WHAT NASS ROLLOVER CASES TELL US

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ABSTRACT

This research provides new insight into the nature, causes and costs of rollover casualties; and the economic benefits of basic countermeasures. The National Accident Sampling System (NASS) is a rich source of data on motor vehicle crashes, particularly if one goes beyond the electronic files. In this work, the author reviewed every NASS case from 2002 through 2004 in which a passenger car, SUV, pickup, or minivan that was less than eleven years old rolled over and produced an AIS 3+ injury (more than 500 cases). From this, we developed a useful new classification for these crashes with AIS 3+ injury: (1) cases with complete ejections, (2) cases in which there was a head or neck injury from roof crush, (3) other rollovers in which the rollover was the most harmful event, (4) cases in which a collision before the rollover was the most harmful event, and (5) cases in which a collision or major change in elevation during the rollover was the most harmful event. We used the NHTSA "Economic Impact of Motor Vehicle Crashes" and the weighting factor for the crashes to determine the total cost of all of these crash injuries. We then estimated the effectiveness of three simple countermeasures – a strong roof, side window glazing that does not break out during the rollover, and an effective belt use reminder – in reducing the severity and cost of these injuries. The results were most dramatic for SUVs where the discounted potential savings were on the order of several thousand dollars per vehicle over its lifetime. Even for passenger cars, the savings would easily justify the cost of these countermeasures. This work demonstrates the high degree of benefit that would far outweigh the cost of the countermeasures even if the affected vehicles were equipped with electronic stability systems.

NASS ROLLOVER FILES

The National Accident Sampling System (NASS) [1], initiated by the National Highway Traffic Safety Administration (NHTSA) more than 25 years ago, is a rich source of data on motor vehicle crashes. Most analysts use only its electronic files and therefore miss the value that is contained in the crash descriptions, scene diagrams, and photographs of the vehicles and scenes that are in the NASS files.
For this work, we examined the details of more than 500 case files from accident years 2002-2004 to determine the critical conditions of rollover crashes. Based on that data, we estimated the effectiveness of countermeasures that are designed to reduce casualties in rollovers.

Specifically, we looked at *all* 2002-2004 NASS rollover cases involving passenger cars, utility vehicles (SUVs), pickups, and minivans that were ten years old or less in which there was at least an AIS 3 injury to an occupant of the vehicle that rolled over. NASS is currently between one fourth and one third of its original design size and rollover cases typically have more serious consequences than other types of crashes. Thus, we assumed that we would get reasonably representative results by combining three years of recent data.

Each rollover vehicle *occupant* who sustained an AIS 3+ injury was considered as a unit for this work. There were more than one such occupants in relatively few rollovers, and in most of those, it was because at least one of the occupants was ejected or there was a major impact either before or during the rollover. In fewer than 2 percent of all cases did we find more than one occupant who sustained an AIS 3+ injury who remained completely in the vehicle.

CLASSES OF ROLLOVERS

In looking at the NASS cases, a natural classification of rollovers suggested itself for quantitative study. We found that the traditional taxonomies were of little use in analyzing rollover injuries. The number of rolls is a valid measure of severity only in the sense that each vehicle roof impact offers additional opportunity to damage a weak roof or to eject an occupant through a failed window. The inherent forces in each roll are low regardless of the number of rolls. The classification of initiation of the rollover (trip over, flip over, climb over, bounce over, etc.) are poorly defined, often incorrectly coded, and of little practical use. Thus, we divided the rollovers into the following classes:

1. Cases where the rollover was the most serious event and an occupant with AIS 3+ injuries was unbelted and ejected.

2. Cases where the rollover was the most serious event and where any occupants were belted and received at least an AIS 3 injury to the head or spinal column.

3. All other cases where the rollover was the most serious event and an occupant had an AIS 3+ injury.

A subclass of these cases are cases where the rollover was the most serious event and where any occupant was belted and received at least an AIS 3 arm or hand injury (the maximum AIS coding for an upper extremity injury) that was due to a partial ejection of the hand or arm.

4. Cases where an initial collision was the most serious event (and the one that probably caused the most serious injury) but where there was subsequent rollover.

A subclass of this group includes cases where there were serious collisions both before and during the rollover.

5. Cases where a rollover was the initial event, but where the most serious event was a collision or a substantial change in elevation as the vehicle was rolling over (where the collision probably caused the most serious injury).

There was one case (NASS 2002-75-110) where 5 people riding in the bed of a pickup each received at least AIS 3 injuries (one was a fatal) when the pickup rolled over. We did not include this case in the analysis.

The justification for this classification is not only that rollover crashes divide into roughly equal sets among, at least for passenger cars, but that each class suggests a unique set of countermeasures as will be discussed later.

ECONOMIC CONSEQUENCES OF INJURIES: A HARM METRIC

Next, using the NHTSA estimates of the economic consequences of injury, we assigned a dollar value to each of the injuries. These values are shown in Table 1. They were determined by taking the direct economic cost of injuries to specific body areas from Appendix H in the NHTSA report, *the Economic Impact of Motor Vehicle Crashes 2000*, [2] multiplying the results by the factors in Appendix A for injury severity in that report to get the specific economic consequences. These results were updated for inflation by multiplying by a factor of 1.15 (roughly 3 percent inflation per year).

Figure 1. An example of a Class 4 NASS case where an initial collision (with a large tree) was the most serious event.

These are the essentially values that NHTSA would use in assessing the economic consequences of new motor vehicle safety standards. They include the actual medical costs associated with the injury,[3] the lost wages, and intangible consequences of injury and death which were determined from studies of people's "willingness to pay" to avoid injury or death based on "wages for high-risk occupations and purchases of safety improvement products."

CASES STUDIED

We studied all rollovers involving passenger cars, SUVs (utility vehicles), pickups, and minivans that were less than 11 years old. That is, for accident year

2004 we included all vehicles of model year 1995 and later that rolled over and had an AIS 3 or greater injury to an occupant. Each unit of study was an occupant who received an injury of AIS 3 or greater or who died as a consequence of the accident. A very substantial majority of these were front seat occupants.

Virtually all occupants who received such AIS 3 or greater injuries who were not in front seats were not restrained. Once the cases were identified, they were classified as noted above. Because of the limitations on vehicles and injuries, our data underestimates the total harm in rollovers by a factor of 1.5 to 2. We will attempt to better quantify the total harm from rollovers in follow-up work.

Figure 2. An example of a Class 5 NASS case where a collision (with a large tree) during a rollover was the most serious event.

HARM IN ROLLOVERS

Because of their total number, the largest total cost is from passenger car rollovers. However, the highest cost per registered vehicle, by a substantial margin, is for SUVs. Their comprehensive cost for AIS 3+ injuries in rollovers is nearly three times as high as for passenger cars. Pickups have about twice the comprehensive cost of passenger cars.

By dollar volume of harm, the largest numbers by far were in Class 1 rollovers of SUVs. This is partly because of the higher rollover rates of these vehicles and the lower safety belt use in them, but those factors do not fully account for the excessive ejections.

Light trucks are also overrepresented in cases where a rollover is a secondary consequence of a serious collision (class 4 rollovers). This suggests that loss of control is a greater problem for light trucks than for passenger cars. Since the rollovers in these cases were almost incidental, for this class of crashes the traditional countermeasures applied to frontal and side crashes are much more likely to be effective. The same is not necessarily true for Class 5 crashes since a significantly stronger occupant compartment and roof will help to reduce roof crush and injuries in these cases.

It is interesting to compare the proportional relations among the five classes of rollovers for specific vehicle types. For example, because of the high cost of head and cervical spine injuries, Class 2 rollovers have a proportionally larger economic impact.

These data show that *each new* SUV comes loaded with an average of at least $3,500 in discounted economic consequence costs for the rollovers they will have during their lifetime. For pickups, the added liability is at least $2,200 and for passenger cars and minivans it is at least $1,200 and $1,700 respectively.

Few if any purchasers of these vehicles are aware of this liability when they purchase a new vehicle. Furthermore, because first and third party auto insurance together pay only a trivial part of the cost of the most serious injuries and fatalities, fewer still are aware that they will bear most of these costs either directly or through non-automobile insurance systems if they are actually seriously injured in a rollover.[4] In fact, Medicaid picks up a significant part of these costs and families themselves must suffer the lost income (and the consequently reduced standard of living) and the extra personal services that are a major consequence of AIS 3+ injuries to a family member.

Table 1. Cost of injury by severity level and body part from *The Economic Impact of Motor Vehicle Crashes 2000.*

AIS	Body Part	Cost	AIS	Body Part	Cost
1	SCI	N.A.	4	SCI	$7,296,260
	Brain	$124,459		Brain	2,939,047
	Lower Extremity	13,820		Lower Extremity	1,161,530
	Upper Extremity	5,548		Upper Extremity	N.A.
	Trunk, Abdomen	10,133		Trunk, Abdomen	480,459
	Face, Head, Neck	9,734		Face, Head, Neck	869,853
2	SCI	N.A.	5	SCI	$10,210,387
	Brain	$686,992		Brain	6,826,032
	Lower Extremity	277,275		Lower Extremity	2,056,783
	Upper Extremity	117,739		Upper Extremity	N.A.
	Trunk, Abdomen	204,573		Trunk, Abdomen	860,798
	Face, Head, Neck	144,749		Face, Head, Neck	1,805,288
3	SCI	$1,506,961	6	All	$ 3,623,787
	Brain	1,306,647			
	Lower Extremity	530,725			
	Upper Extremity	235,160			
	Trunk, Abdomen	266,856			
	Face, Head, Neck	325,650			

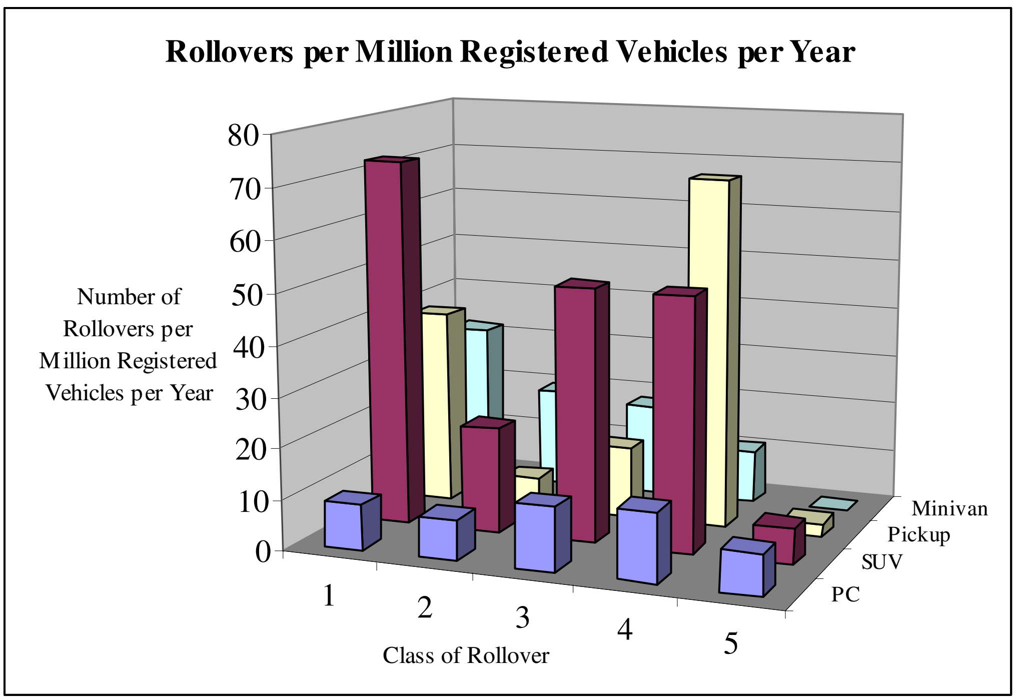

Figure 3. Estimated annual number of rollovers with AIS 3+ injuries by class and vehicle type.

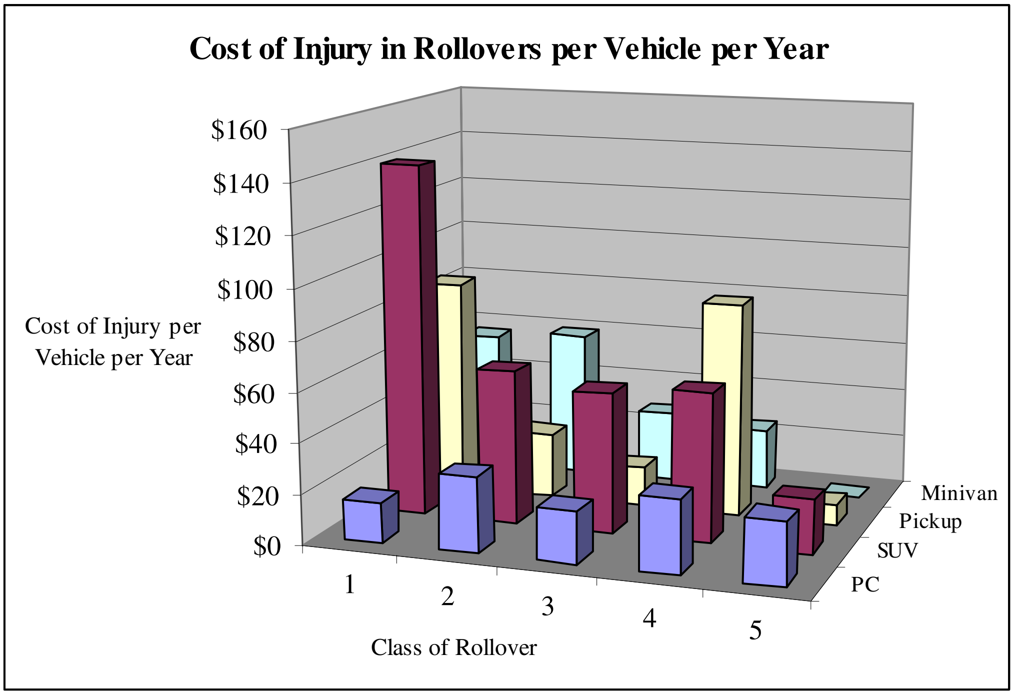

Figure 4. Cost of injury per registered vehicle by type of vehicle and type of injury.

The results of this investigation are shown in Figures 3 and 4. These graphics clearly shows the dramatic difference between passenger cars on one hand, and light trucks on the other. The total annual economic consequence of Annual AIS 3+ injuries in light vehicles in the first ten years of operation is approximately $36 billion. [5]

Figures 3 and 4 show that the spectrum of passenger car rollovers is quite different than the spectrum of SUV and pickup rollovers. The minivan figures are not as reliable because of the small number of minivan cases in the study (in the three years studied, there were only 20 rollovers involving 45 occupants with AIS 3+ injuries). It is nevertheless clear that as a class, minivans have rollover harm that is higher, per vehicle, than for passenger cars. Part of the reason for the relatively low rate of rollover harm in minivans is the demographics of those who own and use them (they are often the family station wagon for people who do not need the personal image from driving an SUV), not that they are inherently particularly safe in rollovers.

- About forty-five percent of passenger car and pickup truck rollover harm is either preceded by a collision that is the most serious event, or involve a collision or other complication during the rollover that is the most serious event (Class 4 and 5 rollovers). For SUVs, only a quarter of the rollovers met those conditions.

This result strongly suggests that about one-third of the harm attributed to rollovers should be reconsidered from the standpoint of appropriate countermeasures. That is, for cases with major collisions before or during a rollover, the traditional assumption that rollover casualties come primarily from ejection that is a consequence of the rollover or from roof crush (the justifications for the dolly rollover test in FMVSS 208 and for the roof crush requirements of FMVSS 216) should be reconsidered. However, it should be noted that some countermeasures – particularly occupant restraint – protect occupants in both circumstances.

- By far the greatest disparity is in complete ejections of occupants in rollovers. The rate of such rollover ejections where the rollover is the most serious event is nearly nine times as high in SUVs, and five times as high in pickups as in passenger cars.

This dramatic difference comes partly from the much higher rollover rates and lower belt use rates in light trucks but those factors do not completely explain the difference. The only other major factor that might account for the higher unrestrained occupant ejection rates is the larger side window openings in SUVs and pickups. It is clear that SUVs and pickups in particular should be a major target of further research and programs to reduce ejection.

The NASS photographs reviewed for this study showed that the roofs in most contemporary vehicles crush extensively in a majority of rollovers where there are serious to fatal injuries. While it is clear that an occupant is safer in a rollover with a safety belt than without, public policy that increases belt use without addressing the problem of roof crush would be irresponsible (see comments below and reference #7). This situation would be analogous to ignoring the unintended injuries that were inflicted by the first generation of air bags.

- Rollovers where a restrained occupant receives an AIS 3+ head or neck (cervical spine) injury are common in all vehicle types but are about twice as high in SUVs and minivans as in passenger cars and pickups.

This finding strongly suggests that a major increase in roof strength would have a substantial benefit in reducing these injuries to people who are taking the responsibility of wearing the available lap and shoulder belts.

RESTRAINT USE

The major disparity in complete ejections between passenger cars and light trucks initially suggested that belt use in the latter was much lower than in the former, and figure 2 confirmed that suspicion. One might expect that when looked at from the standpoint of the proportion restrained by the economic consequences of the injury, only SUVs and pickups show a significant difference which probably results in the exceptional ejection rate in these light trucks.

ROLLOVER COUNTERMEASURES

Next, we looked at the potential savings from obvious, well tested, inexpensive and effective rollover occupant protection countermeasures. The primary countermeasures we considered were the following:

1. Safety belt use which could be substantially increased by installation of a highly effective safety belt use reminder.[6] (Most critical for classes 1,3 and 4)

2. Side windows that do no fail in rollovers (such as laminated glass that is retained in its opening so that even if it breaks it continues to provide a barrier to ejection – see Figure 5). (Class 1)

3. A strong roof that is resistant to crushing during a rollover (such as has been demonstrated by the Volvo XC90 – see Figure 6). A strong roof is important not only to reduce direct injuries from roof crush, but for the protection of side windows and to ensure proper safety belt performance (upper anchorage stability). (Classes 1,2,3 and 5)

Table 2. Restraint use among occupants with AIS 3+ injuries from light vehicle rollovers.

	Belted	Not Belted	Unknown Belt Use
Passenger Car	52%	46%	2%
SUV	30%	61%	9%
Pickup	27%	70%	3%

Table 4. Proportion of harm in rollovers where there was at least one AIS 3+ injury by belt use.

	Belted	Not Belted	Unknown Belt Use
Passenger Car	46%	48%	6%
SUV	43%	49%	8%
Pickup	26%	70%	4%

The secondary countermeasures were:

4. Padding in the head impact area as now required by amendments to FMVSS 201. (Class 2 and 3)

5. Improving safety belt performance. Safety belts are notorious for developing excessive slack in rollovers and many belts have rather poor geometry to hold occupants effectively in rollovers. The best solution would probably be a seat mounted safety belt with a rollover-triggered pretensioner. However, less expensive approaches, such as cinching latch plates that keep lap belts snug or a time delay on the retractor lockup, would have some benefit. (Class 2)

6. Changes to interior design (particularly in the door and foot well areas) to reduce torso and limb injuries from contact with the interior. (Class 3 and 4)

In addition to these elements, two advanced technologies that are currently being commercialized are:

7. Electronic stability systems that will primarily reduce the probability of some of the Class 1, 2, and 3 rollovers. These systems generally reduce oversteer in vehicles so that even though the driver cannot fully control a vehicle, at least it will not yaw so that a rollover is likely. (Classes 1, 2, 3 and 5)

8. Rollover-triggered side curtain air bags. These systems deploy as a vehicle begins to roll (triggered by a combination of the roll angle of the vehicle and its roll rate) and cover the window openings so that the potential for ejection is substantially reduced. (Class 1, 3, 4 and 5)

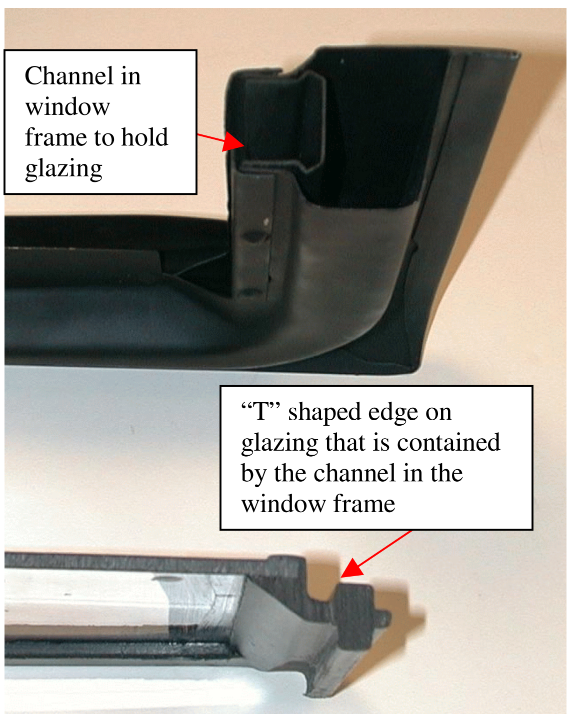

Figure 5. Side window glazing designed with channels and tracks for ejection mitigation.

It is important to note that the effectiveness of these elements may be interrelated. For example, as was pointed out by a Ford engineer in the late 1960s, "It is obvious that occupants that are restrained in upright positions are more susceptible to injury from a collapsing roof than unrestrained occupants who are free to tumble about the interior of the vehicle. It seems unjust to penalize people wearing effective restraint systems by exposing them to more severe rollover injuries than they might expect with no restraints."[7] It is also the case that even window glazing that is designed to reduce ejection will do so only if the window openings and frames are reasonably protected from distortion by a strong roof. Conversely, if the roof does not significantly distort in a rollover, it can generally protect even tempered side glazing.

Occupant ejection could be reasonably addressed by either substantially increased belt use, the use of side window glazing that will contain occupants, or rollover-triggered window curtain air bags. Belt use is the most cost-effective means, but it would not fully address partial ejections. On the other hand, belt use has major benefit in virtually all other crash modes.

Figure 6. A Volvo XC90 with a strong roof after a rollover (NASS Case 2003-79-57).

The cost and weight of the three primary countermeasures would be modest:

- Effective safety belt use reminders would add less than $25 to the retail cost of a vehicle. The added weight would be trivial.

An effective belt use reminder must go well beyond the Ford Belt Minder® system which was shown to raise belt use rates by only about 5 percentage points.[8] Effective systems have been developed in Europe and are recognized there in the European New Car Assessment Program. Highly effective belt use reminders might come about without regulatory pressure if insurance companies worked with auto makers by offering significant medical payment insurance discounts for vehicles that were equipped with them. Such discounts could easily offset the original cost of these systems.

Although belt use is critical to reducing injuries in rollovers, it must be accompanied by other countermeasures.

- Front side glazing that retains occupants (laminated glass with edge holding systems) would, according to NHTSA, have added approximately $50 to the retail price of a vehicle in 1997. Inflation would increase this to less than $65 today.

The cost-effectiveness of this technology would be greatest if it were used only in the front doors because by far the majority of occupants are ejected through these windows. If advanced glazing were used in all side windows, it would increase the retail price of a vehicle by about $140 per vehicle on average. The agency estimated that there would be no weight penalty for any of the alternative side window materials.[9] [10] We have used a compromise figure of $100 as the average increase in the retail price per vehicle for ejection control glazing.

This technology is fully developed and available for production. In its simplest form, it consists of laminated glass that has "T" shaped material glued on to the side edges that fit into channels such that the glass can move up and down, but even if the glass is broken, it cannot pull out of the channels (see Figure 5). NHTSA conducted extensive research into this product in the 1990s. The effectiveness of this countermeasure depends on the vehicle having a strong roof so that the window opening is not substantially distorted from roof impacts.

NHTSA has estimated that the effectiveness of advanced ejection-mitigating glazing in reducing rollover ejection injuries is in excess of 80 percent. It noted that the benefit would be particularly high for light trucks.[11] The 2005 Transportation legislation [12] requires that NTHSA specifically address the problem of occupant ejection.

- A strong roof would, on average, cost less than $100/vehicle.

Research has shown that the addition of well under than 100 pounds of structural material can be added to an existing vehicle to ensure very good roof crush resistance – well beyond that called for even in NHTSA's proposed amendment to FMVSS 216. The use of high strength steels and plastic inserts at buckling points would ensure only minor weight increase for an adequately strong roof. [14] If a roof is designed to provide a high level of crush resistance in the first place, the added material and cost would be substantially less than 100 pounds and $100. Volvo has demonstrated the mass production practicability of strong roof construction.

Electronic stability systems and rollover-triggered side curtain air bags each has the potential to substantially reduce rollover casualties, but their cost in full production is substantially higher than the cost of the three basic countermeasures. Their benefit was not estimated in this work. The added retail cost of either of these technologies has been estimated to be around $250 in large scale production. The extra cost of rollover triggering of side curtain air bags that are already in a vehicle would be $25 to $50. The cost of electronic stability systems assumes that the vehicle already has anti-lock brakes.

BENEFITS OF ROLLOVER COUNTERMEASURES

The effectiveness of each primary countermeasure was assessed against the specific conditions of the crash. In no case was it assumed that the effectiveness would be above 80 percent because of uncertainties about the cases and outcomes and the fact that there might be residual, although less serious injuries even with the countermeasures. However, where there was a complete ejection in an otherwise simple rollover (without complications such as significant collisions or major changes in elevation during the rollover) it was assumed that the combination of a strong safety belt use reminder and retained side window glazing would have an 80 percent effectiveness in reducing the injury below the AIS 3 level, conservatively based on the NHTSA estimate, for example. Thus, the benefits of safety belt use and improved side glazing was high for the first class of rollovers. The benefits of a strong roof were major for the second class.

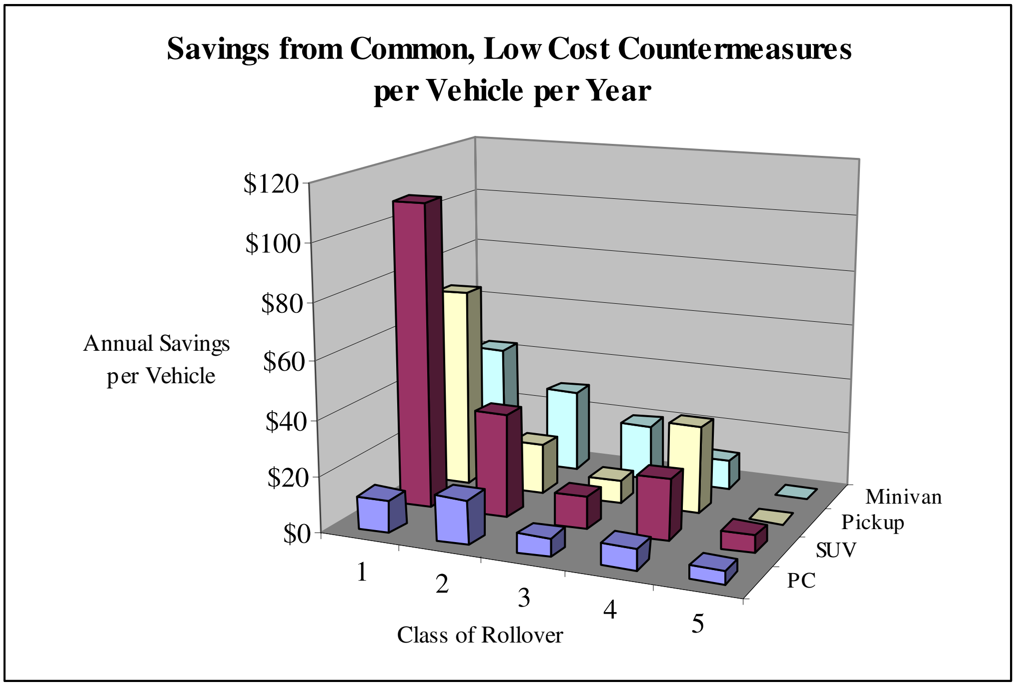

Figure 7. Benefits of basic countermeasures – a strong roof, side glazing designed to contain occupants, and effective safety belt use reminders – from the reduction of rollover AIS 3 or greater injuries. These results should be compared with Figure 4 showing the total economic consequences of AIS 3+ injuries rollovers. It does not include reductions in AIS 1 and 2 injuries.

There has been considerable reluctance to require (or for manufacturers to voluntarily offer) strong belt use reminders because of the experience with ignition interlocks in the early 1970s. We believe that manufacturers and insurance companies could develop a voluntary program, encouraged by changes in the NCAP rating system and insurance premium reductions, to offer and encourage effective belt use reminder systems in new vehicles. Such systems would have benefits well beyond rollovers. However, even in the absence of such systems, improved side glazing or rollover-triggered side curtain air bags would very substantially reduce ejections from vehicles that rollover.

It was assumed that the effectiveness of the three basic countermeasures considered here for the fourth and fifth classes of rollovers, where collisions were the primary source of injury, would be low. Exceptions would be for unrestrained and ejected occupants who were not subject to direct trauma from the collisions.

The results, which are a total saving of half of the comprehensive cost of rollover AIS 3+ injuries, are shown in Figure 5.

OVERALL COSTS AND BENEFITS

In doing this analysis, we found that making conservative assessments of the benefits yielded very high potential savings (over $17 billion per year) from the three simple countermeasures discussed above.

The cost of these three would be around $3.5 billion per year for all new passenger cars, light trucks and vans; so that their benefits would be at least five times the cost. If these were applied only to SUVs and pickups, these countermeasures would yield a benefit more than eight times the cost because of the much higher rate of rollover casualties in them. However, these countermeasures would be cost beneficial even for passenger cars and minivans. Responsible manufacturers have a particular obligation to adopt these countermeasures, even in the absence of regulatory requirements, for SUVs and pickups because of their excessive rollover casualties in comparison with the passenger cars they have typically replaced.

Table 2. Total annual economic consequences of rollovers by type of vehicle and class of rollover (in millions). The sum for all light vehicles is $36.8 billion per year.

Class of Rollover	Passenger Car	SUV	Pickup	Minivan
1. Unbelted Occupant Fully Ejected	$ 2,177	$3,658	$3,359	$ 1,004
2. Belted Occupant w/Head, SC Injury	$ 4,061	$1,600	$1,016	$ 1,062
3. Other Primary Rollovers	$ 2,768	$1,461	$ 612	$ 511
4. Collision Before Rollover	$ 3,925	$1,546	$3,340	$ 439
5. Collision During Rollover	$ 3,399	$ 561	$ 311	$ 0
Total	$16,330	$8,826	$8,638	$ 3,016

Table 3. Total Savings by Type of Vehicle and of Rollover (in millions) from primary countermeasures.

Class of Rollover	Passenger Car	SUV	Pickup	Minivan
1. Unbelted Occupant Fully Ejected	$1,572	$2,822	$2,770	$ 773
2. Belted Occupant w/Head, SC Injury	$2,118	$ 961	$ 688	$ 530
3. Other Primary Rollovers	$ 902	$ 303	$ 329	$ 363
4. Collision Before Rollover	$1,015	$ 560	$1,220	$ 188
5. Collision During Rollover	$ 602	$ 163	$ 8	$ 0
Total	$6,209	$4,809	$5,014	$1,855

Table 4. Upper limit of the cost of countermeasures to reduce rollover injuries.

Countermeasure	Cost per Vehicle	Total Cost (billions)
Safety Belt Use Reminders	$25	$0.4
Improved Side Window Glazing	$100	$1.6
Strong Roof	$100	$1.6
Total	$225	$3.6

This analysis does not account for the savings of AIS 1 and 2 injuries in rollovers, for vehicles more than ten years old, or for the reduction in injuries in non-rollovers. Thus, these countermeasures would have even greater cost effectiveness than is calculated here. The belt use reminder would improve safety in all crash modes while improved occupant compartment integrity and glazing would improve side impact protection.

The total cost of AIS 3 and greater injuries in rollovers of vehicles no more than ten years old – $36.8 billion – is shown in Table 2. Note that only $13.5 billion (just over one-third) is in cases involving a collision as the most serious event, either before or during the rollover. This table does not include any losses from AIS 1 or 2 injuries nor does it include losses in vehicles more than ten years old. The total for all light vehicles is $17.9 billion.

The savings from the countermeasures described in this paper are provided in Table 3. Note that the savings from reducing ejection of unbelted occupants (primarily from improved belt use reminders, improved side glazing, or both) amounts to nearly $8 billion. This counts none of the savings in AIS 1 and 2 injuries, the other savings in non-rollover crashes from these countermeasures, or savings from vehicles more than ten years old. Those savings would probably more than double the benefits. The savings from a reduction in head and spinal column injuries to belted occupants would be over $4 billion, and would come primarily from stronger roofs and the interior padding that is now standard in all new light vehicles.

Estimates of the upper bound costs of these countermeasures, assuming that 16 million light motor vehicles are sold in the U.S. annually, are shown in Table 4.

It can be seen from Table 4 that even considering only the benefits from reductions in AIS 3+ injuries in rollovers of vehicles less than eleven years old, these countermeasures are highly cost-beneficial. Their value would be higher if one considered AIS 1 and 2 injuries, injuries from rollovers of vehicles more than ten years old, and the ancillary benefits in non-rollovers of these countermeasures. It is clear that priority should be given to making these improvements in light trucks where the losses are greatest.

FURTHER THOUGHTS: HISTORY AND POLICY

This research shows the value of the National Accident Sampling System and the NHTSA's estimates of the economic consequences of motor vehicle crashes. This work derives directly from the important work from the 1970s of the late Dr. Anthanasios Malliaris, who developed the harm concept; and Barbara Faigin who produced the first analysis of the cost of injury and Laurence Blincoe who produced the current edition. It is unfortunate that NHTSA did not carry out this type of analysis of rollover injury years ago when it could have saved thousands of lives and serious injuries in rollovers. Based on refinements of this work and on more realistic dynamic testing of vehicle rollover performance and the requirements of the SAFETY-LU legislation, we look forward to major advancements in rollover occupant protection in the near future.

We believe that NHTSA could achieve much of the benefit discussed in this paper by instituting a rollover occupant protection rating in the New Car Assessment Program that gave increasing ratings (number of stars) to vehicles that had stronger roofs and that incorporated other features that improved rollover occupant protection. A proposal has been made to NHTSA for such a rating system (see Appendix A).

When NHTSA proposed the amendment to FMVSS 216 last August, it made the very controversial comment, ". . . if the proposal were adopted as a final rule, it would preempt all conflicting State common law requirements, including rules of tort law." This comment conflicts with the statement in the National Traffic and Motor Vehicle Safety Act of 1966 which says, "Compliance with any Federal motor Vehicle safety standard issued under this title does not exempt any person from any liability under common law." NHTSA's view was based on the Supreme Court decision in *Geier v. Honda*, [15] in which the court held that NHTSA's ability to use more creative means of implementing motor vehicle safety standards involving new technologies and uncertain public acceptance would be compromised by permitting product liability claims against manufacturers that did not implement the most effective safety technology.

An alternative that addresses the highly controversial question of manufacturer liability is discussed in another of this author's publications on how automobile insurance can become a much more effective regulator of motor vehicle safety.[16] The use of consumer information under the New Car Assessment Program could also obviate this controversy.

REFERENCES

[1] Now that a politically correct NHTSA Administrator is gone, the more accurately descriptive original names of the National Accident Sampling System, the Fatal Accident Reporting System, and the Experimental Safety Vehicle Conference should be restored.

[2] Blincoe, Lawrence J., et al., "the Economic Impact of Motor Vehicle Crashes 2000,"

[3] It was suggested by NHTSA staff in a private communication that the assessment of medical costs contained in this work significantly underestimated the cost of rehabilitation following injury.

[4] Nash, Carl E., "A Market Approach to Motor Vehicle Safety . . . That Also Addresses Tort Reform," Product Safety and Liability Reporter, Bureau of National Affairs, Vol. 34, No. 8: Washington, D.C. February 27, 2006, p. 202-212.

[5] It is worth noting that NHTSA estimates that the total direct economic cost of injury today is more than $260 billion and the economic consequences would therefore be on the order of $350 billion. Rollovers account for roughly one quarter of the total loss, or nearly $90 billion annually. Thus, our estimate of the comprehensive cost of rollover casualties is conservative even if one assumes that counting AIS 1 and 2 injuries and counting injuries in vehicles more than ten years old would double our estimate.

[6] See Committee for the Safety Belt Technology Study, "Buckling Up – Technologies to Increase Seat Belt Use," Special Report 278, Transportation Research Board, Washington, D.C. 2003.

[7] Memorandum from J.R. Weaver to H.G. Brilmyer, "Roof Strength Study," Ford Automotive Safety Research Office, July 8, 1968.

[8] Insurance Institute for Highway Safety

[9] The Advanced Glazing Research Team, "Ejection Mitigation Using Advanced Glazing, a Status Report," National Highway Traffic Safety Administration, Washington, D.C.: November 1995.

[10] Willke, Donald, Stephen Summers, Jing Wang, John Lee, Susan Partyka, and Stephen Duffy, "Ejection Mitigation Using Advanced Glazing: Status Report II, National Highway Traffic Safety Administration, Washington, D.C.: August 1999.

[11] Winnicki, John, "Estimating the Injury-Reducing Benefits of Ejection-Mitigating Glazing," National Highway Traffic Safety Administration, Washington, DC. February 1996, DOT HS 808 369.

[12] Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), enacted August 10, 2005, as Public Law 109-59. SAFETEA-LU authorizes the Federal surface transportation programs for highways, highway safety, and transit for the 5-year period 2005-2009.

[13] See, for example, Brian Herbst, Stephen Forrest, Steven E. Meyer, Davis Hock "Alternative Roof Crush Resistance Testing with Production and Reinforced Roof Structures" SAFE, LLC, Golita: SAE 2002-01-2076

[14] In its Regulatory Analysis, NHTSA estimated that increasing roof strength from 1.5 to 2.5 in the FMVSS 216 test would cost $3.45 per vehicle and result in a weight increase of 1.7 pounds.

[15] *Geier v. Honda*, U.S. Supreme Court No. 98-1811, 2000.

[16] Nash, *op cit.*

APPENDIX: A PROPOSED NEW CAR ASSESSMENT PROGRAM RATING SYSTEM

To supplement the basic roof crush requirement, we suggest that the best way to encourage manufacturers to offer a higher and more comprehensive level of rollover occupant protection is through a Rollover Occupant Protection rating in the New Car Assessment Program. A proposed outline for such a rating is as follows:

- ★ Meets basic requirements of all Federal motor vehicle safety standards, including those of the amended FMVSS 201 and 216, and has a (Ford-type) belt-minder level safety belt reminder system.
- ★★ Meets the requirements for one star, has a strength of 2 in the FMVSS 216 test with the pitch angle increased to 10°, and has an advanced level belt use reminder.
- ★★★ Meets requirements for two stars and provides minimal performance under a dynamic roof strength test such as the Jordan Rollover System (including no side window failures)
- ★★★★ Meets the requirements for three stars and has rollover-triggered safety belt pretensioners that minimize occupant excursion in a rollover.
- ★★★★★ Meets requirements for four stars, provides a high level of occupant protection performance in a dynamic roof strength test, and retains the full integrity of all windows in this test, and has a side curtain air bag system.