Head Restraint IWG Document:
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FINAL REGULATORY IMPACT ANALYSIS

FMVSS NO. 202 HEAD RESTRAINTS

FOR PASSENGER VEHICLES

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

November 2004

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EXECUTIVE SUMMARY

The Final Rule

This Final Regulatory Impact Analysis accompanies a final rule to require front seat head restraints in passenger cars, pickups, vans, and utility vehicles to be capable of achieving a height where the top of the head restraint is at least 800 mm (31.5 inches) above the H-point (which represents the normally seated 50th male hip point). The final rule would also add a lower limit on height; head restraints in all front outboard seats may not be less than 750 mm (29.5 inches) from the H-point. The final rule would not require rear outboard head restraints, but would specify that if head restraints are installed they must be at least 750 mm. It also would require in front seats only that the distance between the back of the head form representing the position of a 50th percentile head, in a normally seated position, and the head restraint (defined as backset) be no farther than 55 mm (2.2 inches) in any adjustment position.

Benefits

The benefits of increasing the height of head restraints and limiting the backset of head restraints are estimated to be:

15,272 whiplash injuries reduced in the front seat
1,559 whiplash injuries reduced in the rear seat
16,831 total whiplash injuries reduced

Costs ($2002)

Average costs per vehicle are estimated to be:
$4.51 in front seats
$1.13 in rear seats for vehicles with rear head restraints
$5.42 per average vehicle

Total cost per year is estimated to be $84.2 million ($70.1 million for the front seat and $14.1 million for the rear seat).

Cost Effectiveness

The cost per equivalent life saved is estimated to be:
$2.39 million in front seats
$4.71 million in rear seats
$2.61 million total

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I. INTRODUCTION

There are an estimated 272,088 whiplash injuries per year occurring in police-reported and unreported rear impact crashes. Many of these rear impact crashes are at low speeds. It is the consensus of the biomedical community that, at least on a macroscopic level, whiplash injuries due to rear impact crashes occur as a result of the movement of the head and neck relative to the torso. Minimum height requirements are based on the premise that in the case of no head restraint, both the bending moment on the neck and the head rotational angle is maximized, resulting in cervical hyperextension (movement beyond the normal range of motion).

When Federal Motor Vehicle Safety Standard (FMVSS) No. 202, "Head Restraints," was first promulgated in 1969 it was believed that a head restraint height of 700 mm was sufficient to prevent neck hyperextension for most occupants and, therefore, mitigate whiplash injuries. However, current research indicates that whiplash may occur as a result of head and neck movement insufficient to cause hyperextension. Height requirements beyond the current levels are intended to prevent whiplash injuries by further limiting the movement of the head and neck. It is also widely believed that reducing the gap between the occupant's head and the head restraint should reduce the movement of the head relative to the torso, and thus result in lower whiplash rates.

The Final Rule upgrades FMVSS No. 202 by requiring head restraints to be higher, closer to the head, and be available in front outboard positions. Head restraints are not required in the rear outboard seating positions. The Final Rule harmonizes many parts, but not all of FMVSS No. 202 with the Economic Commission for Europe Regulation No. 17 (ECE 17) - Uniform Provisions Concerning The Approval Of Vehicles With Regard To The Seats, Their Anchorages And Head Restraints (Head Rests). Although ECE 17 regulates rear seat head restraints, it does not require them. The width and gap measurements in FMVSS 202 for adjustable restraints differ from those found in ECE 17. Further, the final rule adds requirements for backset and adjustment retention locks for front outboard seating positions. The final rule also contains an optimal dynamic test not found in ECE 17.

II. BACKGROUND

Current Standard

Since January 1, 1969, passenger cars have been required by FMVSS No. 202 to have head restraints in the front outboard seating positions. FMVSS No. 202 also applies to light trucks manufactured after August 31, 1991. The standard requires that either of two conditions be met:

1) During a forward acceleration of at least 8g on the seat supporting structure, the rearward angular displacement of the head reference line shall be limited to 45° from the torso reference line: or

2) Head restraints must be at least 700 mm (27.5 inches) above the seating reference point in their highest position and not deflect more then 100 mm (4 inches) under a 373 Nm (3,300 inch-pound) moment. The lateral width of the head restraint, measured at a point either 65 mm (2.56 inches) below the top of the head restraint or 635 mm (25 inches) above the seating reference point, must be not less than 254 mm (10 inches) for use with bench seats and 171 mm (6.75 inches) for use with individual seats. The head restraint must withstand an increasing rearward load until there is a failure of the seat or seat back, or until a load of 890N (200 pounds) is applied.

The head restraint evaluation[1] performed by NHTSA in 1982 on passenger cars found that the effectiveness of integral restraints was 17 percent in reducing rear impact injuries, while adjustable head restraints were 10 percent effective in reducing rear impact injuries. An integral head restraint consists of a seat back high enough to meet the 750 mm (27.5 inch) height requirement. An adjustable head restraint consists of a separate head restraint pad that is attached to the seat back by sliding metal shaft(s). The head restraint may be adjustable to several positions. The difference in effectiveness found in the 1982 evaluation may have been due in

1 Kahane, C., "An Evaluation of Head Restraints, Federal Motor Vehicle Safety Standard 202" NHTSA, February 1982, DOT HS- 806-108, pg 46.

part to adjustable restraints not being as high as integral restraints when in their lowest position and not being properly positioned.

While the 1982 evaluation estimated the benefits of any injury in a rear impact, for the most part, head restraints are designed to reduce whiplash injuries. Page 86 of the same evaluation provides data that can be used to estimate the benefit of head restraints for just whiplash injuries. The data in the 1979 NASS data file were used because the effectiveness statistics were calculated using these data. The Agency is not aware of any more recent statistics on effectiveness of head restraints in passenger cars. Combining non-towaways and towaways, whiplash injuries were the only injury in 60 percent of the cases. Thus, the effectiveness of head restraints in reducing whiplash injuries can be estimated to be 28.3 percent (17/0.6) for integral restraints and 16.7 percent (10/0.6) for adjustable restraints. This assumes that head restraints are only effective in reducing whiplash injuries.

General Summary of Comments to NPRM

There were 48 separate submissions to the docket (NHTSA-2000-8570) for the FMVSS No. 202 NPRM.

These included submissions from the following types of people and organizations:
1 consumer; 9 vehicle manufacturers and their associations; 2 seat suppliers; 2 equipment suppliers; 4 insurance companies and their associations; 1 standards organization; 1 research institute; 2 biomechanical researchers; 2 physicians; 1 doctor of osteopathic medicine; 6 chiropractors; 1 Senator; 1 Congressmen; 2 State Legislators; 1 advocate organization; and 1 group of university students.

Nearly all commenters who stated a preference indicated support for some type of upgrade to FMVSS 202. Vehicle manufacturers indicated a preference to have the upgrade limited to harmonization with the ECE. This would include the proposed height requirements, energy absorption, gap limits, and rear seat head restraints as optional equipment.

Advocates for Highway Safety (Advocates) believed the proposal was basically sound and would advance the cause of occupant safety, but in some areas asked the agency to consider more stringent requirements. One area of particular concern for Advocates was the allowance of adjustable head restraints to have minimum heights less than that of fixed head restraints. Transport Canada (016) was supportive of the changes proposed in FMVSS No. 202 and expected they would result in reduced injury and societal cost.

Insurance organizations were very supportive of most aspects of the proposal. However, the Insurance Institute for Highway Safety (IIHS) indicated that, although they support a dynamic test procedure in concept and in the past supported maintaining a dynamic test option in FMVSS No. 202, the time might not be right to incorporate a dynamic test option in this upgraded regulation.

III. THE FINAL RULE

The Final Rule requires that head restraints in all front outboard seats, when adjusted to their lowest possible adjustment position, be higher (at least 750 mm or 29.5 inches) than they are currently required to be at their highest position (at least 700 mm or 27.5 inches). It also requires head restraints in front outboard seats to be able to achieve a greater height at their maximum height adjustment in front outboard seats (at least 800 mm (31.5 inches)), and lock positively in that position. Head restraints in all front outboard seats are subject to a new requirement limiting the amount of backset to less than 55 mm (2.2 inches) at any height adjustment position between 750 and 800 mm.

This final rule does not require head restraints in rear outboard designated seating positions. However, if manufacturers choose to install head restraints in rear outboard seating positions, these head restraints must meet a height of 750 mm and meet the same strength, position retention, and energy absorption requirements of the front outboard head restraints.

The definition of a rear head restraint: This final rule provides an objective definition and a test procedure for determining the presence of a rear head restraint. In developing this objective methodology we considered several alternatives. We decided that a vehicle would be considered to have a rear head restraint if any portion of the rear outboard seat back structure has a height equal to or greater than 700 mm in any position of adjustment, as measured with the J826 manikin.

We chose this method for the following reasons. Based on the survey of vehicles used to determine the cost effectiveness of this regulation, we found that the 700 mm threshold captured all of the seats that had adjustable cushion components at the top of the seat back; i.e., what the general public would probably consider to be a head restraint.[2] Thus, this method would in fact allow us to regulate most rear adjustable head restraints and some rear integral head restraints currently on the market. Further, this definition of the rear head restraint will allow the manufacturers to provide a relatively tall seat back (up to 700 mm) without having to comply with rear head restraint requirements. We anticipate that such taller seat backs might offer some safety benefits to a certain portion of rear seat occupants. We note that the current head restraint standards do not require a height of above 700 mm even for front head restraints.

Because rearward visibility remains a concern, we note that the manufacturer will be able to determine whether a seat back structure above 700 mm is consistent with the amount of rearward visibility they wish to provide.

This final rule harmonizes the Federal requirements for head restraints with the head restraint regulation of the United Nations/Economic Commission for Europe (UN/ECE), except to the extent needed to provide increased safety for vehicle occupants. In some instances, achieving increased safety in a cost effective manner made it necessary for us to go beyond or take an approach different from that in the ECE regulation. For example, this final rule limits the amount of backset between the head restraint and the occupant's head, while ECE 17 does not. We note that in most situations where this rule is harmonized with the substance of the ECE requirements, the actual regulatory language is nevertheless drafted differently in order to facilitate enforcement. Specifically, we have found it necessary to specify different compliance

[2] The survey included twelve 1999 model year vehicles (9 passenger cars, 1 minivan, and 2 SUVs). Five of the twelve vehicles featured rear seating systems that fell under our definition of the rear head restraint.

procedures to facilitate their interpretation and enforcement under our statutory provisions. For example, there are differences in the way in which gaps within head restraints are measured.

The discussions that follow provide a brief description of those instances in which the final rule does or does not harmonize with the ECE regulations. ECE No. 17 allows for a 25 mm height allowance if any fixed vehicle structure such as the roof or header limits the height of the head restraint to less than the required height. The final rule limits this allowance to interference with the rear window area or the roof -line. ECE No. 17 allows head restraints to have "non-use" positions where the height requirements need not be met as long as those positions are "clearly recognizable to the occupant" or the head restraint automatically returns to a position intended for use. The final rule does not contain the "clearly recognizable" provision, but rather specifies performance requirements that distinguish the non-use position. ECE requires that an adjustable head restraint in its lowest position have a gap no larger than 25 mm between the head restraint and the seat back. No method of measurement is given. The final rule allows a 60 mm gap, consistent with all other gap allowances, and provides a specific measurement method. Finally, the energy absorption test in the final rule uses a linear rather than a pendulum impactor.

The new rule modifies many of the test procedures used for certifying compliance to Standard No. 202. However, manufacturers still have the option of certifying compliance in one of two ways: the first option is a series of dimensional, strength and energy absorption requirements. The second option consists of a dynamic test with associated performance criteria and a static width requirement. With the second option, manufacturers must demonstrate compliance with the 50^{th} percentile male Hybrid III test dummy specified in Part 572 Subpart E. For the dynamic compliance test for all outboard seats, the head restraint is set at a height position selected by the manufacturer and backset is set at the rearmost position of adjustment (if adjustable). The dynamic test requirement includes a head-to-torso rotation limit of 12 degrees. Further, the rule limits HIC_{15} to 500 for all the dynamic compliance option tests.

Height Requirements

FMVSS 202 currently requires that all front outboard head restraints be capable of achieving a height where the top of the head restraint must be at least 700 mm (27.5 inches) above the seating reference point measured parallel to the torso reference line. This final rule changes this requirement to 800 mm (31.5 inches) above the H-point for front seat head restraints, and requires a lower limit on front head restraints and optionally provided rear head restraints of not less than 750 mm (29.5 inches) above the H-point. The new requirements will result in integral front seat head restraints having a minimum height of 800 mm (31.5 inches); adjustable front seat head restraints would be capable of achieving a height of 800 mm (31.5 inches) and could not be adjusted lower than 750 mm (29.5 inches).

The alteration in the height requirement is intended to prevent whiplash injuries by requiring that the head restraints be high enough to limit the rearward movement of the head and neck. Research conducted since the implementation of the previous height requirements has shown that head restraints should be at least as high as the center of gravity (CG) of the occupant's head to adequately control motion of the head and neck relative to the torso.

Advocates for Highway and Auto Safety (Advocates) (034) commented that they did not believe that adjustable head restraints in the front or rear should have an adjustment position lower than 800 mm. Advocates did not believe that sufficient justification was provided in the NPRM for allowing a 750 mm height for adjustable restraints in front seats. Advocates added that an 800 mm height was desirable for rear seats unless the agency could show that the benefits are offset by blocked vision.

Volkswagen (035) and Porsche (039) commented that the ECE regulation allowed head restraints to have a lower maximum height so as to provide a maximum of 25 mm of clear space between the head restraint and any fixed vehicle structure. Volkswagen and Porsche both believed that FMVSS No. 202 should incorporate such a position. Porsche provided data that showed that several of its models had less than 750 mm of distance between the H-point and the roofline.

Insurance Corporation of British Columbia (ICBC) (012) reported that in a study done for them by Biokinetics and Associates Ltd. the data showed that properly adjusted head restraints in the field doubled after an education program. General Motors North America (GM) (046), DaimlerChrysler Corporation and Mercedes Benz USA (Daimler) (027) and Alliance Automobile Manufacturers (AAM) (029) commented on the need for a NHTSA/Industry education program on head restraint adjustment.

Backset Requirement

In the NPRM, NHTSA proposed a new requirement that head restraints must have a backset of less than 50 mm (2 inches), at any adjustment position. Backset would be measured at any point between a height of 750 mm and 800 mm. The consensus of the biomechanics community was that the backset dimension has an important influence on the forces felt by the neck and the length of time a person is disabled by injury. This has been based on both physical tests, computer modeling and real world crash data. Some researchers have seen further potential injury reduction as the backset goes to zero, allowing no relative motion between the head and torso upon rear impact.

The Alliance commented that whiplash injury protection pertaining to head restraint backset was not adequately gauged by the head-to-head restraint backset measurements alone (i.e., neck biomechanics were not accounted for). The Alliance added that a functional requirement may be more appropriate but should be based on further biomechanical research.

University of Michigan Transport Research Institute (UMTRI) (020) comments based on data from their studies noted that at 50 mm of backset, 13 percent of drivers would have their preferred head position interfered with, and a hair margin (distance between the scalp and edge of hair) of 25 mm, 33 percent of the drivers' hair would touch the head restraint. UMTRI continued that mainly small stature individuals, with the seat back angle more upright than 25 degrees, would most likely experience some discomfort. UMTRI estimated that with current seat designs, a backset of 91 mm would accommodate the preferred head position of 99 percent of the population. UMTRI continued that if NHTSA required a 50 mm backset, manufacturers would produce seats that will have a larger mean selected seat back angle than the typical 22 degrees of the current seat designs, and if seats were designed with the mean selected seat back angle of 25 degrees, all but a small percentage of occupants would be accommodated.

GM commented that people with ponytails and hair clips would be especially affected by the 50 mm backset requirement.

Ford (028) commented that their customer complaints have increased in recent years related to head restraint comfort, and it is believed to be correlated to head restraints that were closer to the head.

The Association of International Automobile Manufacturers, Inc. (AIAM) (022) recommended a backset requirement of 64 mm. Both Ford and GM recommended that the backset limit be increased to 80 mm. Ford added that from recent studies, there was reason to believe that a backset of 70 mm would further reduce injuries.

Daimler commented that there was not adequate knowledge to show that 50 mm of backset was necessary.

ICBC and Transport Canada supported the 50 mm backset limit. ICBC commented that a backset of 50 mm always resulted in better head restraint performance than higher values, and 50 mm was sufficient to significantly reduce whiplash. ICBC continued that they based their conclusions on database for 2001 vehicles that showed 49 of 164 vehicles from 19 manufacturers with 50 mm or less backset.

The agency was aware at the time of the proposal that the NPRM would not guarantee a 50 mm backset for all occupants. The seat back angle of 25 degrees was chosen precisely because, as UMTRI pointed out in their comments, this is on the edge of the range of normally selected seat back angles and probably more likely to be selected by larger occupants. Therefore it provides a worst-case measurement condition for backset. This angle is consistent with the methods used by ICBC, IIHS and RCAR as well as being consistent with the seat back angle used by ECE 17 when measuring head restraint height if there is no manufacturer specified angle. The agency agrees with IIHS that it is very important to measure backset with a 25-degree seat back angle when the seat back angle is adjustable.

The argument of those who object to the 50 mm of backset for front seats do not seem to be against 50 mm of backset for any particular occupant. In fact, as alluded to by ICBC, the vast body of research indicated that 50 mm of backset was preferable to any larger value. This was confirmed by the comments of Tenser (026). The argument against it assumes some occupants will select a steeper than 25 degree seat back causing the backset to be reduced to a value below 50 mm, which causes interference with the normal position of the head or discomfort due to close proximity. The arguments related to occupant discomfort aren't as persuasive when viewed with the knowledge that, as ICBC commented, 49 of 164 vehicles from MY 2001 meet the 50 mm backset limit.

In general, the NHTSA computer modeling results using a 50^{th} Hybrid III dummy can be summarized in the following way. The lowest relative head rotation value was seen for the head restraint height positions between 750 and 800 mm, with a backset between 0 and 50 mm. The average head rotation change was about 20 degrees when going from 50 mm to 100 mm backset. Therefore, NHTSA believes that a head restraint that can limit backset to 50 mm and achieve a height of 800mm with a minimum height of 750 mm would be best.

As a response to balance safety with the concerns about comfort and backset, the agency looked at measurement variability for backset at VRTC and found that it was +/- 5 mm. Honda reported in their comments that the variability in the measurement was from +/- 5 mm to +/- 8.5 mm. So, the agency decided that to increase the backset limit to 55 mm, the manufacturers' target would have to be lower (close to 50 mm) because of measurement and manufacturing variability.

Adjustment Retention Requirement

The modification of the existing height requirements and the addition of a backset requirement are expected to improve the performance of all head restraints. Adjustable restraints are most often criticized because they are not positioned properly by motorists and they do not lock in position. The performance of adjustable head restraints may be further improved if steps are taken to ensure that restraint remain in position after they have been set by the user. The benefit of the locking requirement is to keep the head restraint in the adjusted position. Most commenters to the Technical Report were in favor of locks on adjustable head restraints. In addition to the benefit of maintaining their position of adjustment, the agency believes that if the head restraint locking mechanism can prevent the head restraint from being pushed down or back by the head during the crash sequence, there is a less likelihood of injury to the occupant.

The final rule requires that adjustable head restraints for the front outboard seating positions must lock in any position of adjustment closest to, but not less than 800 mm (31.5 inches) under application of a downward force. Head restraints in all outboard-seating positions must lock in the highest position and any position of adjustment closest to, but not less than 750 mm (29.5 inches) for front seat outboard head restraints. Finally, if backset is adjustable to less than 55 mm, the head restraint must lock in any backset position when the height is adjusted between 750 mm and 800 mm for front seat outboard head restraints, under application of a rearward load.

The agency believed that this is important for designs that adjust vertically as well as rotate for backset adjustment. Positive locking of the head restraint is not required in other adjustment positions than indicated above, but is not forbidden. The tests are written such that an initial small load is applied to the head restraint and the reference position of the loading devise (spherical head form for backset retention and cylindrical test device for height retention is recorded. The loading reference position is measured with this load applied to eliminate positioning variability associated with the soft upholstery of the head restraint. The loading device cannot move more than 25 mm when coming up to this initial reference load as a check on head restraints that have no lock. A larger load of 500 N (56.2 lbs) for vertical loading and a load sufficient to generate a 373 Nm (3,300 inch lb) moment for rearward loading is then applied to test the locking mechanism. Finally, the load is then reduced back to the initial value and the head form is checked against its initial position. It must be within 13 mm (0.51") of its initial position to pass. The test was designed assuming, if the locking mechanism fails, the head form would not return to its original position.

Harmonization

The process of global harmonization in the field of vehicle regulatory requirements began in 1949. The Geneva Convention on Road Traffic and Signs was created by the United Nations, Economic Commission for Europe (ECE) to examine the problem of vehicle movement across countries. This convention formally permitted the temporary passage of road vehicles from one country to another without meeting national vehicle construction and use regulatory requirements, so long as a list of minimum specific requirements was met. Since then, most countries around the world have become signatories to it.

It is the opinion of many that global harmonization would eliminate the barriers to trade resulting from unwarranted differences in vehicle regulations and certification and compliance procedures. Compliance with multiple regulatory frameworks reduce vehicle affordability as it imposes substantial cost due to design and manufacturing constraints. These constraints extend the time needed to develop new products, thus preventing manufacturers from responding quickly to the needs of consumers world-wide. The agency favors harmonization as long as safety is improved or the safety effects are neutral. The ECE has two regulations pertinent to the upgrading of Standard No. 202. ECE 17 pertaining primarily to seats, seat anchorage, and any attached head restraints, while ECE 25 applies to head restraints whether or not they are attached to a seat.

Harmonization with all other aspects of ECE

In addition to modification of the height harmonization with ECE 17 would entail adding maximum gap dimensions (a gap is defined as either see-through holes in the head restraint or the distance between the top of the seat and the bottom of an adjustable head restraint) and energy absorption requirements to FMVSS 202. Harmonization would also require reducing the head restraint width for bench seats from 254 mm (10 inches) to 170 mm (6.7 inches). Since most head restraints probably meet the gap and energy absorption criteria in ECE 17, putting these requirements in FMVSS 202 should not add significantly to safety or to cost.

a. Width

NHTSA believes that the final rule should not incorporate the portion of ECE 17 that would allow a 170 mm (6.7inches) wide head restraint on front outboard seats which are part of a bench seats rather than the 254 mm (10 inches) required by FMVSS 202 because this may degrade the level of safety currently available. Based on the length of bench seats, occupants seated on bench seats compared to occupants of single seats are freer to position themselves such that they are not directly in front of the head restraint. This is especially true if they don't use their safety belts. Thus, the wider the head restraint, the more likely it will provide benefits to occupants.

b. Gaps

In order to eliminate head restraint designs that have gaps so large that they would detract from the safety aspects of the head restraints, the Final Rule establishes maximum gap requirements similar to ECE 17. For fixed designs, ECE 17 allows a maximum 60 mm (2.36 inches) gap in the head restraint. This is to prevent the head from getting too far into the gap in the head restraint. The gaps in the head restraint may be used for visibility. For height adjustable restraints, 60 mm (2.36 inches) gaps are allowed in the head restraint and a 25 mm (0.98 inches) gap is allowed between the head restraint in its lowest adjusted position and seat. The agency is not aware of the exact rationale used by the Europeans in developing the specific gap limits. Nonetheless, in the absence of independent test data the gap requirements in the proposed regulation are, with one exception, identical to the ECE 25 specifications. This exception is for the gap requirement between the head restraint and seat, when the head restraint is in the lowest position. The ECE requirement does not contemplate back set adjustability and simply allows no more than a 25 mm (0.98 inch) gap. In addition the ECE provides no procedure for measurement of this gap. The final rule requires this gap cannot be greater than 60 mm (2.36 inches) in any position of backset adjustment when measured by the same method used for the other gaps.

GM believes the gap requirement to be identical to ECE 17 and does not object to it. Daimler has no specific concerns for the gap requirements as related to seats, but believes limiting gaps in rear seats will lead to a loss in visibility.

Advocates believes that the agency has not provided sufficient supporting data to support the rationale used for the gap limits proposed. They stated that it would be capricious to adopt even partial harmonization, as well as to establish new, independent requirements, controlling these kinds of specific design features of head restraints without a well-founded basis in the rulemaking record.

Visibility Aspects

A common consumer complaint about head restraints is that they reduce visibility to the rear of the vehicle. There are two areas of concern. The first is the driver's head restraint. When the driver has the vehicle in reverse and turns his/her head to see behind the vehicle, a properly positioned head restraint, depending on its width, may be in the line of sight of the driver, forcing the driver to lean to the side to see around the head restraint or to straighten up to see over the head restraint. (Some head restraints have openings, but looking through these relatively narrow gaps does not seem to be a preferred way of backing up). The majority of drivers would not be affected by the head restraint height increase because the line of sight of a 50th percentile male is approximately 690 mm, which is below the 726 mm average lowest head restraint height currently in the fleet for front seat (Table IV-3). Therefore, at least 50 percent of the male driving population and over 50 percent of the female drivers have to lean around current head restraints to look rearward. An increase in the head restraint height requirement will not adversely affect these drivers. Head restraints with a minimum height of 750 mm (29.5 inches) will cause a much higher percentage of drivers (many of those 47 percent of current drivers that leave their head restraint in the lowest position) to straighten up or to lean to the side to see around the head restraint. The physical difficulty of straightening up or leaning to the side while looking backwards depends upon the flexibility of the driver. Those drivers with neck, shoulder, or back problems, and some elderly drivers, may find it difficult or painful to straighten up or lean to the side and look back. Drivers could use the exterior mirror systems on the vehicle to back up, but that does not seem to be the preference of drivers.

The second area of concern is how rear seat head restraints reduce the direct visibility of the driver when looking backward and the indirect visibility of the driver when looking through the inside rearview mirror. The agency did not propose that head restraints be installed in the center seating position of the front or rear seats. These positions would be even less cost effective than the rear outboard seating positions and they further reduce rear visibility. The agency proposed that the rear seat head restraints need not be able to be raised as tall as the front seat head restraints. There are several vehicle models already on the road with rear seat head restraints that meet the proposed rule rear seat height requirements. The final rule only requires this height when a rear seat head restraint is provided.

An informal survey of NHTSA employees of different heights was performed in a MY 1999 Toyota Camry, which meets the rear seat height of 775 mm (29.5 inches). The rear seat head restraints were adjusted to their highest point. The findings of the survey were that drivers could still see well to the rear of the vehicle over the top of the raised head restraints, but the head restraints do reduce visibility. However, this is just one model and there may be large differences in the vision blockages caused by rear head restraints. Again, drivers could use the exterior mirror systems on the vehicle to observe following traffic. However, there may be blind spots using the exterior mirror that could have been seen by the driver using the interior rear view mirror that may now be blocked by the rear seat head restraint. Rear head restraints could cause a change in driver behavior, forcing them to use exterior mirrors more or to be even more cautious and turn their head to the side to check for vehicles. For many drivers it is preferable to have as much visibility as possible to the rear of the vehicle using the interior rear view mirror. There are many potential visibility impacts and potential changes in driver behavior that could impact on lane change maneuvers. Their overall impact on crash avoidance is difficult to determine.

Lead Time

The NPRM stipulated that the upgraded regulation be effective three years after the first September 1, after publication of the final rule. However, in the interim, compliance with ECE 17 or the current version of FMVSS No. 202 is allowed. There were few comments related to the lead time proposed. Honda commented that application of the final rule should not be limited to the front seats, but that an additional three years of lead-time be added for rear seat head restraints, over and above the three years for front seat head restraints. Porsche commented that limited line manufacturers should be given additional lead-time, or if a phase-in was utilized, they should be given until the end of the phase-in period.

The effective date will be September 1, 2008.

IV. RESEARCH

A 1993 study[3], found that backset had the largest influence on head-neck motion, with the maximum head-torso displacement increasing with increasing backset. The study also found that the increased stiffness of the seat-back frame resulted in slightly increased maximum head-torso displacement, but a stiffer lower seat-back cushion combined with a deeper upper seat-back cushion resulted in a clear reduction of the head-torso displacement.

A study[4] of 26 rear end crashes involving 33 front seat occupants in Volvo cars was made in Sweden during 1987-88. The study investigated neck injuries sustained in rear end crashes and correlated the severity of the injuries with the various crash, occupant, and vehicle parameters. All injuries in the study were of minor severity (AIS 1). Seventy percent of the occupants suffered neck injuries with symptoms localized in the neck only. The study found that there was a relation between an increase in backset and the severity and length of neck symptoms. That is, a distance of more than 100 mm between the head and the head restraint correlated with an increased risk of neck long term injuries in rear end collisions, and reducing the backward movement of the head in relation to the chest might be of primary importance.

A neck injury criterion (NIC) to mathematically model and predict neck injuries in low-speed rear-end automobile crashes has been proposed[5] based on the relative acceleration and velocity between the top and the bottom of the cervical spine. In the study, none of the subjects' NIC values exceeded the previously proposed $15m^2s^2$ threshold, yet overall 33 percent of the tests

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3 Mats Y. Svensson, Per Lovsund, Yngve Haland and Stefan Larson, The Influence of Seat-Back and Head-Neck Motion During Rear-Impact presented at the 1993 International IRCOBI Conference on the Biomechanics of Impact, 8-10 September, Eindhoven, The Netherlands,

4 Olsson I, Bunketorp O, Gustafsson C, Planath I, Norin H, Ysander L, An In-Depth Study of Neck Injuries in Rear End Collisions 1990 International Conference on The Biomechanics of Impact.

5 Wheeler JB, Smith TA, Siegmund GP, Brault JR, King DJ. Validation of The Neck Injury Criterion (NIC) Using Kinematic and Clinical Results From Human Subjects in Rear-End Collision. IRCOBI Conference 1998.

resulted in symptoms. Of the 42 subjects tested 22 (52%) reported symptoms at either 4 or 8km/h speed change. One reason the NIC may not have predicted the occurrence of whiplash symptoms in the test subjects was because NIC is based on a pressure gradient injury mechanism model that predicts dorsal root ganglion pathology, while the precise source of the tested subjects' symptoms was not known. It was not possible to verify by histopathological examination whether or not dorsal root ganglia injury occurred to the test subjects. Furthermore, no significant differences were noted in post-impact clinical examinations for reflex, sensory, or upper extremity muscle strength, which suggested that the test subject symptoms were not nerve based. NIC was not able to predict the presence of symptoms in the test population. This study suggests that further refinement may be necessary for NIC.

Head Restraint Height in The Vehicle Fleet

Table IV-1 presents data on the difference between the proposal and measurements of head restraint height and backset taken on 14 model year (MY) 1999 models at the highest adjusted height for the head restraint. For example, the MY 1999 Toyota Camry was measured and the driver's seat highest head restraint position was 781 mm (30.75 inches) or 19 mm (0.75 inches) lower than the proposed height of 800 mm (31.5 inches).

Sales weighted averages derived from these measurements are shown in the Tables IV-2, IV-3, and IV-4. They represent the differences between the measured heights and the proposed standard. Averages in the front seat are for the driver and right front passenger positions and in the rear seat are for the right and left rear passenger positions. Both the lowest height and highest height are used for calculations made in the safety benefit and cost sections of this analysis.

Table IV-1
Measured at the Highest Head Restraint Height
Number of Inches Head Restraint Has to be Increased and Backset Reduced to Meet Final Rule Requirements 800 mm (31.5 Inches) Front and 750 mm (29.5 Inches) Rear Height (Ht) and 55 mm (2.17 Inch) Backset (BS) Note: Values in the table are in Inches

Make	**Driver**		**Right Front Pass.**		**Right Rear Pass.**		**Left Rear Pass.**	
	Ht	**BS**	**Ht**	**BS**	**Ht**	**BS**	**Ht**	**BS**
Toyota Camry*	0.75	0	0.75	0	0	0.19	0	0.39
Honda Accord	1.25	0.78	1.75	0.78	2.75	+	2.75	+
Taurus/Sable	3.0	1.37	3.25	0.09	4.5	1.87	6.25	1.87
Chevy C1500 /GMC	0.25	0	0.5	0	...	...	...	...
Chevy S-10	0.25	0	0.25	0	...	...	...	...
Neon	0	2.36	1.0	0.78	3.0	+	3.5	+
Saab 9-5	0.25	0	0.25	0	0	0	0	0
Lumina	1.0	0.59	1.25	0.49	5.5	+	5.25	+
Grand Cherokee*	2.75	1.77	3.25	0	1.37	2.75	1.37	2.75
Chevy. Cavalier	1.37	1.28	1.25	1.08	2.12	2.16	2.75	2.55
Malibu	0.75	0	1.0	0	5.0	+	4.0	+
Cadillac	0	1.89	1.75	2.36	4.12	4.13	4.75	+
Caravan*	0.5	0.39	1.75	0.33	2.0	1.37	1.75	1.37
Explorer*	2.62	2.95	2.5	3.15	0	1.08	1.5	1.82

* These vehicles have adjustable rear seat head restraints. Some of the other vehicles have integral restraints that consist of a lump in the seat back that raises the height of the seat back.
+ Head restraint too low to measure backset by ICBC device.
Note: Of the vehicles with adjustable head restraints:
In the front seat, 6 had positive locking mechanisms for height and 6 did not.
In the rear seat, 3 had positive locking mechanisms for height and 3 did not.

Table IV-2
Measurements at **Highest** Head Restraint Height
Number of Inches Needed to Meet Final Rule Required Height
(800 mm (31.5 inches) in front seat and 750 mm (29.5 inches) in rear seat)

	Front Seat	**Rear Seat**
Integral Head Restraint	1.2	3.9
Adjustable Head Restraint	1.4	1.0
Average	1.3	2.6

Table IV-3
Measurements at **Lowest** Head Restraint Height
Number of Inches Needed to Meet Proposed Height
(750 mm (29.5 inches) in front and rear seat)

	Front Seat	Rear Seat
Integral Head Restraint	-.8	3.9
Adjustable Head Restraint	1.5	3.7
Average	0.9	3.8

Table IV-4
Measurements at Highest Head Restraint Height
Number of Inches Needed to Meet Proposed
Backset

	Front Seat	Rear Seat
At 50 mm	0.9	1.8
At 55 mm	0.7	1.6

Distribution of Head Restraints

In the 1982 Evaluation of passenger car front seat head restraints, 62 percent were adjustable head restraints and 38 percent were integral. In the 1988 to 1996 NASS-CDS report, which includes whatever model year of vehicle had head restraints, the mix was 77 percent adjustable and 23 percent integral for passenger cars. NHTSA found that in a sample of MY 1998 passenger cars representing 47 percent of passenger car sales, 93 percent were adjustable and only 7 percent were integral head restraints. Thus, there has been a significant trend towards adjustable head restraints in the front seat of passenger cars.

The distribution of adjustable and integral head restraints for light trucks is very different. In the 1988 to 1996 NASS-CDS, 23 percent of the front seat light truck head restraints were adjustable and 77 percent were integral. In a sample of MY 1998 light trucks representing 72 percent of light truck sales, a sales weighted distribution found 20 percent adjustable and 80 percent integral head restraints.

Sales-weighting cars and light trucks by calendar year 1998 sales results in 9.06 million vehicles (an average of 58 percent of the vehicles) having adjustable head restraints and 6.49 million (an average of 42 percent of the vehicles) having integral restraints (based on 8.15 million passenger cars and 7.40 million light trucks totaling 15.55 million vehicles).

While the agency has some information on the distribution of head restraints in the rear seat, the information is not very complete. About half of the vehicles with rear seats have "head restraints" and half do not. However, some of the so-called "head restraints" are far from the height being required and they may constitute just a lump at the top of the seat back. Whether the manufacturers would extend these into integral head restraints or change the design and add an adjustable head restraint is not known. It appears that most of the European passenger cars are using adjustable head restraints in the rear seat. Whether this is in consideration of visibility concerns through the inside rearview mirror or not, is not known.

Active Head Restraints

Table IV-5 shows rear impact sled test data generated by Viano, et al., and one vehicle crash test performed by NHTSA for the Saab active head restraint (AHR). Viano did not report the model year (MY) of the seats, but based on the publication dates of the data, MY 2000 would be a reasonable assumption. In addition, we assume that these AHR seats are very similar if not identical to those in current production. The NHTSA FMVSS 301 crash test was a MY 2003 vehicle. In all cases the test dummy was the Hybrid III 50th percentile male. Three head restraint positions were used in these test; up, mid and down. The backset values are reported, but these head restraints did not have an independently adjustable backset.

The first four rows of data are for an "up" head restraint in order of increasing ΔV. There is a clear trend towards increasing head-to-torso rotation as the ΔV increases. The FMVSS No. 202 dynamic test has a ΔV of 17.2 km/h. Therefore, the range of head-to-torso rotation of 4.6 to 6.5 degrees would be most representative of what would be expected in the FMVSS No. 202 test. The average value in these tests is 5.6 degrees, which is 46% [5.6/12] of the proposed 12 degree performance value.

The fifth row of data shows that at the mid height position the head-to-torso rotation is 83% [10/12] of the performance value. This test was performed at a 23.5 km/h ΔV. One would expect an even smaller head-to-torso rotation at the 17.2 km/h FMVSS No. 202 test speed. Thus, even at the mid height adjustment, an AHR should easily meet the proposed performance limit.

Table IV-5
Rear Impact Crash Test Results for Active Head Restraints

Test Type	Vehicle	DeltaV km/h	backset mm	HR position in height	HIC15	head to torso rotation (deg)	Source
Sled	Saab 9-5+SAHR	12.8	35	up	11	1	Table 4 in Ref. 1
Sled	Saab 9-3 SAHR	16	41 - 43	up		4.6 - 6.5	Table 14.2 in Ref. 2
Vehicle	Saab 9-3 2003 MY	25	26	up	75.1	8	NHTSA FMVSS 301 test
Sled	Saab 9-5+SAHR	30	35	up	39	11	Table 4 in Ref. 1
Sled	Saab 9-3 SAHR	23.5	46	mid	35	10	Table 14.2 in Ref. 2
Sled	Saab 9-3 SAHR	16	48 - 65	down		13.3 - 16	Table 14.2 in Ref. 2

Reference 1: Viano, D., Olsen, S., "The Effectiveness of Active Head Restraint in Preventing Whiplash," Journal of Trauma, Injury, Infection, and Critical Care, Vol. 51, No. 5, 2001.

Reference 2: Viano, D., "Role of the Seat in Rear Crash Safety," Society of Automotive Engineers Inc., Warrendale, PA, 2002

V. BENEFITS

The Safety Problem

NHTSA estimates that between 1988 and 1996, there were 805,851 occupants with whiplash injuries annually in the outboard seating positions of passenger cars, light trucks, and vans in towaway and non-towaway, police reported and unreported, nonrollover impacts. The average cost (including medical cost, household productivity loss, wage loss, legal, insurance administration, emergency services, and workplace costs; excluding property damage) of such an injury is $9,994, resulting in a total annual cost of approximately $8.0 billion. However, since the agency believes head restraints will be most effective in rear impacts, the benefits analysis will be restricted to this crash mode in which there are an estimated 270,861 whiplash injuries annually, costing about $2.7 billion.

It is estimated from National Automotive Sampling System - Crashworthiness Data System (NASS-CDS) data that between 1988 and 1996, there were 70,307 occupants with whiplash injuries (non-contact AIS 1 neck injuries) annually in the outboard seating positions of passenger vehicles[6] in police-reported towaway nonrollover rear impacts (see Table V-1a). Whiplash injuries can occur at low speeds and many times the occupant doesn't know they have been injured for several hours. Thus, adjustments must be made to account for injuries in non-towaway police reported crashes and for crashes that are not reported to the police.

Data on non-towaway whiplash injuries are not available in the NASS-CDS data base since 1988. The agency examined data in two states, Pennsylvania (1997, State data file) and Indiana (1996, State data file) that had data elements on body region of injury and towaway versus non-towaway police reported crashes. In rear impacts in Pennsylvania, there were 2,840 outboard occupants in towaway crashes and 5,815 in non-towaway crashes with a whiplash injury (defined

6 Passenger vehicles include: passenger cars (PC), light trucks and vans (LTVs), which include pickups, vans and sport utility vehicles under 10,000 pounds GVWR.

using Pennsylvania data as a neck injury, with no visible sign of injury but a complaint of pain.) Thus, the multiplier from police reported towaway injuries to total police reported injuries would be 3.05 [(5,815 + 2,840)/2,840]. In rear impacts in Indiana, there were 2,074 outboard occupants in police reported towaway crashes and 4,096 in police reported non-towaway crashes that had neck injuries, with a complaint of pain. Thus, the multiplier from police reported towaway injuries to total police reported injuries would be 2.97 [(4,096 + 2,074)/2,074]. There is no statistically significant difference between these two multipliers. On average, the multiplier from towaway injuries to total injuries is 3.0. Thus, we estimate the annual estimated number of police-reported whiplash injuries in rear crashes to be 210,921 (70,307 x 3).

Based on estimates provided in a NHTSA report[7], the multiplier from police-reported crashes to all crashes, including unreported crashes, for AIS 1 injuries is 1.29. Thus, the annual estimated number of total whiplash injuries in rear crashes, police- reported and unreported is 272,088 (210,921 x 1.29). This assumes the same relationship between whiplash injuries and unreported injuries as for all other AIS 1 injuries.

Out of the 70,307 estimated whiplash injuries in towaway crashes, an estimated 5,440 (7.7 percent) were in rear outboard seating positions. The annual estimated number of total whiplash injuries in rear outboard seating positions, police- reported and unreported, is 21,053 (5,440 x 3 x 1.29). Of the 5,440 whiplash injuries in rear seats in towaway crashes, only 564 (10.4 percent) were in vehicles with head restraints in the rear seat as coded by NASS CDS. The number of vehicles with head restraints in the rear outboard seats has increased dramatically over the last several years. Based on the MY 1999 vehicles with rear seat head restraints and MY 1998 sales, an estimated 41 percent of the MY 1999 fleet have head restraints that were at least 750 mm (29.5 inches) in some position of adjustment, 39 percent have a rear seat but no head restraints,

[7] "The Economic Cost of Motor Vehicle Crashes, 1994" NHTSA, DOT HS 808 425, July 1996, Pg. 9.

and 20 percent have no rear seat. Out of the possible 80 percent of the fleet with a rear seat, 41 percent have a head restraint. Thus, 51 percent (41/80) of the possible rear seat injury cases for new models would now have a head restraint. The average effectiveness of current rear head restraints in the rear seat is estimated to be about 14.67 percent (8.8/0.6). This is derived as follows: It is assumed that the height of the pre-standard rear bench seat is the same as the height of the pre-standard front seat (559 mm or 22 inches). Based on the sample of rear seats measured, current head restraints average 25.6 inches tall. Using data provided later in the analysis, increasing height from 22 inches to 25.6 inches results in an 8.8 percentage improvement in effectiveness. Dividing by 0.6 factors the effectiveness up from all injuries to just whiplash injuries. Then the expected number of rear seat outboard whiplash injuries for a fleet of MY 1999 vehicles if they had no rear seat head restraints would be 21,429 based on the following calculations:

Potential Whiplash = AW/(1-pe)
where AW = actual whiplash
p = presence rate of head restraints
e = effectiveness
p represents the rate of head restraint presence in all crashes. It is derived from the presence rate in injury crashes, but must be adjusted to reflect those saved from injury by head restraints. This adjustment is made using the following formula:

$p_i/\{1-e(1-p_i)\}$.
Where e = effectiveness of head restraint and p_i presence rate of head restraints among injured occupants
Thus p = .104/1-(.1467(1-.104)) = .1197
.104= percent rear whiplash injuries
.1467 effectiveness
21,053/[1-(.1197 presence x .1467 effectiveness)] = 21,429 in potential whiplash cases
21,429 x .1467 x .51 = 1,603 whiplash injuries saved by MY 1999 head restraints
21,429 - 1,603 = 19,826 remaining rear seat outboard whiplash injuries

There is no need to make the same adjustment for front seat head restraints, since essentially all vehicles in the 1988-96 period already had front seat head restraints. Table V-1(b) provides the target population projected number of annual towaway whiplash injuries for a fleet of MY 1999 vehicles at their current rate of head restraint installation. There would be an estimated 251,035 (272,088 - 21,053) front outboard and 19,826 rear outboard whiplash injuries for a total of 270,861 occupants injured in towaway and non-towaway, reported and unreported rear crashes.

Table V-1(a)
Whiplash Injuries in Outboard Seating Positions Distribution of
Restraint Type by Vehicle - (NASS-CDS) 1988-1996, Towaway Annualized Data

Vehicle	Integral	Adjustable	None	Unknown	Total
Car	13,291	43,355	4,323	277	61,246
Truck	3,041	1,188	4,804	28	9,061
Total	16,332	44,543	9,127	305	70,307

Table V-1(b)
Projected Target Population for MY 1999 Fleet
Annual Estimate of Whiplash Injuries

	Front Seat Outboard	Rear Seat Outboard	Total
Whiplash Injuries	251,035	19,826	270,861

Table V-2
Distribution of Integral and Adjustable Head Restraints
Annualized NASS-CDS Data 1988 - 1996, Towaways

Head Restraint Type When Known	Whiplash Injuries	Ratio
Integral	16,331	.27
Adjustable	44,542	.73
Total	60,873	1.00

The distribution of injuries by type of head restraint is in the ratio of 0.27 to 0.73 (Table V-2).

The distribution of front seat outboard injuries by restraint type is:

Integral head restraint = .27 x 251,035 = 67,779

Adjustable head restraint =.73 x 251,035 = 183,256

About 30 percent of all occupants involved in police-reported towaway rear impact crashes receive a whiplash injury. In police-reported towaway rear impact crashes (see Table V-3), the whiplash injury rates for integral and adjustable head restraints for LTVs and PCs did not show any predictable pattern as a function of occupant height. The results are counter to the past agency findings in the Kahane evaluation based on police-reported towaway and non-towaway crashes, that integral head restraints were more effective than adjustable head restraints due to a large portion of occupants not pulling up their adjustable head restraints. On average, for passenger cars the whiplash injury rate (31.75 per hundred occupants in police-reported towaway rear impacts) for integral head restraints was higher than the whiplash injury rate (27.99) for adjustable head restraints. For LTVs, the average whiplash rate (30.57) for adjustable head restraints was slightly higher than the whiplash injury rate (30.53) for integral head restraints.

One reason that this more recent data did not find that integral head restraints had superior effectiveness as compared to adjustable may be the scarcity of data points. The actual number of cases is provided in the "whiplash raw" columns. Those cells with less than 50 data points have very wide confidence intervals around them compared to those cells with hundreds of cases. Another factor may be that the relative difference in height between adjustable head restraints in their down position and integral head restraints may have gotten smaller since the Kahane evaluation was performed. Kahane (pg. 107) estimated that adjustable head restraints were 635 mm (25 inches) and 724 mm (28.5 inches) high when in the down and up positions, respectively. This was in comparison to an average height for integral head restraints of 724 mm (28.5 inches). The current agency data finds that adjustable head restraints in front seats have a 711 mm (28 inch) and 765 mm (30.1 inch) height in the down and up positions, respectively. Current front seat integral head restraint designs have an average height of 770 mm (30.3 inches). So the average difference between the adjustable head restraint in the down position and the integral head restraints has been reduced from 89 mm (3.5 inches) to 58 mm (2.3 inches). Today, as in the past agency evaluation, there is almost no difference between the adjustable head restraints in the up and integral head restraints, in front seats. Finally, other possible reasons for the lack of difference in the performance of integral and adjustable head restraints may be the more common availability of position locks on adjustable head restraints and vehicle occupants being more aware of the need for proper adjustment of their head restraint.

For individuals 5 feet 9 inches and shorter in front outboard seats, the whiplash injury rates (37.94 for integral and 31.0 for adjustable) were higher in passenger cars than the front outboard whiplash injury rates (17.14 for integral and 20.65for adjustable) in light trucks and vans with fewer data points.

For a height 5 feet 10 inches and over, LTVs had higher whiplash injury rates than passenger cars for both adjustable and integral head restraints. The LTVs whiplash injury rate for integral head restraints was 56.71 for front outboard seats, while for passenger cars the integral head restraint injury rate was 35.72. For adjustable head restraints, the whiplash injury rate for LTVs was 30.19, and the whiplash injury rate for cars was 28.04. These differences in rates are generally not statistically significant. There are two statistically significant comparisons in the data set. 1) For integral head restraints in trucks, when comparing tall individuals with short individuals, the injury rates of 17.14 versus 56.71 are statistically significant. 2) For integral head restraints in the front outboard seating, the injury rates for short individuals in cars versus those in trucks (37.94 and 17.14 respectively) are statistically significant. The following is a breakout of the differences in selected whiplash rates for the period 1988 to 1996.

Table V-3 Whiplash Rate Comparison From 1988 -1996 NASS
Front and Back Outboard Occupants

Car	Integral vs Adjustable	31.75 to 27.99
Truck	Integral vs Adjustable	30.53 30.57
Integral	Car vs Truck	31.75 30.53
Adjustable	Car vs Truck	27.99 30.57

Front Outboard only

Car	Short	Integral vs Adjustable	37.94 31.00
Car	Tall	Integral vs Adjustable	35.72 28.04
Car	Integral	Short vs Tall	37.94 35.72
Car	Adjustable	Short vs Tall	31.00 28.04
Truck	Short	Integral vs Adjustable	17.14 20.65
Truck	Tall	Integral vs Adjustable	56.71 30.19
Truck	Integral	Short vs Tall	17.14 56.71*
Truck	Adjustable	Short vs Tall	20.65 30.19

Front Outboard only

Integral	Short	Car vs Truck	37.94 17.14*
Integral	Tall	Car vs Truck	35.72 56.71
Adjustable	Short	Car vs Truck	31.00 20.65
Adjustable	Tall	Car vs Truck	28.04 30.19

* difference is significant at 0.05

Table V-3(a)
Cars With Integral Head Restraints in Nonrollover Rear Impacts
1988 - 1996 NASS Annualized Data in Towaway Crashes

Height ins.	Seat Position	Whiplash raw	Whiplash weighted	Whiplash rate*
5 ft 9 ins & under	Front outboard	152	8,937	37.94
5 ft 9 ins & under	Back outboard	10	407	11.59
5 ft 10 ins & over	Front outboard	49	3,172	35.72
5 ft 10 ins & over	Back outboard	2	86	44.85
unknown	Front outboard	22	623	12.36
unknown	Back outboard	5	65	9.54
Total		240	13,290	31.75

* Whiplash rate is the number of whiplash injuries per 100 occupants in rear impacts.

Table V-3(b)
Cars With Adjustable Head Restraints in Nonrollover Rear Impacts 1988 - 1996 NASS
Annualized Data in Towaway Crashes

Height ins.	Seat Position	Whiplash raw	Whiplash weighted	Whiplash rate
5 ft 9 ins & under	Front outboard	607	29,193	31.0
5 ft 9 ins & under	Back outboard	1	6	1.10
5 ft 10 ins & over	Front outboard	232	9,932	28.04
unknown	Front outboard	111	4,224	17.17
Total		951	43,355	27.99

Table V-3(c)
LTVs With Integral Head Restraints in Nonrollover Rear Impacts 1988 - 1996 NASS
Annualized Data in Towaway Crashes

Height ins.	Seat Position	Whiplash raw	Whiplash weighted	Whiplash rate
5 ft 9 ins & under	Front outboard	46	926	17.14
5 ft 10 ins & over	Front outboard	23	2,058	56.71
unknown	Front outboard	3	57	6.25
Total		72	3,041	30.53

Table V-3(d)
LTVs With Adjustable Head Restraints in Nonrollover Rear Impacts 1988 - 1996 NASS
Annualized Data in Towaway Crashes

Height ins.	Seat Position	Whiplash Raw	Whiplash Weighted	Whiplash Rate
5 ft 9 ins & under	Front outboard	14	413	20.65
5 ft 10 ins & over	Front outboard	9	286	30.19
unknown	Front outboard	6	488	52.74
Total		29	1,187	30.57

IIHS Ratings

IIHS has conducted surveys of head restraints in 1995, 1997, 1999, 2001, 2002 and 2003 Table V-4(a) and (b) show the 1999 data broken out by vehicle models and the IIHS ratings for the head restraints. The IIHS rating criteria depends upon the height and backset of the head restraint (see Figure 1).

Table V-4(a)
IIHS Head Restraint Evaluations, MY 1998 Vehicles

Type of vehicle	**Number of Models by Ratings**					
	good	**Acceptable**	**marginal**	**poor**	**not measured**	**total**
Passenger car	5	21	40	94	13	173
Pickup	0	5	5	11	3	24
Utility	0	6	9	18	7	40
Large Van	0	3	0	2	0	5
Total	5	35	54	125	23	242

Table V-4(b)
Head Restraint Evaluations as a Percent, 1998 Vehicles Model

Type of vehicle	**Ratings**					
	good	**Acceptable**	**marginal**	**poor**	**not measured**	**total**
Passenger car	2.1	8.7	16.5	38.9	5.4	71.5
Pickup	0	2.1	2.1	4.6	1.2	9.9
Utility	0	2.5	3.7	7.4	2.9	16.5
Large Van	0	1.2	0	0.8	0	2.1
Total	2.1	14.4	22.3	51.7	9.5	100

Because of variations in the shapes of head restraints, it is not possible to accurately correlate head restraint height as measured by IIHS and the height as measured by the method in FMVSS 202. The IIHS method measures the height as the distance down from the top of the head and the FMVSS 202 method measures up from the H-point along the torso line. Figure 1 is a graphical depiction of how head restraints of 700 mm (27.5 inch), 750 mm (29.5 inch) and 800 mm (31.5 inch) fare with respect to the IIHS dimensional rating technique. This graph is derived from equation V-1, below, which converts height as measured by IIHS to the approximate height measured by FMVSS 202. For any backset up to 70 mm (2.8 inch), the 800 mm (31.5 inch) high head restraint is always rated "good." A 700 mm (27.5 inch) high head restraint can never be rated better than poor for any backset. A 750 mm (29.5 inch) high head restraint is "good" for backsets up to 30 mm (1.2 inch) and "acceptable" for backsets up to 73 mm (2.9 inch).

$H=(755-IH)\cos\theta + (254+B)\sin\theta$..........Eq. V - 1

Where: Vertical distance from H-Point to top of head (50^{th} percentile male) = 755 mm

Horizontal from H-Point to back of head (50^{th} percentile male)=254 mm

$\theta = 25°$

H = Height as measured by FMVSS 202

IH = Height as measured by IIHS

B = backset

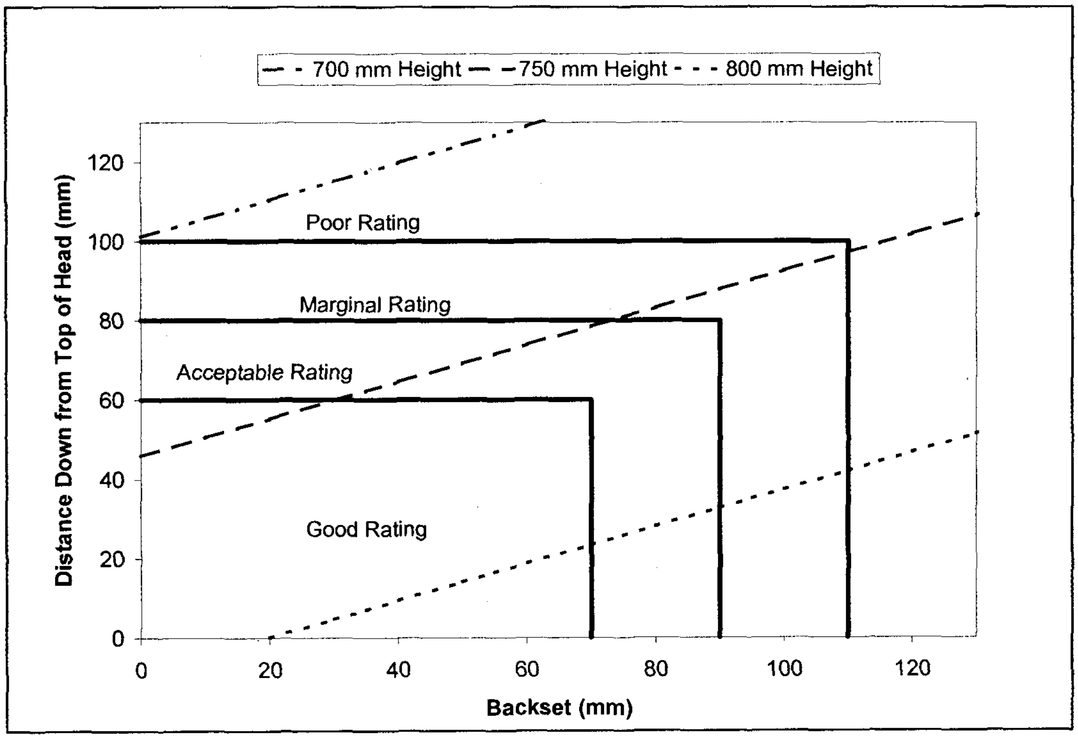

Figure 1. Head Restraint Ratings

The Insurance Institute for Highway Safety study (1999) on head restraints compared the neck injury rate of restraints rated as good to those rated as poor, acceptable to poor and marginal to poor using logistic regression based on damage severity and other factors. For both male and female drivers, head restraints rated as good were associated with a lesser likelihood of neck injuries than head restraints rated poor. The study found the following results:

Table V-5
Logistic Regression on the Odds of Neck Injury –
Odds Ratios, Tort and Add-on States Only

Effect	Male Driver	Female Driver	Total
Good vs. poor	0.90*	0.64**	0.76**
Acceptable vs. poor	1.53**	0.63	0.92
Marginal vs. poor	1.17	0.88	1.00

* A 0.90 measurement means that male drivers in models rated good had a 10 percent lower risk of neck injury than in vehicles rated poor.
** Statistically significant difference

Using the IIHS criteria, moving the height of the head restraint to 800 mm (31.5 inches) and a backset of less than 50 mm (two inches) would put the entire fleet of current restraints into the good category. According to IIHS, comparing a "Good" head restraint to a "Poor" head restraint would show a reduction of approximately 24 percent in whiplash injuries. Even though this result is shown to be statistically significant, the agency is not convinced of the magnitude of the result, because the "Good" category is made up of only three models that are all Volvos.

Similarly, there are 5 models in the acceptable category, and it is hard to believe that there is a 53 percent higher rate of injury for males in vehicles rated acceptable compared to those rated poor. However, the agency believes the results of this study are directionally correct.

Results of NHTSA Evaluations

Passenger Cars

Kahane[8] determined the effectiveness of head restraints in reducing injury in rear impact crashes by examining Texas state accident files for 1968 model year vehicles (pre FMVSS 202: 88% of vehicles had no head restraints) and 1969 model year vehicles (post FMVSS 202: only 12% of

[8] Kahane, C., "An Evaluation of Head Restraints, Federal Motor Vehicle Safety Standard 202" NHTSA, February 1982, DOT HS-806-108

vehicles had no head restraints). Kahane estimated a 17% effectiveness of integral head restraints and 10% effectiveness of adjustable head restraints in reducing injury in rear impact crashes for adult drivers. The overall effectiveness of head restraints for passenger cars was estimated to be 13.1%.

Kahane has postulated that an increase in restraint height from 686 to 787 mm (27 to 31 inches) would give an additional 9.5 percentage point reduction (based on a curvilinear relationship) in injuries (see Table V-6). Again, this estimate must be divided by 0.60 to get the effectiveness for whiplash injuries alone. This would result in a 15.8 percent (9.5/0.6) reduction in whiplash injuries. [Throughout the rest of the benefit section, there will be references to the Kahane report and these estimates will be divided by 0.60 to translate from effectiveness in any rear impact injury to effectiveness for whiplash injuries].

Kahane (1982) estimated the relationship between head restraint height on whiplash injury risk by matching the computed overall effectiveness of integral and adjustable head restraints in the fleet to that obtained from the Texas state files. The relationship between percent of injury reduction versus head restraint height is shown in Figure 2.

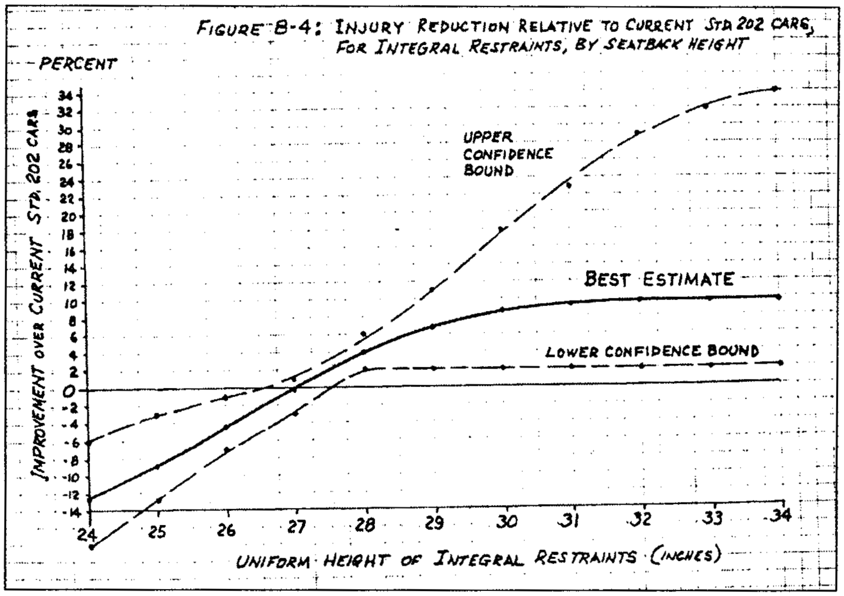

Figure 2. Effectiveness versus head restraint height (Kahane, 1982)

The values presented in Table V-6 were calculated by Kahane for this analysis using data from his original evaluation.

TABLE V-6
INJURY REDUCTION - RELATIVE TO CURRENT STANDARD 202 CARS - FOR INTEGRAL RESTRAINTS BY SEATBACK HEIGHT

Uniform Height of Integral Restraints (inches)	Best Effectiveness Estimate	Improvement over current FMVSS 202 Cars (%) Confidence Bounds	
		Lower	Upper
24	-12.4	-18	-6
25	-8.9	-13	-3
25.6*	-6.1	-10	-2.5
25.7*	-5.6	-9.5	-2
25.8*	-5.1	-8	-1.5
26	-4.2	-7	-1
27	-0.1	-3	1
27.5* (current standard)	2.0	0	4
28	4.0	2	6
29	6.6	2	11
29.5*	7.5	2	14
30	8.3	2	18
30.1*	8.4	2	18.5
30.2*	8.5	2	19
30.3*	8.6	2	20
31	9.4	2	23
31.5*	9.6	2	26

Source: Kahane, C., "An Evaluation of Head Restraints, Federal Motor Vehicle Safety Standard 202" NHTSA, February 1982, DOT HS-806-108, Pg 46. *These were calculated after Kahane's analysis, to be used in this Head Restraint analysis.

Light Trucks

A 2001 agency study[9] that was limited to pickup trucks, evaluated eight state files for the period 1993 to 1998, and found that head restraints reduced overall injury risk in light trucks in rear impact crashes by an estimated 6.08 percent. It is unclear why this effectiveness is more than half of that estimated by Kahane for pre and post-FMVSS 202 passenger cars. There may be reasons related to the demographics of the individuals who occupy pickups in comparison to passenger cars. Most pickup occupants are males. There may be reasons associated with the relative stiffness of the rear of each vehicle type. Pickups are typically body-on-frame vehicles, which would tend to be stiffer than passenger cars. In addition, the rear bumper height of pickups would tend to be higher than that of passenger cars. Finally, pickups have the rear window or backlight area directly behind and in some instances, very close to the occupant.

Based on the Walz analysis that showed the effectiveness of head restraints in light trucks to be 6.08 percent, an analysis of pre-1989 light trucks (these vehicles were not required to meet FMVSS 202) was conducted to determine if there was a difference in the height of the seat backs in light trucks and those in pre-FMVSS 202 passenger vehicles that cause the difference in effectiveness between the current vehicles and the pre-1989 vehicles (Table V-7). The data show that the sales weighted average seat back height of light trucks was approximately 546 mm (21.5 inches). This average height is not significantly different from the average seat back height of pre-standard passenger cars that was 559 mm (22 inches). Since the Walz study found that the

[9] Walz, M. C., "The Effectiveness of Head Restraints in Light Trucks," Federal Motor Vehicle Safety Standard 202" NHTSA Technical Report, April 2001, DOT HS-809-247, Pg 45.

effectiveness for light trucks in preventing all injuries was 6.08 percent as opposed to 13.1 percent for passenger cars, and since light trucks make up approximately 50 percent of vehicle sales, an adjustment of the light truck effectiveness was considered. However, the Walz study was based only on pickup trucks, and pickups have a unique seat arrangement and a different load path compared to other vehicles. We believe that both the front and rear seats of SUVs and vans are more similar to passenger car front seats (cantilevered seat back, free-standing seats) and that the 13.1 percent effectiveness rate would be appropriate for these vehicles as well. Thus, the effectiveness rate for front and rear seats of passenger cars, SUVs and vans will be 13.1%, while 6.08% will be used for pickups. From Table V-7a, pickups make up roughly 62% of all LTVs while SUVs and Vans make up the remaining 38%. With these weights, the average effectiveness for LTVs is 8.72%. The average effectiveness against whiplash injury is 14.53% (8.72/0.6). The equivalent effectiveness for passenger cars against whiplash injury is 21.83% (13.1/0.6). The effectiveness adjustment factor for LTVs is thus 0.6656 (14.53/21.83).

Table V-7

Vehicles	1989 MY Sales	H-pt Height	% of Sales	Weighted Sales
Dodge Full Size	82,642	19.3	0.046445	0.896389
Chevy Full Size	551,209	23.0	0.309781	7.124961
GMC Full Size	153,938	21.4	0.086514	1.85139
Ford Full Size	587,911	21.0	0.330408	6.938558
Dodge Dakota	88,673	19.5	0.049834	0.971772
Ford Ranger	273,336	21.0	0.153616	3.225927
Chrysler Arrow (import)	41,642	22.3	0.023403	0.521885
	1,779,351		1	21.53088

Table V-7a

Front and Rear Outboard Occupants of Towed Passenger Vehicles in Nonrollover Rear Impacts

Body Type	Seat Position	Occupants	Front Truck Occupants	% Total
Car	Front Outboard	57158		
Car	Rear Outboard	4089		
Oth Lt Truck	Front Outboard	191		
Oth Lt Truck	Rear Outboard	80		
SUV	Front Outboard	1902	1902	25.30%
SUV	Rear Outboard	1094		
Van	Front Outboard	926	926	12.32%
Van	Rear Outboard	177		
Pickup	Front Outboard	4689	4689	62.38%
Pickup	Rear Outboard	0		
			7517	100.00%

Estimated Effectiveness for Increasing the Height of Head Restraints

As shown in Table IV-2, the agency has estimated that the present fleet of vehicles has an average front seat outboard head restraint maximum height of 767 mm (30.2 inches), (33 mm (1.3 inches) less than the Final Rule requirement of 800 mm (31.5 inches)). This estimate combines together, on a vehicle population-weighted base, both adjustable head restraints in their highest position and integral head restraints. Based on the 1982 evaluation by Kahane (see Table V-6), it is estimated that raising the height of the head restraint from 767 mm to 800 mm (30.2 inches to 31.5 inches) in the fleet will result in increased effectiveness against injury of 1.1 percentage points for rear impact injuries (derived by subtracting the effectiveness of the lower height from the effectiveness of the higher height in Table V-6) and a 1.83 (1.1/0.6) percentage point increase for whiplash injuries above the present fleet effectiveness. Note that these estimates were calculated for integral head restraints, but this final rule has a height requirement for adjustable head restraints. Thus, for analysis purposes it is assumed that the adjustable head restraints perform as integral head restraints, assuming they have the same height.

The agency also attempted to determine what percent of the population would benefit from a 800 mm (31.5 inch) height, in comparison to a 767 mm (30.2 inch) height. Data exist on sitting height for 5th, 50th and 95th males and females. Using the following variation on equation V-1

$H=(755-\Delta CG)\cos\theta + (254 + B)\sin\theta$..........Eq. V - 2

Where: H = head restraint height as measured by FMVSS 202

ΔCG = distance to head CG down from top of 50th percentile male head;

B = backset

θ = the angle between vertical line and the torso line =25°

In order to apply this equation we made the following simplifying assumptions:

1. The CG of an adult's head is 105 mm below the top of their head.
2. The CG of the 95th percentile male head is 53 mm above that of the 50th percentile male head CG.
3. The CG of a 95th female head is 53 mm above that of the 50th percentile female head CG.
4. The head restraint height at or above the center of gravity of the head is sufficient.

From the first assumption we calculate the vertical distance from the H-point to the CG of a 50th percentile male and female head is 746 mm and 687 mm, respectively when seated with a torso angle of 25° from the vertical. The current standard of 700 mm (27.5 inches) will be above the center of gravity (C.G.) of a 50th male up to an 80 mm backset. Similarly, 800 mm (31.5 inches) height will cover a 95th male up to a backset of 133 mm (5.2 inches) and 750 mm (29.5 inches) height will cover a 50th male up to a backset of 125 mm (4.9 inches). If we restrict backset to 55 mm (2.2 inches), a 767.7 mm (30.2 inches) high head restraint will cover a 95^{th} male, i.e., it covers 95 percent of the male population.

The agency has estimated the percentage of the general adult population that is covered by the old requirements and the percentage of the general adult population that will be covered by the new final rule. By "covered" we mean that the top of the head restraint is at or above the center of gravity of the occupants' head. This is not meant to imply that there would be no further benefit to head restraint height above the head center of gravity. Tables V-8a and V-8b show the simulation results of the relationship between the current standard and the new final rule for males and females. It is assumed that for the current standard a backset of 75 mm is used because backset is a function of height. The present FMVSS No. 202 standard, of 27.5 inches and an average backset of 75 mm, is estimated to cover 25 percent of the male population and 87 percent of the female population. The new FMVSS No. 202 Standard, of 800 mm (31.5 inches) and 55 mm backset, will cover 99.7 percent of the male population and all females. The current average vehicle height and backset covers approximately 91 percent of the male population and all females. The difference between the current vehicle fleet and the final rule would be approximately 9 percent for males.

Estimates for rear seat only occupants were also calculated. From NASS CDS (1988 to 1996) the agency found that the average height of rear seat occupants13+ years old is 65.8 inches. 700 mm head restraints and 55 mm backset covers occupants 67 inches and shorter. 750 mm head restraints and 55 mm backset covers occupants 74 inches and shorter. This implies that backset benefits applied to rear seat occupants 66 inches and shorter corresponds to approximately 60 percent of the rear seat occupants. And a head restraint height of 750 mm and shorter covers approximately 97 percent of the rear seat occupants.

Table V-8a
Percent of Adult Males

Requirements	**Covered by Height Alone: Backset = 75 mm**	**Covered by Height and Backset: Backset = 55 mm**
Current 202 Height = 700 mm	16.8 %	25.0 %
Current average Vehicle Height = 767 mm	90.8%	94.7%
Final Rule Height = 800 mm	99.3%	99.7 %

Table V-8b
Percent of Adult Females

Requirements	**Covered by Height Alone: Backset = 75 mm**	**Covered by Height and Backset: Backset = 55 mm**
Current 202 Height = 700 mm	80.3 %	86.9 %
Current average Vehicle Height = 767 mm	99.9%	100%
Final Rule Height = 800 mm	100%	100 %

Based on a survey of 282 occupants, the agency found that 47 percent of those with adjustable head restraints, had the head restraints in the down position. Another 51 percent of drivers raised their head restraints from the lowest position, but not necessarily to the highest position. The remaining two percent had an unknown position. We assume an equal distribution of head restraints with unknown adjustment. We are assuming that if a person takes time to raise the head restraint, he or she raises it to a position that is comfortable and as high as the C.G. of the head. We are further assuming that there is a random distribution of occupant height and head restraint adjustment; i.e., we are not assuming that all short people had the head restraint adjusted down and that all tall people had the head restraint adjusted up. Thus, it is estimated that 52 percent had the adjustable head restraint in the up position.

The average lowest driver height for adjustable head restraints in the present fleet was 28.0 inches (the lowest height comes into play when the adjustable head restraint is in the down position). The requirement in the final rule is 750 mm (29.5 inches) for the lowest height. Based on the Evaluation by Kahane, it is estimated that raising the lowest height from 711 mm to 750 mm (28.0 to 29.5 inches) will result in a 3.5 percentage point increase in effectiveness for all rear impact injuries and 5.83 (3.5/0.6) percentage point increase in effectiveness for whiplash injuries above the present fleet effectiveness for adjustable head restraints. Based on the survey, the 5.83 percentage point increase applies to 48 percent of the occupants in vehicles with adjustable head restraints.

Determining the effectiveness of raising average head restraint height in the rear seat is a more involved process, because the baseline height of the seats are different in the rear seat and with more children sitting in the rear seat, the average height of rear seat occupants is not the same as front seat occupants.

In the Kahane evaluation, the average front seat height of pre-standard seats was 559 mm (22 inches). The average height of adjustable front seat head restraints in the down position was 648 mm (25.5 inches) and the average height of front seat integral head restraints was 711 mm (28 inches). Head restraint heights have increased over time. The average height in the lowest position for the front outboard position adjustable head restraints for the 14 MY 1999 vehicles measured was 711 mm (28.0 inches). This is 64 mm (2.5 inches) higher than the adjustable head restraints low point in the late 1970's and the same height as the average integral restraint at that time.

It is assumed that the height of the rear bench seat is the same as pre-standard front seat (559 mm (22 inches)). Based on the sample of vehicles measured, the current vehicles with head restraints in the rear seat measured at the lowest head restraint height in the rear seat are 668 mm (26.3

inches) tall. Thus, the effect of increasing height from 668 to 750 mm (26.3 to 29.5 inches) was determined from Kahane evaluation as an 10.47 percentage point improvement in effectiveness for all rear impacts or 17.45 percent for whiplash injuries (10.47/0.6).

The second set of benefits is an incremental benefit of going from today's head restraints to the final rule requirements. The average lowest head restraint height (for those with or without a head restraint) is 653 mm (25.7 inches), 97 mm (3.8 inches) lower than the required 750 mm (29.5 inches). Incidentally, 655 mm (25.7 inches) is the average of those models with adjustable rear head restraints in the lowest position, and 650 mm (25.6 inches) is the average for those models without rear head restraints. The average height for all rear seats, those with and those without head restraints is 653 mm (25.7 inches). Based on Kahane evaluation, going from 653 mm to 750 mm (25.7 inches to 29.5 inches) in the front seat would increase effectiveness by 13.1 percentage points for rear impact injuries and 21.83 (13.1/0.6) percentage points for whiplash injuries. However, the occupancy rate of the rear seat in terms of height is much different than the front seat (see the following table, 34 percent of the front seat occupants are 5'10" or more, while only 17 percent of the rear seat occupants are 5'10" or more).

Percent of occupants by height and seating position
All occupants in NASS 1988-96

	5'9" and under	**5'10" and over**	**Total**
Front outboard	66%	34%	100%
Back outboard	83%	17%	100%

Research on Backset

In the analysis of the benefits of increasing head restraint height, it was shown that since height as measured in FMVSS No. 202 is a function of backset the benefits of a height increase depend on the assumed backset. The agency also believes that there would be an increase in effectiveness for the backset requirement in addition to the height requirement. NHTSA believes the proposal for backset will result in an increase in effectiveness based on several factors. First, studies have found that if the head is against the head restraint the occupant does not suffer any whiplash symptoms. Second, NHTSA computer generated models have shown that the reduction of the backset and an increase in the height of the head restraint reduces the level of neck loading and relative head-to-torso motion that may be related to the incidence of whiplash injuries. Third, the IIHS study comparing good, acceptable and poor head restraints and neck injuries gives an indication that backset is related to injury risk. The agency believes that reducing backset will reduce the injury rate. Later, the agency will calculate benefits based on backset requirements.

Olsson[10], (1990) conducted an in-depth study of neck injuries in rear end collisions in order to investigate injury severity and injury mechanisms in correlation with occupant and vehicle parameters. In this study 33 occupants in 26 rear end collisions were examined (Table V-9). Extensive interviews and medical examinations were carried out and reconstructions were made of the impact sequence through which injury mechanisms were postulated. The horizontal and vertical distances between the head and the head restraint just before impact were estimated with the occupant sitting in the impacted car or in a similar car after the crash. Olsson found that the duration of neck symptoms was significantly related to the horizontal distance between the head and the head restraint at the time of the accident and, to some extent, to the deformation of the occupant's car. Head restraint height (which ranged in the marginal to acceptable category according to the IIHS rating) did not have an association with whiplash injury outcome in this study.

[10] Olsson, I. et al, "An In-Depth Study of Neck Injuries in Rear End Collisions," International Conference on the Biomechanics of Impacts (IRCOBI), 1990.

Though this study indicates that backset was better correlated with duration of neck symptoms ($p<0.01$ at the 99 percent confidence interval) than head restraint height, it is difficult to estimate the injury reduction due to reduction in backset from this study since other factors such as DeltaV, seatback stiffness and compliance, head restraint height, and age and gender of occupant may influence injury outcome. The sample size of this study is insufficient to examine all these factors simultaneously. Note, in Table V-9, the horizontal distance from the back of the head to the head restraint is the backset. The height is the vertical distance from the top of the head to the top of the head restraint.

Table V-9

Field data of rear impact crashes in Gothenburg region during 1987-88 (Olsson, et al., 1990)

DeltaV (km/h)	Impact Pulse	Seatback Rotation (deg)	Age (years)	Height (cm)	Aware	Head-head restraint horzontal distance cm)	Head-head restraint vertical distance (cm)	Duration of symptoms
16	stiff	>15	46	182		8	14	0
16	stiff	11-15	42	184	no	23	12	>12 months
16	soft	0	51	181	yes	7	15	>12 months
13	stiff	0	23	183	no	8	14	0-7 days
16	stiff	0	51	179	no	5	8	0-7 days
12	stiff	11-15	49	185	no	6	12	0-7 days
12	stiff	1-10	38	186	no	6	10	0-7 days
19	stiff	11-15	47	181	no	10	10	0
19	stiff	0	22	186	no	18	17	>12 months
17	stiff	0	51	173	no	16	6	>12 months
13	stiff	1-10	34	172	yes	9	5	7-30 days
5	stiff	0	36	189	no	17	7	>12 months
19	stiff	1-10	62	179	no	12	13	>12 months
19	stiff	11-15	61	173	yes	10	6	4-11 months
19	stiff	0	59	167	no	0	4	7-30 days
24	soft	11-15	42	176	yes	9	10	>12 months
22	stiff	1-10	34	163	no	4	4	7-30 days
27	stiff	>15	60	176	no	6	13	7-30 days
27	stiff	>15	59	164	no	10	3	1-3 months
9	soft	0	50	171	no	6	6	0-7 days
24	stiff	0	77	168	no	8	5	0-7 days
30	soft	0	19	184	no	9	13	0-7 days
30	soft	0	20	187	no	10	15	>12 months
11	stiff	0	46	182	no	10	12	>12 months
9	stiff	0	36	176	no	7	10	7-30 days
18	stiff	1-10	36	194	yes	7	20	0-7 days
9	stiff	0	54	156	yes	5	1	0
9	stiff	0	86	153	no	5	3	>12 months
9	stiff	0	41	188	no	6	9	0-7 days
15	stiff	0	49	172	yes	3	11	0-7 days
18	stiff	11-15	28	175	no	8	11	>12 months
16	stiff	1-10	64	177	no	.	.	>12 months
16	stiff	1-10	61	164	no	.	.	0

Viano[11] et al. (2001) examined the effectiveness of the Saab head restraints by examining insurance accident reports of single event rear crashes. Additional information was obtained by way of a peer review questionnaire, which was mailed to the occupants in these rear impact crashes. The mean age of the occupants was 45±14 years, the mean occupant height was 176±9 cm, and the mean Delta V of the crashes was 8±4 km/h. Injury outcome was coded into four categories: 1) No injury, 2) Short-term neck pain lasting < 1 week, 3) Medium term whiplash injury lasting < 10 weeks, and 4) Long-term whiplash injury lasting > 10 weeks. Comparisons of injury outcome were made between the Saab 900 and Saab 9-3 seats (Table V-10). The Saab 9-3 seat incorporates the Saab active head restraint (SAHR) systems while the Saab 900 seats have conventional head restraints. The Saab 900 seat has a backset of 30 mm for a 50th percentile male occupant. For the SARH in the Saab 9 –3, the statically measured backset is not the metric for comparison. This is because the head restraint moves towards the occupant head during the rear impact event, thus reducing the backset even farther. The head restraint height of the Saab seats is approximately 760 mm in the high position. The Saab 900 and 9-3 have comparable rear structure so that any change in rear impact risk cannot be attributed to differences in structural design between the Saab 900 and 9-3.

Viano conducted sled tests at 12.5 km/h DeltaV with Hybrid III 50th percentile male dummy with rear impact dummy (RID) neck in these Saab seats. The head to torso rotation for the Saab 900 was 6 degrees greater than that of the Saab 9-3.

[11] Viano, D.C., et al, "The Effectiveness of Active Head Restraint in Preventing Whiplash," Journal of Trauma, Volume 51, Number 5, pp 959 – 969, 2001.

Table V-10
Injury Outcome in Rear Crashes For Occupants in Saab Seats

Seat Type	**No. of Cases**	**Percent Injured (mid to long term injury)**	**Backset (mm)**	**Neck extension (deg)**
Saab 900	48	14.6%	30-50	6
Saab 9-3	38	5.2%	NA	0
Injury reduction		9.4%		
Effectiveness		64%		

The effectiveness of the Saab 9-3 over the Saab 900 can be attributed to not only the head restraint geometry (backset, head restraint height) but also the seatback characteristics. The Saab 9-3 has a much higher recliner stiffness than the Saab 900. Therefore, this study is unable to separate the benefits of reduced backset in reducing whiplash injury risk from the benefits due to head restraint height and seatback design.

Farmer, Wells, and Lund[12] (2002) in a recent report of The Insurance Institute For Highway Safety (IIHS), examined automobile insurance claims to determine the rates of neck injuries in rear end crashes for vehicles with and without redesigned head restraints and/or seats. They noted from this study that the improved geometric fit of head restraints (reduced backset and increased head restraint height) in many newer vehicle models is reducing the risk of whiplash injury. They found that for vehicles with active head restraints, there was a 43 percent reduction in injury claims and for vehicles with a passive head restraint there was an 18 percent reduction in injury claims.

IIHS noted that the key to reducing whiplash injury risks in rear-end crashes was to keep the occupants head and torso moving together. The redesigned seats and head restraints were

[12] Farmer, Charles, Wells, JoAnn, Lund, Adrian, "Effects of Head Restraint and Seat Redesign on Neck Injury Risk in Rear –End Crashes," Insurance Institute For Highway Safety, October 2002.

intended to reduce the differential motion of the head and torso. One such redesigned seat with passive head restraint system is the 2000 Ford Taurus. The measurements for the Ford Taurus 1999 and 2000 are shown in Table V-11 (A and B).

Table V-11A
IIHS Taurus data (October Status Report)
All distances measured in IIHS format in mm

Name	Lock	Horizontal (backset)		Vertical	
		Down	Up	Down	Up
1999 Taurus	No	120*	95	175	130
1999 Taurus	No	125	85	165	125
2000 Taurus	yes	65	70	80	30
Delta (average)		57.5	20	90	97.5

* assumed

Table V-11B
All distances measured in NHTSA format in mm

Name	Lock	Horizontal (backset)		Vertical	
		Down	Up	Down	Up
1999 Taurus	No		95	684	714
1999 Taurus	No	125	85	695	714
2000 Taurus	yes	65	70	747	794

Although there is an 18 percent reduction in the insurance injury claims, it is not possible to separate out the effects of head restraint height, backset and seat redesign. According to Kahane (1983), the injury reduction due to increase in head restraint height from 690 mm to 750 mm is 4.3%. However, it is difficult to separate the benefits due to reduced backset and an optimally designed seatback.

Rear impact sled tests with volunteers and anthropomorphic test devices indicate that having the head restraint sufficiently high and as close as possible to the head (small backset) would reduce the relative motion between the head and torso and thereby reduce the risk of whiplash injury in a rear impact (Viano (2002); Svensson, (1999); and Siegmund, (1999). However, a relationship between backset and whiplash injury risk could not be developed by examining field data as done by Kahane (1982) for head restraint height. This is partly because it is difficult to separate the effectiveness due to head restraint height and backset as well as the seat design from case observations in the field. Therefore, an attempt is made to estimate benefits of backset reduction by examining controlled laboratory experiments.

Svensson[13] (1993) conducted sled tests using the Hybrid III 50th percentile male dummy fitted with the RID neck. The results showed that the backset had the most significant influence in reducing relative motion between the head and torso. For a head restraint height of 770 mm, a backset of 100 mm produced 33 degree of head-to-torso rotation while a backset of 40 mm produced a maximum head to torso rotation of 12 degree in 12.5 km DeltaV sled tests.

Siegmund (1999) examined the kinematic responses of 42 human volunteers (21 male and 21 female) in vehicle-to-vehicle rear impact crash tests at 4 and 8 km/h DeltaV. The volunteers were between the ages of 20 and 40 years and were within 10th to 90th percentile in height and weight of their age and gender category. The seated height was checked to ensure that the subject's head and not their neck contacted the head restraint. This ensured that the head restraint was sufficiently high and at least nearly as high as the head cg. The volunteers were relaxed and were unaware of the impending crash. Regression analysis (ANOVA) was conducted to determine the effect of specific occupant characteristics, head restraint position, and seated posture factors on peak kinematic responses (head/torso translation and rotation, neck extension, etc.) The results of the analysis indicated that relative head restraint position (backset and height) affect the magnitude and timing of peak kinematic responses more than occupant related factors such as age and gender. Further, the effect of backset on the kinematic responses was more than two times that of head restraint height in this study.

Yoganandan[14] conducted rear impact sled tests with the Hybrid III 50M dummy similar to the FMVSS 202 upgrade dynamic option (DeltaV=17.8 km/h). The dummy was placed in a rigid seat with head restraint height at 750 mm or 800 mm and backset at 100 mm, 50 mm and 0 mm from the back of the head. The head restraint tested was not attached to the seat in its same manner, as a production head restraint would be. Rather the head restraint was connected to the seat back with a fixture that allowed vertical and horizontal adjustments. The nature of this test setup allowed a significant amount of displacement in the head restraint during the dynamic testing, which might not be typical of an actual OEM design. Nonetheless, the results indicated that change in head restraint height between 750 mm to 800 mm had a small effect on head-to-torso rotation. However, there was significant difference in head-to-torso rotation for different backsets (Table V-12). The reduction in head-to-torso rotation for different backset is in the same range as that obtained by Svensson for head restraint height of 770 mm.

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[13] Svensson, M., et al. "The Influence of Seat-Back and Head Restraint Properties on the Head-Neck Motion During Rear-Impact,"1993 International Conference on the Biomechanics of Impacts, Eindhoven, Netherlands, 1993.
[14] Yogandandan, et al., "Small Female and Large Male Responses in Rear Impact," Forty Sixth AAAM Conference, 2002.

Table V-12.
Head to torso rotation of Hybrid III 50 M in 17.8 km/h rear impact sled tests with different head restraint height and backset (Yoganandan, 2002)

Restraint Height =	**750 mm**	**800 mm**
Backset=0 mm	0 deg	1 deg
Backset=50 mm	19 deg	16 deg
Backset=100 mm	40 deg	41 deg

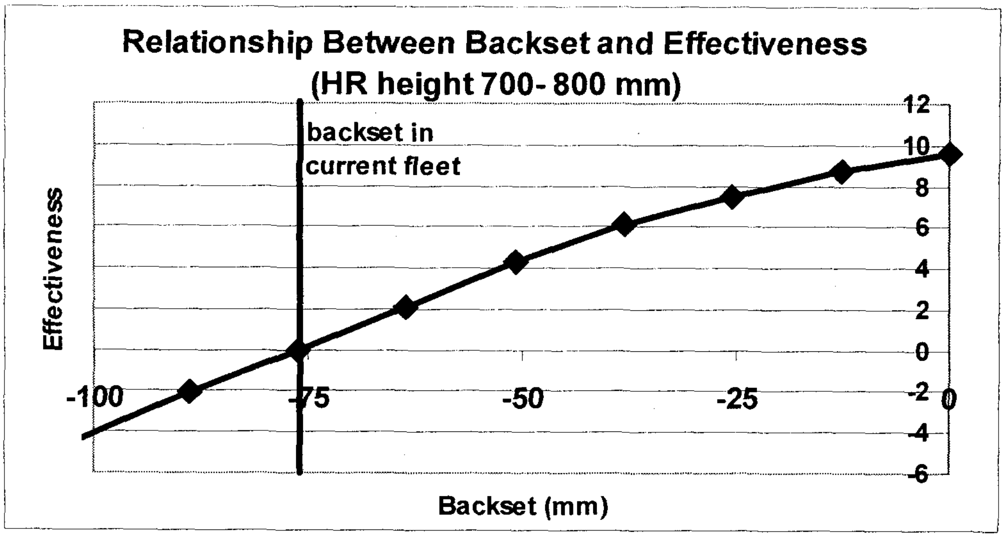
The studies by Siegmund (1999) and Yoganandan (2002) assume a relationship between kinematics and whiplash injury. However, such a relationship between occupant kinematics and the production of whiplash has not yet been determined. Generally however, impact related injury is likely the result of excessive stress or strain in a particular tissue, and is induced by either 1) direct external application of force, 2) indirect forces set up by relative motion, 3) internal forces set up by muscle contraction, or some combination of the three. Minimizing occupant kinematics could potentially minimize the excessive stress or strain due to head restraint contact and due to relative motion between the head and torso, thereby possibly reducing the potential for injury.

In fact, recent innovative seat designs use this very concept of minimizing the relative motion between the head and torso. Lundell, et al. (1998) in a research paper describing the development of the Volvo WHIPS seat noted that a high and fixed-in-position head restraint positioned close to the head is beneficial in reducing whiplash injury. Further, the SAHR seat design (Viano, 2000) is based on the concept that reducing relative motion between the head and torso will reduce whiplash injury risk.

Head Restraint Backset Effectiveness Estimates:

The laboratory experiments and the field test data presented earlier indicate that, for the average adult occupant, head restraints that are reasonably high (above 750 mm), changes in backset of the head restraint has greater influence on occupant kinematics (and in turn injury outcome) than equivalent changes in head restraint height. However, it is difficult to estimate a relationship between changes in whiplash injury risk for concomitant changes in backset. For this analysis we assume that the effectiveness of reducing head restraint backset is at least as much as an equivalent increase in head restraint height. For head restraint height between 700 and 800 mm, we assume the effectiveness of backset (from 100 mm to 0 mm) is the same as the relative effectiveness of head restraint heights between 650 and 750 mm. As seen in Figure 2, the greatest gain in benefits from increases in head restraint height is obtained between 660 mm (26 inches) and 787 mm (31 inches), above 787 mm the curve tends to be asymptotic.

For head restraint heights at the lower end of the 700 mm to 800 mm range and those below 700 mm, reduced backset may not have a significant effect on whiplash injury risk because the head restraint is not high enough relative to the occupant head. The backset effectiveness is determined relative to the backset effectiveness of the current fleet (average backset = 75 mm). At 75 mm the effectiveness of backset is approximately zero. As the backset is reduced, the effectiveness of backset increases. At zero backset, the effectiveness of backset is approximately 10 percent. This relationship is shown in Figure 3.



Effectiveness Vs. Backset for Head Restraint Heights between 700 to 800 mm.

Figure 3

The increase in head restraint effectiveness when head restraints of front seats in the current fleet (average head restraint height = 767 mm and average backset = 75 mm) comply with FMVSS 202 upgrade (head restraint height = 800 mm and backset = 55 mm) can be estimated separately for change in head restraint height and backset by using Figures 2 and 3. The increase in effectiveness due to increased head restraint height is 1.68% to 3.5% while the increase in effectiveness due to reduced backset is 3.5% for 55 mm. The overall effectiveness of the head restraint is assumed to be the higher of the two estimates i.e., 3.5%. Since head restraints are meant to only reduce whiplash injury, the head restraint effectiveness in reducing whiplash injuries is 3.5%/0.6 = 5.83%.

A similar analysis can be conducted for the rear seat as well. The average backset of rear seats in the fleet is 121 mm and height is 650 mm. These measurements change depending upon which alternative the agency is analyzing in the rear seat. The agency considered four Alternatives for the rear seat.

Alternatives 1-4 for rear seats are:

Alternative 1: Any rear seat that measures 700 mm or higher, must meet 750 mm at its lowest height, backset would be required.

Alternative 2: All rear seats must be 750 mm or higher, backset would be required.

Alternative 3: Would harmonize with ECE 17/25, any rear seat that measures 700 mm or higher, must meet 750 mm at its lowest height. Backset is not required.

Alternative 4: Any head restraint that measures 700 mm, must meet the height and backset requirements at 700 mm.

For Alternative 1, the average backset was 97.6 mm and the average height was 668 mm. From Figures 2 and 3, the effectiveness due to increased head restraint height (to 750 mm) is 10.47% and that due to reduced backset (to 55 mm) is 7.5%. The overall effectiveness of rear seat head restraints is assumed to be the higher of the two estimates, which is 10.47%. Accounting for effectiveness to reduce whiplash injuries, the total effectiveness of upgrading rear seat head restraint height in Alternative 1 is 10.47/0.6 = 17.45%.

Based on the sample of vehicles measured for Alternative 1, the current head restraints measured at the lowest head restraint height in the rear seat are 668 mm (26.3 inches) tall. The effect of increasing height from 668 to 750 mm (26.3 to 29.5 inches) was determined from the Kahane evaluation as an 10.47 percentage point improvement in effectiveness for all rear impacts or 17.45 percent for whiplash injuries (10.47/0.6).

Table V-13 gives a breakout of the estimated effectiveness for passenger cars, due to height and backset.

Table V-13
Passenger Car Effectiveness Estimates

	Height	Backset	Higher Effectiveness
Front Seat: Integral	1.68	5.83	5.83
Adjustable: up	1.68	5.83	5.83
Adjustable: Down	5.83	5.83	5.83
Rear Seat Alt. 1	17.45	7.5	17.45
Rear Seat Alt. 2 Integral	20.92	6.0	20.92
Adjustable: up	3.41	12.17	12.17
Adjustable: Down	21.0	12.17	21.0
Rear Seat Alt. 3	17.45	7.5	17.45
Rear Seat Alt. 4	19.63	12.83	19.63

In computing effectiveness, only the effectiveness of increased head restraint height or of reduced backset, which ever was higher, was used. The combined effectiveness of the increased height and reduced backset was not considered. Therefore, the computed effectiveness (considering either backset or height) underestimates the true effectiveness of head restraints by increasing height and reducing backset simultaneously. Since determining combined effectiveness is not possible, the agency notes that these estimates may underestimate the true effectiveness.

Benefits Accrued from Increasing Height and Reducing Backset

In the front seat, there are 67,779 annual whiplash injuries in seats with integral head restraints, and 183,256 whiplash injuries in seats with adjustable head restraints. The total number of front seat whiplash injuries is 251,035. Integral and adjustable head restraints injuries are combined since the effectiveness derived in Table V-13 is the same for both at 5.83 percent.

Effectiveness rates were calculated based on potential injuries. Therefore, an estimate of potential whiplash injuries, which include both those currently injured and those saved by current head restraints, will be estimated as follows:

Pw = Cw/(1-pe)

Where:

Pw = Potential whiplash injuries with no head restraints

Cw = Current total whiplash injuries

p = portion of on-road fleet with Cw injuries with head restraints (100%)

e = effectiveness of current head restraint systems

For front seat Integral head restraints:

Pw = 67,779/(1-1*.283) = 94,531

For front seat Adjustable head restraints:

Pw = 183,256/(1-1*.167) = 219,995

Total front seat potential injuries = 94,531 + 219,995 = 314,526

The number of whiplash injuries that could have been prevented if there were head restraints with a height of 31.5 inches and a backset of 55 mm or less is:

For the front seat head restraint: 314,526 x 0.0583 = 18,337

Our calculation is based on the assumption that half the fleet will be passenger cars and half will be light trucks. Using the adjusted effectiveness for light trucks, injuries prevented are:

For passenger cars: 18,337 x 0.5 = 9,169

Light trucks: 0.6656 x 18,337 x 0.5 = 6,103

Total benefit for the front seat is estimated to be: 15,272 (6,103 + 9,169) whiplash injuries.

For the rear seat there were 21,429 rear seat whiplash injuries. No whiplash injuries occurred in the rear outboard seats of pickup trucks. As noted earlier, the effectiveness of head restraints in SUVs and Vans is likely to be similar to that of passenger cars rather than pickups. Therefore, the passenger car effectiveness rate will be used for the LTV rear seat injuries as well. Also the agency has decided to define the presence of a head restraint if the seat back/head restraint height in any position of adjustment is more than 700 mm. As a result of this definition only 41.7 (5/12) percent of the vehicles would be considered as having a rear seat head restraint (Table VI-3). The effectiveness value for height in the measured vehicles in the rear seat is 21 percent (different from Table VI-3 because it was calculated on a subset of the data i.e., 12.6/0.6 = 21) and the effectiveness value for backset in the rear seat of the measured vehicles is 14.17 percent (Table VI-3).

The agency has estimated that a 750 mm head restraint height would offer whiplash protection to nearly the entire population of rear seat occupants. By requiring rear head restraints to be at least

750 mm, the final rule harmonizes with ECE 17 and ECE 25 which stipulate that optional rear adjustable head restraints cannot have a "use position" less than 750 mm. As a result, the agency has decided that any adjustable or integral head restraint that measures 700 mm must meet a height requirement of 750 mm. The benefits for this option (Option One) are calculated as follows:

Y = A x 5/12 x B x C x D

Where Y is injuries reduced

A is total injuries

B is effectiveness (see page 57)

C is the percentage of adjustable head restraints in the up and down positions (52% and 48% respectively)

D is the split of passenger cars to light trucks (0.5)

5/12 is the number of vehicles that meet the standard

Rear Seat Alternative One: Only rear seat with head restraints that meet 700 mm must meet 750 mm at its lowest height in the rear. All the benefits in this option accrue due to the height effectiveness. As stated earlier, only the higher of the two heights or backset is used.

Passenger cars using height effectiveness: 21,429 x 5/12 x 0.1745 x 0.5 = 779.5

Light trucks using height effectiveness: 21,429 x 5/12 x 0.1745 x 0.5 = 779.5

Total benefit for the rear seat is estimated to be 1,559 whiplash injuries.

Total benefits from front and rear seats are a reduction: 16,831(15,272 +1,559) whiplash injuries.

Rear Seat Alternative Two: all vehicles must meet 750 mm in the rear. Some of the benefits accrue due to height and some accrue due to the backset.

Y = A x 1/3 x B x C x D

Where 1/3 is the portion of injuries attributed to each of the three vehicle sets that make up the representative vehicle sample. The three sets of vehicle types are 1) those with adjustable head restraints. These are further divided into two groups, one with the head restraint adjusted up (52%) and the other with the head restraint adjusted down (48%). 2) Integral head restraints that met the old standard of 700 mm. 3) Integral head restraints that did not meet the old standard.

The benefits for this option for adjustable head restraints are calculated as follows:

Passenger cars using height effectiveness: 21,429/3 x 0.21 x 0.48 x 0.5 = 360

Light trucks using height effectiveness: 21,429/3 x 0.21 x 0.48 x 0.5 = 360

Passenger cars using backset effectiveness: 21,429/3 x 0.1217 x 0.52 x 0.5 = 226

Light trucks using backset effectiveness: 21,429/3 x 0.1217 x 0.52 x 0.5 = 226

Total benefit for adjustable head restraints for the rear seat is estimated to be 1,172 whiplash injuries.

Passenger cars using height effectiveness for integral restraints: 21,429x 2/3 x 0.2092 x 0.5 = 1,494

Light trucks using height effectiveness for integral restraints: 21,429x 2/3 x 0.2092 x 0.5 = 1,494

Total benefit for the rear seat for integral head restraints is estimated to be 2,988 (1,494+1,494) whiplash injuries. Total rear seat benefits are: 4,160 (1,172+2,988) whiplash injuries.

Total benefits from front and rear seats are a reduction: 19,432 (15,272 + 4,160) whiplash injuries.

Rear Seat Alternative Three

Section 6(a)(3)(C) of E.O. 12866 and section 205 of the Unfunded Mandate Reform Act (UMRA) generally require an agency issuing an economically significant rule to identify and consider a reasonable number of regulatory alternatives although this final rule is not significant. The European standard is the most viable alternative to this rule making. It requires the same height requirement as this final rule, but there is no backset requirement.

This final rule and ECE17/25 specify practically identical front and optional rear head restraint height requirements. Note: In "theory" they are not identical because of how rear seat head restraints are identified. For integral head restraints, the ECE 17/25 requires the front head restraints reach a height of 800 mm and rear head restraints reach the height of 750 mm. For adjustable head restraints, The ECE 17/25 requires that front head restraints be capable of reaching a height of 800 mm, and have no "use positions" with a height of less than 750 mm. The optional rear adjustable head restraints must reach the height of at least 750 mm and cannot have any "use positions" below that height. This final rule likewise requires that the front integral head restraints reach a height of 800 mm above the H-point. The optional rear integral head restraints must reach the height of 750 mm above the H-point. For adjustable head restraints, the front head restraints must be capable of reaching the height of at least 800 mm above the H-point, and both front and optional rear head restraints cannot have an adjustment position below 750 mm above the H-point, unless it is a "non-use" position.

Using the height effectiveness in Table V-13 and a breakout of adjustable head restraints in the ratio of 52 percent to 48 percent for adjustable restraint up and adjustable restraint down: (see formula on page 57 and Table V –13 for effectiveness).

For the front seat head restraint for passenger cars adjustable up:

219,995 x 0.52 x 0.5 x 0.0168 = 961

Adjustable down: 219,995 x 0.48 x 0.5 x 0.0583 = 3,078

Integral head restraint: 94,531 x 0.5 x 0.0168 = 794

Total benefit for front seat passenger cars = 4,833 (961+3,078+794)

A similar calculation is made for light trucks, since we are assuming that light truck sales equal 50 percent of total sales.

Total benefit for front seat light trucks = 3,217 (4,833 x .6656)

Total passenger car and light truck front seat benefits = 8,050 whiplash injuries reduced.

Calculations for the rear are the same as those calculated earlier in the section.

For passenger car rear seats = 586

For light truck rear seats = 586

Total benefit for rear seat is estimated to be 1,172 whiplash injuries.

Total benefits from the ECE height requirement which have no backset back set requirement benefits, for front and rear seats for passenger cars and light trucks is a reduction of 9,222 whiplash injuries.

Rear Seat Alternative Four: any adjustable or integral head restraint vehicle that measures 700 mm, must meet the requirements at 700 mm. All the benefits for this alternative accrue due to the height measurements. The benefits for this alternative are calculated as follows:

Passenger cars using height effectiveness: 21,429 x 3/12 x 0.1963 x 0.5 = 525.5

Light trucks using height effectiveness: 21,429 x 3/12 x 0.1963 x 0.5 = 525.5

Where 3/12 is the number of vehicles in this group and 0.1963 is the height effectiveness.

Total benefit for the rear seat is estimated to be 1,051 whiplash injuries.

Table VII-5(b)gives a summary of benefits for the various alternative that have been considered for the rear seat.

Table VII-5 (b)

Summary of Benefits for Different Options

Assumption for rear seat requirement		**Benefits**
Any adjustable or integral HR vehicle that measures 700 mm at highest height, must meet requirements at 750 mm at lowest height	Front	15,272
	Rear	1,559
	Total	16,831
All vehicles must meet 750 mm at lowest height	Front Seat	15,272
	Rear Seat	3,708
	Total	19,432
ECE requirement for height, 800 mm front seat, 750 mm rear seat, no backset requirement.	Front Seat	8,050
	Rear Seat	1,559
	Total	9,609
Any adjustable or integral HR vehicle that measures 700 mm at highest height, must meet requirements at 700 mm at lowest height	Front Seat	15,272
	Rear Seat	1,051
	Total	16,323

Whiplash Injury Costs

The average comprehensive costs of a whiplash injury, in 2002 dollars, is estimated to be \$9,994[15], resulting in a total annual cost of over \$2.7 billion for 270,861 whiplash injuries. The \$9,994 is comprised of \$6,843 in economic cost and \$3,151 in quality of life impacts. The \$9,994 estimate is based on the maximum injury per occupant being an AIS 1 injury. For this analysis, the agency examined all whiplash injuries, whether they were the highest AIS level or not. Although whiplash is by definition an AIS 1 neck injury, a small percentage of whiplash injuries were labeled as AIS greater than 1. Table V-14 shows the distribution of occupant injuries of those in rear impact towaway crashes.

Table V-14
Distribution of Injuries

	Towaway Crashes NASS 1988-96
Whiplash Injury Only (AIS 1)	34.2%
AIS 1 Other than Whiplash	60.8%
AIS Greater than 1 (Whiplash)	5.0%
Total	100.0%

15 Source: Data supplied by Pacific Institute for Research and Evaluation, Personal Communications 11/26/02. These estimates were later increased to \$2002 economics using the Consumer Price Index for all urban consumers.

VI. COSTS

In Table VI-1, cost estimates derived from tear down studies of head restraints from a variety of motor vehicles are listed along with sales and total estimates. Although the cost estimates are from LTV's, they are the most recent estimates available and we do not believe there is much difference between the head restraint of a LTV and that of a passenger car. Therefore, we believe that the estimates for LTVs are a good proxy of the estimates for passenger cars. From Table VI – 1, the costs for two head restraints are:

Average unweighted consumer cost = $34.54 ($483.58/14)

Sales weighted average cost = $89,692,554/2,847,686=$31.50

Sales weighted average of integral head restraints= $28,051,053/870,443=$32.23

Sales weighted average of adjustable head restraints=$61,641,502/1,977,243=$31.18

Data from Table VI-1 and additional data from the study are used to calculate the cost per inch of head restraint (see Table VI-2). Table VI-2 [16]gives the tear-down cost per inch of head restraint. Although in most cases the height increase necessary to pass the final rule is assumed to be attained by increasing the height of the head restraint, for some seat designs, the height increase can only be attained by increasing the seat back height. The agency has taken this into consideration, and believes that Table VI-2 is a representative sample of the vehicles in the fleet.

16 Fladmark, G. and Khadilkar, A., "Cost Estimates of Head Restraints in Light Trucks/Vans and Cost Estimates of Lower Cost Antilock Brake Systems. Final Report, U.S. Department of Transportation, 22 July 1994, page 21.

Table VI-1
Cost Estimates of MY 1992 Head Restraints both Driver and Passenger

Head Restraint System	Consumer Costs $1993	Consumer Costs $2002	1998 Model Sales
Chevy S10 PU /Integral	26.40	31.02	214,314 $6,647,870
GMC Sonoma/Integral	26.40	31.02	50,483 $1,565,947
Ford Econoline /Integral	24.37	28.63	156,924 $4,493,236
Ford Explorer /Integral	28.12	33.04	390,460 $12,901,423
Ford Mountaineer/Integral	28.12	33.04	43,539 $1,438,598
Toyota Previa/Sienna /Integral	58.04	68.19	14,723 $1,003,978
Subtotal Integral	(210.23)	(224.95)	870,443 28,051,053
Ford F150 PU /Adjustable	28.11	33.03	723,867 $23,909,979
Dodge Caravan /Adjustable	35.51	41.72	268,238 $11,190,702
Town and Country/ Adjustable	35.51	41.72	65,679 $2,740,081
Voyager/Adjustable	35.51	41.72	144,341 $6,021,806
Jeep Cherokee/ Adjustable	31.98	37.57	134,031 $5,035,236
Isuzu PU /Adjustable	19.81	23.27	13,419 $312,294
Chevy Silverado /Adjustable	16.86	19.81	40,890 $809,855
Sierra/CK Pickup/Adjustable	16.86	19.81	586,778 $11,621,549
Subtotal Adjustable	(220.15)	(258.65)	1,977,243 $61,641,502
Total	(411.6)	(483.6)	2,847,686 $89,692,554

Table VI-2
Cost Per Inch of Head Restraint

Head Restraint System	**Total consumer cost both driver and front passenger**	**Net cost per restraint less any adjustment hardware and assembly cost**	**Height of restraint system studied**	**Consumer cost per inch**
Chevy S10/ Sonoma PU Integral	31.02	28.04/2=14.02	11 inches	$1.27/inch 264,797 $337,552
Ford Econoline Integral	28.63	27.48/2=13.74	10-3/4 inches	$1.28/inch 156,924 $200,631
Ford Explorer Mountaineer/ Integral	33.04	32.28/2=16.14	9-3/4 inches	$1.65/inch 433,999 $718,239
Toyota Previa Integral	68.19	56.46/2=28.23	9 inches	$3.14/inch 14,723 $46,184
Subtotal Integral				870,443 $1,302,607
Ford F150 PU Adjustable	33.03	21.60/2=10.80	9 inches	$1.20/inch 723,867 $868,343
Dodge Caravan Voyager/Town Country Adjustable	41.72	30.36/2=15.18	4-3/4 inches	$3.20/inch 478,258 $1,528,205
Jeep Cherokee Adjustable	37.57	31.58/2=15.79	7 inches	$2.26/inch 134,031 $302,295
Isuzu PU Adjustable	23.27	17.48/2=8.74	7-3/4 inches	$1.13/inch 13,419 $15,137
Chevy CK/Sierra Silverado Adjustable	19.81	14.76/2=738	6-3/4 inches	$1.09/inch 627,668 $686,032
Subtotal adjustable				1,977,243 $3,400,011
Total				2,847,686 $4,702,619

Data from Table VI-2 are used to calculate average cost per inch of head restraints.

Weighted average vehicle cost per inch of head restraint in 2002 dollars

=$4,702,619/2,847,686 =$1.65

Weighted average vehicle cost per inch of integral head restraints in 2002 dollars

=$1,302,607/870,443 =$1.50

Weighted average vehicle cost per inch of adjustable head restraints in 2002 dollars =

$3,1400,011/1,997,243 =$1.70

These data indicate that there is little difference in the cost of head restraints and that there is little difference in the cost per inch of head restraints between integral and adjustable head restraints. The average cost of $31.50 per head restraint and $1.65 per inch of head restraint is appropriate for this analysis.

Tables IV-1, 2, and 3 present data on the difference between the final rule and measurements taken on 14 MY 1999 models of head restraint height and backset. For example, the MY 1999 Toyota Camry was measured and the driver's seat highest head restraint position was 30.75 inches or 0.75 inches lower than the proposed height of 31.5 inches.

It is assumed that the cost increase of raising the height of head restraints is the cost of increasing the highest head restraint position up to the 800 mm (31.5 inches) in the front seat or to 750 mm (29.5 inches) in the rear seat. The agency has not added any cost to increase the lowest head restraint position up to the 750 mm (29.5 inch) minimum for either front or rear seats. Since the cost of head restraints was very similar between adjustable and integral head restraints, the agency assumes that the true cost will be to raise the highest height of the head restraint and that changes in design, at no additional variable cost, can be accomplished to cover the minimum height requirements.

Light vehicle sales in the U.S. totaled 15.55 million units in 1998. There were 8.14 million car sales and 7.40 million truck sales in the U.S. in 1998. All of these vehicles will have to have the height of the front outboard seat head restraints increased. From Table IV-2, the average front outboard seat head restraint will have to be raised 1.3 inches to comply with the new standard. The cost of raising front outboard seat head restraints an average of 1.3 inches (see Table IV-2) is $4.29 per vehicle (1.3 x 2 head restraints x $1.65) per inch. This results in a fleet cost of $66.7 million ($4.29 x 15.55 million).

Approximately 41 percent of the 1999 model year vehicles have head restraints in the outboard rear seats and 20 percent have no rear seats (e.g., pickup trucks with no rear seats). Therefore, if head restraints were required, approximately 39 percent (1 - .41 - .20) of the vehicles would need a new rear seat head restraint, while approximately 41 percent would need to have their current rear seat head restraint height increased. It will be assumed that the ratio of integral to adjustable head restraints found in the current fleet will be maintained for the vehicles that add or modify head restraints.

Alternative one: Any adjustable or integral head restraint vehicle that measures 700 mm, must meet the requirements at 750 mm.

The cost of increasing the adjustable and integral head restraints an average height of 1.25 inches is: $12.8 million ($1.65 x 2 x 1.25 x $15.55 x 0.8 x 0.25)(3/12 of the vehicles fall in this category).

Alternative two: All vehicles must meet 750 mm.

The cost of increasing the adjustable head restraints an average height of 0.935 inches is: $12.8 million ($1.65 x 2 x 0.935 x 15.55 x 0.8 x 0.33). It is assumed that 33 percent of the vehicles have adjustable head restraints

The cost of increasing the integral head restraints that meet the standard an average height of 3.06 inches is: Approximately $41.8 million ($1.65 x 2 x 3.06 x 15.55 x 0.8 x 0.33).

The cost of increasing the integral head restraints that did not meet the standard an average height of 3.9 inches is: Approximately $54.29 million ($1.65 x 2 x 3.97 x 15.55 x 0.8 x 0.33). This results in a fleet cost of $108.9 million ($12.8+ $41.8 + $54.3 million).

Alternative three: ECE requirement for height, 800 mm front seat, 750 mm rear seat, no backset requirement.

The cost of increasing the adjustable and integral head restraints an average height of 1.25 inches is: $12.8 million ($1.65 x 2 x 1.25 x $15.55 x 0.8 x 0.25).

Alternative four: Any adjustable or integral vehicle that measures 700 mm must meet requirements at 700 mm

The cost of increasing the adjustable and integral head restraints an average height of 1.25 inches is: $12.8 million ($1.65 x 2 x 1.25 x $15.55 x 0.8 x 0.25).

Table VI- 3

Highest Rear Seat Head Restraint Height

Make/Model	Restraint Type	Highest Restraint Height (Inches)
Toyota Camry	Adjustable	29.8
Saab 9 –5	Fixed	31.3
Jeep Grand Cherokee	Adjustable	28.13
Dodge Caravan	Adjustable	27.63
Ford Explorer	Adjustable	29.0

Table VI-3 shows a representative sample of the vehicles that qualify under the definition of a rear head restraint as provided in the final rule. There were 12 vehicles with rear seat measured, and these five vehicles attained a height of 700 mm seat back height or head restraint height in any adjustment position. The five vehicles represent 41.7 (5/12) percent of the vehicles with rear seats. The rear seat head restraints in these vehicles would have to be modified to have a minimum height of 750 mm (29.5 inches).

The agency also believes that there will be a small cost to add locking mechanisms to those head restraints that don't have locking mechanisms. These are simple devices for height adjustment locking that are estimated to cost about $0.16 per head restraint. Based on our survey of 14 vehicles, half of the adjustable head restraints had locking mechanisms (6 of 12 in the front seat and 3 of 6 in the rear seat). Assuming about 70 percent (see Table VI-2) of the fleet will have adjustable head restraints in the front seat, and a third of the vehicles with rear seats (80 percent of all vehicles) will have optimally provided adjustable head restraints in the rear seat, the estimated cost for locking mechanisms is:

Front seat = $0.16 x 2 x .70 = $0.22 per vehicle x 15.55 million vehicles = $3.4 million, and

Rear seat = $0.16 x 2 x 0.33 = $0.108 per vehicle x 0.80 x 15.55 million = $1.3 million

The combined total is $4.7 million for locking mechanisms for height. The agency believes that there are positive benefits to be gained from the locking mechanism, but at this time the agency is unable to calculate the benefits of adding a locking mechanism to the head restraint.

It is believed that the mechanism that allows an adjustable head restraint to tilt forward can easily be designed to lock the head restraint in that position at no additional cost.

The total estimated cost for head restraints to meet the final rule equals

Front Seat Head Restraints $66.7 million +

All Rear Seat Restraint Raised $12.8 million +

Locking Mechanism for height $4.7 million

Total = $84.2 million.

The cost for the front seat is $70.1 (66.7+3.4) million and the cost for the rear seat is $14.1 (12.8+1.3) million. The average costs per vehicle are estimated to be:

$4.51 ($70.1/15.55) in front seats

$1.13 ($14.1/12.44(15.55 x 0.8)) in rear seats for vehicles with rear head restraints

$5.42 ($84.2/15.55) per average vehicle

The agency believes that the backset requirements will not add cost to the vehicle. There will be some redesign costs to both increase the height and reduce the backset, but the agency believes that the backset requirement is a design change that can be implemented at the same time as height is increased, with no increase in head restraint cost.

The agency has concluded that adding the backset requirement would not add significant cost to the certification testing. There is a one-time capital expenditure of $7,250 for the ICBC (Insurance Corporation of British Columbia) head-form test device. It took one of the agency technicians approximately 45 minutes at a cost of 34 dollars per hour to measure one seating position. Thus, we estimate costs to average $102 per vehicle ($34 x .75 hours x 4 seats per vehicle).

The agency believes that there may be some additional costs that could be attributed to the redesigning of some rear seats or some rear seat head restraints in SUVs and minivans, and possibly in some hatchbacks or station wagons if a manufacturer continues to provide a head restraint in these positions. Some SUVs and minivans have foldable seats, to create more usable storage space, which might encounter problems if the new requirements for optional head restraints in the rear seat prevent those seats from folding forward. These head restraints may need to be redesigned to fold so that the seat can be folded flat.

It is difficult to estimate the redesign costs of these vehicles because we believe the number of vehicles affected is very small, and also there is no consistent method to determine which vehicles would be affected. No commenters to the NPRM provided cost estimates for these potential redesigns. The costs would only be incurred at the manufacturers choosing.

VII. COST EFFECTIVENESS

This section combines costs and benefits to provide a comparison of the estimated injuries prevented per dollar spent. It should be noted that costs occur when the vehicle is purchased, but the benefits accrue over the lifetime of the vehicle. Benefits must therefore be discounted to express their present value and put them on a common basis with costs.

In some instances, costs may exceed economic benefits, and in these cases, it is necessary to derive a net cost per equivalent fatality prevented. An equivalent fatality is defined as the sum of fatalities and nonfatal injuries prevented, converted into fatality equivalents. This conversion is accomplished using the relative values of fatalities and injuries measured using a "willingness-to-pay" approach. This approach measures individuals' willingness to pay to avoid the risk of death or injury based on societal behavioral measures, such as pay differentials for more risky jobs.

Table VII-1 presents the relative estimated rational investment level to prevent one injury, by maximum injury severity. The data represent average costs for crash victims of all ages. AIS is an anatomically based system that classifies individual injuries by body region on a six point ordinal scale of risk to life. In the past, the agency assumed that whiplash injuries were valued based on the relative costs of MAIS 1 head/face/neck injuries. However, for this analysis the agency obtained an estimate from the files used to create MAIS 1 injury costs that was specific to whiplash. This analysis found that the comprehensive cost of an MAIS 1 whiplash injury was $9,566 in 2000 economics (including $6,550 in economic impacts and $3,016 in quality of life impacts). The comprehensive cost of a fatality was derived from "The Economic Impact of Motor Vehicle Crashes 2000", page 62. The ratio of 0.0029 in Table VII-1 was calculated for whiplash injuries only. The calculation is $9,566/$3,346,967. The consumer price index (CPI) for all urban consumers annual values are 179.9 for 2002 and 172.2 for 2000, making a multiplier of 1.0447 (179.9/172.2). Thus, the total comprehensive costs in 2002 economics are $9,994 (1.0447 x $9,566). This estimate is comprised of $6,843 in economic impacts and $3,151 in quality of life impacts.

Table VII-1
Comprehensive Fatality and Injury Relative Values

Injury Severity	2000 Relative Value* per injury
MAIS 1	.0029 (only valid for whiplash injury)
MAIS 2	.0458
MAIS 3	.0916
MAIS 4	.2153
MAIS 5	.7124
Fatals	1.000
*includes the economic cost components and valuation for reduced quality of life	

Table VII-1 shows the estimated equivalent fatalities for the height and backset changes to the head restraint. About 345 whiplash injuries (1/0.0029) are estimated to be equivalent to one fatality.

Table VII-2
Alternative One: Equivalent Fatalities

	Injury Benefits	Equivalent Fatalities
Front Seat	15,272	44.27
Rear Seat	1,559	4.52
Total	16,831	48.79

Table VII-2 (a)
AlternativeThree: Equivalent Fatalities

	Injury Benefits	Equivalent Fatalities
Front Seat	8,050	23.34
Rear Seat	1,559	4.52
Total	9,609	27.86

The following is an example of the calculation of the cost per equivalent fatalities for head restraints before discounting.

Alternative One:

Front Seat Head Restraint $70.1 million /44.27 = $1.58 million

Rear Seat Head Restraint $14.1 million /4.52 = $3.12 million

Total $84.2 million /48.78 = $1.73 million

Alternative Three:

Front Seat Head Restraint $70.1 million /23.34 = $3.00 million

Rear Seat Head Restraint $14.1 million /4.52 = $3.12 million

Total $84.2 million /27.86 = $3.02 million

Appendix V of the "Regulatory Program of the United States Government," April 1, 1990 - March 31,1991, sets out guidance for regulatory impact analyses. One of the guidelines deals with discounting the monetary values of benefits and costs occurring in different years to their present value so that they are comparable. Historically, the agency has discounted future benefits and costs when they were monetary in nature. For example, the agency has discounted future increases in fuel consumption due to the increased weight caused by safety countermeasures, or decreases in property damage crash costs when a crash avoidance standard reduced the incidence of crashes, such as with center high-mounted stop lamps. The agency has not assigned dollar values to the reduction in fatalities and injuries, thus those benefits have not been discounted. The agency performs a cost-effectiveness analysis resulting in an estimate of the cost per equivalent life saved, as shown on the previous pages. The guidelines state, "An attempt should be made to quantify all potential real incremental benefits to society in monetary terms of the maximum extent possible." For the purposes of the cost-effectiveness analysis, the Office of Management and Budget (0MB) has requested that the agency compound costs or discount the benefits to account for the different points in time that they occur.

There is general agreement within the economic community that the appropriate basis for determining discount rates is the marginal opportunity costs of lost or displaced funds. When these funds involve capital investment, the marginal, real rate of return on capital must be considered. However, when these funds represent lost consumption, the appropriate measure is the rate at which society is willing to trade off future for current consumption. This is referred to as the "social rate of time preference," and it is generally assumed that the consumption rate of interest, i.e. the real, after-tax rate of return on widely available savings instruments or investment opportunities, is the appropriate measure of its value.

Estimates of the social rate of time preference have been made by a number of authors. Robert Lind[17] estimated that the social rate of time preference is between zero and 6 percent, reflecting the rates of return on Treasury bills and stock market portfolios. More recently,

17 Lind, RC, "A primer on the Major Issues Relating to the Discount Rate for Evaluating National Energy Options," in Discounting for Time and Risks in Energy Policy, 1982, (Washington, D.C., Resources for the Future, Inc.).

Kolb and Sheraga[18] put the rate at between one and five percent, based on returns to stocks and three month Treasury bills. Moore and Viscusi[19] calculated a two percent real time rate of time preference for health, which they characterize as being consistent with financial market rates for the period covered by their study. Moore and Viscusi's estimate was derived by estimating the implicit discount rate for deferred health benefits exhibited by workers in their choice of job risk.

Three different discount values are shown as a sensitivity analysis. The 2 and 4 percent rates represent different estimates of the social rate of time preference for health and consumption. The 7 percent figure is the current OMB requirement, which represents the marginal pretax rate of return on an average investment in the private sector in recent years.

Safety benefits occur when there is a crash severe enough to potentially result in occupant death and injury, which could be at any time during the vehicle's lifetime. For this analysis, the agency assumes that the distribution of weighted yearly vehicle miles traveled are appropriate proxy measures for the distribution of such crashes over the vehicle's lifetime(see Tables VII-3(a and b)).

18 J. Kolb and J.D. Sheraga, "A Suggested Approach for Discounting the Benefits and Costs of Environmental Regulations," unpublished working papers.

19 Moore, M.J., and Viscusi, W.K.,"Discounting Environmental Health Risks: New Evidence and Policy Implications," Journal of Environmental Economics and Management, V.18, No. 2, March 1990, part 2 of 2.

Table VII-3 (a)

Light Trucks Vehicle Miles Traveled and Discount Factor

Light Trucks						
Vehicle Age (years)	**Vehicle Miles Traveled**	**Survival Probability**	**Weighted Vehicle Miles Traveled**	**Fraction of Total VMT**	**7 Percent Mid-Year Discount Factor**	**7 Percent Present Discounted Value Factor**
-------	---------	-----------	---------	---------	---------	
1	12,885	0.998	12,859	0.0839	0.9667	0.0811
2	12,469	0.995	12,407	0.0809	0.9035	0.0731
3	12,067	0.989	11,934	0.0778	0.8444	0.0657
4	11,678	0.980	11,444	0.0746	0.7891	0.0589
5	11,302	0.967	10,929	0.0713	0.7375	0.0526
6	10,938	0.949	10,380	0.0677	0.6893	0.0467
7	10,585	0.924	9,781	0.0638	0.6442	0.0411
8	10,244	0.894	9,158	0.0597	0.602	0.0360
9	9,914	0.857	8,496	0.0554	0.5626	0.0312
10	9,594	0.816	7,829	0.0511	0.5258	0.0268
11	9,285	0.795	7,382	0.0481	0.4914	0.0237
12	8,985	0.734	6,595	0.0430	0.4593	0.0198
13	8,696	0.669	5,818	0.0379	0.4292	0.0163
14	8,415	0.604	5,083	0.0332	0.4012	0.0133
15	8,144	0.539	4,390	0.0286	0.3749	0.0107
16	7,882	0.476	3,752	0.0245	0.3504	0.0086
17	7,628	0.418	3,189	0.0208	0.3275	0.0068
18	7,382	0.364	2,687	0.0175	0.326	0.0057
19	7,144	0.315	2,250	0.0147	0.286	0.0042
20	6,913	0.217	1,873	0.0098	0.2673	0.0026
21	6,691	0.232	1,552	0.0101	0.2498	0.0025
22	6,475	0.196	1,269	0.0083	0.2335	0.0019
23	6,266	0.169	1,059	0.0069	0.2182	0.0015
24	6,064	0.143	867	0.0057	0.2039	0.0012
25	5,869	0.121	710	0.0046	0.1906	0.0009
			------	------		
			153,706	1.0000		0.6315

Table VII-3 (b)
Passenger Cars Vehicle Miles Traveled and Discount Factor

Passenger Car Vehicle Age		Survival	Weighted	Fraction of	7 percent Mid- Year Discount	Present Discount
(Years)	'VMT	Probability	'VMT	VMT	Factor	Value Factor
1	13533	0.995	13465.3	0.1063	0.9667	0.1028
2	12989	0.988	12833.1	0.1013	0.9035	0.0915
3	12466	0.978	12191.7	0.0962	0.8444	0.0813
4	11964	0.962	11509.4	0.0909	0.7891	0.0717
5	11482	0.938	10770.1	0.0850	0.7375	0.0627
6	11020	0.908	10006.2	0.0790	0.6893	0.0544
7	10577	0.87	9202.0	0.0726	0.6442	0.0468
8	10151	0.825	8374.6	0.0661	0.602	0.0398
9	9742	0.775	7550.1	0.0596	0.5626	0.0335
10	9350	0.721	6741.4	0.0532	0.5258	0.0280
11	8974	0.644	5779.3	0.0456	0.4914	0.0224
12	8613	0.541	4659.6	0.0368	0.4593	0.0169
13	8266	0.445	3678.4	0.0290	0.4292	0.0125
14	7933	0.358	2840.0	0.0224	0.4012	0.0090
15	7614	0.285	2170.0	0.0171	0.3749	0.0064
16	7308	0.223	1629.7	0.0129	0.3504	0.0045
17	7014	0.174	1220.4	0.0096	0.3275	0.0032
18	6731	0.134	902.0	0.0071	0.326	0.0023
19	6460	0.103	665.4	0.0053	0.286	0.0015
20	6200	0.079	489.8	0.0039	0.2673	0.0010
		11.946	126,678	1		0.6922

Multiplying the percent of a vehicle's total lifetime mileage that occurs in each year by the discount factor and summing these percentages over the 20 (passenger cars) or 25 (LTV's) years of the vehicle's operating life, results in the following multipliers for the average of passenger cars and light trucks: 0.8766 at a 2 percent discount rate, 0.7775 at a 4 percent discount rate and 0.6618 at a 7 percent discount rate. These values are multiplied by the equivalent lives saved to determine their present value (e.g., Table VII-4 (a) 44.27 x 0.8766 = 38.81). The costs per equivalent life saved for passenger cars and light trucks are then recomputed and shown in Table VII-4 (b) e.g., ($70.1 million/38.82=$1.81 million, $14.1 million/3.96 = $3.56 million and 84.2/42.77 = $1.97 million).

Table VII-4 (a)
Alternative One: Equivalent Lives Saved

Base Equivalent	2 percent	4 Percent	7 percent
	x 0.8766	x 0.7775	x 0.6618
Front 44.27	38.82	34.44	29.31
Rear 4.52	3.96	3.51	2.99
Total 48.79	42.77	37.93	32.29

Table VII-4 (b)
Discounted Costs per Equivalent Life Saved (in millions)

Base Equivalent	Undiscounted	2 percent	4 percent	7 percent
Front seat $70.1	$1.58	$1.81	$2.04	$2.39
Rear seat $14.1	$3.12	$3.56	$4.01	$4.71
Total $84.2	$1.74	$1.97	$2.22	$2.61

Table VII-4 (c)
Alternative Three: Equivalent Lives Saved

Base Equivalent	2 percent	4 Percent	7 percent
	x 0.8766	x 0.7775	x 0.6618
Front 23.34	20.46	18.15	15.45
Rear 4.52	3.96	3.51	2.99
Total 27.86	24.42	21.66	18.44

Table VII-4 (d)
Alternative Three: Discounted Costs per Equivalent Life Saved (in millions)

Base Equivalent	Undiscounted	2 percent	4 percent	7 percent
Front seat $70.1	$3.00	$3.43	$3.86	$4.54
Rear seat $14.1	$3.44	$3.56	$4.01	$4.71
Total $84.2	$3.07	$3.45	$3.89	$4.57

Table VII-5 (a)

Summary of Cost and Benefits for Different Options

Assumption for rear seat requirement	**Inches**	**Number of Vehicles Involved ***	**Costs**	**Benefits**	**Costs per Equivalent Life Saved**
Any adjustable or integral HR that measures 700 mm, must meet requirement at 750 mm	29.5 inches, requires 3 adjustable head restraints to be higher	5 of 12 in our test qualify, 3 of these need more height	$14.12 million for height and locks	1,559 height and backset benefits	$4.71 million
All vehicles must meet 750 mm	29.5 inches	10 of 12 need more height	$110 million for height and locks	4,160 height and backset benefits	$13.78 million
ECE requirement for height, 800 mm front seat, 750 mm rear seat, no backset requirement.	29.5 inches, requires 3 adjustable head restraints to be higher	5 of 12 in our test qualify, 3 of these need more height	$14.12 million for height and locks	1,559 height and backset benefits	$4.71 million
Any adjustable or integral HR that measures 700 mm, must meet requirement at 700 mm	27.5 inches	5 of 12 in our test – 4 adjustable and one integral	$1.65 million for locks **	1,051 backset benefits***	$0.82 million

* Excludes 20 percent of passenger vehicles with no rear seat.
**Adds lock for a tilt head restraint, considered integral
*** Note, 60 percent of benefit at 750 mm for height of rear seat occupants.

Tables VII-5(a) and (b) gives a summary of the Four options that were considered, calculations for any adjustable or integral head restraint that measures 700 mm, must meet requirement at 700 mm were not shown in the text with the other two options.

Table VII-5 (b)

Summary of Costs, Benefits and Costs per Equivalent Life Saved for Different Options

Assumption for rear seat requirement		**Costs**	**Benefits**	**Costs per Equivalent Life Saved**
Any adjustable or integral HR that measures 700 mm, must meet requirement at 750 mm	Front Seat	$70.1	15,272	$2.39 mil
	Rear Seat	$14.1	1,559	$4.71 mil
	Total	$84.2	16,831	$2.61 mil
All vehicles must meet 750 mm	Front Seat	$70.1	15,272	$2.39 mil
	Rear Seat	$110.2	4,160	$13.78 mil
	Total	$180.3	19,432	$4.8 mil
ECE requirement for height, 800 mm front seat, 750 mm rear seat, no backset requirement.	Front Seat	$70.1	8,050	$4.54 mil
	Rear Seat	$14.1	1,559	$4.71 mil
	Total	$84.2	9,609	$4.57 mil
Any adjustable or integral HR vehicle that measures 700 mm, must meet requirements at 700 mm	Front	$70.1	15,272	$2.39 mil
	Rear	$1.65	1,051	$0.82 mil
	Total	$71.75	16,323	$2.29 mil

Comparison of cost per equivalent life saved estimates in past NHTSA rulemakings

The agency examined some of the past NHTSA rulemakings, which required protection for rear seat occupants, to compare the cost per equivalent life saved with this final rule for head restraints. The three NHTSA rulemakings with specific requirements for rear seat passengers for which cost per equivalent life saved has been evaluated are:

1) FMVSS 208 requirement for rear seat outboard lap/shoulder belts,
2) FMVSS 214 passenger car side impact protection requiring a test dummy in the rear seat in the dynamic side impact test, and
3) FMVSS 201 upper interior head protection, which included target points around the upper interior of light vehicles, including areas near rear seat passengers.

Table VII-6 shows the results from these analyses (updated to $2000).

The cost per equivalent life saved for FMVSS 208 depended significantly on belt use in the rear seat. The agency believed that it could increase the use of belts in the rear seat and bring down the cost per equivalent life saved.

Note that the high costs per equivalent life saved in FMVSS 208 and FMVSS 201 were for light trucks and not for the combination of passenger cars and light trucks. While for this FMVSS 202 final rule, the cost per equivalent life saved for Option 2 (requiring head restraints at 750 mm for all rear outboard seats) of $13.78 million is for all passenger cars and light trucks to have required head restraints. This is much higher than previous rulemakings issued by the agency for a combination of passenger cars and light trucks.

Table VII-6
Cost Per Equivalent Life Saved Estimates
Involving the Rear Seats of Passenger Vehicles
($2002 in million)

	FMVSS 208 Rear Seat Lap/Shoulder Belts – Outboard*	FMVSS 214 Passenger Car Side Impact Protection	FMVSS 201 Upper Interior Head Protection
Front Seat Total			0.53
Passenger Cars		0.62	0.52
Light Trucks			0.55
	15.7% to 70% belt use		
Rear Seat Total	5.65 to 1.28		4.42
Passenger Cars	4.91 to 1.10	3.91	2.87
Light Trucks	**13.88** to 3.28		**10.33**
Front and Rear Seat			0.92
Passenger Cars		0.97	0.88
Light Trucks			0.96

VIII. REGULATORY FLEXIBILITY ACT

The Regulatory Flexibility Act of 1980 (Public Law 96-354) requires agencies to evaluate the potential effects of their proposed and final rules on small businesses, small organizations and small government jurisdictions.

Section 603 of the Act requires agencies to prepare and make available for public comment a preliminary regulatory flexibility analysis (PRFA) describing the impact of proposed rules on small entities. Section 603(b)of the Act specifies the content of a PRFA. Each PRFA must contain:

- A description of the reasons why action by the agency is being considered;
- A succinct statement of the objectives of, and legal basis for, the proposal;
- A description of and, where feasible, an estimate of the number of small entities to which the proposal will apply;
- A description of the projected reporting, record keeping and other compliance requirements of the proposal including an estimate of the class of small entities which will be subject to the requirement and the type of professional skills necessary for preparation of the report or record;
- An identification to the extent practicable, of all relevant Federal rules which may duplicate, overlap or conflict with the proposal.

NHTSA has considered the effects of this rulemaking action under the Regulatory Flexibility Act and hereby certify that the final rule would not have a significant economic impact on a substantial number of small entities.

The final rule would directly affect motor vehicle manufacturers, alterers and seating manufacturers. For passenger car and light truck manufacturers, NHTSA estimates that there are only about four small manufacturers in the United States. These manufacturers buy their seats from a seat manufacturer and install them. Thus, the redesign change will be accomplished by a seat manufacturer.

There are approximately 30 seating manufacturers in the U.S. Many of these are small businesses. The final rule is expected to have an impact on these small businesses by changing the requirements for head restraints. However, raising the height of an integral or adjustable head restraint or changing the design of a head restraint for the backset requirement is not a novel or complex task. There are already seats in production that meet these criteria. However, making design changes for numerous makes and models at the same time could present a challenge for these small businesses. The agency does not believe that this will have a significant economic impact on these small businesses.

NHTSA notes that final stage vehicle manufacturers and alterers could also be affected by this final rule. Most final stage manufacturers and alterers purchase seats from a seat manufacturer and install them in van conversions or other types of vehicles. The final rule would not have any significant effect on final stage manufacturers or alterers.

Small organizations and small governmental units would not be significantly affected since the potential cost impacts associated with this action should only slightly affect the price of new motor vehicles.

For the reasons discussed above, the agency believes the economic impact on small entities that would most likely be affected by this final rule, vehicle manufacturers, seating manufacturers, final stage manufacturers and alterers, would be small. While the small vehicle manufacturers would face additional compliance costs, the agency believes that seating manufacturers would likely provide much of the engineering expertise necessary to meet the new requirements.

UNFUNDED MANDATES REFORM ACT ANALYSIS

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 2002 results in about $113 million (110.66/98.11 = 1.127). The assessment may be included in conjunction with other assessments, as it is here.

These effects have been discussed in detail in previous sections of this Final Regulatory Impact Analysis. To summarize, NHTSA is issuing this final rule to require head restraints be raised to an average of 800 mm (31.5 inches) in the front outboard positions and 750 mm (29.5 inches) in the rear outboard positions, also to have a back set of no less than 55 mm at any adjustment position under the authority of 49 U.S.C. 322, 30111, 30115, 30117 and 30166; delegation of authority at 49 CFR 1.50.

The final rule will would improve the safety of individuals traveling in passenger vehicles.

The cost of the proposed rule is estimated to be $84.2 million.

IX. COSTS AND BENEFITS OF HEAD RESTRAINTS IN CENTER SEATING POSITIONS

The agency has examined the implications of requiring a head restraint in both the front and rear center seating positions. The following is an analysis of head restraints in the front and rear center seating positions of passenger vehicles.

Costs

The data indicate that there is little difference in the cost per inch of head restraints between integral and adjustable head restraints. The average cost of $15.75 per head restraint and $1.65 per inch of head restraint estimated previously are used in this analysis.

Approximately 20 percent of the light vehicle fleet would be required to have a head restraint in the front center seating position. The number of vehicles that would need a front center head restraint is 3.11 million (.2 x 15.55m). The average cost of current head restraints is $15.75. If the agency were to propose the same height for the center front seat head restraints as for front outboard head restraints, the average head restraint would have to be raised 33 mm (1.3 inches) to meet the 800 mm (31.5 inch) proposal. The cost of raising the average head restraint 33 mm (1.3 inches) is $2.15 (1.3 x $1.65). Average total cost of the front center head restraint is $17.90 ($15.75 + $2.15). Total cost of installing a front center head restraint and raising the height is $55.67 million (3.11 million vehicles x $17.90).

The average height needed, to be added to a center backseat head restraint was determined by examining the vehicles without adjustable head restraints in the rear seat from Table IV-1.

Table IX - 1
Vehicles Without Adjustable Head Restraints -- Rear Center Seat

Vehicles	Inches to be Raised	1998 Sales	Sales Weighted Inches
Accord	4.75	401,071	1,905,087
Neon	4.75	78,533	373,032
Lumina	7.375	177,631	1,310,029
Cavalier	2.435	256,099	623,601
Malibu	6.5	223,703	1,454,070
Cadillac	4.935	182,151	898,915
Total	Average 4.976*	1,319,188	6,564,734

* The weighted average number of inches the head restraint needed to be raised was 4.976 (6,564,734/1,319,188) inches.

Light vehicle sales in the U.S. totaled 15.55 million units in 1998. There were 8.14 million car sales and 7.40 truck sales in the U.S. in 1998. Approximately 79 percent of these vehicles will have to have the rear center position installed with a head restraint (some vehicles do not have rear seat or center seating position). The number of vehicles that would need to have the rear center seat raised is approximately 12.29 (.79 x 15.55) million. The cost of raising the rear center seat an average of 127 mm (5 inches) is approximately $8.25 ($1.65 x 5) per vehicle. The total cost of raising the rear center seat to meet the height of the regulation would be $101.39 million ($8.25 x 12.29 million vehicles). The cost of adding a locking mechanism is $0.16. Cost of adding a locking mechanism to the front center seats is: $0.5 million (.2 x 15.5 million x.16). Cost of adding a locking mechanism to the rear center seats is: $2.0 million (.79 x 15.5 million x.16). Total cost of locking mechanism is $2.5 million.

Total cost of front and rear center seats head restraints is $159.56 million ($55.67 + $101.39 + $2.5).

Benefits

Table IX - 2
Whiplash Injuries in Center Seating Positions
(Based on Tow-away Crashes in NASS-CDS 1988 to 1996)

Body-type	Seat Position	Whiplash Raw	Annual Average Whiplash Weighted
Car	Front Center	2	133
Light Truck	Front Center	2	316
Subtotal		4	449
Car	Back Center	7	1,363
Light Truck	Back Center	2	149
Subtotal		9	1,512
Total		13	1,961

There were an annual average of 449 whiplash injuries in the front center seating position and 1,512 whiplash injuries in the rear center seating position in tow-away crashes. On average, the multiplier for tow-away crash injuries to total injuries in police reported crashes is 3.0 (see V-2). Thus, we estimate the annual number of police-reported whiplash injuries in the front center seat in rear crashes to be 1,347 (449 x 3.0). The multiplier from police-reported crashes to all crashes, including unreported crashes, for AIS 1 injuries is 1.29 (see V-2). Thus, the annual estimated number of total whiplash injuries in the front center seat, in rear crashes, police-reported and unreported is 1,738 (1,347 x 1.29).

Similarly, for the rear center seating position, the estimated total number of whiplash injuries is 5,851 (1,512 x 3 x 1.29).

The effectiveness for head restraints is dependent upon the height and backset of the head restraint. For the front center seat, the result of adding a head restraint and then raising the head restraint to the height 800 mm (31.5 inches) and a backset of 55 mm or less, the effectiveness would be an estimated 5.83 percent (the effectiveness number is calculated from Kahane, C., "An Evaluation of Head Restraints, Federal Motor Vehicle Safety Standard 202" NHTSA, February 1982, DOT HS-806-108, Page 280 and Table V-6 of this document, which is an expanded version of Kahane's Table B-6).

Thus, the adjusted benefits of head restraints in the front center seat are: 1,738 x 0.0583 = 101 whiplash injuries reduced. Using the adjusted effectiveness for light trucks, injuries prevented are:

Light trucks: 101 x 0.6656 x 0.5 = 34

Passenger cars 101 x .5 = 52

For the rear seat, the effectiveness of a 750 mm (29.5 inch) head restraint and a backset of 55 mm or less is estimated to be 21.83 percent (13.1/.6)(see Table V-6). Thus, the adjusted benefits of head restraints for the rear center seating position is estimated to be 5,851 x 0.2183 = 1,277 whiplash injuries reduced.

Light trucks: 1,277 x 0.6656 x 0.5 = 425

Passenger cars 1,277 x .5 = 639

Total benefits are: 86 whiplash injuries reduced in the front center seat plus 1,064 whiplash injuries reduced in the rear center seat = 1,150 whiplash injuries reduced annually.

<u>Cost Per Equivalent Fatality</u>

From Table VII-1, approximately 345 whiplash injuries are estimated to be equivalent to one fatality. Therefore, in the front center seat there would be approximately 0.25 (86/345) equivalent fatalities prevented. In the rear center seat there would be approximately 3.08 (1,064/345) equivalent fatalities prevented.

Cost /Equivalent Fatality Before Discounting

Front Center Seat Head Restraint $56.17 million /0.25 = $224.68 million

Rear Center Seat Head Restraint $103.39 million /3.08 = $33.57 million

Both Positions $159.56 million/3.33 = $47.92 million

As discussed in Chapter VII, benefits accrue over the twenty to twenty five year lifetime of the passenger vehicle while costs occur when the vehicle is purchased. Benefits are discounted to present value so that costs and benefits are compared on an equal basis.

Discounted Cost/Equivalent Fatality

Table IX-3(a)
Equivalent Lives Saved

Base Equivalent	2 percent	4 Percent	7 percent
	x 0.8871	x 0.7946	x 0.6844
Front Center 0.25	0.22	0.19	0.17
Rear Center 3.08	2.70	2.39	2.04
Both 3.33	2.92	2.59	2.20

Table IX-3(b)
Discounted Costs per Equivalent Life Saved

	2 percent	4 percent	7 percent
Front seat	$256.31 million	$288.98 million	$339.50 million
Rear seat	$38.29 million	$43.17 million	$50.72 million
Total	$54.66 million	$61.63 million	$72.40 million

For front center seat head restraints, the cost per equivalent life saved is $339.50 million at a 7 percent discount rate based on the effectiveness for increasing the height of head restraints and assuming a backset of less than 55 mm. For rear center seat head restraints, the cost is $50.72 million at a 7 percent discount rate. For both front and rear center seat combined, the cost per equivalent life saved is $72.40 million at a 7 percent discount rate.

Visibility

Having center seat head restraints limits to some extent the driver's ability to observe traffic behind the vehicle using the rearview mirror. When a vehicle is in reverse, center head restraints may limit visibility when the driver turns his/her head to back up. In addition a front center seat head restraint may limit vision through the right side second seat window when the driver is considering a lane change maneuver to the right. The agency cannot quantify these potential losses in visibility, nor the potential impact this loss in visibility could have on safety.

Conclusion

The agency is not requiring center seat head restraints because of the significant costs and relatively minor safety impact of these devices at the center seat position.