty factor for net benefits. The value of G largely depends on the value of statistical life (VSL). The cost is based on recent meta-analyses of the wage-risk value of VSL. These meta-analyses deployed different statistical methodologies and assumptions. But, generally, these studies show that an individual's willingness-to-pay (WTP) for reduction in premature fatalities is from $1 million to

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22223-2218)

\$10 million[52]. In the past, when a \$3.0 million VSL was the DOT guideline for cost-benefit analysis, the agency used this \$1-\$10 million as the range for G and assumed the value of G is normally distributed with its mean equal to \$5.5.million. However, in 2008 DOT has issued a new guideline requiring a \$5.8 million VSL to be used for cost-benefit analysis. The corresponding comprehensive cost is estimated to be \$6.1 million. To reflect this change and to be consistent with the cost-benefit analysis described in the previous chapters, the normal distribution for G has been revised to reflect the comprehensive cost per fatality. Thus, the distribution for G has a mean of \$6.1 million. The range of this factor also shifts rightwards from 1 to 10 millions to \$1.6 to \$10.6 million.

C. Quantifying the Uncertainty Factors

This section establishes the appropriate probability distributions for the primary uncertainty factors that were identified in the previous section.

Initial injury benefits, IB_i, as previously described, probability distributions for individual MAIS injury benefit can not be established independently due to interdependency of these values. To address this issue, a beta probability distribution for the overall benefit is established first. Then it was used to derive the probability distribution for individual MAIS injury benefits through the simulation process.

The initial mean total injury benefit is 2,506 (non-fatal and fatal injuries combined). Therefore, the beta distribution for the overall initial benefit has a mean of 2,506 and uniformly distributed between 802 and

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[52] a: Mrozek, J.R. and L.O. Taylor, What determines the value of a life? A Meta Analysis, Journal of Policy Analysis and Management 21 (2), pp. 253-270,

b: Viscusi , W. K., The Value of Life: Estimates with Risks by Occupation and Industry, Economic Inquiry, Oxford University Press, vol. 42(1), pages 29-48, January, 2004, and

c: Viscusi, W. K. & Aldy, J.E., The Value of a Statistical Life: A Critical Review of Market Estimates through Out the World, Journal of Risk and Uncertainty, Kluwer Academic Publishers, vol. 27(1), pages 5-76, August, 2003.

4,210. The range is set to be a 68 percent deviation from the mean. To satisfy the normal distribution constraints, two shape parameters α and β are both equal to 5. The values of α and β were determined to ensure that the mean would be 2,506 and the 95 percent confidence bound would be close to that of a normal distribution.

After the variation for the overall initial benefits was established, IB_i for each i, was derived by applying their respective proportion to the overall initial benefits. Figure IX-1 depicts the simulated probability distribution for individual initial MAIS injury benefits, IB_i. As shown, the range of the distribution for MAIS 5 injury benefits for GVWR > 6000 pounds is very narrow. This is due to extremely small number of MAIS 5 injuries. Its distribution almost can be treated as a constant distribution.

The proportions used to derive the individual initial MAIS injury are treated as constants. They were represented by their respective mean proportion shown in the initial mean total benefits. The ratio of the mean total initial benefit for that from vehicles with GVWR no greater than 6000 pounds to that from vehicles with GVWR greater than 6000 pounds is 91.3: 8.7. Therefore, the total initial benefits are distributed into these two vehicle weight categories by this ratio, i.e., benefits from vehicles with GVWR no greater than 6000 pounds constantly comprised about 91.3 percent of the total initial benefits.

Similarly, within each a GVWR category, the distributions of initial injury benefits into individual MAIS and fatal injury levels are treated as constants based on their mean proportions. Table IX-1 presents these constants. As shown, for example, for vehicles no greater than 6000 pounds, 10.9 percent of the initial benefits would be fatal injury benefit, 1.2 percent would be MAIS 5 injury benefit, and so on so forth.

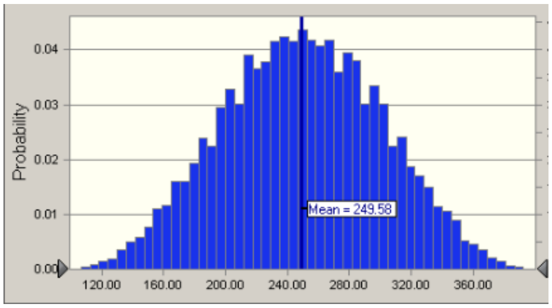
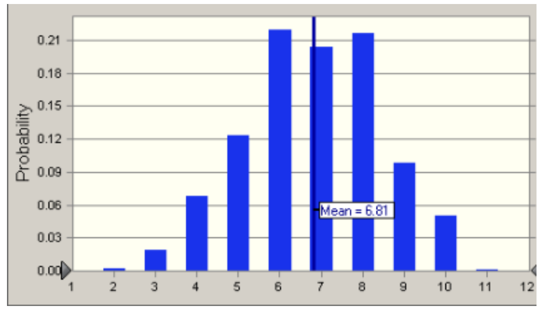
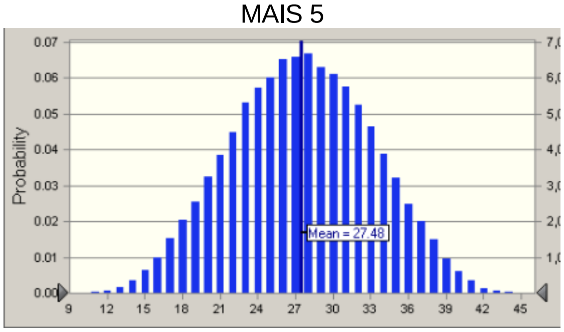
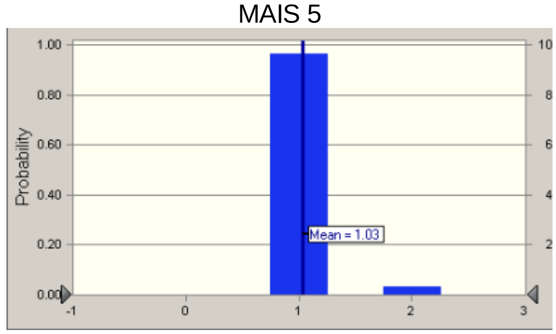
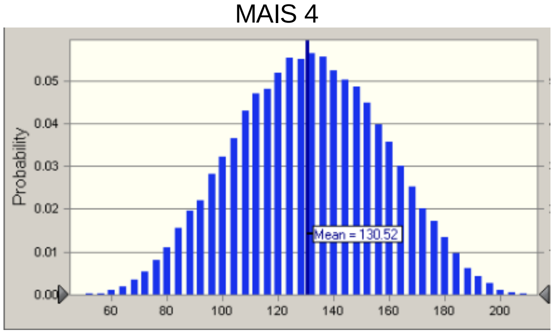
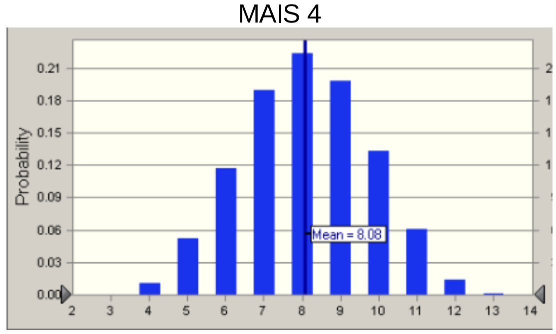
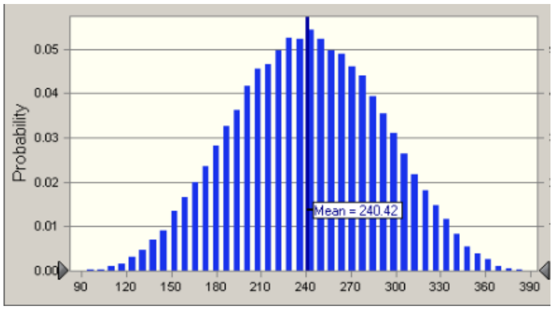
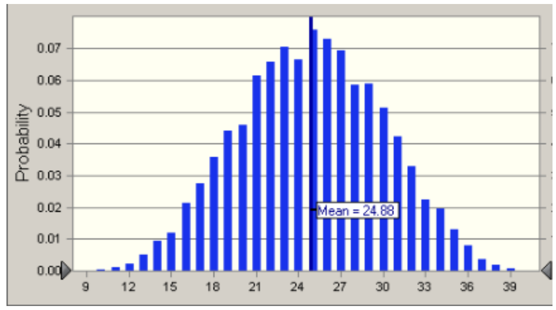
GVWR ≤ 6000 Pounds	**GVWR > 6000 Pounds**
Fatalities  Mean = 250	Fatalities  Mean = 7
MAIS 5  Mean = 27	MAIS 5  Mean = 1
MAIS 4  Mean = 131	MAIS 4  Mean = 8

Figure IX-1
Probability Distributions for Initial Injury Benefits (IB_i)

GVWR ≤ 6000 Pounds	**GVWR > 6000 Pounds**
MAIS 3	MAIS 3

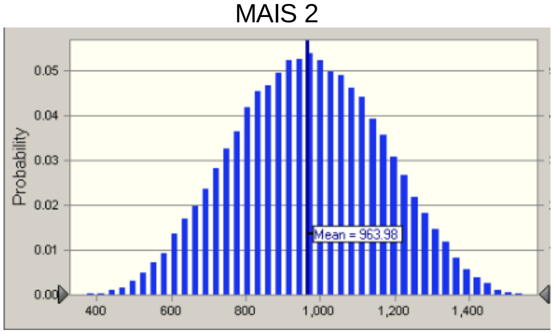


Mean = 240

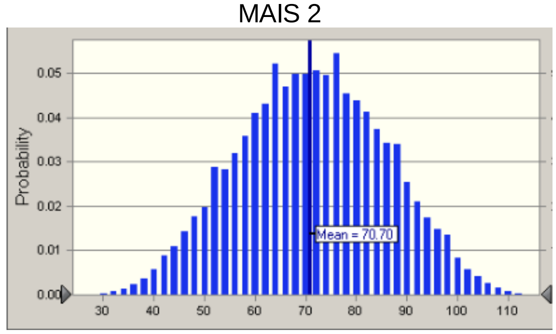


Mean = 25

MAIS 2	MAIS 2

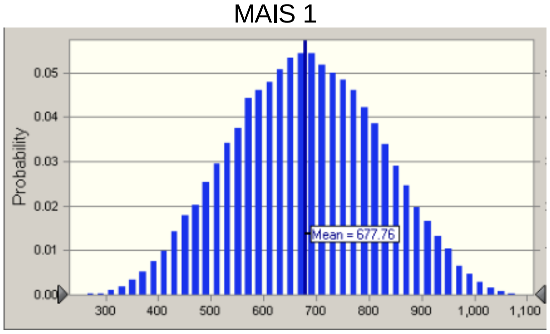


Mean = 964

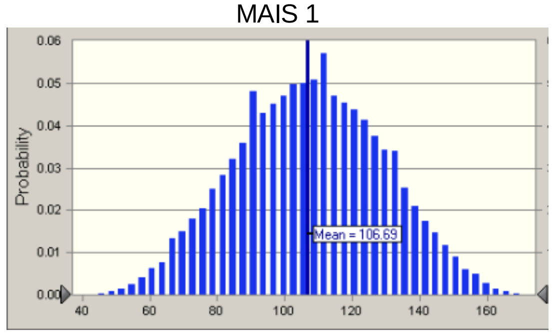


Mean = 71

MAIS 1	MAIS 1



Mean = 678



Mean = 107

Figure IX-1 - Continued
Probability Distributions for Initial Injury Benefits (IB_i)

Table IX-1
Proportion of Initial Injury Benefits (IB_i)

Injury Severity	Vehicle GVWR	
	≤ 6000 pounds	> 6000 pounds
MAIS 1	0.296	0.489
MAIS 2	0.421	0.324
MAIS 3	0.105	0.114
MAIS 4	0.057	0.037
MAIS 5	0.012	0.005
Fatality	0.109	0.032
Total	1.000	1.000

Source: 1996-2006 CDS

Overall adjustment factor, a_i, as previously described, is a product of series of five adjustments (i.e., = vehicle-sales factor * failure-rate factor * safety-belt-use factor * multiple-cause factor *ESC factors). Of these 5 adjustments, only uncertainty surrounding the ESC factor is considered for estimating the variation of a_i. The ESC factor is 1 minus ESC effectiveness. The 90 percent confidence bounds of the mean ESC effectiveness for PCs and LTVs were used to generate the variation for a_i. For vehicles with GVWR no greater than 6000 pounds, their ESC effectiveness is the weighted effectiveness of PCs and LTVs. For vehicles over than 6000 pounds, the ESC effectiveness is set to be the maximum of that of PCs and LTVs. The choice of a greater effectiveness between PCs and LTVs for GVWR greater than 6000 pounds vehicles which were exclusively LTVs corresponds to the methodology used in the final regulatory impact analysis for FMVSS No. 126, Electronic Stability Control Systems[53].

The remaining four factors are treated as constant and do not contribute to the variation of a_i. The process of deriving these constants were described in the benefit chapter and are not repeated here. The following lists these constant values:

Vehicle-Sales Factor = 1.1310

Failure-Rate Factor = 0.8204 for GVWR ≤ 6000 pounds

= 0.4000 for GVWR > 6000 pounds

[53] DOT Docket Number NHTSA-2007-27662

Safety-Belt-Use Factor = 1.1293 for MAIS injuries; = 1.2145 for Fatalities

Multiple-Cause Factor = 1 (no adjustment) for MAIS injuries

= 0.9265 for fatalities.

Figure IX-2 depicts the simulated probability distributions for the overall adjustment factors by injury severity and GVWR weight category. As shown, the mean overall adjustment factor is 51 and 54 percent respectively for MAIS injury and Fatalities for vehicles with GVWR no greater than 6000 pounds and 21 and 21 percent for vehicles with GVWR greater than 6000 pounds.

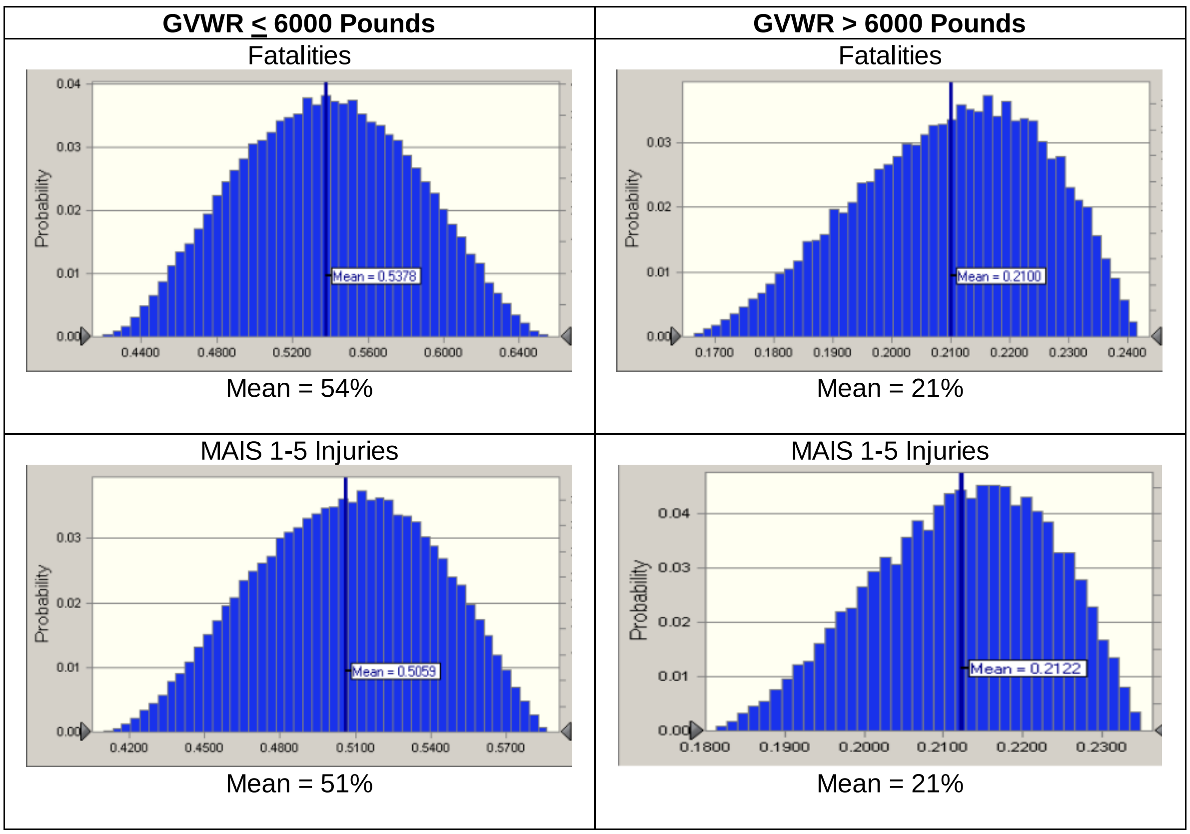


Figure IX-2
Simulated Probability Distribution for Overall Adjustment Factor (a_i)
by Injury Severity and GVWR Category

Injury-to-fatality equivalent ratios (r_j) are treated as constants. Table IX-2 lists the injury-to-fatality equivalent ratios which are used to translate non-fatal injuries to fatal equivalents. These ratios were corresponding to a $5.8 million of VSL.

Table IX-2
Injury-To-Fatality Equivalence Ratios (r_i)*

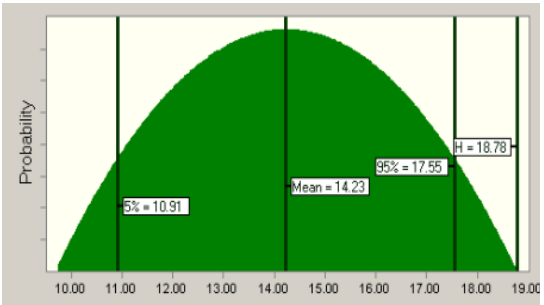
	Injury-To-Fatality Equivalence Ratios
MAIS 1 (r_1)	0.0028
MAIS 2 (r_2)	0.0436
MAIS 3 (r_3)	0.0804
MAIS 4 (r_4)	0.1998
MAIS 5 (r_5)	0.6656
Fatality (r_6)	1.0000

* Based on $5.8 million value of statistical life

Cumulative lifetime discount factors (d). These factors are treated as constants. At a 3 percent discount, d is equal to 0.82 for vehicles with GVWR no greater than 6000 pounds and 0.80 for vehicles with GVWR greater than 6000 pounds. The corresponding factors at a 7 percent discount are 0.66 and 0.62. These discount rates are the combined discount rates for passenger cars and light trucks/vans.

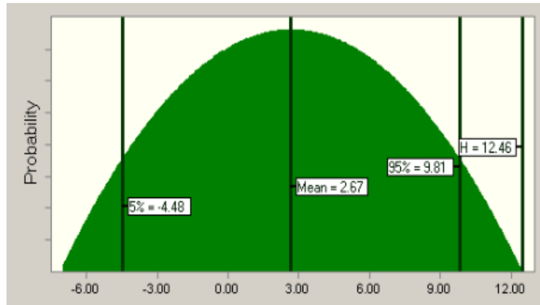
Average added weights per affected vehicle, w_i, is believed most likely would range between 9.68 to 18.78 pounds for vehicles with GVWR no greater than 6000 pounds and -7.13 to 12.46 pounds for vehicles with GVWR greater than 6000 pounds. This is based on the agency's observation that manufacturer's concerns on fuel economy outweigh technology cost concerns. The agency does not have data indicating what advanced materials would most likely be used by the manufacturers. Therefore, the agency assumes that weight gain would be evenly distributed around the mean. To achieve this non-skewness of the probability distribution and the range requirement, a beta probability distribution is chosen to describe the average added weights. Figure IX-3 depicts the added average weight distribution by GVWR category.

GVWR $\leq$ 6000 Pounds



Mean = 14.23 Pounds

GVWR > 6000 Pounds



Mean = 2.67 Pounds

Figure IX-3
Beta Probability Distribution for Average Added Weights (w_i) by GVWR Category

<u>Unit technology cost per vehicle, c_i,</u> is a function of average added weights and varies with the added weight. For a given average added weight gain, the analysis assumes that the cost is uniformly distributed. The uniform distribution for c_i would be established by two parameters: maximum ($c_{i,max}$) and minimum ($c_{i,min}$) costs, i.e.,

$$c_i(w_i, x) = \frac{1}{c_{i,max}(w_i) - c_{i,min}(w_i)}, \; c_{i,max}(w_i) \leq x \leq c_{i,min}(w_i)$$
$$= 0, \text{ otherwise}$$

Where, w is the added weight (lbs).

At any given average added weight gain, the minimum and maximum costs are 10 percent deviated from the mean cost.   However, the overall shape of the distribution for this factor is primarily determined by the probability of added weights. The unit cost is further adjusted by an assembly-cost factor (discussed below) to derive the actual cost for cost estimates. Figure IX-4 shows the distribution which was generated through the simulation. As shown, the mean unit technology is $48.22 for vehicles with GVWR $\leq$ 6000 pounds is $69.12 for vehicles with GVWR > 6000 pounds.

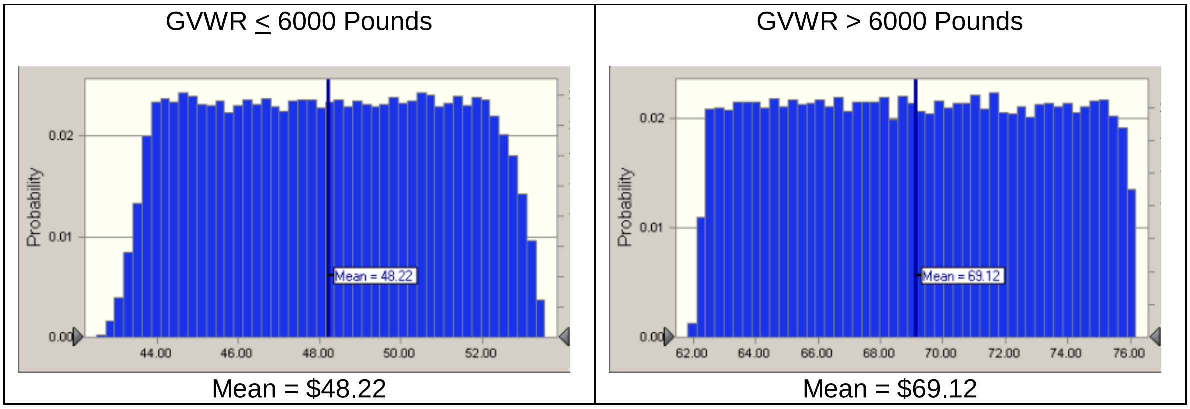


Figure IX-4
Simulated Probability Distribution for Unit Technology Cost Per Vehicle (c_i)
by GVWR Categories

Assembly cost adjustment factor a_s, is a function of added weights (i.e., technology). Although, the assembly costs-technology relationship is not known, an adjustment of 0 to 25 percent above the estimated unit technology cost is believe to be sufficient to address the variation around this factor. Therefore, at a given weight, the distribution for a_s is a beta distribution with its value ranging between 0 and 0.25. Furthermore, the agency assumes that a more advanced technology (i.e., less weight gain) would be more likely to be associated with a higher assembly cost. Thus, the beta distribution describing this factor continuously varies with added weights with its shape transitioning from a negatively skewed curve to a positively skewed one. The beta distribution for the lowest weight gain (i.e., the most advanced technology) is set to having a 70 percent of chance that the adjustment factor would be higher than 0.125 (an average of 0 and 0.25). By contrast, the beta distribution is reversed at the highest weight gain – a 70 percent of chance that the adjustment factor would be less than 0.125. In transitioning to the mean weight gain, the beta distribution is transformed to a uniform distribution around the mean 0.125. To satisfy all these constraints, the two shape parameters α and β were established as linear functions of the added weights. These two parameters can be noted as follows:

$$\alpha = 2 - (w_i - w_m)/(w_h - w_m),\ \beta = 2, \text{ when } w_i \leq w_m$$

$$\alpha = 2,\ \beta = 2 + (w_i - w_m)/(w_h - w_m), \text{ when } w_i > w_m$$

Where, w_i = added weights

w_m = mean added weight

w_h = maximum added weight

Basically, both α and β move between 2 and 3. The pair (α, β) is approximated to be (3, 2) at the lowest weight gain, (2, 2) at the mean weight gain, and (2, 3) at the maximum weight gain.

Combining the unit technology and the assembly cost adjustment factor derives the adjusted unit technology cost which is the base unit cost for estimating the total technology cost of the rule. In order words, the adjusted unit technology cost = $(1 + a_s) * c_i$. Figure IX-5 shows the distribution which was generated through the simulation. As shown, the mean adjusted unit technology is $54.25 for vehicles with GVWR $\leq$ 6000 pounds is $78.24 for vehicles with GVWR > 6000 pounds.

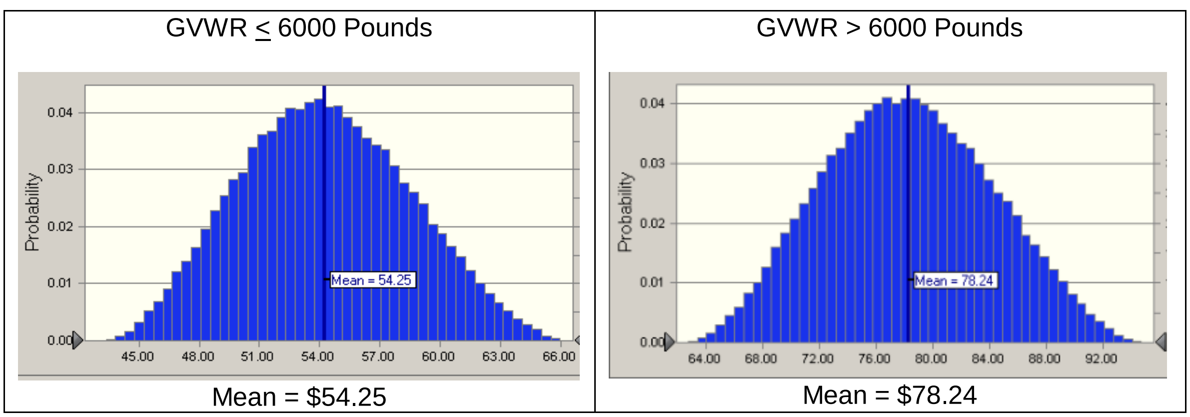


Figure IX-5
Simulated Probability Distribution for Adjusted Unit Technology Cost Per Vehicle (a_s*c_i) by GVWR Categories

<u>Unit lifetime fuel economy per affected vehicle, cfe_i</u>, is a function of average added weights. At a given average weigh, it is treated as uniformly distributed and ranges between a 15 percent deviation from the mean unit price. In other words, at a given weigh, the unit lifetime fuel economy price range is (0.85*mean unit price, 1.15*mean unit price). However, the shape of the curve primly is determined by the distribution of

the added weights. Figure IX-6 depicts the simulated probability distribution for cfe_i by discount rate and GVWR category.

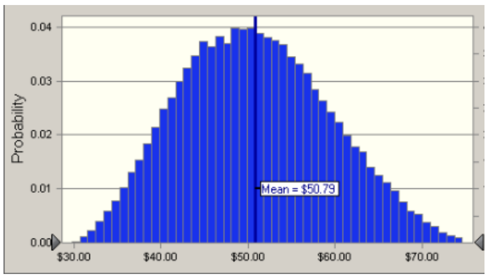
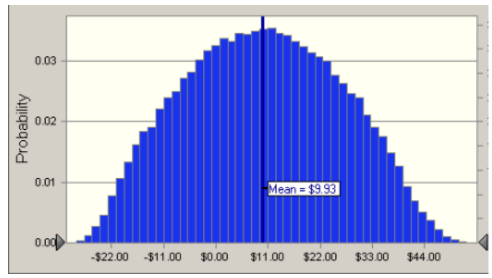
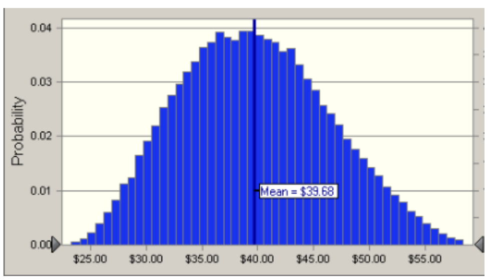
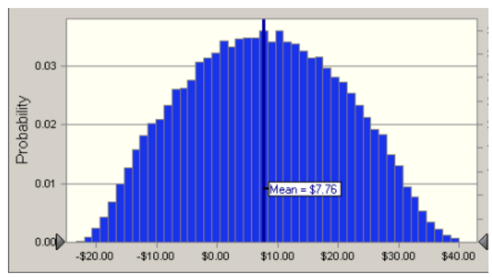
	GVWR $\leq$ 6000 pounds	GVWR > 6000 pounds
at 3% Discount	 Mean = $50.79	 Mean = $9.93
at 7% discount	 Mean = $39.68	 Mean = $7.76

Figure IX-6
Unit Lifetime Fuel Economy Cost Per Vehicle (cfe_i)
by Vehicle GVWR and Discount Rate
(2007 Dollar)

Number of new vehicles, v_i, is treated as constant. The total number of new passenger vehicles is projected to be 17 million. Of these, 12.8 million are vehicles with a GVWR no greater than 6000 pounds and 4.2 million greater than 6000 pounds. Therefore, v_1 = 12.8 million and v_2 = 4.2 million.

Vehicle failure rate, F_i is treated as constant. The value for vehicles with GVWR no greater than 6000 pounds is 0.8204 and is 0.4000 for vehicles with GVWR greater than 6000 pounds.

Cost per fatality, G, comes with great variation that is mostly centered on the value of statistical life (VSL). Recent meta-analysis of the wage-risk value of VSL shows that an individual's willingness-to-pay (WTP) for reduction in premature fatalities is from $1 million to $10 million[54]. The agency used this as the range for G and assumes the value of G is normally distributed with its mean equal to $5.5.million when $3.0 million VSL was the basis for cost-benefit analysis. However, DOT issued a new guideline requiring $5.8 million VSL to be used for cost-benefit analysis. The corresponding compressive cost would be $6.1 million. Corresponding to the main body of the analysis, the $6.1 million should be the mean. With this change, the range of the distribution also shifts rightwards. The revised normal distribution therefore has a mean of $6.1 million with standard error of $1.5 million. This distribution generates a 95 percent bounds for the mean ($3.6 million, $8.6 million). Figure IX-7 shows the normal probability distribution for G.

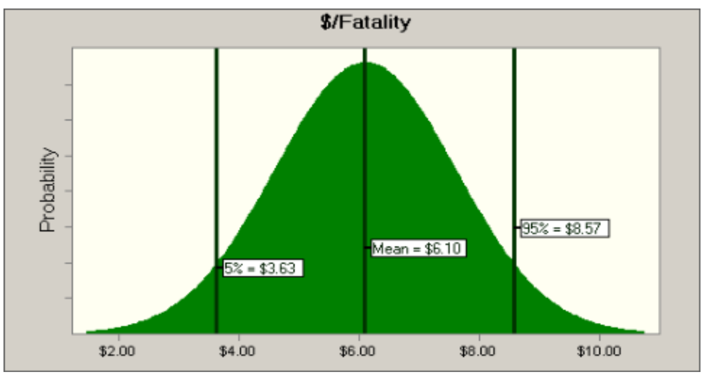


Figure IX-7
Probability Distribution for Comprehensive Cost Per Fatality (G) (Millions 2007 $)

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[54] a: Mrozek, J.R. and L.O. Taylor, What determines the value of a life? A Meta Analysis, Journal of Policy Analysis and Management 21 (2), pp. 253-270.

b: Viscusi , W. K., The Value of Life: Estimates with Risks by Occupation and Industry, Economic Inquiry, Oxford University Press, vol. 42(1), pages 29-48, January, 2004.

c: Viscusi, W. K. & Aldy, J.E., The Value of a Statistical Life: A Critical Review of Market Estimates through Out the World, Journal of Risk and Uncertainty, Kluwer Academic Publishers, vol. 27(1), pages 5-76, August, 2003.

D. Simulation Results

The Monte Carlo simulation first randomly selects a value for each of the significant factors based on their probability distributions. Then, the selected values are fed into the model to forecast the results. Each process is a trial. The simulation repeats the process until a pre-defined accuracy has been accomplished. Since Crystal Ball is a spreadsheet-based simulation software, the simulation model actually is a step-wise process, i.e., the simulation estimates gross benefits, the net benefits (after redistribution of gross benefits through the injury redistribution process), fatal equivalents, cost-effectiveness, and net benefits. Therefore, each of these forecasted results had certainty bounds. This uncertainty analysis conducted a total of 10,000 trials before the forecasted mean results reached 99 percent precision. Even if the later criterion was reached first, the trial numbers generally are very close to 10,000. These criteria were chosen to ensure the simulation errors ($\approx \frac{1}{10{,}000}$) would be very close to 0. Therefore, the results highly reflect the probabilistic nature of the uncertainty factors.

Table IX-4 summarizes the simulated injury benefit results at no discount level after about 10,000 trials. As shown, undiscounted, the rule would eliminate 87 - 187 fatalities and 700 - 1,466 MAIS 1-5 injuries with 90 percent certainty. These fatalities and injuries equate to 125 – 260 equivalent lives.

Table IX-4
Simulated Injury Benefits
No Discount

	Vehicle Weight (GVWR)		
	≤ 6000 lbs	> 6000 lbs	Combined
Fatalities Reduced			
Mean	134	1	136
Range	44 - 251	0 - 3	44 - 253
90% Certainty	86 - 185	1 - 2	87 - 187
MAIS Injuries Eliminated			
Mean	1,032	45	1,077
Range	364 – 1,870	16 - 77	382 – 1,939
90% Certainty	671 – 1,408	29 - 60	700 – 1,466
Equivalent Lives Saved			
Mean	189	3	192
Range	63 - 336	1 - 6	64 - 340
90% Certainty	123 - 256	2 - 4	125 - 260

Note: due to rounding errors, the sum of two weight categories might be added to the combined figures.

Tables IX-5 and IX-6 summarize the simulated cost-effectiveness and net benefit results at 3 and 7 percent discount, respectively. As shown, <u>at a 3 percent discount rate</u>, the rule would save 103 – 213 equivalent lives with a 90 percent certainty. Of these saved lives, about 101-210 were from vehicles with GVWR less or equal to 6000 lbs and 2 - 3 were from vehicles from GVWR greater than 6000 lbs. With the same 90 percent certainty, the rule would have a net cost of $1,096 - $1,413 million. At this discount level, the rule would produce a net cost per equivalent fatality of $5.7 to $12.3 million. It is unlikely that the rule would produce a net cost per equivalent fatality less than $3.5 million. The chance that the rule would produce a net cost per equivalent fatality less than $6.1 million is also very slim. However, if $8.7 million is the threshold, the rule would meet it with a 64 percent certainty. The rule would generate a positive net benefit with an 18 percent certainty.

<u>At a 7 percent discount rate</u>, the rule would save 82 – 171 equivalent lives with a 90 percent certainty. At this discount level, the rule would produce a net cost per equivalent fatality of $6.4 to $13.9 million with a 90 percent certainty. Most likely, the rule would not generate a cost per equivalent fatality that is less than $3.5

million or $6.1 million. However, the rule would generate a cost per equivalent fatality less than of $8.7 million with a 45 percent certainty. It is most likely that the rule would not produce a positive net benefit.

Table IX-5
Simulated Cost-Effectiveness and Net Benefits at 3% Discount
(2007 Dollar)

	Vehicle Weight (GVWR)		
	≤ 6000 lbs	**> 6000 lbs**	**Combined**
Equivalent Lives Saved			
Mean	155	2	157
Total Range	52 - 276	1 - 5	53 - 279
90% Certainty Range	101 - 210	2 - 3	103 - 213
Technology Costs*			
Mean	$568.6 M	$132.2 M	$700.8 M
Total Range	$449.6 - $694.6 M	$106.0 - $160.4 M	$572.4 - $844.2 M
90% Certainty Range	$497.8 - $643.2 M	$116.2 - $149.0 M	$628.4 - $776.9 M
Fuel Economy Cost			
Mean	$532.3 M	$16.8 M	$549.1 M
Total Range	$311.5 - $807.5 M	-$49.7 to $89.3 M	$282.1 - $867.9 M
90% Certainty Range	$391.9 - $687.0 M	-$28.2 to $62.0 M	$401.3 - $708.9 M
Total Net Cost**			
Mean	$1,100.9 M	$149.0 M	$1249.9 M
Total Range	$813.2 - $1,425.1 M	$67.0 - $236.6 M	$931.3 - $1,615.3 M
90% Certainty Range	$954.5 - $1,256.2 M	$102.3 - $195.9 M	$1,096.0 - $1,412.5 M
Cost-Effectiveness (CE)			
Mean	$7.5 M	$64.7 M	$8.4 M
Total Range	$3.3 - $23.4 M	$22.3 - $213.8 M	$3.9 - $25.0 M
90% Certainty Range	$5.1 - $11.1 M	$38.1 - $95.2 M	$5.7 -$12.3 M
Certainty that CE ≤ $3.5 M	0.0%	0.0%	0.0%
Certainty that CE ≤ $6.1 M	24.5%	0.0%	10.3%
Certainty that CE ≤ $8.7 M	78.2%	0.0%	63.8%
Net Benefit (NB)			
Mean	-$156.7 M	-$134.3 M	-$291.1 M
Total Range	-$1,264.0 to $1,697.9 M	-$223.9 to -$46.2 M	-$1,435.5 to $1,562.5 M
90% Certainty Range	-$646.9 to $414.5 M	-$182.1 to -$87.0 M	-$788.6 to $289.2 M
Certainty that NB > $0	29.5%	0.0%	18.4%

M: million
* same for all discount rate
** = technology cost + fuel economy

Table IX-6
Simulated Cost-Effectiveness and Net Benefits at 7% Discount
(2007 Dollar)

	Vehicle Weight		
	≤ 6000 lbs	**> 6000 lbs**	**Combined**
Equivalent Lives Saved			
Mean	125	2	126
Total Range	42 - 222	1 - 4	43 - 224
90% Certainty Range	81 - 169	1 - 2	82 - 171
Technology Costs*			
Mean	$568.6 M	$132.2 M	$700.8 M
Total Range	$449.6 - $694.6 M	$106.0 - $160.4 M	$572.4 - $844.2 M
90% Certainty Range	$497.8 - $643.2 M	$116.2 - $149.0 M	$628.4 - $776.9 M
Fuel Economy Cost			
Mean	$415.9 M	$13.1 M	$429.0 M
Total Range	$244.5 - $628.3 M	-$39.3 to $69.6 M	$222.7 - $670.9 M
90% Certainty Range	$306.2 - $536.9 M	-$21.9 to $48.5 M	$313.4 - $554.6 M
Total Net Cost**			
Mean	$984.4 M	$145.3 M	$1,129.8 M
Total Range	$736.2 - $1,257.2 M	$77.4 - $218.5 M	$871.0 - $1,432.2 M
90% Certainty Range	$864.4 - $1,111.3 M	$107.7 - $183.3 M	$1,003.9 - $1,261.9 M
Cost-Effectiveness (CE)			
Mean	$8.3 M	$135.6 M	$9.4 M
Total Range	$3.7 - $26.3 M	$210.6 - $62.0 M	$4.4 - $28.8 M
90% Certainty Range	$5.7 - $12.3 M	$174.2 - $97.5 M	$6.4 - $13.9 M
Certainty that CE ≤ $3.5 M	0.0%	0.0%	0.0%
Certainty that CE ≤ $6.1 M	11.0%	0.0%	2.4%
Certainty that CE ≤ $8.7 M	64.8%	0.0%	44.7%
Net Benefit (NB)			
Mean	-$224.5 M	-$135.6 M	-$360.1 M
Total Range	-$1,099.2 to $1,281.0 M	-$210.6 to -$62.0 M	-$1,298.2 to $1,159.8 M
90% Certainty Range	-$620.5 to $235.9 M	-$174.2 to -$97.5 M	-$763.1 to $106.2 M
Certainty that NB > $0	18.9%	0.0%	9.5%

M: million
* same for all discount rate
** = technology cost + fuel economy

Appendix A: Potential Rollover Impacts from Improvements to FMVSS No. 216

Vehicles that do not meet the upgraded strength requirements of FMVSS No. 216 will require design modifications that could result in added weight to the roof and roof support structure[55]. To the extent that these changes impact the upper structure disproportionately, they have the potential to increase the height of the vehicle's center of gravity (cg). This, in turn, could increase the propensity of the vehicle to roll over under some impact or maneuvering circumstances. This appendix examines the potential impact of this effect on vehicles that must be redesigned to meet higher roof strength standards. First an examination is made of the change in rollover propensity that could result for the 4 vehicles for which the agency has finite element models to estimate changes. An analysis of potential safety impacts is then made based on a larger sample of vehicles based on gross estimates of added weight derived from regressions established in Chapter V of this analysis. Finally, an examination is made of vehicle models that have undergone redesigns that resulted in increased roof strength to determine whether they experienced concurrent degradation in rollover propensity.

Methodology

NHTSA research has firmly established the relationship between a vehicle's physical characteristics and its rollover propensity. As an ongoing part of NHTSA's New Car Assessment Program (NCAP), NHTSA developed a ratings system to measure the propensity of vehicles to roll over in a crash. This system is based upon the Static Stability Factor (SSF). The SSF is a measure of the vehicle's physical tendency to roll over given its basic dimensions. It is essentially a measure of how top-heavy the vehicle is relative to its track width. Specifically, it is a function of the vehicle's track width and center of gravity. The formula for SSF is:

SSF = T/(2*cg)

Where T = track width (the distance measured between the centers of the right and left tires along the axle)

cg = the height of the center of gravity of the vehicle, typically measured in a laboratory to determine the height of the center of the vehicle's mass.

SSF is used in conjunction with a formula that was developed to predict the actual probability of a vehicle experiencing a rollover in a single vehicle crash given its SSF. This formula is derived from real world crash experience and its relationship to SSF. SSF is the single variable in this formula. Thus, a change in a vehicle's SSF will produce a change in its estimated rollover propensity. The formula is:

$$R = 1/(1+e^{2.8891+1.16868*\ln(SSF-0.9)})$$

Where R = the rollover probability of the vehicle in police reported single vehicle crashes.[56]

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[55] NHTSA estimates that about 82% of all vehicles <=6,000 lbs. GVWR and 93 of all vehicles > 6,000 lbs. GVWR would require changes to meet the upgraded standard.

[56] This cg analysis addresses only single vehicle crashes because the formula derived for SSF is specific to that group. Basically, the crash dynamics of multi-vehicle crashes are so different that we do not feel that it would be appropriate to assume a similar relationship for both single and multi-vehicle crashes. Prior impact is the likely cause of rollover in 97 percent of fatal multi-vehicle crashes that result in rollovers (i.e., impact occurs <u>prior</u> to the rollover in 97 percent of cases), and this would obscure any direct relationship to subtle changes in cg characteristics. Only a small portion of rollover fatalities (16%) occur in multi-vehicle crashes, so even in the unlikely event that there is some minor influence from cg, it would not have a significant impact on fatalities.

A modified version of this formula has been developed for application to vehicles that tip up in NHTSA's NCAP rollover test. However, none of the 4 vehicles that were analyzed using the finite element model vehicles fall into this category.

This formula thus provides a basis for estimating the safety impact of shifts in cg from design changes made to comply with FMVSS No. 216.

Estimated Shift in cg – 4 examples

There is very little data available to estimate the impact on cg that might result from changes to FMVSS No. 216. NHTSA has estimates of possible design changes based on finite element models (FEM) created for 4 different vehicles. During initial research in the roof crush upgrade program, the agency selected four vehicles that already had FEMs created for roof strength modeling improvements. These four vehicles were a 1998 Plymouth Neon sedan, a 1999 Ford E-150 Van, a 1997 Dodge Caravan, and a 1998 Chevrolet S-10 pick-up. The Neon and E-150 represented vehicles that could not withstand a roof crush force of twice their weight, when applying load via the FMVSS No. 216 test device. Through an iterative process, improvements were made within the FE models until the Neon and E-150 could withstand a roof crush force of about 20 percent greater than 2.5 times their vehicle weight (about 3.0 times greater). The Caravan and S-10 represented vehicles that could withstand a roof crush of over 2.5 times their vehicle weight. Through this same iterative process, improvements were made until the Caravan and S-10 could withstand a roof crush force of about 20 percent greater than 3.0 times their vehicle weight (about 3.6 times greater). The agency thus has an analysis of possible design changes for 2 models under a 2.5 SWR load, and 2 models under a 3.0 SWR load.

The FE models were run by the National Crash Analysis Center - George Washington University (NCAC), and a cost teardown analysis of the model improvements were developed by Ludtke & Associates and reported to the agency under contract DTNH22-00-C-02008. A complete discussion of the results of these models is included in Chapter V. The added weight from the changes estimated by Ludtke is summarized in Tables V-1 through V-4 in Chapter V. To estimate the impact these changes would have on cg, NHTSA engineering staff examined the nature of the changes and estimated their location relative to the cg. A new cg was then calculated based on these changes.

This process and the resulting estimates are summarized in Table A-1. Table A-1 lists the baseline factors as well as the modified factors that result from our analysis.

Table A-1

Hypothetical Impact of Increase in Rollover Propensity

Caused by Raised Center of Gravity

	3.0 Load Requirement		2.5 Load Requirement	
	Chevy S-10	Caravan	Neon	E-150
Track Width (mm) =	1384.3	1612.9	1475.74	1770.38
Baseline cg (inches) =	23.07	26.57	20.59	31.3
Modified cg (inches) =	23.22	26.59	20.61	31.37
Baseline cg (mm) =	586.13	674.88	522.99	795.02
Modified cg (mm) =	589.87	675.43	523.58	796.75
Baseline SSF =	1.1809	1.1950	1.4109	1.1134
Modified SSF =	1.1734	1.1940	1.4093	1.1110
Baseline Rollover Propensity =	0.1970	0.1881	0.1087	0.2527
Modified Rollover Propensity =	0.2020	0.1887	0.1090	0.2552
Change in Rollover Propensity =	.0050	.0006	.0003	.0025

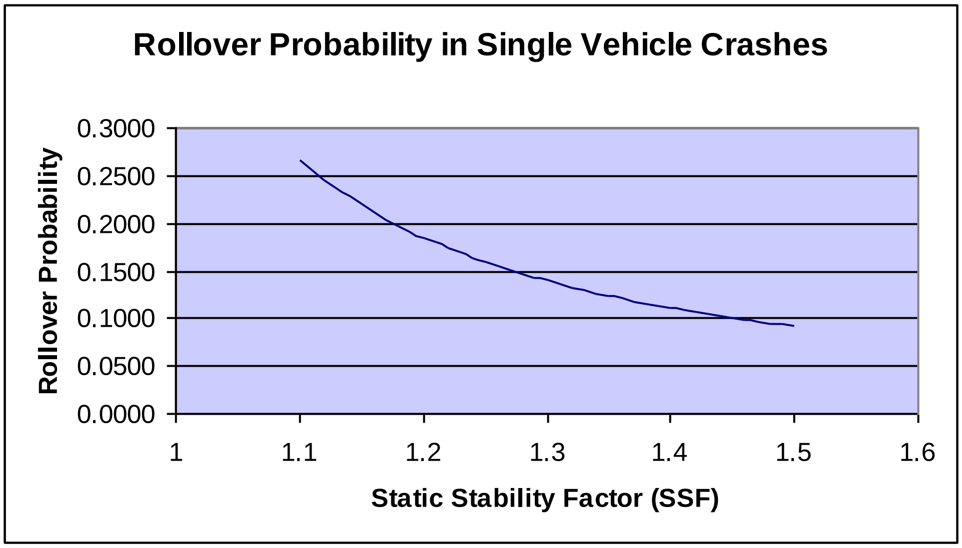
Uncertainty and Caveats

These calculations illustrate a method that might be used to estimate potential impacts from weight shifts that affect cg. Unfortunately, the information from these four finite element models is of limited use in analyzing possible cg impacts for a number of reasons:

1) <u>The 4 vehicles available for analysis are not representative of the fleet.</u> The E-150 15 passenger van was chosen as a likely worst case (among the vehicles for which finite element models were available) based on its low SSF. The Neon is a relatively small passenger car. Both the Chevy S-10 and the Caravan were analyzed for a 3.0 load factor. However, as noted in the body of this analysis, the actual SWR achieved for a 3.0 standard will be higher due to allowance for worst-case vehicle loads, compliance margins, and two-sided testing requirements. The impact on these few models is thus unlikely to be representative of a fleet with a wide variety of roof and rollover characteristics.

The importance of individual vehicle characteristics is apparent from the SSF model that drives this analysis. This is demonstrated in Figure A-1, which illustrates the relationship between SSF and the probability of rollover in single vehicle crashes. There is an obvious decrease in the rate of change in the slope of the curve as SSFs improve. This implies that vehicles with low SSFs experience larger changes in their rollover probability when their cg changes than do vehicles with higher SSFs. The practical result is that a given SSF change in a vehicle with a low SSF could have a much more significant impact than the same SSF change in a vehicle with a high SSF.

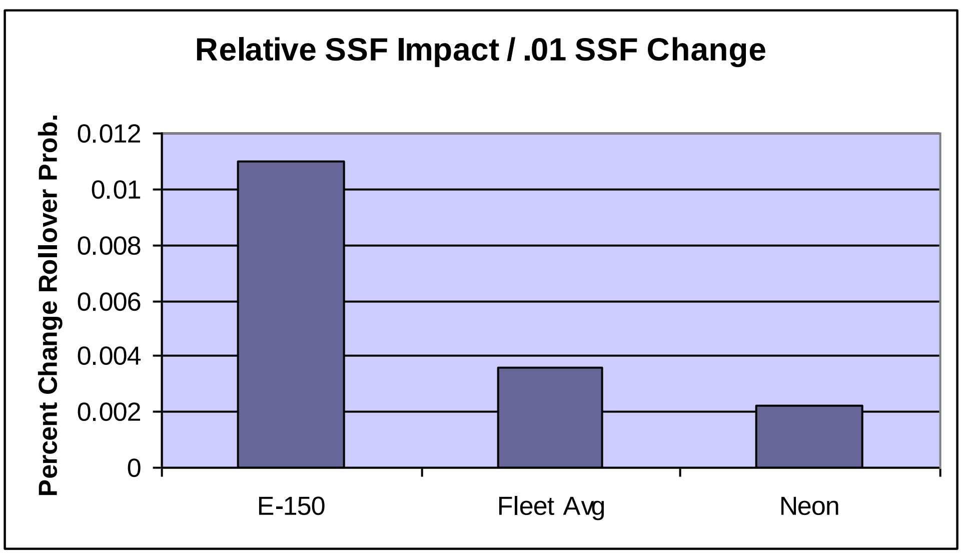
Figure A-1



To put this in perspective, NCAP SSF ratings for recent model vehicles were derived from a recent NHTSA study on historical trends in SSF ratings.[57] This study examined SSF trends from passenger vehicles for model years 1975-2003. The average SSF rating across all 2003 MY passenger cars and LTVs was 1.30. Based on the rollover probability formula, an increase of .01 in the SSF for a vehicle with a 1.30 SSF increases the probability of injury by .0036, i.e., by less than 4 tenths of a percent. By contrast, the Neon has an SSF of 1.41 and the E-150 has an SSF of 1.10. At these SSF levels, an increase of .01 SSF would increase the probability of injury by .0022 and .0110 respectively. The Neon thus experiences an impact that is about 60 percent of the fleet average while the E-150 experiences an impact that is 3 times as high as the fleet average. These relative impacts are shown graphically in Figure A-2.

Thus, all other things being equal, the Neon results would understate the impact on the fleet somewhat, but the E-150 results would greatly overstate the expected impact on the fleet. To determine the actual fleet impact on cg and SSF however, more specific data regarding vehicle changes is required. Unfortunately, although the SSF is known for a large sample of the fleet, the expected change in cg, and thus the change in SSF for the overall fleet, is unknown.

Figure A-2



[57] Walz, Marie C., *Trends in the Static Stability Factor of Passenger Cars, Light Trucks, and Vans*, NHTSA, U.S.

Department of Transportation, Washington, D.C., DOT-hs-809-868, June, 2005.

2) <u>The structural changes that were estimated by NCAC for specific models were not based on a design goal to minimize cg impact.</u> Manufacturers can mitigate or neutralize adverse impacts on cg by using high strength lightweight materials, by adjusting track width, by utilizing slightly wider tires, or by reducing the placard pressure of their tires. While it isn't clear what design strategy the manufacturers might take, assuming they choose to avoid changes in rollover risk, they could mitigate such impacts using any of these design approaches.

Manufacturers generally strive to maintain or improve their NCAP ratings to help market their vehicles. The Agency believes that this concern over NCAP ratings would preclude a design strategy that unnecessarily increases cg and degrades SSF. Support for this conclusion can be found in recent vehicle designs. Table A-2 lists the SSF ratings and roof strength for recent model vehicles. The sample of vehicles in Table A-2 includes all vehicles for which both SSF and roof strength ratings were available. They are grouped with similar sized vehicles to show the ratings within similar groups. These data indicate that many most recently designed vehicles with stronger roofs also have higher SSFs. It's unclear whether this represents an overt design decision on the part of manufacturers or whether it is due to other factors, but it does demonstrate that current designs generally reflect both higher levels of roof strength and higher levels of rollover resistance. Manufacturers are thus experienced in designs that maintain both aspects of vehicle safety.

Table A-2

Vehicle Rollover Resistance (SSF) and Roof Strength Ratings

Type	Vehicle	SSF	Strength to Weight Multiple (5" of plate displacement)
Small Car	2007 Scion TC	1.38	4.62
	2006 Honda Civic	1.43	4.50
	2007 Toyota Yaris	1.33	4.03
	2006 Chrysler Crossfire	1.48	2.87
	2003 Chevrolet Cavalier (4-door)	1.39	277
	2003 Ford Focus (Hatchback)	1.29	2.76
	2003 Mini Cooper	-	2.31
Midsize Car	2006 Volkswagen Jetta	1.36	5.13
	2006 Mazda 5	-	4.42
	2007 Toyota Camry	1.42	4.31
	2006 Mitsubishi Eclipse	1.46	3.55
	2008 Honda Accord	1.42	3.52
	2003 Mazda 6	1.46	3.4
	2006 Hyundai Sonata	1.44	3.16
	2003 Chevrolet Impala	1.36	3.15 / 2.84
	2006 Ford Mustang	1.53	2.68
	2007 Pontiac G6	1.46	2.27
	2001 Ford Taurus	1.43	2.03
Fullsize Car	2006 Ford Five Hundred	1.43	3.88
	2005 Buick Lacrosse	1.39	2.59 / 2.39

	2006 Lincoln LS	1.45	2.58 / 2.45
	2007 Chrysler 300	1.41	2.50
	2007 Buick Lucerne	1.45	2.35
	2003 Ford Crown Victoria	1.51	2.02
Minivan	2007 Dodge Caravan	1.23	3.04
	2004 Nissan Quest	1.36	2.78
	2003 Ford Windstar	1.26	2.20
Small SUV	2003 Subaru Forester 1402 4145	1.24	4.81
	2004 Honda Element 1576 4453	1.15	4.31
	2007 Honda CR-V 1529 4560	1.22	2.58
Mid-size SUV	2002 Nissan Xterra 1573 5004	1.09	3.46
	2001 Mitsubishi Montero 1724 4730	1.11	2.65
	2003 Kia Sorento 1906 5467	1.16	1.96
	2004 Land Rover Freelander 1640 4542	-	1.72
Full-size SUV	2006 Volvo XC90 2020 5640	1.21	4.55
	2006 Subaru Tribeca 1907 5700	1.24	3.86
	2006 Hummer H3 2128 5850	1.12	3.37
	2007 Ford Edge 1916 5300	-	3.29
	2007 Saturn Outlook 2133 6400	1.23	2.73
	2004 Cadillac SRX 1961 5897	-	2.62
	2002 Ford Explorer 1857 5300	1.04	2.35
	2004 Chrysler Pacifica 2018 5780	1.30	2.21
	2007 Jeep Grand Cherokee 1943 5700	1.17	2.18
	2003 Chevrolet TrailBlazer 2019 5750	1.16	2.16
Over-size SUV	2003 Ford Expedition	1.11	2.38

	2007 Chevrolet Tahoe	1.12	2.06
Compact Pickup	2005 Nissan Frontier	-	3.96
	2007 Toyota Tacoma	1.14	4.41 / 3.29
	1998 Chevrolet S-10	1.15	2.76
	2007 Chevrolet Colorado	-	2.17
Full-size Pickup	2007 Toyota Tundra	-	3.32
	2002 Dodge Ram 1500 Regular Cab Pickup	1.16	2.48
	2006 Honda Ridgeline	1.29	2.37
	2004 Chevrolet Silverado	1.20	2.33
	2007 Ford F150	1.18	2.32
	2001 GMC Sierra	-	1.92
	2003 Ford F-250	-	1.72
	2006 Dodge Ram 1500	1.24	1.67
Full-size Van	2006 Dodge Sprinter	-	2.57
	2007 Chevrolet Express	1.10	2.27
	1999 Ford E-150	1.11	1.88

Hypothetical Fleet Impact

The 4 evaluated vehicles are not representative of the vehicle fleet and are thus insufficient to derive a reliable estimate of potential impacts of raising cg. To derive an estimate for the broader fleet, rollover estimates were developed for all vehicles in our test sample for which the necessary data were available. To be included in this analysis, the following data were required:

Maximum unloaded vehicle weight

Roof height

Track width

Center of gravity

The first three factors were available for all 76 of our test vehicles, but, center of gravity was not available for 9 of these vehicles. We also required that the tested vehicle or a more current market equivalent have measurable sales during model year 2006, and, in cases where more than one model year was tested of the same vehicle, only the most recent model was used. This eliminated 16 older vehicles from the mix, leaving a total of 51 vehicles in this exercise. The purpose of this exercise is to demonstrate the potential impacts of adding weight to the upper parts of vehicles without taking offsetting measures to maintain cg height. The full sample of eligible vehicles is thus used regardless of their actual performance in meeting any given SWR. This relatively large sample gives a better cross section of vehicle types with their differing body characteristics.

To illustrate the potential impact of shifting cg on these vehicles, we utilized the initial quadratic regressions that were developed in Chapter V of this analysis. These regressions expressed an approximation of added weight to meet a specific SWR standard based on the weight of the vehicle. The basic equation was developed for 2-sided 2.5 SWR and modified for alternate SWRs using a variety of factors. The basic formula was:

Awt = 3.338739*10-6*wt-0.015569*wt+29.830194

Where Awt = estimated added weight to meet 2.5 SWR for a vehicle weighing Wt

Wt = weight of subject vehicle

In chapter V, markup factors of 2.0 and 0.2 were developed for alternate SWRs of 3.0 and 1.5 respectively, i.e., the results obtained directly from the regression for 2.5 multiplied by 2.0 would estimate the results for a 3.0 SWR. Multiplied by 0.2 they would estimate the results for a 1.5 SWR. Using this relationship, the added weight for each vehicle was estimated. The portion of this weight that would occur at the roofline is the average portion estimated for the 4 finite element vehicles discussed above (roughly 65%). Since the initial equations were based on add-on solutions rather than full redesign solutions, only half of the added weight predicted by the equations was applied to the sample vehicles. This is roughly consistent with the upper end of the range selected to estimate the base impacts in the body of this report, which was established at the median point of the model results.

As was done in the body of the FRIA, the 51 vehicles were split into groups representing vehicles over and under 6,000 lbs. GVWR. Each group was analyzed at the SWR level required in the final rule – 3.0 for vehicles under 6,000 lbs. GVWR and 2.0 for vehicles over 6,000 lbs. GVWR. Each group represents predicted impacts on single vehicle crashes for their specific group only. The results that were derived from each vehicle were thus weighted according to the relative sales of that vehicle within the GVWR group.[58]

The basic relationship used to calculate the new cg is derived as follows:

$cg_n = (w*cg+w_a*r)/ (w+w_a)$

Where cg_n = new center of gravity

w = unloaded vehicle weight

cg = initial center of gravity

w_a = net added weight at roof level

r = roof height where weight is added

In this algorithm, cg, w, and r are measured characteristics specific to each vehicle. Initial cg is measured using an inertial parameters measurement device, a two-axis pendulum that measures periods of oscillation. Added weight at roof level (w_a) is an estimate based on engineering judgment of the net impact of changes described in the finite element models for the Neon, E-150, Taurus, and Explorer. These changes were examined to determine the extent to which structural changes might translate to weight added at the roof level. To the extent that these changes were cg neutral they were ignored. Structural changes that were not cg neutral were deflated to their equivalent values if spread solely at the roof level. This involved a level of engineering judgment. The proportion of total added weight that was judged to impact cg for the 4 vehicles with finite element models (roughly 65%) was assumed for all 51 vehicles in the exercise.

The new cgs listed in Table A-3 were used to calculate new SSFs, which were then used to calculate a revised rollover probability (the formulae for this process were discussed previously). Added rollovers were calculated by applying the change in rollover probability to the portion of police-reported single vehicle crashes that would be experienced by vehicles that do not meet the requirements of the proposal. As noted in Chapter V, based on annual sales volumes, passenger vehicles < 6,000 lbs. GVWR that failed to meet the 3.0 load factor proposal represent 82% of the tested fleet and vehicles > 6,000 lbs. GVWR that failed to meet the 1.5 load factor alternative represent 40% of the tested fleet. It is assumed that these same portions will apply to crash involvement for the specific vehicle types.

Under these assumptions, each vehicle was examined and new cg estimates were established based on the revised weight distributions. The revised cg estimates were used to compute revised SSFs for each vehicle. These were then used to calculate the change in rollover crashes that would occur if each specific

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[58] Relative weights were derived from the most recently available sales data for the period covering January through

vehicle was representative of the entire fleet. Rollover crashes were determined based on 1.9 million single vehicle crashes with roughly 85% coming from vehicles <6,000 lbs. GVWR and 15% from vehicles > 6,000 lbs. GVWR. These values were estimated based on average incidence in 2004-2006 as measured in the GES. Passenger cars accounted for 46% of all single vehicle crashes during this period and LTVs accounted for 54%. The proportions of crashes involving vehicles by GVWR were assumed to match their relative sales rates, with all passenger cars and roughly 75% of LTVs being under 6000 lbs. GVWR. These values were then adjusted to reflect the installation of ESC in the vehicle fleet using the same methods described in the benefits section of this FRIA. After applying the corresponding failure rates for each weight category, this left a target population of 636,000 single vehicle crashes for vehicles < 6,000 lbs. GVWR, and 47,900 for vehicles > 6,000 lbs. GVWR.

Table A-4 summarizes the process used to estimate changes in cg for each of the vehicles in the < 6,000 lbs GVWR category. The table is presented in 3 parts as Tables A-4a, 4b, and 4c. The process shown in the tables moves sequentially for each vehicle through each table in turn. Table A-4a documents the basic vehicle parameters, the new cg, and the base ssf. Table A-4b shows the new ssf, the change in ssf, the shift in rollover probability, and the change in total rollover crashes and injuries that would result. In Table A-4c, the added rollover injuries are translated into an injury profile and converted to fatality equivalents. Tables A-5a, 5b, and 5c list the same information for vehicles > 6,000 lbs. GVWR. The revised injury profile was derived by applying a non-rollover injury profile to the cases that were previously rollovers in lieu of a rollover injury profile. The injury profiles were obtained by examining 2004-2006 GES data which stratifies injury severity using KABCO definitions. To make this compatible with the MAIS stratification used in this analysis, a translator derived from 2000-2006 GES and 1982-1986 NASS was used to convert the profile to the Abbreviated Injury Scale. The injury profiles, along with the cost/equivalent fatality factors, are shown in Table A-3 below.

Table A-3

August 2006 obtained online (www.autonews.com) from the Automotive News Data Book.

Rollover and Non-Rollover Injury Profiles, and Equivalent Fatality Factors, by Injury Severity Level

	MAIS 0	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal
Rollover Profile =	46.66%	41.41%	6.41%	2.57%	0.60%	0.23%	2.12%
Non-Rollover Profile =	78.03%	18.74%	2.05%	0.68%	0.15%	0.06%	0.29%
Equivalent Fatality Factor =		0.0028	0.0436	0.0804	0.1998	0.6656	1

Table A-4a

Revised Center of Gravity (cg) Calculation Inputs and Results, Vehicles < 6,000 lbs. GVWR

MAKE	Max Weight	Predicted Initial Added Weight	Adjusted Added Weight (0.5)	Added Weight at Roofline	CG (Height in.)	Roof Height	New cg	Track Width	ssf
2007 Toyota Yaris	2321	23.36	11.68	7.63	21.68	57.2	21.80	58.1	1.3399
2003 FORD FOCUS	2749	24.52	12.26	8.01	22.51	53.9	22.60	58.65	1.3028
2003 CHEVY CAVALIER	2809	24.88	12.44	8.13	20.58	53.3	20.67	57	1.3848
2006 HONDA CIVIC	2875	25.33	12.67	8.28	20.8	54.4	20.90	59.6	1.4327
2007 Scion tC	2970	26.08	13.04	8.52	21.37	55.15	21.47	59.3	1.3875
2003 SUBARU FORESTER	3131	27.63	13.81	9.03	23.64	61.3	23.75	58.7	1.2415
2003 MAZDA 6	3243	28.91	14.45	9.44	20.76	56.4	20.86	60.4	1.4547
2006 VW JETTA	3308	29.73	14.86	9.71	21.94	57.65	22.04	60.2	1.3719
2006 MAZDA 6	3333	30.06	15.03	9.82	20.76	56.7	20.87	60.6	1.4595
2007 Chrysler Crossfire	3340	30.15	15.08	9.85	19.82	51.2	19.91	58.95	1.4871
2001FORD TAURUS	3353	30.33	15.16	9.91	21.7	56.1	21.80	61.8	1.4240
2006 FORD MUSTANG	3450	31.71	15.86	10.36	20.44	54.5	20.54	62.4	1.5264
2006 HYUNDAI SONATA	3458	31.83	15.92	10.40	21.39	57.7	21.50	61.7	1.4423
2003 Chevrolet Impala *	3466	31.95	15.98	10.44	22.49	57.3	22.59	61.55	1.3684
2004 HONDA ELEMENT	3565	33.52	16.76	10.95	27.18	70.4	27.31	62.2	1.1442
2007 Honda CRV	3566	33.54	16.77	10.96	25.37	65.7	25.49	61.6	1.2140
2005 Buick LaCrosse	3568	33.57	16.78	10.97	22.16	57.4	22.27	61.6	1.3899
2008 Honda Accord	3607	34.22	17.11	11.18	21.24	58.1	21.35	62.6	1.4736
2007 Toyota Camry	3680	35.50	17.75	11.60	21.85	57.3	21.96	61.8	1.4142
2004 Lincoln LS *	3755	36.89	18.44	12.05	20.89	56.1	21.00	60.65	1.4517
2006 FORD 500	3815	38.05	19.03	12.43	22.57	61.1	22.70	64.35	1.4256
2007 Pontiac G6	3948	40.81	20.40	13.33	20.68	55.6	20.80	59.8	1.4458
2007 Chevrolet Colorado	3971	41.31	20.65	13.49	27.21	76.15	27.38	58.55	1.0759
2003 Ford Crown Victoria *	4008	42.13	21.06	13.76	21.39	56.8	21.51	64.35	1.5042
2007 Buick Lucerne	4070	43.54	21.77	14.22	21.66	57.6	21.79	62.75	1.4485
2002 NISSAN XTERRA	4115	44.60	22.30	14.57	27.35	70.1	27.50	59.65	1.0905
2007 Toyota Tacoma	4154	45.54	22.77	14.88	26.84	69.6	26.99	63.2	1.1773
2004 Nissan Quest *	4175	46.05	23.03	15.04	24.74	69.5	24.90	67.3	1.3601
2001 MITSUBISHI MNTRO	4219	47.15	23.57	15.40	27.61	68	27.76	61.5	1.1137
2003 KIA SORENTO	4255	48.06	24.03	15.70	26.78	68.5	26.93	62.2	1.1613
2006 Subaru Tribeca	4255	48.06	24.03	15.70	25.05	65.75	25.20	62.15	1.2405
2007 Ford Edge	4298	49.18	24.59	16.07	27.48	66.75	27.63	65.05	1.1836
2005 NISSAN FRONTIER	4323	49.84	24.92	16.28	26.96	69.05	27.12	61.8	1.1461
2002 FORD EXPLORER	4343	50.38	25.19	16.46	28.26	68.8	28.41	58.5	1.0350
2007 Chrysler 300	4360	50.83	25.42	16.61	22.42	58.25	22.56	63.05	1.4061

2007 Dodge Caravan	4523	55.43	27.71	18.11	25.78	68.9	25.95	63.5	1.2316
2004 Chrysler Pacifica *	4676	60.06	30.03	19.62	25.55	65.9	25.72	66	1.2916
2006 HUMMER H3	4700	60.82	30.41	19.87	29.12	73.4	29.31	65.25	1.1204
2006 VOLVO XC90	4826	64.91	32.45	21.20	26.55	70.2	26.74	64.1	1.2072
2007 Jeep Grand Cherokee	4888	67.00	33.50	21.89	26.56	67.7	26.74	62	1.1672
2003 CHEVY TRAILBLZER	4967	69.74	34.87	22.78	26.93	69.5	27.12	62.6	1.1623

Table A-4b
Revised Center of Gravity (cg) Calculation Inputs and Results, Vehicles < 6,000 lbs. GVWR (contd)

MAKE	ssf	new ssf	delta ssf	Baseline Rollover %	Revised Rollover %	Added Rollovers	Rollover Injuries
2007 Toyota Yaris	1.3399	1.3326	0.0074	0.1268	0.1290	1402	1877
2003 FORD FOCUS	1.3028	1.2976	0.0052	0.1387	0.1405	1157	1550
2003 CHEVROLET CAVALIER	1.3848	1.3788	0.0060	0.1148	0.1162	950	1273
2006 HONDA CIVIC	1.4327	1.4258	0.0069	0.1040	0.1055	903	1209
2007 Scion tC	1.3875	1.3810	0.0065	0.1141	0.1157	1009	1351
2003 SUBARU FORESTER	1.2415	1.2358	0.0058	0.1633	0.1661	1736	2325
2003 MAZDA 6	1.4547	1.4477	0.0070	0.0997	0.1010	849	1137
2006 VOLKSWAGEN JETTA	1.3719	1.3657	0.0062	0.1180	0.1196	1033	1384
2006 MAZDA 6	1.4595	1.4518	0.0077	0.0988	0.1003	922	1235
2007 Chrysler Crossfire	1.4871	1.4804	0.0067	0.0939	0.0951	732	981
2001FORD TAURUS	1.4240	1.4174	0.0065	0.1059	0.1073	888	1189
2006 FORD MUSTANG	1.5264	1.5190	0.0074	0.0877	0.0888	713	956
2006 HYUNDAI SONATA	1.4423	1.4349	0.0074	0.1021	0.1036	940	1259
2003 Chevrolet Impala *	1.3684	1.3623	0.0061	0.1189	0.1205	1020	1366
2004 HONDA ELEMENT	1.1442	1.1388	0.0054	0.2241	0.2288	2936	3933
2007 Honda CRV	1.2140	1.2083	0.0057	0.1772	0.1803	2004	2684
2005 Buick LaCrosse	1.3899	1.3830	0.0069	0.1135	0.1152	1062	1423
2008 Honda Accord	1.4736	1.4660	0.0076	0.0962	0.0976	867	1161
2007 Toyota Camry	1.4142	1.4071	0.0071	0.1080	0.1095	999	1338
2004 Lincoln LS *	1.4517	1.4440	0.0076	0.1003	0.1018	937	1255
2006 FORD FIVE HUNDRED	1.4256	1.4174	0.0082	0.1055	0.1073	1106	1482
2007 Pontiac G6	1.4458	1.4375	0.0083	0.1014	0.1031	1051	1407
2007 Chevrolet Colorado	1.0759	1.0692	0.0067	0.2977	0.3073	6071	8131
2003 Ford Crown Victoria *	1.5042	1.4958	0.0084	0.0911	0.0925	866	1160
2007 Buick Lucerne	1.4485	1.4399	0.0086	0.1009	0.1026	1079	1445
2002 NISSAN XTERRA	1.0905	1.0845	0.0059	0.2786	0.2861	4777	6399
2007 Toyota Tacoma	1.1773	1.1708	0.0065	0.1993	0.2038	2856	3825
2004 Nissan Quest *	1.3601	1.3514	0.0087	0.1211	0.1235	1530	2049
2001 MITSUBISHI MONTERO	1.1137	1.1077	0.0060	0.2524	0.2587	4038	5409
2003 KIA SORENTO	1.1613	1.1548	0.0065	0.2107	0.2156	3124	4184
2006 Subaru Tribeca	1.2405	1.2331	0.0074	0.1638	0.1673	2251	3015
2007 Ford Edge	1.1836	1.1772	0.0064	0.1952	0.1995	2698	3614
2005 NISSAN FRONTIER	1.1461	1.1394	0.0068	0.2225	0.2282	3614	4841
2002 FORD EXPLORER	1.0350	1.0296	0.0055	0.3660	0.3773	7170	9603
2007 Chrysler 300	1.4061	1.3974	0.0087	0.1098	0.1118	1273	1705
2007 Dodge Caravan	1.2316	1.2235	0.0081	0.1681	0.1722	2585	3462

2004 Chrysler Pacifica *	1.2916	1.2830	0.0085	0.1426	0.1458	2022	2708
2006 HUMMER H3	1.1204	1.1131	0.0073	0.2457	0.2530	4662	6244
2006 VOLVO XC90	1.2072	1.1986	0.0086	0.1810	0.1859	3153	4223
2007 Jeep Grand Cherokee	1.1672	1.1593	0.0079	0.2064	0.2122	3671	4917
2003 CHEVROLET TRAILBLZR	1.1623	1.1541	0.0081	0.2100	0.2162	3930	5264

Table A-4c
Revised Center of Gravity (cg) Calculation Inputs and Results, Vehicles < 6,000 lbs. GVWR (contd)

MAKE	Added Rollover Injuries	Net Impact MAIS 0	Net Impact MAIS1	Net Impact MAIS2	Net Impact MAIS 3	Net Impact MAIS 4	Net Impact MAIS5	Net Impact Fatal	Equivalent Fatalities
2007 Toyota Yaris	1877	-589	426	82	35	8	3	34	46
2003 FORD FOCUS	1550	-486	351	68	29	7	3	28	38
2003 CHEVROLET CAVLIER	1273	-399	289	55	24	6	2	23	31
2006 HONDA CIVIC	1209	-379	274	53	23	5	2	22	29
2007 Scion tC	1351	-424	306	59	26	6	2	25	33
2003 SUBARU FORESTER	2325	-729	527	101	44	10	4	43	57
2003 MAZDA 6	1137	-357	258	50	21	5	2	21	28
2006 VOLKSWAGEN JETTA	1384	-434	314	60	26	6	2	25	34
2006 MAZDA 6	1235	-387	280	54	23	6	2	23	30
2007 Chrysler Crossfire	981	-308	222	43	19	4	2	18	24
2001FORD TAURUS	1189	-373	270	52	22	5	2	22	29
2006 FORD MUSTANG	956	-300	217	42	18	4	2	17	23
2006 HYUNDAI SONATA	1259	-395	285	55	24	6	2	23	31
2003 Chevrolet Impala *	1366	-428	310	60	26	6	2	25	33
2004 HONDA ELEMENT	3933	-1234	892	171	74	18	7	72	96
2007 Honda CRV	2684	-842	608	117	51	12	5	49	65
2005 Buick LaCrosse	1423	-446	323	62	27	6	2	26	35
2008 Honda Accord	1161	-364	263	51	22	5	2	21	28
2007 Toyota Camry	1338	-420	303	58	25	6	2	24	33
2004 Lincoln LS *	1255	-394	284	55	24	6	2	23	31
2006 FORD FIVE HUNDRED	1482	-465	336	65	28	7	3	27	36
2007 Pontiac G6	1407	-441	319	61	27	6	2	26	34
2007 Chevrolet Colorado	8131	-2551	1843	355	154	37	14	149	198
2003 Ford Crown Victoria *	1160	-364	263	51	22	5	2	21	28
2007 Buick Lucerne	1445	-453	328	63	27	7	2	26	35
2002 NISSAN XTERRA	6399	-2007	1451	279	121	29	11	117	156
2007 Toyota Tacoma	3825	-1200	867	167	72	17	7	70	93
2004 Nissan Quest *	2049	-643	465	89	39	9	3	37	50
2001 MITSUBISHI MNTERO	5409	-1697	1226	236	102	24	9	99	132
2003 KIA SORENTO	4184	-1313	949	182	79	19	7	77	102
2006 Subaru Tribeca	3015	-946	684	131	57	14	5	55	74
2007 Ford Edge	3614	-1134	819	158	68	16	6	66	88
2005 NISSAN FRONTIER	4841	-1519	1097	211	91	22	8	89	118
2002 FORD EXPLORER	9603	-3013	2177	419	181	43	16	176	234
2007 Chrysler 300	1705	-535	387	74	32	8	3	31	42
2007 Dodge Caravan	3462	-1086	785	151	65	16	6	63	84

2004 Chrysler Pacifica *	2708	-850	614	118	51	12	5	50	66
2006 HUMMER H3	6244	-1959	1416	272	118	28	11	114	152
2006 VOLVO XC90	4223	-1325	957	184	80	19	7	77	103
2007 Jeep Grand Cherokee	4917	-1542	1115	214	93	22	8	90	120
2003 CHEVROLET TRLBLZR	5264	-1651	1193	229	99	24	9	96	128
SALES WEIGHTED AVERAGE IMPACT, Vehicles < 6,000 lbs. GVWR =									71

Table A-5a
Revised Center of Gravity (cg) Calculation Inputs and Results, Vehicles >6,000 lbs. GVWR

MAKE	Max Weight	Predicted Initial Add Weight	Adjusted Added Weight (0.5)	Add Weight at Roofline	CG (Height in.)	Roof Height	New cg	Track Width	ssf
2007 Chevrolet Express	6330	32.53	16.26	10.63	30.91	81.60	30.99	68.00	1.1000
2007 Ford F-150	5940	27.58	13.79	9.01	31.30	75.60	31.37	67.00	1.0703
2007 Chevrolet Tahoe	5524	22.85	11.43	7.47	30.09	73.40	30.15	68.20	1.1333
2001 GMC Sierra *	7100	43.80	21.90	14.31	25.90	76.50	26.00	68.60	1.3243
2007 Saturn Outlook	4936	17.16	8.58	5.61	27.48	69.50	27.53	67.10	1.2209
2007 Toyota Tundra	5685	24.61	12.31	8.04	29.01	75.50	29.08	67.90	1.1703
2006 DODGE RAM 1500	6000	28.31	14.15	9.25	27.38	75.50	27.45	68.00	1.2418
2004 CHEVROLET SILVERADO	6300	32.13	16.07	10.50	27.40	70.10	27.47	65.00	1.1861
2003 FORD EXPEDITION	6155	30.24	15.12	9.88	29.39	77.60	29.47	67.00	1.1398
2006 HONDA RIDGELINE	4498	13.68	6.84	4.47	25.93	69.90	25.97	67.10	1.2939

Table A-5b
Revised Center of Gravity (cg) Calculation Inputs and Results, Vehicles > 6,000 lbs. GVWR (contd)

MAKE	ssf	new ssf	delta ssf	Baseline Rollover %	Revised Rollover %	Added Rollovers	Added Rollover Injuries
2007 Chevrolet Express	1.1000	1.0989	0.0011	0.2674	0.2686	59	79
2007 Ford F-150	1.0703	1.0693	0.0010	0.3057	0.3072	72	96
2007 Chevrolet Tahoe	1.1333	1.1325	0.0008	0.2336	0.2343	32	43
2001 GMC Sierra *	1.3243	1.3223	0.0020	0.1316	0.1322	31	41
2007 Saturn Outlook	1.2209	1.2200	0.0009	0.1735	0.1740	22	30
2007 Toyota Tundra	1.1703	1.1691	0.0012	0.2042	0.2051	41	55
2006 DODGE RAM 1500	1.2418	1.2404	0.0014	0.1632	0.1639	30	41
2004 CHEVROLET SILVERADO	1.1861	1.1848	0.0013	0.1936	0.1944	40	53
2003 FORD EXPEDITION	1.1398	1.1387	0.0012	0.2278	0.2288	48	64
2006 HONDA RIDGELINE	1.2939	1.2929	0.0010	0.1418	0.1422	17	23

Table A-5c
Revised Center of Gravity (cg) Calculation Inputs and Results, Vehicles > 6,000 lbs. GVWR (contd)

MAKE	Added Rollover Injuries	Net Impact MAIS 0	Net Impact MAIS 1	Net Impact MAIS 2	Net Impact MAIS 3	Net Impact MAIS 4	Net Impact MAIS 5	Net Impact Fatal	Equivalent Fatalities
2007 Chevrolet Express	79	-25	18	3	1	0	0	1	2
2007 Ford F-150	96	-30	22	4	2	0	0	2	2
2007 Chevrolet Tahoe	43	-14	10	2	1	0	0	1	1
2001 GMC Sierra *	41	-13	9	2	1	0	0	1	1

2007 Saturn Outlook	30	-9	7	1	1	0	0	1	1
2007 Toyota Tundra	55	-17	12	2	1	0	0	1	1
2006 DODGE RAM1500	41	-13	9	2	1	0	0	1	1
2004 CHEVY SLVRDO	53	-17	12	2	1	0	0	1	1
2003 FORD EXPDITION	64	-20	15	3	1	0	0	1	2
2006 HONDA RIDGLINE	23	-7	5	1	0	0	0	0	1
SALES WEIGHTED AVERAGE IMPACT, Vehicles > 6,000 lbs. GVWR =									1
SALES WEIGHTED AVERAGE IMPACT, ALL VEHICLES =									72

Tables A-4 and A-5 summarize the calculated results for the 51 vehicles in our sample. Each individual row represents the impact of a full fleet with that vehicle's characteristics. The sales weighted average impact across the sample of vehicles in each weight category is listed at the bottom of Tables A-4c and A-5c. The combined total for both classes is also listed at the bottom of Table A-5c. The results indicate that, if manufacturers were to redesign their vehicles with weight increases near the upper end of the range estimated in this analysis without maintaining the existing center of gravity, 72 equivalent fatalities or over one third of the 190 equivalent fatalities expected to be produced by increased roof strength from this rule could be offset by added rollover crashes.

Potential Countermeasures

Ultimately, the impact that revisions to FMVSS No. 216 will have on the frequency of rollover crashes will depend on how manufacturers choose to address the issue. As noted above, there are a number of weight shifting options that could be used to maintain or improve current cgs. These include:

1) Removing weight from elsewhere above the center of gravity.
2) Adding weight below the center of gravity
3) Using high strength alloys and other light-weight materials.
4) Increasing the track width of the vehicle.

Removing weight from above the center of gravity would likely be the least costly approach, but could, in some instances, create design challenges. Adding weight below the center of gravity would be relatively simple, but could prove costly and might clash with corporate fuel economy strategies. Substituting high strength alloys and other light-weight materials would probably add cost, but would allow for minimal weight impacts. Minor modifications to the vehicle's track width would be easily accomplished within normal design cycles given enough leadtime. Changes in OEM tire characteristics could be a simple short run solution.

Regardless of which approach manufacturers choose, the challenge they face for this standard is similar to that which they face with any redesign of their vehicle – to optimize the vehicles' performance and safety using the most efficient design and production methods. The agency believes that manufacturers are fully capable of balancing these factors without compromising safety. To examine this issue, the agency analyzed the SSF and roof strength of a number of vehicles that were recently redesigned with higher roof strength.

In the Notice of Proposed Rulemaking (NPRM) for FMVSS No. 216, one of the unresolved issues was the relationship, if any, between roof strength and rollover resistance. If vehicle manufacturers need to add structural weight to the roof area of the vehicle, it would be natural to expect that the center of gravity (CG) would increase and the static stability factor (SSF) for the vehicle would decrease. However, in practice, there are many other vehicle design characteristics that could offset or eliminate any potential change in rollover stability due to adding weight to the roof.

Since 2001, when NHTSA issued a Request for Comments on FMVSS No. 216, "Roof crush resistance," the agency has conducted quasi static roof crush testing on 75 vehicles. These vehicles ranged in model years from 1997 to 2008 and included a wide variety of vehicles styles. All of these vehicles were under 10,000 lbs gross vehicle weight. This analysis will evaluate these test results to look for any trends between higher roof strength and rollover stability as measured by SSF and CG height. Some of the roof crush tests were conducted as part of a two-sided test series. For comparison, only the first test of the vehicle will be discussed. The peak strength to weight ratio (SWR) within 127 mm is used as the performance measure for the roof crush tests.

The static stability factor (SSF), the track width and the center of gravity for all the test data was obtained from the New Car Assessment Program (NCAP) rollover propensity testing. To avoid complications from multiple options for these vehicles, the minimum SSF was reported for each vehicle make and model. Of the 75 vehicles in the roof crush tests, 59 of the vehicles had matching test data from the NCAP rollover program. For these vehicles, the SSF, CG height and track width were recorded.

Figure 1 shows a wide scatter between SSF and peak SWR, with no clear trends between the two variables. Since the SSF is a ratio of the track width and CG heights, the influence of any potential changes in the track width can be removed by plotting the CG height against the peak SWR. Figure 2 shows a wide scatter between CG height and peak SWR. Although, two clusters based on CG height can be seen, which seem to separate the car-like vehicles from the high ground clearance LTVs. However the two groups of CG heights have similar distributions of Peak SWR.

Figure 1 Minimum SSF and Peak SWR

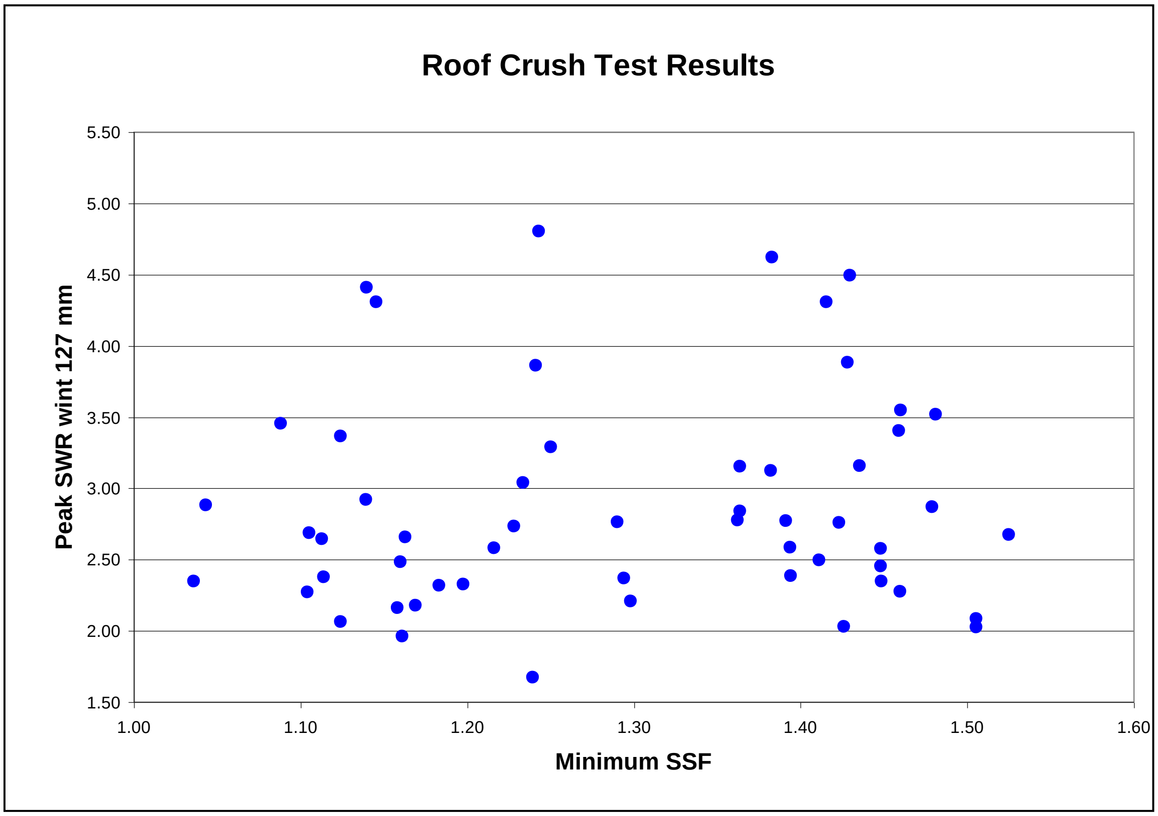
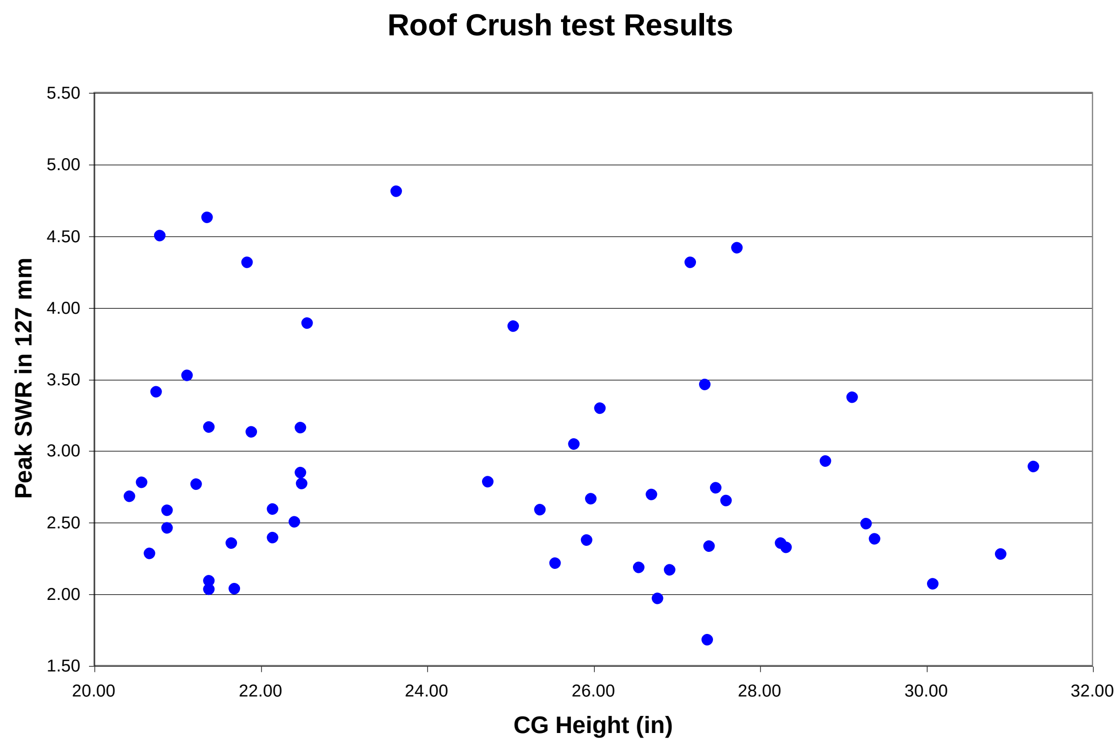


Figure 2 CG height and Peak



SWR

Another way to examine any potential relationship between roof strength and rollover stability is to limit this analysis to vehicles that have been tested before and after a redesign. This analysis should provide a direct comparison of similar vehicle types. Ten pairs of redesigned vehicles were identified. These pairs of vehicles were identified from NCAP test lists and may be a complete modification of vehicle specifications or a subtle retuning of restraint systems. These pairs were confirmed using the IIHS web site and are believed to represent before and after vehicle designs.

Half of the vehicle pairs, shown in Table 1 below, increased SWR. For SSF, six vehicle pairs had an increase (equating to increased stability), while only one redesigned vehicle had a decrease, and one redesigned vehicle stayed the same. Two of the vehicle pairs did not have rollover NCAP results for one of the vehicles. Of the eight pairs of vehicles with known CG height, only two resulted in increases in CG height.

Table 1: Redesigned Vehicle Pairs

Test	Make	Model	Year	UVW (kg)	GVWR (lbs)	Peak SWR	SSF	CG (in)	Model Status
296	CHEVROLET	Express	2003	2,873	9601	2.04			Older Model
521	CHEVROLET	EXPRESS	2007	2,471	8600	2.27	1.10	30.91	Redesigned Model
145	CHEVROLET	TAHOE	2001	2,190	6,500	2.92	1.14	28.8	Older Model
523	CHEVROLET	TAHOE	2007	2,462	7100	2.06	1.12	30.09	Redesigned Model
143	DODGE	RAM1500	2002	1,980	6,350	2.48	1.16	29.29	Older Model
428	DODGE	RAM1500	2006	2,287	6,700	1.67	1.24	27.38	Redesigned Model
142	FORD	CROWN VICTORIA	2001	1,787	5,237	2.09	1.51	21.39	Older Model
308	FORD	CROWN VICTORIA	2003	1,791	5,804	2.02	1.51	21.39	Redesigned Model
294	FORD	F150 PICKUP	2003	1,842	6049	2.88	1.04	31.3	Older Model
525	FORD	F150 PICKUP	2007	2,413	7050	2.32	1.18	28.33	Redesigned Model
146	FORD	MUSTANG	2002	1,391	4,365	2.58			Older Model
421	FORD	MUSTANG	2006	1,527	4,340	2.68	1.53	20.44	Redesigned Model
440	HONDA	ACCORD	2004	1,413	4,080	2.76	1.42	21.235	Older Model
563	HONDA	ACCORD	2008	1,476	4299	3.52	1.48	21.129	Redesigned Model
147	HONDA	CRV	2002	1,478	4,320	2.66	1.16	25.985	Older Model
547	HONDA	CRV	2007	1,529	4560	2.58	1.22	25.37	Redesigned Model
144	TOYOTA	CAMRY	2002	1,400	4,090	3.12	1.38	21.9	Older Model
535	TOYOTA	CAMRY	2007	1,468	4470	4.31	1.42	21.85	Redesigned Model
295	TOYOTA	TACOMA	2003	1,404	5104	2.69	1.11	26.71	Older Model
529	TOYOTA	TACOMA	2007	1,489	4550	4.41	1.14	27.74	Redesigned Model

Examination of Table 1 reveals that most of the redesigned vehicles did not have a significant change in the peak SWR. To better examine the effect of increasing roof strength, the vehicles in Table 1 were limited only to the vehicle redesigns which had greater than a 0.5 increase in peak SWR. Table 2 lists the three pairs of vehicles that had a > 0.5 increase in the peak SWR. For these vehicles, the SSF increased for all three vehicles, suggesting increased stability. Two of the redesigned vehicles had almost no change in the CG height. The third, the redesigned Toyota Tacoma, raised its CG height by over an inch, but this was offset by an increase in the vehicle track width.

Table 2. Redesigned vehicle pairs with > 0.5 increase in SWR.

MAKE	MODEL	YEAR	UWR	SWR	SSF min	cg (in)
TOYOTA	CAMRY	2002	1400	3.12	1.38	21.9
TOYOTA	CAMRY	2007	1468	4.31	1.42	21.85
TOYOTA	TACOMA	2003	1404	2.69	1.11	26.71
TOYOTA	TACOMA	2007	1489	4.41	1.14	27.74
HONDA	ACCORD	2004	1476	2.76	1.42	21.24
HONDA	ACCORD	2008	1413	3.52	1.48	21.13

NHTSA has evaluated a number of vehicles in support of the FMVSS No. 216 rulemaking program. While one might expect that an increase in roof strength should be associated with a reduction in rollover stability, NHTSA testing has revealed no such trend. This is consistent with the view that manufacturers currently have sufficient design flexibility to offset any potential increase in roof weight by other changes in the vehicle.

Discussion

Changes made to meet increased roof strength requirements could result in very minor shifts in the CG of passenger vehicles. For the 2 FEM models that were measured to the proposed force level, the predicted change in CG is below the measurable level of accuracy for CG. We are physically unable to accurately determine CGs within approximately 0.5% of the measured height,[59] which is the equivalent of roughly plus or minus 3 mm. The predicted changes in CG were less than 2 mm for the E-150 and less than 1 mm for

[59] See An Overview of a Vehicle Inertia Measurement Facility by Heydinger, Coovert, Lawrence, Durisek, and Guenther, 27th International Symposium on Automotive Technology and Automation, ISATA Paper 94SF034, October, 1994.

the Neon – roughly the width of a pencil line. For the sample of 51 vehicles in the simulation exercise, resulting changes in CG typically ranged from 0.1 to 0.2 inch, or roughly 2-5 mm. Nonetheless, when applied to the Agency's SSF rollover probability model and projected across the full vehicle fleet, these tiny shifts result in an analytical prediction that a small number of crashes will become rollovers, and that a small number of fatalities and injuries will occur which will offset a portion of the benefits from increased roof strength.

The agency believes there is a great deal of uncertainty regarding the actual changes that manufacturers will initiate in response to this rule, but there are numerous ways to address both roof strength and rollover propensity simultaneously and there is evidence from current NCAP ratings that manufacturers are routinely doing so. Manufacturers generally strive to maintain or improve their NCAP ratings to help market their vehicles. The Agency believes that this concern over NCAP ratings would preclude a design strategy that unnecessarily increases CG and degrades SSF. Further, agency testing of 10 redesigned vehicles with higher roof strengths found that manufacturers had maintained ssf levels while increasing roof strength in newly redesigned models.

Ultimately the impact that revisions to FMVSS No. 216 will have on the frequency of rollover crashes will depend on how manufacturers choose to address the issue. Regardless of which approach manufacturers choose, the challenge they face for this standard is similar to that which they face with any redesign of their vehicle – to optimize the vehicle's performance and safety using the most efficient design and production methods. The agency believes that manufacturers would adopt a strategy that prioritizes maintaining or improving a vehicle's current rollover mitigation characteristics.

Appendix B, Docket Summary

This Appendix summarizes selected docket comments and agency responses for comments related to costs and benefits of this rulemaking. Many of these comments and responses are also addressed in the body of the analysis.

Benefits:

Compliance Margin

Safety Research & Strategies, Inc. (SRS) stated that the strength to weight ratio (SWR) need only increase an average of less than 10 percent because manufacturers already have built-in compliance margins of 20-25%. SAFE argued that in their experience the typical safety margin is 10%-15%, and in some cases is less than 5%.   Public Citizen (PC) argued that NHTSA must provide evidence for its assertion that vehicles will generally over-comply with the standard.

NHTSA Response: As noted in both the PRIA and elsewhere in this FRIA, the sample of vehicles tested by NHTSA had SWRs that exceeded the requirements of FMVSS 216 by considerable margins, averaging well in excess of the 20% margin assumed by the Agency. In the course of subsequent industry meetings and docket comments, the Agency has not received any factual information contradicting this assumption. Moreover, we note that whatever assumption NHTSA uses will affect both costs and benefits since costs will be estimated to the same level that benefits will be calculated to.

Weight Impacts on Safety

Safety Research and Strategies Inc. (SRS) stated that increased SWR can be achieved through improved and optimized design and use of stronger lightweight materials such as high strength steel and structural foam. They stated that the average additional weight needed to bolster the SWR of a mid-sized SUV to 3.5

is less than 30 pounds.

The Center for Auto Safety (CAS) stated that costs and weight impacts can be minimized by new designs, materials, and technologies that can be used to substantially increase roof strength at little or no added cost or weight. They cited plastic inserts designed by L&L Products (L&L) as an example of such technologies.

The Alliance of Automobile Manufacturers (AAM) stated that the effect of increased weight would be disproportional to larger vehicles which would increase the mass mismatch between large and small vehicles and negatively impact safety.

NHTSA Response: NHTSA agrees that weight impacts can be mitigated through the use of advanced design and lightweight materials. In fact, the Agency believes that manufacturers will strive to minimize the weight impacts of the standard for a number of reasons related to both vehicle safety and fuel economy. However, it is still likely that for some part of the fleet there will be weight penalties associated with stronger roofs. However, we also note that mass mismatch is not the only impact of weight change. NHTSA's extensive study of vehicle compatibility indicates that adding weight to vehicles also has a positive impact on overall safety due to increased protection in a variety of crash types, including single vehicle crashes. In fact, the study indicates that the benefits from added weight outweigh the dis-benefits due to increased mass incompatibility. NHTSA views projections of safety impacts due to weight changes as problematic because the specific weight changes for vehicles and their subsequent interaction in future crash modes is highly speculative.

<u>Target Population</u>

The Center for Auto Safety (CAS) and Advocates for Highway and Auto Safety (AHAS) argued that improving roof strength would impact ejection and that mitigated ejections should therefore be included in the agency's benefit calculations. AHAS also argued that rear seat occupants should be covered by the revised standard. SAFE argued that roof crush increases the likelihood of glass fracture and deforms vehicle structure, thereby increasing the possibility of ejection. They also argue that roof crush reduces the effectiveness of restraint systems, decreases the effectiveness of rollover air curtains, and decreases the ability of occupants to be extricated from the vehicle. Xprts,LLC (XPRTS) disagreed with several of NHTSA's target population restrictions. They stated that ejected occupants, rear seat occupants, and children under 12 should be included. They also argue that roof crush can cause thoracic and spinal injuries, and that upper extremity injuries from ejection through side windows should also be included. Many of these points were repeated in a separate submission by the Center for Injury Research (CIR) signed by one of the XPRT authors. Consumers Union (CU) and Public Citizen (PC) also argued that stronger roofs would reduce ejections and better maintain the performance of other safety features such as safety belts, air bags, and door locks. PC also argued that unbelted occupants would benefit from stronger roofs.

NHTSA Response: To examine the inclusion of different categories of injuries in the target population, the agency has conducted several analyses of ejections in rollovers. The first study was a statistical analysis examining the relationship between intrusion and ejection. In this study,[60] Strashny examined 36 different Probit models examining belted cases, unbelted cases, complete ejections, all ejections (including both complete and partial ejection), continuous models, dichotomous models, adjusted models based on both quarter turns and roof exposures, as well as unadjusted models. In all, there were 18 models for complete ejections and 18 for all ejections. Strashny found that there was no significant relationship between the level of intrusion and the probability of complete ejection in any of the 18 full ejection models. For all ejections, which include partial ejections, he found some level of significance for 8 of the 18 models, indicating that a minority of the models found a possibility that some partial ejections might be influenced by stronger roofs. However, 12 of the models found no statistically significant relationship between intrusion

[60] Strashny, Alexander, "The Role of Vertical Roof Extrusion in Predicting Occupant Ejection," National Center for Statistics and Analysis, in press.

and all ejections. We note that partial ejections that meet the other inclusion criteria are a part of the target population for this rulemaking.

The Agency then conducted a detailed examination of all fatal complete ejection cases that were excluded from the target population. A panel of 3 safety engineers independently examined each case to determine whether a) for ejections through open doors there was deformation in the door latch area where the root cause could be directly attributed to roof crush, and b) for ejections through windows the broken glass through which the occupant was ejected was directly related to deformation of the roof rather than dynamic crash impulse or roof to ground contact. The panel concluded that there were no cases that met either of these criteria. Therefore, based on these findings and Strashny's finding of no correlation between intrusion and ejection probability, all cases of total ejection were excluded from the target population unless their MAIS level injury occurred inside the vehicle prior to ejection.

For occupants who were unbelted but not fully ejected, we could not establish a relationship between roof crush injuries and the magnitude of roof crush. Strashny analyzed the relationship between intrusion and injuries to unbelted occupants and found no significant correlation. This is not unexpected because unbelted occupants essentially become flying objects inside vehicles as they roll over and head injuries can occur at multiple interior locations. Therefore, only belted occupants are included in the target population.

Regarding the other categories of injuries noted in the comments, partially ejected occupants were already included in the target population, and the agency has decided to include rear seat occupants in the target population based on schematics submitted by both industry and contractors indicating that some design solutions contemplated for increased roof strength might benefit rear seat occupants as well as front seat occupants. These designs solutions included both stronger B-pillars and stronger B to C-pillar load paths. The agency has also decided to include belted children in the target population.

Quality of Database

CAS stated that NHTSA used data which was not relevant to its analysis, and ignored or misinterpreted much of the data from another data set that involved rollover crashes with at least 6 inches of roof crush. CIR argued that the data base used by NHTSA was scant and that parts of it were not relevant to head injury. PC also stated that many of the cases used in the agency's analysis were not relevant or were mischaracterized in the accident report.

NHTSA Response: The agency disagrees tat the data set it used was irrelevant to its analysis. The Crashworthiness Data System is the best available sources for detailed information on crash and injury characteristics. In addition, the cases we examined were those that meet specific guideline for inclusion in the target population. The agency's engineering staff examined the cases individually and disagrees with commentors contentions. We note that for the final rule the methods used to estimate benefits are no longer tied as closely to specific case details, and also that a larger data base is now in use which significantly increases the sample size.

Value of Life

AHAS stated that the $3.5 million value of a statistical life used by the agency is too low. They cited several studies that mention values significantly higher than the $3.5 million value. They conclude that the agency's valuation is at the lower end of values used by other departments and agencies of the Federal government. PC also stated that $3.5 million is below what many juries award and that some nonfatal injuries can also exceed this value.

NHTSA Response: On February 5th, 2008, the U.S. Department of Transportation officially increased the value of statistical life that should be used by various DOT modes to $5.8 million. This value was based on an extensive review of current literature. The official DOT guidance also recommends that a range of values, $3.2 million and $8.4 million, be analyzed in recognition of the uncertainty that exists surrounding this issue.

Pass/Fail Rates

The Alliance of Automobile Manufacturers (AAM) stated that NHTSA underestimated the number of vehicles that would need to be redesigned to comply with the proposed requirements. They stated that manufacturing processes require that all vehicles that share a common body shell be modified to the requirements of the heaviest vehicle offered with that body. Thus, the weight of optional engines, transmissions, suspension systems, etc., should be considered in estimating the portion of the fleet that must be redesigned.

NHTSA Response: NHTSA agrees with AAM that this would be a factor in vehicle redesigns. In the PRIA the agency estimated failure rates based on the performance of specific vehicles, but did not make adjustment for worst-case vehicle weights. NHTSA has adopted this procedure for the FRIA. The agency notes that, in addition to increasing the portion of the fleet that will be modified, this will effectively increase the fleet average roof strength to a level above the minimum requirements of the standard because lighter weight versions of each body shell will still meet the higher standard based on the maximum weight for vehicles that share the same body shell.

Benefit Methodology - Curves

Safety Analysis and Forensic Engineering (SAFE) stated that the ability of a roof to resist roof crush is directly related to the energy the roof can resist, not necessarily the peak force. They further stated that the NHTSA benefit estimates were flawed because of their assumption that the shape of the force vs. displacement curves would be the same regardless of roof strength. SAFE argued that in their experience force vs. deflection curves for stronger roofs almost always reach peak force much faster and tend to remain at a fairly high level of force throughout the test, unlike weak designs, which may drop off dramatically after reaching peak force. They also noted that they had conducted inverted drop tests in which incremental increases in roof strength result in exponential reductions in roof crush.

NHTSA Response: In the vehicle modifications study, the finite element analysis (change in energy deflection) the profile curves were coarsely estimated by using a linear scaling approach. While this approach is clearly not a real-world representation, it provided a uniform methodology that the agency could use to compare all the NHTSA vehicle test data points in a similar format. The agency used this approach to estimate the incremental shift that might occur due to added strength requirements. A change in deformation modes could either increase or decrease the predicted impact of higher strength requirement on any specific vehicle, but lacking comprehensive modeling and exact product plans for the vehicle fleet, predicting changes in deformation modes is problematic. Moreover, linear scaling is not intrinsically biased in either direction, so to the extent that deformation modes do change on specific vehicles, the overall impacts should be minimized. The agency recognizes that there may be specific vehicle designs that, when coupled with specific design changes, would experience reductions in roof crush that would either exceed or be less than those that occur under an assumption of linear scaling. Without specific design schematics for every model vehicle, the agency believes that the assumption of linear scaling is a reasonable method to estimate the relative performance of vehicles under different roof strength scenarios.

Approach

Advocates for Auto and Highway Safety (AAHS) stated that the approach used to estimate benefits is subject to considerable uncertainty due to the limited number of cases that fit the narrow target population that are saved by the proposed rule. This issue was also noted by AAM.

Chrysler had a number of specific concerns regarding the methodology employed in the PRIA. Chrysler argued that 1) There is an inconsistent injury severity relationship with post-crash headroom, pre-crash headroom, and occupant height in Austin et al, the paper on which the agency relied to establish its basic benefit relationships. 2) The agency should not assume that the relationship between post crash headroom and AIS 2+ injuries can be used as a surrogate for fatal injuries. 3) The agency did not provide a rationale for the inconsistent trend in effectiveness rates across injuries of different severities. 4) The effectiveness estimates should be adjusted for confounding effects such as rollover severity, occupant age, gender, vehicle type, and end-over-end rollover. 5) Approach B, which was adopted by the agency to overcome data limitations, is not justified. 6) The linear-scaled mass increase that the agency estimated for the Dodge Ram pickup based on a finite element model of the Ford E-150 Van is too low to represent vehicles over 6000 lbs. GVWR. 7) The agency's finite element model analysis of the Dodge Neon is based on deficient test data. 8) The linear scaling applied by the agency to estimate the center of gravity shift does not appear to accurately reflect the impact of changes anticipated by Chrysler for their Dodge Ram 1500 pickup. 9) The agency did not account for the impact on safety that would result from added mass incompatibility due to larger weight changes on heavier vehicles. 10) The agency scaled the force deflection curves under the assumption that roof load carrying capacity can be increased without any change in deformation mode. 11) The agency has not justified the choice of 7 vehicles it used to establish the load-deflection relationship and has not justified the deterministic relationship in light of variability found among the 7 vehicles. 12) The agency did not demonstrate that the 20 vehicles that it tested are representative of the current fleet, and thus its conclusions that a 2.0 standard would accomplish little and that 32.4% of the fleet would fail the proposed standard are suspect. 13) The data in Tables IV-1 and IV-2 of the PRIA should match those in Table 5 of Austin et al but they do not. 14) It is unclear which years data were used for estimating the target population. 15) The agency did not explain how the adjustment was made to reflect the average number of non-convertible light vehicle rollover fatalities in FARS from 1997 through 2002.

NHTSA Response: NHTSA's responses to these comments are as follows: 1) The comment is correct that Austin et al contains the following findings: (1) occupant height is not related to injury severity, (2) vehicle headroom is not related to injury severity, and that (3) occupant height is not related to vehicle headroom. However, we do not agree that these findings contradict the result that post-crash headroom is a statistically significant predictor of injury severity. Post-crash headroom is a function of occupant height, vehicle headroom, and intrusion. Even if these factors do not have a strong enough independent effect to achieve statistical significance, it is reasonable that a variable that combines the three factors could achieve significance. Furthermore, this outcome is similar to statistical models where independent effects are not statistically significant while interaction terms involving the same factors do achieve significance.

2) We do not agree that the relationship in Austin et al is based only on AIS 2 or greater injuries. The relationship is based upon a cumulative logistic regression with four categories: no injury, AIS 1, AIS 2, and AIS 3 or greater (including fatalities). The results of this model are in Table 6. The comment appears to be referring to Table 7. Table 7 was requested by a peer reviewer to ensure that the results in Table 6 were not driven by AIS 1 injuries. Ideally, the fatality cases would be included in a separate category from the AIS 3 or greater survivors, but there were not enough fatality cases in NASS-CDS from 1997 through 2001 to estimate this model.

3) Chrysler stated that the analysis assumes without justification that the distribution of injuries is a characteristic of post-crash headroom. Our justification is the statistically significant relationship between post-crash headroom and injury severity identified in Table 5 of Austin et al. Chrysler also questioned the fact that the effectiveness for serious injuries (AIS 3 through 5) is much lower than the effectiveness for the other injury categories. We agree that this result was likely due to insufficient data. Additional data are now available to expand the data set. Upon adding additional years of NASS-CDS data, the effectiveness

estimate for serious injuries becomes much more similar to the estimate for minor and moderate injuries.

4) The purpose of including control variables such as number of quarter-turns and occupant age in the multivariate model of injury severity was to determine whether the bivariate relationship between post-crash headroom and injury severity was spurious. The fact that the effect of post-crash headroom on injury severity remained statistically significant even when adding five control variables indicates that post-crash headroom has an effect independent of the other controls, i.e., the relationship is not spurious. The finding that the control variables have a statistically significant effect does not necessarily indicate that they must be accounted for in the calculation of effectiveness. However, it suggests that controlling for the confounding factors would have little or no consequence for estimation of effectiveness because the relationship between the independent variables was not strong enough to explain anyway the effect of post-crash headroom.

The relationship among the independent variables with the strongest theoretical possibility is the relationship between the type of rollover (number of quarter turns or end-over-end) and post-crash headroom. To further explore whether we need to account for the additional control variables, we calculated effectiveness in two situations: (1) occupants of vehicles with two to four quarter-turns to the side (lower severity) and (2) occupants of all other rollover vehicles (higher severity). The lower severity situation accounts for 75% of the weighted number of occupants, which meant that the higher severity situation did not have enough cases to provide a more detailed analysis. The effectiveness estimates for serious and fatal injuries in the lower severity crashes was a little higher than the overall estimate and in the higher severity crashes was a little lower than the overall effectiveness. While this finding confirms that rollover severity is one of the factors that affects injury severity, it also suggests that controlling for severity does not substantively change the relationship between post-crash headroom and injury severity.

The effect of controlling for rollover severity on the effectiveness estimates for the moderate (MAIS 2) and minor (MAIS 1) injuries is more complex. The effectiveness estimate for preventing moderate injuries is much higher for higher severity rollovers than for lower severity rollovers. The same relationship appears to a smaller degree for minor injuries. We believe that these results are due in part to relatively small case counts for minor injuries (especially in the higher severity rollovers) and in part to high variation in the weights for the moderate injuries. Regardless, the results do not suggest that controlling for rollover severity would attenuate our estimation of effectiveness.

5) As explained in the PRIA, Approach B was adopted to overcome distortions caused by the small sample of relevant cases contained in our databases. The PRIA states that "…. due to a combination of a small sample of relevant cases and unknown data elements, this analysis suffered from gaps in data and spikes in case weights. An alternative analysis was thus performed based on a construct, which assumes a probability of occupant height in each vehicle equal to the national distribution of occupant heights (Approach B). This was done to mitigate the impact that specific driver characteristics had in determining the inclusion of the case. The theory behind this is that any size occupant might have been involved in a crash of each case's specific intrusion magnitude. By reflecting the probability that the occupant was of a height that would benefit from specific reductions in roof crush, the spikes in case weights would be minimized. The agency recognizes that this method assumes a random relationship between the height of drivers and the headroom that exists in vehicles that they purchase. To the extent that driver's height and vehicle headroom are actually related, this second approach loses credibility. However, the agency did examine the relationship between vehicle headroom and occupant size and found "no perceptible trends." Chrysler stated that there does not seem to be a reason to introduce approach B, and that it was not clear what its beneficial impact would be. We believe the discussion in the PRIA adequately explains the reason for establishing Approach B, as well as its beneficial impact.

6) NHTSA does not have the time or resources to estimate by finite element analysis the mass gains of every light vehicle sold in the US that might be affected by the proposed roof strength requirement. The

agency recognizes that these 2 vehicles are a poor sample to represent the vehicle fleet and stated so in its analysis. The Dodge Neon and Ford E-150 represent a wide range of vehicle types. We agree that the max laden Dodge Ram 1500 pick-up represents an extreme possibility of increased weight gain. However, it is not representative of the vast majority of vehicles on the road. The agency is conducting several additional tear down studies based on finite element analysis and will incorporate these additional data into the revised analysis.

7) While the Dodge Neon finite element model was not originally intended for roof crush modeling, we believe that the suggested structural modifications/design changes and the associated weight and strength gains are reasonable for the indicated roof strengths.

8) NHTSA recognizes that linear scaling will be less accurate for some vehicles than for others. In the case of the Dodge Ram pickup, Chrysler has provided design changes that exceed those that would be predicted by linear scaling. However, we note that much of the difference may be due to the fact that changes measured by Chrysler reflect the vehicle equipped to reflect it's maximum load capacity, whereas NHTSA based its estimate on an average capacity version. NHTSA is adjusting for maximum load capacity throughout its final analysis.

9) This is correct. NHTSA did not attempt to estimate safety impacts from increased mass incompatibility. The agency estimated average weight gains of 4 lbs for affected passenger cars and 6 lbs. for affected light trucks. These small increases did not warrant such an analysis. However, we also note that mass mismatch is not the only impact of weight change. NHTSA's extensive study of vehicle compatibility indicates that adding weight to vehicles also has a positive impact on overall safety due to increased protection in a variety of crash types, including single vehicle crashes. In fact, the study indicates that the benefits from added weight outweigh the dis-benefits due to increased mass incompatibility. NHTSA views projections of safety impacts due to weight changes as problematic because the specific weight changes

for vehicles and their subsequent interaction in future crash modes is highly speculative.

10) In the vehicle modifications study, (i.e., the Finite Element Analysis (change in energy deflection)) the profile curves were coarsely estimated by using a linear scaling approach. While this approach is clearly not a real-world representation, it provided a uniform methodology that the agency could use to compare all the NHTSA vehicle test data points in a similar format. The agency used this approach to estimate the incremental shift that might occur due to added strength requirements. A change in deformation modes could either increase or decrease the predicted impact of higher strength requirement on any specific vehicle, but lacking comprehensive modeling and exact product plans for the vehicle fleet, predicting changes in deformation modes is problematic. Moreover, linear scaling is not intrinsically biased in either direction, so to the extent that deformation modes do change on specific vehicles, the overall impacts should be minimized.

11) The agency created average load-deflection curves to facilitate an analysis of the change that would occur in displacement due to stronger roof structures. These curves were based on a sample of vehicles for which the agency had tested and which did not meet the proposed strength requirements. This sample includes a variety of vehicle and body types including passenger cars, vans, SUVs, and pickups. The agency recognizes that there is variation in force-displacement curves among different vehicles. However, it is impractical and unreasonable to expect the agency to derive separate curves for every vehicle in production. The agency does not have the financial or human capitol resources to accomplish this type of effort within a timeframe that is consistent with either the practical need for improved roof safety, or the deadline established by Congress to issue a final rule. The agency believes that it is reasonable to establish an average relationship based on an available sample and apply this relationship across the vehicle fleet.

12) The 20 vehicles the agency tested represent a wide variety of roof structures including every popular

vehicle body type. Nineteen of the twenty vehicles already had roof structures that could withstand 2.0x vehicle weight. The agency believes that this is a sufficiently large sample size from which to draw the conclusion that setting a standard at 2.0 would produce inconsequential safety benefits. The agency also feels this is a reasonable basis for estimating the failure rate for the 2.5 and 3.0 alternatives. The agency has modified these estimates in response to comments from the industry that manufacturing processes require that all vehicles that share a common body shell be modified to the requirements of the heaviest vehicle offered with that body.

13) The data in Tables IV-1 and IV-2 of the PRIA differ from those data used in Austin et al for several reasons. Austin et al used data from 1997-2001 to demonstrate and establish the methodology that was the basis for the PRIA benefit estimates. For the PRIA, the agency reexamined the Austin et al analysis using 1997-2002 data restricted to the sole MAIS injury definition established in the PRIA. The same dichotomous relationship originally found in Austin et al was still present using the modified data base.

14) NASS-CDS data from 1997-2002 were used for estimating the target population. The statement that refers to 1997-2001 data is correct for the specific circumstances it describes (the portion of fully ejected roof-involved rollover injuries where the most serious injury was obtained outside/inside the vehicle).

15) Fatalities were adjusted to reflect the average number of non-convertible light vehicle rollover fatalities in FARS using a standard normalizing procedure – i.e., CDS totals were increased to reflect the difference between FARS totals (which are based on a complete census of fatal crashes), and CDS totals (which are estimated from the CDS sample). The ratio of FARS/CDS fatalities was applied to the CDS based target population.

Roof Crush as a Cause of Injury

A number of commenters including GM, Ford, Nissan, and Safety Analysis Inc (SAI) stated that the statistical correlation Strashny found between roof intrusion and injury does not establish a causal relationship between roof deformation and injury. SAI noted that the studies by both Rains and Strashny merely suggest that there is a relationship. SAI stated that "….when you compare rollover accidents that have significant roof/pillar deformation with other rollover accidents that have very little or no roof/pillar deformation, you are not comparing similar accidents with respect to roof-to-ground impact severity. Just the fact that two vehicles are in a rollover with greater than 2 quarter turns does not mean they are in the same or even similar impact severities." SAI also noted an earlier study (matched pair comparison project) in which production and roll bar-equipped vehicles were tested where the comprehensive forces measured on test dummies were similar regardless of the vehicle roof crush. Ford stated that "The amount of roof deformation is only an indication of the severity of the impact between the roof and the ground…." GM stated that "Observations of injury occurrence at the end of a rollover collision reveal nothing regarding the relationship of roof deformation, roof strength, or roof strength-to-weight ratio injury causation." Nissan stated that deformation and injury severity are both independently associated with roof impact severity.

NHTSA Response: The agency agrees that as a general principle, a statistical correlation does not in itself prove beyond a doubt that a causal relationship exists. However, the Strashny study was designed with a strict focus to only include injury scenarios where the intruding roof was the injury source. The study compared cases where there was intrusion to cases where there was no intrusion and found that as intrusion increases, the probability of, and severity of injury also increases. The study controlled for crash severity using quarter turns, which is the best available metric for rollover severity. Contrary to SAIs contention, the study does not compare crashes over 2 quarter turns as a group. Rather, it compares only crashes of similar severity as defined by each iterative quarter turn exposure. Thus, a vehicle that experienced 3 quarter turns would only be compared to other vehicles that experienced 3 quarter turns. SAI's and Ford's argument seems to imply that any difference in roof intrusion must be due to a difference in impact severity rather than roof strength or design, whereas the Strashny study, by controlling for quarter turns, attempts to minimize differences due to impact severity. Further, the study included only belted cases which minimized the impact of “diving” as an injury cause.

There are logical reasons to believe that a collapsing roof that strikes an occupant’s head at the nearly instantaneous impact velocity experienced when structures deform might cause serious injury. These types of injuries were documented by Rechnitzer and Lane in a detailed investigation of 43 rollover crashes.[61] The agency believes that the statistically significant relationship between roof intrusion and injury found in the Strashny study indicates not just a suggestion, but a probability that roof crush causes injuries.

Regarding the SAI matched pair comparison project, the agency notes that the dummy necks used in the tests are rigid structures that do not allow for the normal bending that occurs in the human spine. The agency believes that lateral bending plays an important role in determining the degree of injury sustained by humans in rollovers, and does not view these results as an adequate measure of human injury during rollover crashes.

Philosophical Objections

PC objected to the concept of discounting future lives saved, arguing that it is an ethically challenged approach that skews the cost-benefit comparison in favor of less stringent standards. They also argue against the use of cost-benefit analysis in making policy decisions, arguing that it ignores the idea that not all costs have the same moral or ethical value. They argue that regulatory costs represent the cost to industry of what it should have done as a good corporate citizen in the absence of regulation, and are thus merely the appropriate price for participation in society.

NHTSA Response: Discounting of future costs and benefits is a standard analytical practice widely accepted by economists, courts, and academia as a necessary adjustment to reflect the basic concept of time preference. Rather than skewing the cost-benefit in favor of less stringent standards, it properly adjusts future impacts so that the results are not improperly skewed to favor delayed impacts over immediate impacts. In a world of limited resources, society would choose programs that provide benefits immediately or in the near future over programs that provide the same nominal benefits in the far future. The agency will continue to discount future cost and benefit impacts as properly required by OMB guidelines.

PC's argument that the costs of regulation represent the cost to industry of being a good corporate citizen fails to consider that cost-benefits analysis is conducted at the consumer level. Although the initial investment needed to modify vehicles to meet new safety standards is borne by the industry, ultimately these costs are passed on to consumers in the form of higher vehicle prices. Moreover, in the case of roof crush standards, there is potentially a significant weight penalty that will affect the vehicle's fuel efficiency and increase lifetime fuel costs for consumers. The price that consumers must pay for incremental reductions in risk is a legitimate consideration for policy makers in determining the advisability and/or extent of safety regulations.

Scope of Analysis

PC argued that NHTSA should consider a 3.5 SWR alternative. They argue that roof crush benefits will be small until a substantial increase in roof strength is required.

NHTSA Response: In light of subsequent testing indicating that some current vehicles are capable of meeting 3.5 SWR, NHTSA agrees that this option should be analyzed and has expanded the analysis accordingly.

Calculation Errors

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[61] Rechnutzer, George and Lane, John, "Rollover Crash Study, Vehicle Design and Occupant Injuries," Monash

PC stated that NHTSA's analysis contained mathematical errors in Table VII-1. PC stated that the equivalent fatalities calculation was incorrect because they could not replicate the results listed in the table for several injury levels.

NHTSA Response: NHTSA does not agree that the equivalent fatalities were incorrectly calculated in Table VII-1. Rather, PC's comment reflects the fact that the fatalities and injuries prevented listed in the table were rounded for presentation purposes while the calculation of equivalent fatalities was based on the un-rounded values previously calculated. The equivalent fatalities in Table VII-1 accurately reflect the previously calculated values and their translation based on the relative factors shown in the table.

Allocation of Costs to Other Safety Standards

Several commenters asserted that the cost of strengthening roofs should be partitioned to other safety countermeasures. The Center for Injury Research (CIR), suggested that the costs of FMVSS 216 should be allocated to side impact, frontal offset, and rollover crashes. The Center for Auto Safety (CAS) stated that "Some manufacturers are already using substantially stronger occupant compartments to improve their performance in frontal offset tests and side impact tests. The cost of increased roof crush – which can be successfully engineered into a vehicle only by improving occupant compartment strength generally – must be apportioned among all crash modes. No more than one-third of the cost of the improved roof strength should be allocated to improve rollover occupant protection."

NHTSA Response: The agency agrees that structural changes can potentially have consequences in crash modes other than those for which they were intended. In the case of roof crush, CIR and CAS apparently anticipate that reinforcements added to roof structures will also contribute to added protection in side impact or offset crashes. However, determining these impacts is highly problematic, and the

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University, 1994.

suggestion that costs should be equally divided between 3 crash modes assumes that all three modes would benefit equally from the changes and that all structural changes specifically required to meet the roof crush standard will also contribute to safety in those modes. Neither of the commentors provided any information to support such a contention. CIR did cite several examples of cases where manufacturers had made changes to the IIHS frontal offset crash test which also increased roof strength for those vehicles, but this does not suggest an equal apportionment of costs. The agency believes that most of the reinforcement/redesign involved to increase roof strength would not produce significant results in other modes. For example, side impact crashes might benefit from B-pillar reinforcements that extend below the window sill, but these represent only a small portion of the design changes anticipated to meet FMVSS 216 upgrades, and in many cases they would not be used at all.

Also, the concept of cross-allocating design costs would, in theory, work both ways. If the agency were to allocate costs required to achieve higher roof strength to other crash modes, then shouldn't the agency partially allocate costs to improve safety to other crash modes to roof crush? Failure to properly account for all such interactions would result in a gross undercounting of the full costs of improving safety. Even if the agency had the data needed to properly allocate such costs, the only way such a scheme would work would be if all regulations were promulgated simultaneously, a practical impossibility.

The only practical way to address this issue would be to measure the safety impacts in other modes. The agency has noted, for example, that adding weight above the center of gravity could result in an increased propensity to roll over (although, for reasons discussed elsewhere in this analysis, the agency does not expect manufacturers to do this). Also, several commenters have asserted that added weight will aggravate cases of size-safety mismatch. There are a number of hypothetical safety impacts that the agency is unable to evaluate because they depend on the mix of specific design changes that manufacturers eventually choose to adopt. The agency acknowledges that these impacts could occur to some extent, but also notes that some would improve safety and some would make it worse. These secondary impacts are thus to some extent offsetting, which would mitigate their overall impact.

<u>Costs:</u>

Responses to the NPRM

In Ford's supplemental comments of May 16, 2006, the differences between various vehicles' minimum and maximum UVW were depicted to demonstrate how the potential weight swings lower the SWR at the maximum UVW. This was especially significant with the heavy body-on-frame full size vans and pick-ups. A vehicle design that provided a 2.5 SWR for a maximum UVW ¾ ton pick-up would result in a 4.32 SWR for the same pick-up at the minimum UVW.

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Responses to the SNPRM

The Alliance of Automobile Manufacturers in the December 21, 2006 response provided the following table of added weight and cost necessary to meet the 2.5, 3.0 and 3.5 SWRs for their members' large SUVs and pickup trucks:

Vehicle Type	Baseline Vehicle Weight	Effect of Mods to reach 2.5 SWR +20%	Effect of Mods to reach 3.0 SWR +20%	Effect of Mods to reach 3.5 SWR +20%

Large SUV	5600 lbs to 7200 lbs	Add 60-67 lbs over baseline	Add 150-270 lbs over baseline	Add 250-540 lbs over baseline
Costs		Variable $38-58	Variable $60-90	Variable $110-130
		Fixed $40M-75M	Fixed $80M-90M	Fixed $80M-180M
Large Pickup Truck	5800 lbs to 8900 lbs	Add 38-68 lbs over baseline	Add 85-260 lbs over baseline	Add 120-520 lbs over baseline
Costs		Variable $55-185	Variable $100-200	Variable $165-525
		Fixed $11M-77M	Fixed $11M-218M	Fixed $11M-660M

The Alliance commissioned an independent study by Magna Steyr to demonstrate how an existing vehicle could be modified to satisfy NHTSA's proposed roof crush resistance requirements in the near-term and long-term.

The Magna Steyr analysis indicated that a generic representative vehicle (GRV) crew cab pickup truck could be modified to meet the 2.5 + 20% requirement within 3 years with a weight increase of 73 lbs and at variable cost of $76 for high volume vehicles and $98 for low volume vehicles using current steel technology. With more leadtime, Magna Steyr could develop high strength designs incorporated in the new vehicle platform which could potentially lose 11 lbs over the baseline vehicle at a variable cost of $60 for high volume and $75 for low volume. The unloaded GRV baseline vehicle weighed 7,357 lbs with an initial roof SWR of 1.6.

To demonstrate a 2.5 + 20% SWR compliance of the Ford E-150 van, Magna Steyr's modifications required more component changes, more reinforcements, and more weight gain than NHTSA's estimate. This was due to NHTSA's use of the vehicle's unloaded test weight (5,030 lbs) verses the maximum vehicle weight of the van's common structure (model variants E-250 and E-350 of 7,245lbs).

In the Alliance's response of March 27, 2008, they stated that a range of 25-50 percent increase should be applied to the cost and weights of their December 26, 2006 submission when a vehicle is tested as a two-sided 2.5 SWR instead of a single sided 3.0 SWR. Thus a two-sided test at 2.5 SWR would yield a cost of approximately $50 to $85 for a large SUV and $68 to $275 for a large pickup truck.

Public Citizen in their comments of March, 27 2008, noted the Ohio State Study showed that a Ford Explorer could be modified to have a roof performance of the Volvo XC90 for about $81.

The Center for Auto Safety on March 27, 2008 commented that some manufacturers – including Toyota, General Motors, Ford, and Subaru – are already producing cars and light trucks with substantially stronger occupant compartments in recognition of the occupant protection principals put forth by DeHaven. These manufacturers are using high strength steel in key parts of the occupant compartment structure primarily to improve occupant protection in offset frontal and side impacts. The cost of increased roof strength – which can be engineered into the vehicle only by improving the overall occupant compartment strength, must be apportioned among all crash modes. Thus, no more than one-third the cost of the improved roof strength should be allocated to improved rollover occupant protection.

Advocates for Highway and Auto Safety on March 27, 2008 commented that NHTSA should not base their benefits in any final rule on the exaggerated figures provided by the Alliance of Automobile Manufacturers, for the weight and cost of complying with 2.5X, 3.0X, or 3.5X roof crush resistance. The Alliance estimates cost add an additional $130 for a large SUV to comply with the 3.5X alternative.

CONFIDENTIAL data removed.

Appendix C. Comprehensive Costs

Comprehensive costs which include both economic impacts and lost quality (or value) are used in the cost-effectiveness and net benefit analyses. The agency develops the comprehensive costs for fatalities and MAIS injuries every few years by thoroughly surveying all cost components that are associated with automobile accidents. Cost components include costs for medical, emergency service (EMS), market productivity, household productivity, insurance administration, workplace loss, legal, travel delay, property damage, and quality-adjusted life years (QALYs). The most recent estimates were developed in 2002[62]. Table C-1 shows estimated costs by injury severity levels for both crash avoidance and crashworthiness countermeasures. The difference between these two sets of costs is that travel delay and property damage costs which were typically associated with crash avoidance countermeasures were excluded from the costs for crashworthiness countermeasures.

Table C-1
Comprehensive Costs
(2000 $)

Injury Severity	Comprehensive Cost (for Crash Avoidance)	Comprehensive Cost* (for Crashworthiness)
MAIS 1	$15,017	$10,396
MAIS 2	$157,958	$153,157
MAIS 3	$314,204	$306,465
MAIS 4	$731,580	$720,747
MAIS 5	$2,402,997	$2,384,403
Fatality	$3,366,388	$3,346,966

Source: Table VIII-9 of “The Economic Impact of Motor Vehicle Crashes 2000”

[62] Blincoe, L., *et al.*, The Economic Impact of Motor Vehicle Crashes 2000, Washington, DC, DOT HS 809 446, May 2002.

* Excluding traffic delay and property damage

These comprehensive costs were derived using an earlier DOT guideline on the value of a statistical life (VSL) of $3.0 million. Recently, the DOT revised this guideline and raised the VSL from $3.0 million to $5.8 million, with a range of $3.2 million to $8.4 million to reflect uncertainty. VSL includes QALYs, household productivity, and the after-tax portion of market productivity. The increase of VSL to $5.8 million generally is a reflection of rising cost QALYs. In response to the new guideline, the agency has revised all relative costs for non-fatal MAIS injuries. Currently, the agency is conducting research to estimate the relative values for injuries. The revised estimates will be published when they become available. In the interim, the agency has adjusted the unit comprehensive costs first by adjusting each of the cost components to the 2007 value using an appropriate consumer price index. Then, QALYs for MAIS injuries were adjusted further to reflect the revised QALYs within VSL but the relative injury-to-fatal ratios of QALYs were maintained as estimated in the 2000 report. Table C-2 shows the adjusted unit cost estimates in 2007 values by cost items. As shown, the revised comprehensive cost for a fatality is now estimated to be $6.11 million for crash avoidance countermeasures and $6.10 million for crashworthiness countermeasure. The QALYs for a fatality is estimated to be $4.9 million. QALYs for MAIS injuries were derived by applying QALY injury-to-fatality ratios published in the 2000 report to the $4.9 million. The relative injury/fatal ratios under “comprehensive cost” are used to derive fatal equivalents for benefits accrued from crash avoidance countermeasures and ratios under “injury comprehensive cost” are used for crashworthiness countermeasures.

Table C-2
Unit Costs Reflecting the $5.8 Million Value of a Statistical Life (VSL)
(2007 $)

CPI	Cost Item	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal
1.346066	Medical	$3,204	$21,032	$62,585	$176,747	$447,509	$29,741
1.204077	EMS	$117	$255	$443	$999	$1,026	$1,003
1.277512	Market Productivity	$2,234	$31,960	$91,283	$135,977	$560,451	$760,577
1.277512	Household Produce	$731	$9,354	$26,924	$35,782	$190,743	$244,696
1.204077	Insurance. Admin.	$892	$8,319	$22,749	$38,934	$82,114	$44,695
1.277512	Workplace Cost	$322	$2,495	$5,450	$6,002	$10,464	$11,117
1.204077	Legal Costs	$181	$5,998	$19,034	$40,559	$96,153	$122,982
1.277512	Travel Delay	$993	$1,081	$1,201	$1,276	$11,697	$11,687

1.204077	Property Damage	$4,628	$4,761	$8,187	$11,840	$11,374	$12,369
1.277512	QALYs	$9,118	$186,525	$262,189	$784,778	$2,674,628	$4,889,799
Revised Comprehensive Costs		$22,419	$271,779	$500,045	$1,232,893	$4,086,148	$6,128,667
	Injury Subtotal*	$16,798	$265,937	$490,657	$1,219,777	$4,063,088	$6,104,611
Relative Injury-To-Fatal Ratios							
	QALYs	0.0019	0.0381	0.0536	0.1605	0.5470	1.0000
	Comprehensive Cost	0.0037	0.0443	0.0816	0.2012	0.6667	1.0000
	Injury Comprehensive Cost*	0.0028	0.0436	0.0804	0.1998	0.6656	1.0000

QALYs: Quality-Adjusted Life Years

* Excluding travel delay and property damage and specifically used for crashworthiness countermeasures