DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

49 CFR Part 575

[Docket No. NHTSA–2000–8298]

Consumer Information Regulations; Federal Motor Vehicle Safety Standards; Rollover Resistance

AGENCY: National Highway Traffic Safety Administration (NHTSA), DOT.

ACTION: Response to Comments, Notice of Final Decision.

SUMMARY: The agency has concluded that consumer information on the rollover risk of passenger cars and light multipurpose passenger vehicles and trucks will reduce the number of rollover crashes and the number of injuries and fatalities from rollover crashes. This information will enable prospective purchasers to make choices about new vehicles based on differences in rollover risk and serve as a market incentive to manufacturers in striving to design their vehicles with greater rollover resistance. The consumer information program will also inform drivers, especially those who choose vehicles with poorer rollover resistance, that their risk of harm can be greatly reduced with seat belt use to avoid ejection.

The agency has decided to use the Static Stability Factor to indicate rollover risk in single-vehicle crashes and to incorporate the new rating into NHTSA's New Car Assessment Program (NCAP). As part of these ratings, the agency also has decided to note vehicles that are equipped with ''electronic stability control'' technology, which may reduce the risk of a vehicle getting into an incipient rollover situation. This notice summarizes the comments received in response to the agency's June 1, 2000 Request for Comment regarding the addition of rollover ratings based on SSF to NCAP, our response to those comments, and the procedures and protocol we will use to implement a new rollover consumer information program.

FOR FURTHER INFORMATION CONTACT: For the most up to date vehicle star ratings call the Auto Safety Hotline at 888–327–4236 or refer to NHTSA's website at *www.nhtsa.dot.gov.* For technical questions you may contact Gayle Dalrymple, NPS–23, Office of Safety Performance Standards, National Highway Traffic Safety Administration, 400 Seventh Street, SW, Washington, DC 20590. Ms. Dalrymple can be reached by phone at (202) 366–5559 or by facsimile at (202) 493–2739. For public comments and other information related to previous notices on this subject, please refer to:

DOT Docket No. NHTSA–2000–6859, Docket Management, Room PL–401, 400 Seventh Street, SW, Washington, D.C. 20590 (hours 10:00 a.m. to 5:00 p.m. Monday through Friday) or on the internet at *www.dms.gov/search*, and Docket No. 91–68; Notice 3, NHTSA Docket, Room 5111, 400 Seventh Street, SW, Washington, DC 20590. NHTSA Docket hours are from 9:30 am to 4:00 pm Monday through Friday.

SUPPLEMENTARY INFORMATION:

I. Introduction

This notice outlines the plan the National Highway Traffic Safety Administration (NHTSA) will use to incorporate a new rollover rating of new cars and light trucks into its existing New Car Assessment Program (NCAP). NCAP currently gives consumers crashworthiness ratings for new light vehicles in frontal and side crashes. The ratings are based on vehicle performance with respect to occupant injury criteria gathered in crash tests and are presented using one to five stars, one star for the highest risk and five for the lowest. We intend to use the same star rating system to present the risk of rollover in the event of a single-vehicle crash. One star would represent a Static Stability Factor (SSF) corresponding to a 40 percent or greater risk of a single-vehicle crash resulting in rollover, while five stars would represent an SSF corresponding to a risk of less than 10 percent. Static Stability Factor is one-half the track width of a vehicle divided by the height of its center of gravity. As part of the rating based on SSF, the agency also has to note vehicles that are equipped with ''electronic stability control'' technology, which may reduce the risk of a vehicle getting into an incipient rollover situation.

The agency requested comments on its tentative decision to implement such a program on June 1, 2000.[1] The closing date for comments was August 30, 2000. Twenty-five commenters responded. This notice addresses the major issues presented by the commenters, our response to those comments, and the procedures and protocol we will use to implement a rollover consumer information program based on SSF. For complete background and rationale for the program, please see the June 1, 2000 notice.

II. Background

Rollover crashes are complex events that reflect the interaction of driver, road, vehicle, and environmental factors. We can describe the relationship between these factors and the risk of rollover using information from the agency's crash data programs. We limit our discussion here to light vehicles, which consist of (1) passenger cars and (2) multipurpose passenger vehicles and trucks under 4,536 kilograms (10,000 pounds) gross vehicle weight rating (collectively, ''light trucks'').[2]

According to the 1999 Fatality Analysis Reporting System (FARS), 10,142 people were killed as occupants in light vehicle rollovers, including 8,345 killed in single-vehicle rollovers. Eighty percent of the people who died in single-vehicle rollovers were not using a seat belt, and 64 percent were ejected from the vehicle (including 53 percent who were completely ejected). FARS shows that 55 percent of light vehicle occupant fatalities in single-vehicle crashes involved rollover. The proportion differs greatly by vehicle type: 46 percent of passenger car occupant fatalities in single-vehicle crashes involved rollover, compared to 63 percent for pickup trucks, 60 percent for vans, and 78 percent for sport utility vehicles (SUVs).

Using data from the 1995–1999 National Automotive Sampling System (NASS) we estimate that 253,000 light vehicles were towed from a rollover crash each year (on average), and that 27,000 occupants of these vehicles were seriously injured (defined as an Abbreviated Injury Scale (AIS) rating of at least 3).[3] This includes 205,000

[1] 65 FR 34999 (June 1, 2000).

[2] Light trucks include vans, minivans, sport utility vehicles (SUVs), and pickup trucks under 4,536 kilograms (10, 000 pounds) gross vehicle weight rating.

[3] A broken hip is an example of an AIS 3 injury.

single-vehicle tow-away rollovers with 19,000 serious injuries. Sixty-five percent of those people who suffered a serious injury in single-vehicle tow-away rollovers were not using a seat belt, and 50 percent were ejected (including 41 percent who were completely ejected). Estimates from NASS are that 81 percent of tow-away rollovers occurred in single-vehicle crashes, and 87 percent (178,000) of the single-vehicle rollover crashes occurred after the vehicle left the roadway.

Based on the 1995–1999 General Estimates System (GES) data we estimate that 241,000 light vehicles rolled over each year (on average) in police-reported crashes, and that 57,000 occupants in rollover crashes received injuries rated as K or A on the police injury scale. (The police KABCO scale calls these injuries ''incapacitating,'' but their actual severity depends on local practice. ''Incapacitating'' injury may mean that the injury was visible to the reporting officer or that the officer called for medical assistance.) This includes 205,000 single-vehicle rollovers with 46,000 K or A injuries. Fifty-four percent of those with K or A injury in single-vehicle rollovers were not using a seat belt, and 20 percent were ejected from the vehicle (including 18 percent who were completely ejected). Estimates from GES are that 16 percent of light vehicles in police-reported single-vehicle crashes rolled over. The estimated risk of rollover differs by vehicle type: 13 percent of cars and 14 percent of vans in police-reported single-vehicle crashes rolled over, compared to 24 percent of pickup trucks and 32 percent of SUVs.

The data presented above demonstrate that rollover crashes create a serious safety problem and that a reduction in the number of rollovers can make a significant contribution to motor vehicle safety.

III. Discussion of Commenters' Issues

The Request for Comment (RFC) was published June 1, 2000. The comment period closed August 30, 2000. Twenty-five commenters replied. The respondents were vehicle manufacturers and their associations, testing laboratories, independent researchers, consumer safety groups, an insurance association, a trial attorney, and two consumers. Two commenters agreed with the inclusion of rollover rating in NCAP as it was presented in the RFC. The other commenters were divided among those who opposed the plan (manufacturers, dealers, testing labs) and those who thought it did not go far enough that a minimum standard, based on a dynamic test, is needed for rollover (trial attorney, consumer groups). The commenters raised issues in four areas:

The suitability of SSF as a measure of rollover risk,

- Whether NHTSA's statistical analysis linking SSF to single-vehicle rollover rates was correct,
- Whether consumers are capable of understanding the concept of single-vehicle crash as exposure to rollover, and
- The need for a minimum standard, or consumer information, for rollover based on a dynamic test.

Alternative consumer information programs for rollover prevention were also offered by some commenters. Those four issues and the alternative programs are discussed in this section.

A. SSF as a Measure of Rollover Risk

Many respondents to the RFC believe that SSF is not a good measure of rollover risk for various reasons. Comments and the parties that made them were the following:

- NHTSA has exaggerated the importance of SSF in rollover crashes. Vehicles have little to do with rollover; the driver and road conditions bear so much of the blame that the vehicles should not be rated for rollover.—The Alliance of Automobile Manufacturers (Alliance), Association of Import Automobile Manufacturers (AIAM)
- Isuzu SSF is too simplistic. SSF ignores tire properties, suspension compliance, handling characteristics, antilock brakes, electronic stability control, vehicle shape and structure (post-impact rollover), and tripping factors (tires).—Alliance, University of Michigan Transportation Research Institute, JCW Consulting, SiSan, Automotive Testing Inc., Toyota, Isuzu, Honda

1. Origin of Static Stability Factor

Static Stability Factor is not a measure of rollover resistance invented by the agency. It was introduced to the agency in 1973 by vehicle manufacturers as a scientifically valid potential substitute for the dynamic maneuver tests the agency wanted to develop regarding untripped on-road rollover.[4] The Motor Vehicle Manufacturers Association (which has evolved into the present Alliance of Automobile Manufacturers) stated the following about SSF, ''Although this method does not embrace all vehicle factors relating to rollover resistance, it does involve the basic parameters of [sic] influencing resistance.''

In 1973, all of the manufacturers opposed NHTSA's plans for a standard regarding rollover prevention in extreme accident avoidance maneuvers because of their expectation of negligible benefits, concern about banning vehicle types, degradation of vehicle capabilities including braking traction and handling performance, and unresolved problems with maneuver testing. General Motors presented a very detailed set of comments that remain relevant today. For example, its observations on the effect of restraint use on rollover fatality rates and on the breakdown of the rollover problem between multi-vehicle and single-vehicle crashes and on-road and off-road incidences are largely supported by present data. Likewise, its discussion of the problems of maintaining consistent pavement surface and tire traction properties, the use of automatic controls and outriggers, the types of maneuvers and their relationship to real crashes is still meaningful. We also think its comments regarding SSF (which it called geometric stability measurement) are still accurate. General Motors said:

> Resistance to rollover is mainly influenced by the following factors:
>
> 1. Height of the center of gravity.
> 2. Horizontal distance from center of gravity to wheel track.
> 3. Capability for generating large forces in the lateral direction of the tire contacts due to high tire friction.
>
> Lateral forces sufficient for rollover can result from severe maneuvers under high tire-road friction conditions; from collisions with other vehicles, curbs, or road furniture (signs, lamp posts, guard rails), and from maneuvers in roadside soil capable of sustaining high lateral forces.

General Motors qualified the discussion as pertaining to relatively simple maneuvers, but cautioned against the use of ''special'' braking and steering inputs for rollover maneuver tests as unrepresentative of vehicle operation. It also discussed the relative importance of secondary vehicle characteristics other than those above which are the components of SSF.

> It was noted in a previous section that the dominant factors in flat road rollover resistance are the center of gravity height, track width, and the ability of the tire-road interface to generate high levels of lateral force. Suspension geometry, component stiffness factors, allowable ride travel, and tire stiffness factors also exert a measurable influence on rollover performance. But, these latter factors are considered to be of secondary importance. It should be noted that in many cases, very careful laboratory tests are required to establish the influence of suspension modifications on rollover resistance.

[4] In 1973, NHTSA published an Advance Notice of Proposed Rulemaking on Rollover Prevention (38 FR 9598, April 18, 1973). The comments cited here can be found in NHTSA Docket No. 73–10; Notice 1, comments 11 (MVMA) and 14 (GM).

In its conclusions, General Motors maintained that there was no safety need for the on-road rollover resistance standard the agency intended to propose and that, if the agency decided to act at all, it should pursue consumer information based on SSF.

If any regulation is required, some benefit may be derived at minimal cost by better informing the customer of relative product rollover performance, so he can assess this vehicle performance factor in making his selection in a free market. This information could be based on geometric stability measurements for the full range of highway vehicles.

This comment was made before the NCAP program was established to provide consumer information on safety performance and before the consumer was faced with such a large range of geometric stability (SSF) in non-commercial passenger vehicles. Also, most of the practical difficulties in seeking objective, relevant and repeatable driving maneuver tests discussed by General Motors in 1973 remain unsolved. Note that GM suggested the static laboratory measurement as a substitute for maneuver tests when *only* on-road untripped rollover was under consideration. This is an even stronger endorsement of static measurements than that represented by NHTSA's reasons for using SSF for consumer information on all single-vehicle rollovers, tripped and untripped.[5]

We view the rollover safety problem as 95 percent a problem of tripped rollover and five percent a problem of on-road untripped rollover.[6] Maneuver tests do not represent tripped rollover. Once the vehicle is in a tripping situation (e.g., has left the road), tire traction is largely irrelevant to tripped rollover. Center of gravity height and track width (and to a much lesser extent roll moment of inertia) are the only vehicle properties with general applicability to tripped rollover situations. So, in 95 percent of rollovers, these vehicle properties would be the most relevant vehicle influences on the likelihood of rollover. In the five percent of the problem involving untripped rollover, a choice exists between using static measurements and performance in maneuver tests. To get data to make an informed choice between the two, NHTSA conducted a maneuver test program using 12 vehicles in 1998. That testing confirmed General Motors' opinion of 25 years earlier that the static measurements correspond well to dynamic maneuver tests.[7] It also confirmed that the problems with maneuver testing identified by GM in 1973 are still largely unresolved today. Accordingly, we concluded in our June 2000 notice that there were no practical improvements in rating overall rollover resistance to be gained at this time by using something other than static measurements.

2. The Importance of the Effect of SSF on Rollover Rate

When the agency first sought public comment on rollover issues in 1973, the industry's position was that the frequency of untripped on-road rollovers was too low to justify significant vehicle modifications and constraints on future vehicle design. The vehicle manufacturers questioned the benefit/cost relationship and practicability of a minimum standard on rollover resistance, but they did not deny the relationship between SSF and rollover crashes. The agency's June 2000 plan for consumer information on rollover resistance expressed considerable agreement with the 1973 industry position on rollover and offered a statistical study of modern crash data in order to quantify the relationship between SSF and the incidence of rollovers occurring in single-vehicle crashes. The Alliance responded in August 2000 with the position that vehicle characteristics are now deemed largely irrelevant to the occurrence of rollover crashes and consumer information on vehicle rollover resistance is inherently misleading. The Alliance provided a statistical study purporting to demonstrate that the influence of SSF was limited to three to eight percent of the variability between vehicles in rollover crashes.

While the laws of physics prove beyond question that vehicles with low SSF roll over at lower lateral accelerations than vehicles with high SSF, the effect of SSF must be shown to have a significant influence on the outcome of actual crashes (rollover vs. no rollover) to be worth using for consumer information. It is a fact that types of vehicles with SSFs lower than passenger cars, as a group, have greater numbers of rollover crashes than passenger cars, either as a percentage of all crashes (passenger cars, 1.6 percent; vans, 2.0 percent; pickup trucks, 3.7 percent; SUVs, 5.1 percent) or as a percentage of single-vehicle crashes (passenger cars, 13 percent; vans, 14 percent, pickup trucks, 24 percent; SUVs, 32 percent). The Alliance attributes these differences primarily to differences in the driver and road conditions associated with the various vehicle types, rather than to the characteristics of the vehicles. For example, if young males using alcohol and driving on rural roads with high speed limits are over-represented as drivers of four-wheel drive pickup trucks in crashes, could these road-use variables outweigh the vehicle property to the point of insignificance? According to the current industry view, the correlation between the SSF of a vehicle and its ability to attract risky drivers who operate vehicles under adverse road conditions is the fundamental reason vehicles with low SSF are involved in a higher proportion of rollover crashes.

The agency agrees that driver behavior and road conditions are significant factors in understanding why single-vehicle crashes of any type occur, and that they have a strong influence on whether single-vehicle crashes result in rollover. However, we think that the rollover resistance of the vehicle represented by SSF also exerts a strong influence on whether single-vehicle crashes result in rollover. The statistical study in our previous notice attempted to address the important question of whether road-use differences between vehicles relegate their difference in

[5] Untripped rollover is a rollover induced by tire friction with the driving surface alone, resulting from a driving maneuver and usually occurring on the roadway. Tripped rollovers usually occur when a vehicle runs off the roadway and the tires and wheels contact a tripping mechanism (curb, soft soil, pavement drop off) which causes the vehicle to roll. A much smaller number of tripped rollovers occur on the road as a result of the wheel rim digging into the pavement during an extreme maneuver. Whether or not a vehicle rolls when it encounters a tripping mechanism is highly dependent on the geometric properties represented by SSF. In an untripped rollover, SSF is still very important, but other factors come into play (such as tire properties). Therefore, GM's suggestion to use SSF to characterize a vehicle's tendency for untripped rollover was a very strong endorsement of the relationship between SSF and vehicle rollover.

[6] In 1998, the agency was performing research on driving maneuvers to see if we could develop a way to ameliorate the incidence of onroad, untripped rollover, which we estimated at the time to be less than 10 percent of rollover crashes. The American Automobile Manufacturers Association (one of the predecessors of the Alliance) contracted with Calspan Corporation to review all the cases in NHTSA's Crashworthiness Data System coded as untripped to try to demonstrate that we were misplacing our research funds on a very small problem. Consequently our National Automotive Sampling System team did its own audit of the 1992–96 rollover data and concluded that some tripped rollovers were miscoded as untripped rollovers (typically these were onroad rollovers in which the vehicle was sliding sideways and tripped on its own wheel rim). Using corrected 1992–96 data, our National Center for Statistics and Analysis estimated that 3.7 percent of rollovers are untripped and 3.5 percent are both untripped and onroad, while 4.4 percent of single-vehicle rollovers are untripped. (Research Note, "Passenger Vehicles in Untripped Rollovers," September 1999.)

[7] See the June 1, 2000 Request for Comments for a summary of that research.

rollover resistance to insignificance in actual crash experiences. We analyzed state accident reports in six states (1994–1997) on 184,726 single-vehicle crashes with 36,575 rollovers involving 100 vehicle make/models. The road-use variables available in all six states identified male drivers, young drivers, alcohol involvement, darkness, wet or icy surface, speed limit 55 mph or greater, storm, hill, and curve. We used multiple linear regression because its ''R-squared statistic'' provided an intuitive method of comparing the explanatory power of individual variables and because we could control the effect of the large differences in the number of crash samples for the various vehicles. Each vehicle was represented by its SSF and the average of each road-use variable over the number of crashes in each state. Systematic differences between states in rollover rate due to factors such as accident reporting thresholds were accommodated by the inclusion of a dummy variable for each state. The ''R-squared statistic'' for the complete model was 0.88, indicating that the model explained 88 percent of the observed differences in rollover rate per single-vehicle crash between the vehicle make/models.

The linear regression that used only the SSF and the state dummy variables as predictor variables had an ''R-squared'' of 0.73, which means that almost three-quarters of the variability in rollover risk between vehicle models is explained by the SSF plus the adjustments for state-to-state differences in crash reporting. This is greater than the ''R-squared'' for the best model that used only the road-use variables plus the state dummy variables (0.58). Thus, the SSF appears to have greater explanatory value than the combination of the road-use variables. We conclude that the SSF is not relegated to insignificance by the road-use variables in describing rollover risk.

The Alliance comment criticized the agency's use of linear regression because it operates on averages of road-use variables and cannot consider the possible interaction among variables. For example, the linear regression model would consider that the crashes of a particular make/model may involve 30 percent young drivers, 20 percent with alcohol involvement and 15 percent on curves, but it cannot distinguish crashes in which all of the factors were present simultaneously. The Alliance used logistic regression rather than linear regression in its analysis. Logistic regression operates on every individual crash circumstance sampled, rather than on averages of the road-use variables for crashes of each make/model, and thus can consider interactions among variables. It is a popular statistical tool in the health sciences. The Alliance also introduced the concept of scenario risk in its logistic regression model. In this technique, each combination of road-use variables (with some states providing as many as 14 variables) is a scenario. Scenario risk becomes a continuous variable.

Appendix I of this notice presents a new statistical study which adds another year of state crash data to the database of our previous notice and contrasts analyses of the crash data using logistic regression of individual variables and risk scenarios to the linear regression method used in the previous notice. We found that it made very little difference to the logistic regression models whether the road-use variables were used as individual variables or combined to form risk scenarios, but that the curve estimating rollovers per single-vehicle crash produced by the logistic regression was slightly different from that previously reported for linear regression.

The estimated risk of rollovers per single-vehicle crash is six times as high for a vehicle with an SSF of 1.00 as for a vehicle with an SSF of 1.53 (the range of the observed data) based on the linear regression model. The average slope of the rollover risk versus SSF curve for the linear regression model (Figure 1) in the range of observed data was -0.713. The slope of the corresponding curve of the logistic models is -0.598 or -0.580, depending on whether we use the individual variables or the scenario-risk variable. Both the linear and logistic approaches produced models that fit the data well, and both estimated a coefficient for the SSF term that was very important (in terms of statistical significance and the magnitude of the effect).

The linear regression is judged by the ''R-squared'', a measure of fit that is familiar to many people. The logistic regression is less well known, but it also has a standard measure of fit, the association of predicted probabilities and observed responses. The percentage of concordant pairs for our logistic models was very high (for example, it was 71.4 percent for the six-state combined model).

We can also measure the ''Chi-square'' value for the coefficient of the SSF term in each model to describe the significance of that term. Logistic regression models were calculated for the original six states, plus Ohio and New Mexico, which report rollover only if it is the first harmful event. In seven of the eight states, the ''Chi-square'' statistic for SSF is greater than for any of the other variables in the logistic model using individual variables. In the logistic model using scenario risk to combine all the variables except SSF, the ''Chi-square'' statistic for SSF is greater than that of the scenario risk variable in three of the eight states. This result also contradicts the Alliance's assertion that SSF is relegated to insignificance by the importance of road-use variables on the rollover experience of vehicles in use.

The Alliance's assertion that the effect of SSF on rollover is negligible was not a consequence of the possible superiority of logistic regression over linear, nor of the use of scenario risk rather than individual variables. Instead, the Alliance assertion depends upon a subtle change in the definition of the variables which serve as alternatives to SSF in explaining rollovers.

NHTSA used the number of police-reported single-vehicle crashes as a measure of each make/model's exposure to rollover risk. We did not include collisions with pedestrians or animals in the roadway in our definition of single-vehicle crashes because, while those crashes generate a police report, the collision itself poses no risk of rollover of the vehicle. Our sample size was large enough that we did not need to further investigate pedestrian and animal crashes for relevance. We did include collisions with parked vehicles because they represented a type of roadway departure and a collision with a fixed object, although these collisions offer the least exposure to typical tripping mechanisms.

Our analysis examined the effects of road-use variables because their correlations with SSF were the basis of an alternative theory of rollover causation. It is plausible that the greater rate of rollover of vehicles with low SSF is not caused by low SSF but rather by characteristics of drivers and roads which happen to be correlated with low SSF vehicles. The example of young males being the predominant driver population of particularly low SSF pickup trucks shows that this alternative has plausibility.

However, the Alliance departed from the road-use variables as alternative causes of rollover. The Alliance analysis was not an explanation of alternative theories of rollover causation but rather an attempt to show that there is little, if any, effect of SSF on rollover causation. To do this, the Alliance created a category of ''non-vehicle'' variables. This category allowed the addition of one variable whose effect overwhelmed the effects of all other variables. That variable was ''first harmful event, collision with a traffic unit.'' It separated crashes which were collisions with pedestrians, animals or parked vehicles from other single-vehicle crashes. In essence, the extra variable separates crashes with minimum exposure to tripping mechanisms from all other single-vehicle crashes. This would seem to be a meaningless addition because there is no reason to expect a significant correlation between SSF and collisions with pedestrians, animals and parked vehicles. However, it sets up what the Alliance calls its ''low risk scenario'' which serves as a basis for comparison of rollover risk factors.

The Alliance then compared the effect on rollover risk of increased SSF to the effect on rollover risk made by moving from the scenarios of actual crashes to the ''low risk scenario''. The effect on rollover risk of moving actual crash scenarios to the ''low risk scenario'' is essentially the effect on rollover risk of eliminating tripping mechanisms. The effect is huge. In simplified terms, the Alliance has argued that the effect on tripped rollover gained by an increase of SSF is minimal compared to the effect on tripped rollover of removing tripping mechanisms. The statistical study in Appendix I includes a discussion of how this type of analysis, in which characteristics of the crash itself are used to define the risk scenarios, is equally useful for ''demonstrating'' that seat belts have negligible safety benefit.

We do not find the Alliance analysis persuasive. It may well be true that changing a single-vehicle run-off-the-road crash (where there is a high risk of rollover) into a crash in which the vehicle, for example, hits an animal in the road (where there is no risk of rollover) virtually eliminates the risk of rollover, and may do far more to minimize rollover risk than changing any single vehicle or driver factor. However, the point of this is unclear. One could also show that if vehicles could fly, there would be far fewer rollover crashes, based on the experience of actual aircraft. Since vehicles can not fly, and run-off-the-road crashes can not be changed into different types of crashes, positing these impossibilities as a means of analyzing, or addressing, the real world problem of more than 10,000 Americans dying each year in rollover crashes does not seem either helpful or insightful.

NHTSA seeks ways to address real world safety problems constructively. In the real world, driver and roadway factors are certainly important factors in all crashes, including rollovers. That is why NHTSA spends so much effort to increase belt use, reduce speeding, eliminate impaired driving, and so forth. However, the vehicle is also a significant factor in crash safety. If we take the driver and roadway conditions as givens (for example, a young male driver in a rural area), the physical attributes of different vehicles determine different outcomes when, for example, the vehicle drops two wheels off the road, and the driver responds incorrectly. Some vehicles will roll over much more often than others in these situations. Such vehicle differences have been shown to strongly correlate with rollover resistance expressed by SSF. We believe the American public should have this information available to consider when making purchase decisions.

B. NHTSA's Statistical Analysis Linking SSF to Rollover Rates

The Alliance commented that the method NHTSA used to analyze the statistical relationship between state crash data and SSF used in the RFC failed to take into account possible interactions between the various non-vehicle variables, and therefore underestimated the role of the non-vehicle factors in rollover risk. The possible interaction between alcohol involvement and the crash occurring on a curve in a particular crash was given as an example. The commenter suggested using logistic regression to resolve the problem of variable interaction.

As introduced in the previous section, Appendix I of this notice presents a new statistical study which adds another year of state crash data to the database relied on in our previous notice and contrasts analyses of the crash data using logistic regression of individual variables and risk scenarios to the linear regression method used in the previous notice. The model curves estimating rollovers per single-vehicle crash using logistic regression were nearly identical regardless of whether the road-use variables were entered individually or as combinations in risk scenarios. However, logistic regression does produce a slightly different curve estimating rollovers per single-vehicle crash from that previously reported for linear regression.

Figure 1 shows the comparison between the updated linear regression analysis of the summarized data and the two logistic models (the six-state models using either the individual variables or the scenario-risk variable). The linear regression curve of the previous notice was essentially unchanged by the addition of another year of state crash data (for a total of 226,117 single-vehicle crashes with 45,574 rollovers). The logistic models are very similar to each other, and all the models indicate that the SSF is very important in understanding rollover risk. As noted previously, the average slope of the rollover risk vs. SSF curve estimated by the linear regression model in the range of observed data was −0.713, and the average slope of the corresponding curve of the logistic models is −0.598 or −0.580, depending on whether we use the individual variables or the scenario-risk variable. Also, logistic regression estimates a greater risk of rollover than does linear regression for vehicles with SSFs higher than 1.10.

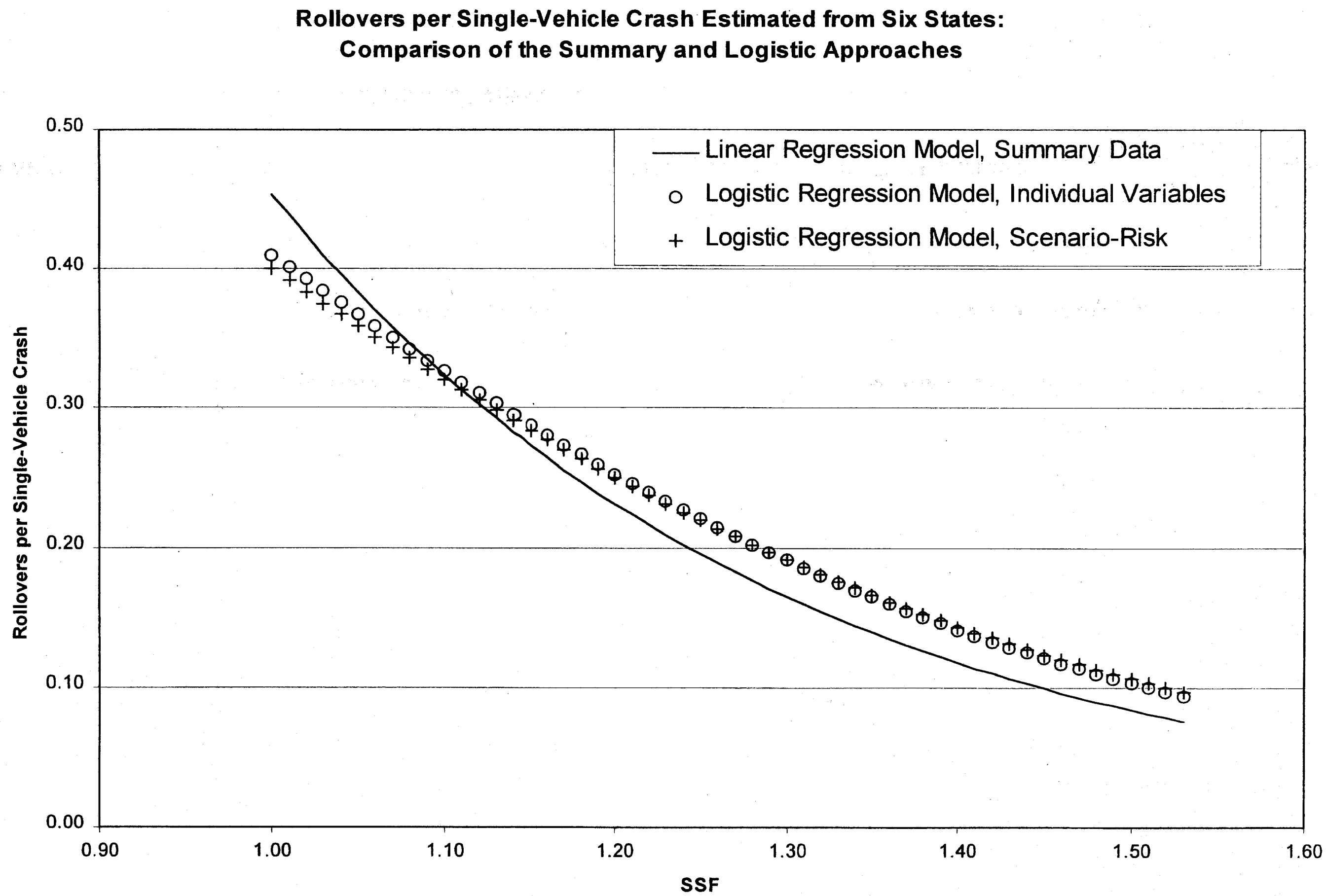

Figure 1 National rollover rate estimated from six states, linear and logistic models

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The logistic regression and linear regression separate the effects of vehicle rollover resistance and those of road-use variables by different processes, and the logistic regression predicts a curve with a lower average slope. The Alliance commented that logistic regression considers the potential effect of variables in combination which may intensify or dilute their individual effects, but that linear regression would neglect combination effects. With this possibility in mind, we considered whether the use of the curve corresponding to logistic regression on individual variables would serve as a better basis of rollover risk for the vehicle star ratings than the linear regression curve proposed in our June 1, 2000 notice.

The proposed rating system was based on equal intervals of risk and positioned the five-star level at a value of SSF achievable by favorably designed family sedans. It also positioned the one-star range where it captured some popular SUVs and pickup trucks of the recent past. The manufacturers of the one-star vehicles generally have improved the current versions of the equivalent vehicles to the two-star level, but we believe the one-star rating ceiling would be stringent enough to discourage companies from returning to old design practices or from importing less advanced vehicles. A fortuitous feature of the ratings based on the linear regression curve was that reasonable one-star and five-star SSF boundaries occurred at predicted levels of rollover risk of 10 percent and 40 percent, permitting three equal intervals of risk between them divisible by ten for the two-star, three-star and four-star boundaries. Having the star rating intervals bounded at 10, 20, 30 and 40 percent rollover risk levels would make the meaning of the ratings easier to explain to consumers. Figure 2 presents the proposed rating system in graphical form. The updated linear regression curve in Figure 1 is nearly identical to the linear regression curve in Figure 2, except that it would set the one star boundary for 40 percent rollover risk at 1.03 instead of 1.04.

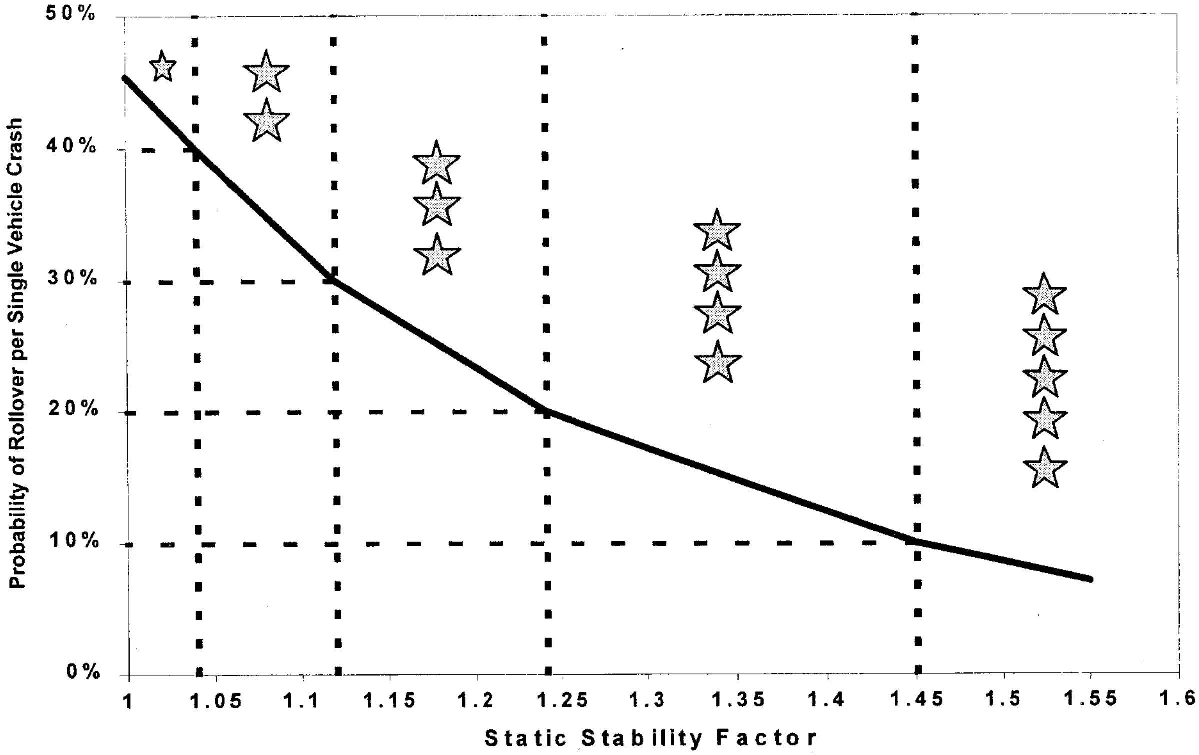

Figure 2 Star rating intervals presented in June 2000 notice, based on linear regression

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We considered the merits of the various ways in which the rollover risk versus SSF curve produced by logistic regression (Figure 1, Individual Variables) could be used to replace that produced by linear regression (also in Figure 1) as the basis for defining rollover risk in the rating system. If the proposed rating intervals in terms of SSF (1.04, 1.12, 1.24, 1.45) were maintained, they would no longer satisfy their rationale of representing equal increments of rollover risk in a single-vehicle crash. Conversely, if the risk intervals at 10, 20, 30 and 40 percent are maintained, the one-star SSF level would become 1.01 and the five-star level would become 1.51. A one-star level of 1.01 is so low that we know of only one vehicle (not in current production) that it would describe. Similarly, a five-star level of 1.51 appears to be out of reach for even the most stable family sedans which have demonstrated very good performance in resisting rollover. We believe that maintaining the 10, 20, 30 and 40 percent star boundaries with the logistic regression curve would have the practical effect of replacing the five-star rating system with a three-star rating system. At the low end of the SSF scale, the distinction between some historically poor performing vehicles and their improved replacements would be lost. At the higher end of the SSF scale, the distinction between some very good performing mid-sized and large sedans and some clearly poorer performing sub-compacts would be lost.

It would appear that the best way to incorporate the rollover risk levels estimated by logistic regression while maintaining the usefulness of the rating system to the consumer is to maintain the proposed one-star and five-star boundaries as closely as possible. This approach would require adjustment of the equal risk intervals between the one- and five-star boundaries to reflect the difference in average slope between the linear regression curve and the logistic regression curve. A five-star boundary of 1.46 corresponds to a rollover risk of less than 12 percent on the logistic regression curve. (The previous boundary of 1.45 would require a statement of risk of 12.1 percent which would not be desirable for consumer information). Similarly, a one-star boundary of 1.05 would correspond to a rollover risk greater than 36 percent. These one-star and five-star boundaries would allow for equal risk intervals of eight percentage points between the other star boundaries. A change from 10 percent risk intervals to eight percent risk intervals would be proportional to the difference in average slope between the linear regression curve and the logistic regression curve. Figure 3 illustrates this idea for using the logistic curve in a revised rating system in a graphical form comparable to Figure 2.

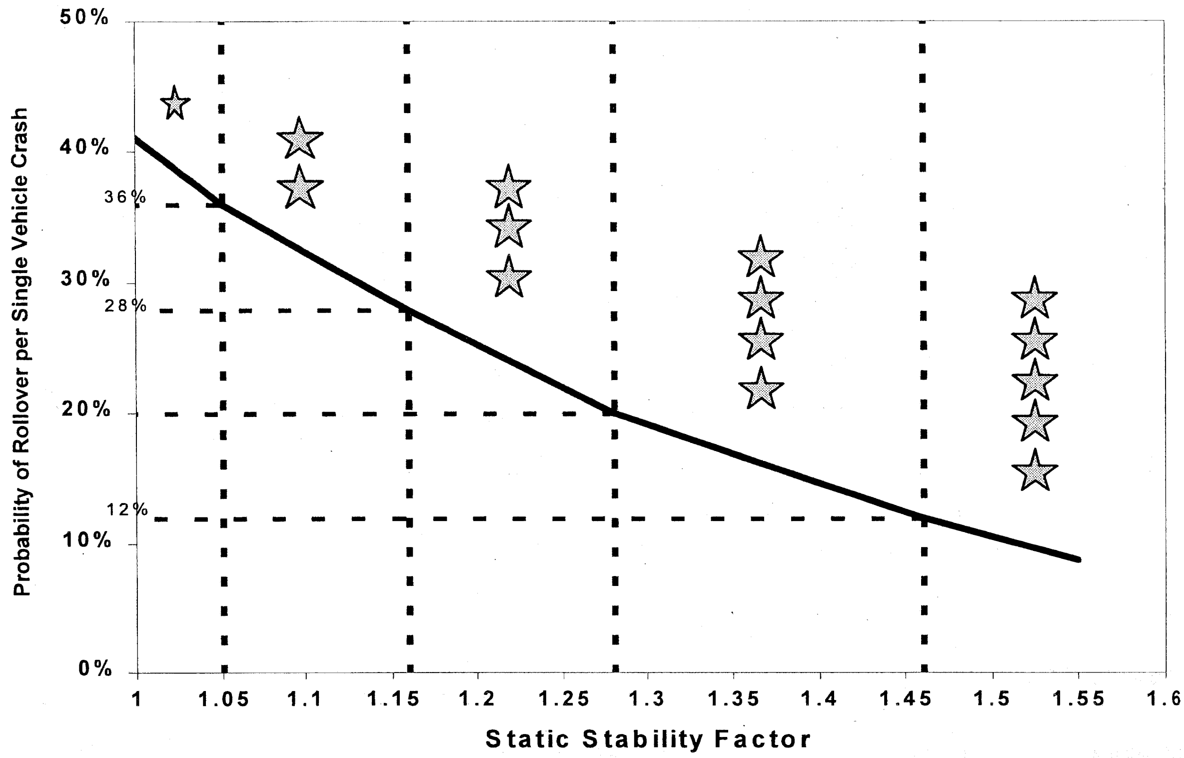

Figure 3 Possible star rating intervals based on logistic regression

However, this idea also has serious drawbacks. It would move the three star level from 1.13 SSF to 1.17 and the four star level from 1.25 to 1.29 because the logistic regression shows less of the asymptotic shape of the raw data (Figure 1 of Appendix 1) than does the linear regression (of the log of SSF) curve previously proposed. This is troubling for two reasons. The shape of the original linear regression curve conforms better than does the logistic regression curve to the expectation that a given increase in SSF produces a substantially greater benefit for a vehicle with a low SSF than for one with a high SSF. Also, NHTSA believes that the proposed star rating levels may have become design goals for manufacturers seeking to improve rollover resistance. A change in star rating levels at this time may have the counterproductive effect of denying manufacturers recognition for substantial improvements in rollover resistance of vehicle designs.

While we do not deny the theoretical advantages of logistic regression cited by the Alliance regarding interactions between road use variables, the similarity in curves describing rollover risk as a function of SSF in the linear and logistic regression approaches suggests that such interactions do not exert a great influence on the effect of SSF. Therefore, we do not believe that the difference in risk analysis methods is great enough to compel a change in the proposed star rating levels to the detriment of manufacturers who are trying to achieve them and to the detriment of consumers who we believe will find the proposed rating system simpler. We also note that the linear regression curve presents a more conservative estimate of rollover risk for vehicles with SSF greater than 1.10, and we anticipate vehicles with SSF lower than 1.10 becoming rare in light of manufacturers' reported efforts at improving rollover resistance.

The rating system that NHTSA will use to define rollover risk and assign star rating is based on the updated linear regression curve in Figure 1 of this section. It would be described verbally as follows:

One Star ★: Risk of Rollover 40 percent or greater in a single-vehicle crash is associated with SSF 1.03 or less.

Two Stars ★★: Risk of Rollover 30 percent or greater but less than 40 percent is associated with SSF 1.04 to 1.12.

Three Stars ★★★: Risk of Rollover 20 percent or greater but less than 30 percent is associated with SSF 1.13 to 1.24.

Four Stars ★★★★: Risk of Rollover 10 percent or greater but less than 20 percent is associated with SSF 1.25 to 1.44.

Five Stars ★★★★★: Risk of Rollover less than 10 percent is associated with SSF 1.45 or more.

C. Comments on Practical Problems with SSF Ratings

1. Difficulty of Improving Vehicles

The Alliance and the import manufacturers' organization, AIAM, asserted that improvements in a vehicle's SSF are not practicable since SSF is largely determined by its vehicle type. That is, the track widths and c.g. heights of pickups, SUVs, vans, and passenger cars are more or less fixed within certain limits. Significant changes to those measurements would simply eliminate the vehicle attributes which are common to the category and which are presumably desirable to consumers. These comments noted, for example, that significantly lowering the c.g. (thus raising the SSF) of an SUV could be accomplished by decreasing ground clearance, but doing so might make it unappealing compared to other vehicles in the SUV category. Conversely, the comments contended that marginal changes to track width and c.g. height small enough to maintain attributes in a vehicle category would not improve rollover risk. They conclude that SSF is not a useful design criterion, and it lacks the potential to reduce rollover rates if current vehicle types are to be preserved.

We disagree that significant improvement in SSF will necessarily eliminate desirable attributes within a class of vehicles. We are aware of a recent redesign of a production SUV [8] in the U.S. that achieved a decrease in c.g. height of approximately 2.0 inches (along with a significant increase in track width) while actually increasing the ground clearance. We estimate those changes represent an improvement in SSF equivalent to at least one star rating interval, and we would expect a significant decrease in rollover risk in single-vehicle crashes.

We also would note that passenger car-based SUV's with significantly better SSFs than traditional, truck-based SUVs have been gaining popularity in the absence of any consumer information program for rollover. The range of SSF among ten SUVs in our 1998 SSF measurements of a group of 32 then-new vehicles was equivalent to a rollover risk reduction of approximately 14 percent using the predictive curve from the linear regression analysis explained in this notice. So-called ''crossover'' vehicles promise even greater improvement. While these vehicles may offer less of some attributes of traditional SUVs, like overall ride height, the increasing popularity of crossover vehicles indicates that those attributes may be less important to consumers than the ones which they maintain in common with traditional SUVs, such as cargo room and traction on snowy roads. Thus, the suggestion that no changes to current vehicle designs are possible without significant customer resistance appears to be an assertion unsupported by what has happened recently in the market.

On the other hand, one of the models that scored highest among the ten SUVs in the 1998 measurements was a more or less traditional design, i.e., it was not passenger car-based.[9] This gives evidence that more stable light truck design is not incompatible with traditional design attributes.

The fact that SUVs are seldom used off-road indicates that not all SUV buyers really want off-road capability. Buyers who are aware of the tradeoff in risk of rollover that such off-road capability usually entails, may decide they can obtain the attributes they want or need in a more rollover-resistant vehicle. As a contrasting example, buyers who desire passenger and cargo capacity may choose a van or minivan over a conventional station wagon after deciding that their priorities outweigh the increase in rollover risk associated with that choice.

We believe that vehicle modifications to improve rollover resistance ratings are both achievable and beneficial. Press accounts suggest that manufacturers are, in fact, making such modifications as they redesign their light trucks. However, the ratings do not force manufacturers to modify vehicles, nor do they force consumers to accept only certain vehicle alternatives. The ratings will have a positive effect on the light vehicle rollover problem by making consumers more aware of trade offs in rollover stability, allowing consumers to make more informed purchase decisions, and influencing their awareness of the need to wear seat belts to prevent ejection in rollover crashes. This improvement will accrue even if the manufacturers make no changes to vehicles whatsoever in response to the program.

2. Possible Consequences of Improving SSF

Honda and the Alliance also suggested that, with a design criterion like a rollover rating based on SSF, manufacturers may be inclined to ''design for the test.'' The manufacturer of a vehicle whose score falls just below a rating cutoff point might be able to make design adjustments that shift the vehicle's score into the next higher category. We believe there is no reason to discourage manufacturers from taking such actions because an improvement in SSF will result in a corresponding improvement in rollover risk. In fact, we believe that a major advantage of SSF, one that distinguishes it from other measures of rollover resistance, is that it ''does no harm.'' Since SSF is a fundamental measure of inherent vehicle stability, there is no realistic risk that increasing SSF will degrade actual rollover rate or have other unintended, negative consequences. In contrast, improvement in other metrics can result in trade-offs that compromise overall safety. For example, maximizing a vehicle's Tilt Table Ratio can be accomplished by trading off some vehicle directional control (oversteer/understeer) characteristics. As another example, it is apparent that the Stability Margin metric can be improved by reducing tire grip, which could decrease driver control of the vehicle.[10]

Furthermore, SSF is relevant to stability under virtually any circumstance, whether it be a run-off-the-road crash, an obstacle avoidance scenario, or even collisions with objects or other vehicles, though it is obviously more significant in some of those events, i.e., single-vehicle crashes, than in others, i.e., collisions, where impact forces can overwhelm other factors.

It was suggested in the comments that vehicle characteristics which an SSF-based rating ignores, like body shape and tire profile, influence rollover rate because they determine how a vehicle interacts with roadside objects and terrain during a crash event. As an example, Honda suggested that lowering a vehicle's c.g., thus improving its SSF, by equipping it with low-profile tires could increase the risk of tripped rollover by making sideward wheel contact with tripping mechanisms more likely. This is speculative and not persuasive. Each single-vehicle crash is, more or less, a unique event, because of the variety and complexity of circumstances involved. Although we agree that tripping usually initiates through interaction of a vehicle's wheels (i.e., tires and/or rims) with the roadway environment, generalizations about the influence of low-profile tires, or differences in body shape, on tripping frequency are extremely difficult to substantiate, given the limitless combinations of terrain, pavement condition, shoulder design, barriers, soil, vegetation, etc. A vehicle feature like taller, more flexible tire sidewalls may help avoid tripping in a few crashes, but is likely to be ineffective in the vast majority of others, and may be counterproductive in some cases. Even if it were possible for a manufacturer to identify tires and rims that were supposedly more resistant to tripping, safe handling and road holding considerations should certainly weigh more heavily in tire and rim selection.

A notable exception to this involves the problem of tire debeading. Clearly, a wheel rim that becomes exposed when a tire debeads either as a precursor to a single-vehicle crash or in the course of one, can become a primary tripping mechanism. We believe that tire and rim combinations that are more resistant to debeading may indeed lessen the risk of rollover in a single-vehicle crash. The agency is already planning to improve debeading requirements in FMVSS No. 109.

A further difficulty in identifying vehicle features that might improve tripping resistance is that crash data is limited. The minute level of detail required to thoroughly analyze the interaction of a vehicle's wheels,

[8] Mitsubishi Montero redesign from model year (MY) 1991–99 design to MY 2000 version of the same nameplate.

[9] Isuzu Rodeo.

[10] These metrics are explained in detail in the June 1, 2000 notice.

undercarriage, body components, etc., with the roadway environment in a run-off-the-road event is generally unavailable in state or national crash databases. NHTSA's NASS–CDS database does contain a high level of detail, but it focuses on a relatively small sampling of crashes. In contrast, the SSF of vehicles in crashes can be determined as long as the data contain a few details about the vehicle, like make and model. Availability of extensive crash data is important for analyses like NHTSA's statistical analysis of crashes in six U.S. states as reported in the RFC and in Appendix I here.

Honda also suggested that problematic suspension behavior such as ''suspension-jacking'' can lead to a higher risk of rollover regardless of SSF, and that this exemplifies why SSF alone is not an adequate indicator of rollover resistance. Although vehicles with particular suspensions, most notably ''swing-axle'' designs, historically may have been associated with rollover, we believe those represent relatively few cases out of a very large population of rollover crashes and that such examples of suspension design are uncommon in current vehicles. Furthermore, suspension behavior is less important than SSF once a vehicle has left the roadway, where factors like shoulder condition and terrain interact with the basic stability characteristics of the vehicle to determine crash outcome.

3. SSF Measurement Accuracy

Honda stated in response to the RFC that the Vehicle Inertia Measurement Facility(VIMF) that NHTSA will use to ascertain SSF is not accurate enough to repeatably give useful vehicle ratings. Honda suggested that for c.g. height measurement the measurement error is the sum of 0.5 percent ''repeatability'' error and 0.5 percent ''accuracy'' error, giving a total measurement error of ±1.0 percent of the measured value. Honda believes an error of that magnitude is significant, compared to the small differences between vehicles being compared, and that a vehicle could be assigned an incorrect number of stars due to measurement error.

Honda appears to have misinterpreted the published reports available on the VIMF. The document cited in Footnote 19 of the RFC does indicate, in Table 1, ''error bounds'' for c.g. height of ±0.5 percent of the measured value.[11] Other documents,[12, 13, 14] describing the design of the VIMF give the same value for ''repeatability'' or ''two standard deviation error'' for c.g. height measurements.

Basically, ''repeatability,'' as used in the referenced documents in regard to the VIMF, is not separate from the ''accuracy'' of the system. It is incorrect to assume that the total VIMF system error in c.g. height measurements is the sum of the 0.5 percent repeatability and 0.5 percent accuracy, for a total system error of one percent in c.g. height measurements. The total system error of the VIMF for c.g. height measurement is 0.5 percent or less, as explained below.

When the VIMF was under development, an error analysis was conducted based on experience with NHTSA's Inertial Parameter Measurement Device (IPMD), a precursor to the VIMF. Over the course of several years, the IPMD underwent successive updates and improvements, culminating in a fifth and final version of the machine that ultimately served as a model for the VIMF. The error analysis accounted for all the known sources of error arising from each system component, for example, platform deflection and vehicle restraint rigidity, as experience with the IPMD had indicated. By mathematical modeling, the contribution of each component to the whole system error was determined. The final design specifications for the VIMF were set by that analysis. Each component was selected or fabricated so as to limit the combined error from all the known contributions to 0.5 percent of the measured value for c.g. height. The details of the error analysis are discussed in the referenced documents.

Since it was designed and constructed, the accuracy of the VIMF has been evaluated using a custom-built calibration fixture with a known c.g. location. This fixture is a heavy weldment made from stock steel plates and box section beams whose individual c.g. locations are easily determined by geometry. Because it is a very rigid body and is fabricated from such geometrically simple components, the calibration fixture's c.g. location, as well as its mass moments of inertia, are known theoretically, and it is thus a benchmark for reckoning the accuracy of the VIMF. The calibration fixture can be set up in either a light or heavy configuration, the latter achieved by adding weight in precise locations to increase the c.g. height by a known amount. In the light configuration, the fixture is representative of the mass and c.g. height of a mid-size passenger car. In the heavy configuration, it is representative of a light truck.

In calibration tests using this fixture, the VIMF consistently measures the c.g. location to within 0.5 percent of the known value. Tables 6 and 7 of the 1995 Heydinger paper cited here indicate that the VIMF was able to measure the c.g. height of the fixture to within 0.46 percent (2.6 mm in 561.2 mm) and 0.32 percent (2.6 mm in 809.2 mm) of its theoretically known values in the light and heavy configurations, respectively. Those results correspond well with the VIMF error analysis which predicts that the degree of accuracy should be somewhat higher when measuring heavier, higher c.g. vehicles. That is, the measurement accuracy for vehicles which are likely to fall into the lower SSF categories is significantly better than 0.5 percent.

While we believe the NHTSA measurements will be sufficiently accurate, no degree of measurement accuracy can prevent borderline cases. There is always a possibility of a vehicle score falling so close to a cutoff point between star ranges that applying even a small amount of measurement uncertainty to the score results in ambiguity about the category to which the vehicle belongs. This situation is characteristic of any rating scheme and is no different from what currently exists in the NHTSA frontal and side NCAP. We plan to use conventional rounding methodology to determine the SSF of each test vehicle to two decimal places and assign stars based on that result.

If a manufacturer determined that one of its models was on the border between star levels, the manufacturer could, if it wished, make changes to the vehicle to improve its SSF to the point where it falls comfortably in the higher category. If the vehicle was indeed on the border, the changes necessary would probably be very minor, and it would be voluntary, not mandatory.

D. Consumers' Ability to Understand SSF as a Measure of Rollover Risk in the Event of a Single-vehicle Crash

Some commenters had misgivings about consumers' abilities to understand and use the new rollover rating information in three areas. They believe:

- Consumers are not capable of understanding that the star rating

[11] Heydinger, G.J., *et al*; ''Measured Vehicle Inertial Parameters—NHTSA's Data through November 1998''; Society of Automotive Engineers 1999–01–1336; March, 1999.

[12] Heydinger, G.J., *et al*; ''The Design of Vehicle Inertia Measurement Facility''; SAE Paper 950309; February 1995.

[13] Bixel, R.A., *et al*; ''Developments in Vehicle Center of Gravity and Inertial Parameter Estimation and Measurement''; SAE Paper 950356; February 1995.

[14] Heydinger, G.J., *et al*; ''An Overview of a Vehicle Inertia Measurement Facility''; Intl. Symposium on Automotive Technology; Paper 94SF034; October 1994.

describes the risk of rollover in the event that the vehicle is involved in a single-vehicle crash.

• Consumers will not find the information useful in making a vehicle choice.

• Even if consumers use the information, the new program will not lead to a decrease in rollover crashes. Each of these areas are discussed and responded to below.

1. Are Consumers Capable of Understanding That the Star Rating Describes the Risk of Rollover in the Event That the Vehicle Is Involved in a Single-vehicle Crash?

Auto manufacturers and the National Automobile Dealers' Association (NADA) believe that consumers are not capable of understanding that the star rating describes the risk of rollover in the event that the vehicle is involved in a single-vehicle crash. The following is a list of comments and the commenters who made them:

• Consumers will be confused because the rollover ratings are not in terms of injury risk like other NCAP ratings—Alliance

• Consumers will not understand that the rollover ratings do not include crashworthiness attributes—AIAM

• Consumers will think the rollover risk is the life-time rollover risk from driving the vehicle or the risk of rollover each time they drive the vehicle—Alliance, Suzuki, Toyota, Honda

• Consumers will think risk is the same for all drivers in all conditions and have the false impression that the vehicle design is the principal cause of rollover—Suzuki, NADA

The language that will be used in consumer information products concerning this rollover rating (see Section IV) was developed using the outcome of focus group testing. As discussed in the June 2000 notice, in April 1999 NHTSA conducted a series of six focus groups to examine ways of presenting comparative rollover information. As a result of the comments to our June 2000 notice, NHTSA conducted another series of focus groups in November 2000. Two versions of explanatory language were presented to a total of 12 groups of nine consumers each in two different cities. NHTSA asked the focus groups to evaluate a short version of rollover rating explanatory language that read as follows:

Description of Rollover Resistance Rating

Most rollover crashes occur when a vehicle runs off the road and is tripped by a ditch, soft soil, a curb or other object causing it to roll over. These are called single-vehicle crashes because the crash did not involve a crash with another vehicle. The Rollover Rating is an estimate of your risk of rolling over if you have a single-vehicle crash. The Rollover Rating essentially measures how ''top-heavy'' a vehicle is. The more ''top-heavy'' the vehicle, the more likely it is to roll over. The lowest rated vehicles (1-star) are at least 4 times more likely to roll over than the highest rated vehicles (5-stars).

• Here are the Rollover Ratings:

In A Single-vehicle Crash, a vehicle with a rating of:

Five Stars ★★★★★
Has a risk of rollover of less than 10%
Four Stars ★★★★
Has a risk of rollover greater than 10% but less than 20%
Three Stars ★★★
Has a risk of rollover greater than 20% but less than 30%
Two Stars ★★
Has a risk of rollover greater than 30% but less than 40%
One Star ★
Has a risk of rollover greater than 40%

We also asked the focus groups to evaluate the following longer version:

Description of Rollover Resistance Rating

• Thousands of crashes occur each year when a driver loses control of his/her vehicle and runs off the road. These are called single-vehicle crashes because the crash did not involve a collision with another vehicle. Once the vehicle leaves the road it can hit an object (pole, tree, guardrail, etc.), or the wheels can contact a ditch, soft soil, a curb or other object, tripping the vehicle and causing it to roll over. Single-vehicle rollovers can also occur on the road, but most rollover crashes occur when a vehicle runs off the road, usually sliding sideways.

• The National Highway Traffic Safety Administration (NHTSA) has provided consumers with frontal and side impact crash test ratings for several years. Because more than 10,000 people die each year in rollover crashes, NHTSA has added a Rollover Rating to provide consumers with better overall safety information on new vehicles.

• The Rollover Rating is an estimate of your risk of rolling over if you have a single-vehicle crash. If that happens, the risk of rollover for the highest rated vehicles (5-star) is less than 10%, but that risk factor increases by a factor of 3 to 4 for the lowest rated vehicles (1-star).

• The Rollover Rating essentially measures how ''top-heavy'' a vehicle is. The more ''top-heavy'' the vehicle, the more likely it is to roll over. Based on a study of 185,000 single-vehicle crashes, this measurement has been shown to relate very closely to the real-world rollover experience of vehicles.

• NHTSA's Front and Side Crash Test Ratings predict a vehicle occupant's chance of serious injury if the vehicle is involved in that type of crash. The Rollover Rating predicts the risk of a rollover if your vehicle is involved in a single-vehicle crash. (It does not, however, predict the likelihood of that crash.)

• While the Rollover Rating does not directly predict the risk of injury or death, keep in mind that rollovers have a higher fatality rate than other kinds of crashes. Even the highest rated vehicle can roll over, but you can reduce your chance of being killed in a rollover by about 75% just by wearing your seat belt.

• Here are the Rollover Ratings:

In A Single-vehicle Crash, a vehicle with a rating of:

Five Stars ★★★★★
Has a risk of rollover of less than 10%
Four Stars ★★★★
Has a risk of rollover greater than 10% but less than 20%
Three Stars ★★★
Has a risk of rollover greater than 20% but less than 30%
Two Stars ★★
Has a risk of rollover greater than 30% but less than 40%
One Star ★
Has a risk of rollover greater than 40%

The focus group testing pointed out areas of difficulty in comprehension that were addressed in writing the final language.

Focus group participants felt that while the shorter explanation was too short to fully comprehend the rating, the longer version was overwhelming and included unnecessary information. Based on the focus group inputs, we have developed the following language:

Description of Rollover Resistance Rating

• Most rollover crashes occur when a vehicle runs off the road and is tripped by a ditch, curb, soft soil, or other object causing it to roll over. These crashes are usually caused by driver behavior such as speeding or inattention. These are called single-vehicle crashes because the crash did not involve a collision with another vehicle. More than 10,000 people die each year in all rollover crashes.

• The Rollover Resistance Rating is an estimate of your risk of rolling over if you have a single-vehicle crash. It does not predict the likelihood of that crash. The Rollover Resistance Rating essentially measures vehicle characteristics of center of gravity and track width to determine how ''top-heavy'' a vehicle is. The more ''top-heavy'' the vehicle, the more likely it is to roll over. The lowest rated vehicles (1-star) are at least 4 times more likely to roll over than the highest rated vehicles (5-stars).

- The Rollover Resistance Ratings of vehicles were compared to 220,000 actual single-vehicle crashes, and the ratings were found to relate very closely to the real-world rollover experience of vehicles.
- While the Rollover Resistance Rating does not directly predict the risk of injury or death, keep in mind that rollovers have a higher fatality rate than other kinds of crashes. Remember: Even the highest rated vehicle can roll over, but you can reduce your chance of being killed in a rollover by about 75% just by wearing your seat belt.
- Here are the Rollover Resistance Ratings:

In A Single-Vehicle Crash, a vehicle with a rating of:

Five Stars ★★★★★
Has a risk of rollover of less than 10%
Four Stars ★★★★★
Has a risk of rollover between 10% and 20%
Three Stars ★★★★★
Has a risk of rollover between 20% and 30%
Two Stars ★★
Has a risk of rollover between 30% and 40%
One Star ★
Has a risk of rollover greater than 40%

The length of the final version is midway between the two versions tested. It adds information not included in the tested short version that participants felt was particularly important in understanding the information and/or particularly compelling to cause them to pay attention to the information. It deletes information in the tested long version that participants felt was unnecessary and/or confusing. In addition, the explanation of the star ratings was simplified because the original format seemed to cause some confusion about whether more stars or less stars was a better rating. Finally, NHTSA has chosen to use the term ''Rollover Resistance Rating'' rather than ''Rollover Rating'' as this seemed to help participants understand the rating.

The potential confusions cited by the commenters did not occur in the focus groups. From the discussions during the focus groups, it is clear that participants are aware that rollover is heavily influenced by driver and road characteristics. In almost all groups the first cause of rollover cited by participants was speed. Participants also mentioned road conditions and driver behavior and/or experience as factors. However, the participants also seemed to understand that the vehicle can also play a part in determining whether or not a rollover occurs, and that this rating was only a measure of that factor.

NHTSA notes that the explanatory language will be used in the Buying a Safer Car brochure, and other places that present the star ratings. This brochure's primary focus is how a person can purchase a safer vehicle. It does not include extensive discussion of driver behaviors that can increase safety, as those types of issues tend to be addressed by other agency programs. NHTSA will include additional information about rollover in the form of Q&A's on the agency's website, and is considering developing additional rollover consumer information, both of which would be more appropriate places for discussion of other factors that can reduce the risk of rollover.

2. Will Consumers Find the Information Useful in Making a Vehicle Choice?

The commenters listed below believe that even if consumers do understand the risk represented by the stars, this information will not be useful to them in choosing a vehicle. They assert the following:

- Consumers pick a vehicle class before they select a particular model. There are not enough differences in star ratings among vehicles in the same class to make the information useful to consumers. The stars reflect only tiny differences on each side of the dividing line.—Alliance, Ford, BMW, CU
- The difference in SSF made by options and configurations available on a single vehicle are too great to allow meaningful ratings—Alliance

While it is true that many consumers limit their vehicle choices early in the purchase-decision process (*e.g.,* must be an SUV), many others are also considering vehicles in more than one class (*e.g.,* a van or an SUV). As the availability of rollover resistance rating information becomes more widely known, consumers will begin to know that certain types of vehicles have better ratings than others. In addition, while we cannot predict the final spread of ratings for the 2001 models that will be tested, in our research there was usually a two- to three-star rating range for each class. Thus, by his or her vehicle choice alone, a consumer could reduce his or her chance of a rollover in a single-vehicle crash by up to 24% in some cases.

In addition, another safety benefit of the NCAP program is the general improvements manufacturers have made to vehicles as the result of publishing such ratings. These improvements benefit all consumers regardless of their choice of vehicle. Over the years, manufacturers have responded to the frontal NCAP program and as a result the number of models achieving a five-star rating today is 2.7 times what it was when the program started in 1979. As for the criticism that star ratings do not indicate the tiny difference among vehicles near the dividing lines, this is also true for the frontal and side NCAP ratings. Just as with these ratings, the actual scores for the vehicles will be available on the NCAP website to anyone who is interested.

Finally, with regard to comments that options can cause wide difference in the rating for a specific model, over the years that we have been researching vehicle inertial parameters, four-wheel drive is the only equipment option for which we have observed a large potential effect on SSF. NHTSA intends to test the most common versions of all vehicles. Where two- and four-wheel drive versions of the same vehicle are available, we will test them both and report them as separate models. We will accurately describe the actual test vehicle in the literature reporting the rating.

Manufacturers who believe there are significant differences in SSF for different vehicle configurations may fund an optional NCAP measurement, just as they may fund optional frontal or side NCAP tests. Then if the difference in equipment or configuration makes a difference in the SSF, that difference will be available to the public.

3. Even If Consumers Use the Information, Will the New Program Lead to a Decrease in Rollover Crashes?

Some commenters believe that even if consumers do use the new ratings, the outcome of that use will be other than what we desire. The following are comments and who made them.

- Rollover ratings will encourage consumers to purchase cars instead of trucks and cars are less safe than trucks.—Alliance
- A system based on RO/SVC may cause the choice of a less-safe vehicle because it doesn't take the make/model's risk of becoming involved in a crash into account.—Suzuki, Tenneco
- Consumers will think that if they drive a vehicle with a high SSF they

will be immune to rollover and this will lead them to drive unsafely—Alliance

• There is no demonstrated safety benefit of rollover rating.—Alliance, BMW

The best indicator of the potential benefits of any new ratings program is the frontal NCAP program. As discussed previously, there are now many more five-star vehicles than when the frontal NCAP program started. Research also indicates that a five-star rating correlates to enhanced real-world safety. Therefore, all consumers benefit from these improvements in the vehicle fleet even if they don't make purchase decisions based on the star ratings. Both of these types of analysis will be possible for side impact and rollover NCAP after an adequate number of years of experience. There is no evidence that consumers have responded to vehicles with high frontal NCAP scores or other safety features by riskier driving behavior, and no reason to believe that they will respond differently to rollover ratings. Similarly, there is no indication that consumers believe they are immune to injury by driving a vehicle with a five-star frontal or side NCAP rating or with additional safety features.

NHTSA disagrees that cars are less safe than light trucks. Occupant fatality rates (average 1991–98, FARS data) across all crash types indicates that large cars have a lower fatality rate than SUV's and small pickup trucks, and the same as the rate for standard pickups. Medium cars have a rate about the same as SUV's and lower than the rate for small pickup trucks. Small cars and small pickup trucks have about the same rate. See Figure 4. If we narrow the picture to rollover crashes, as in Figure 5, we see that SUV's and small pickups have the highest rates, at least 75 percent higher than the rate for small cars. The rates for medium and large cars are below any of the light truck types.

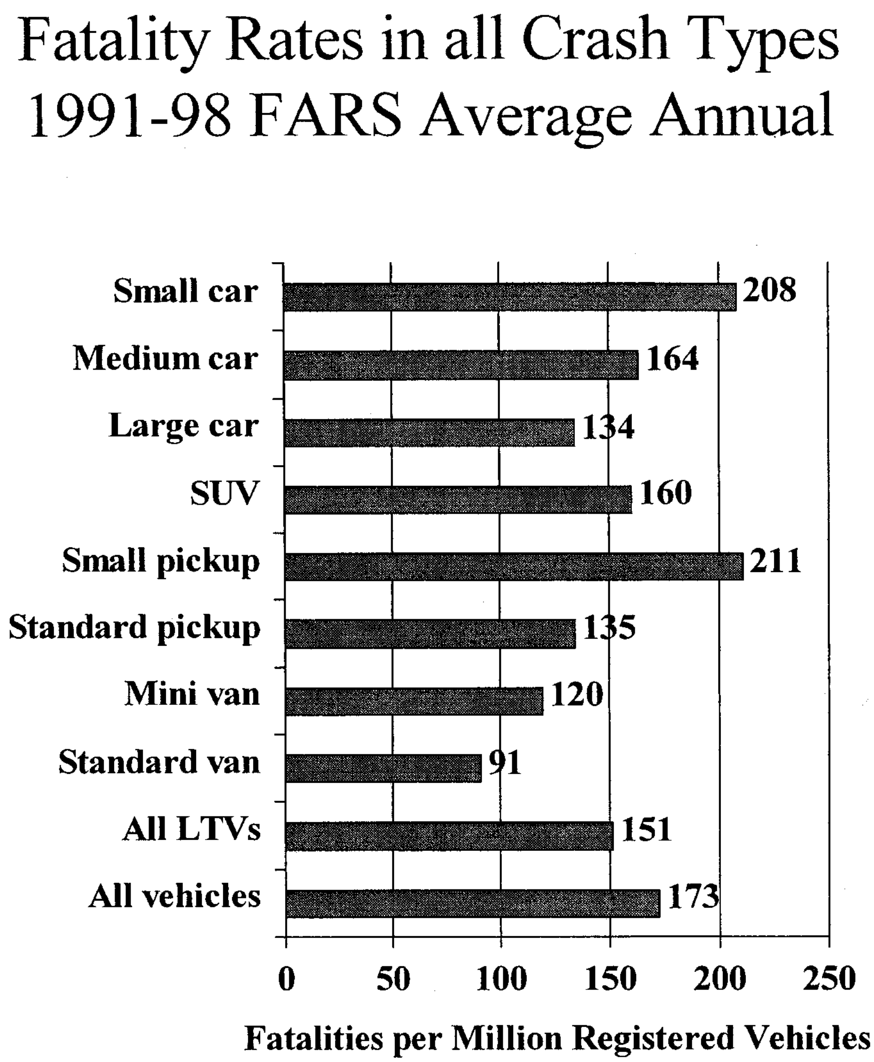

Figure 4 Fatality Rates in all Crashes by Vehicle Type1991-98 annual average

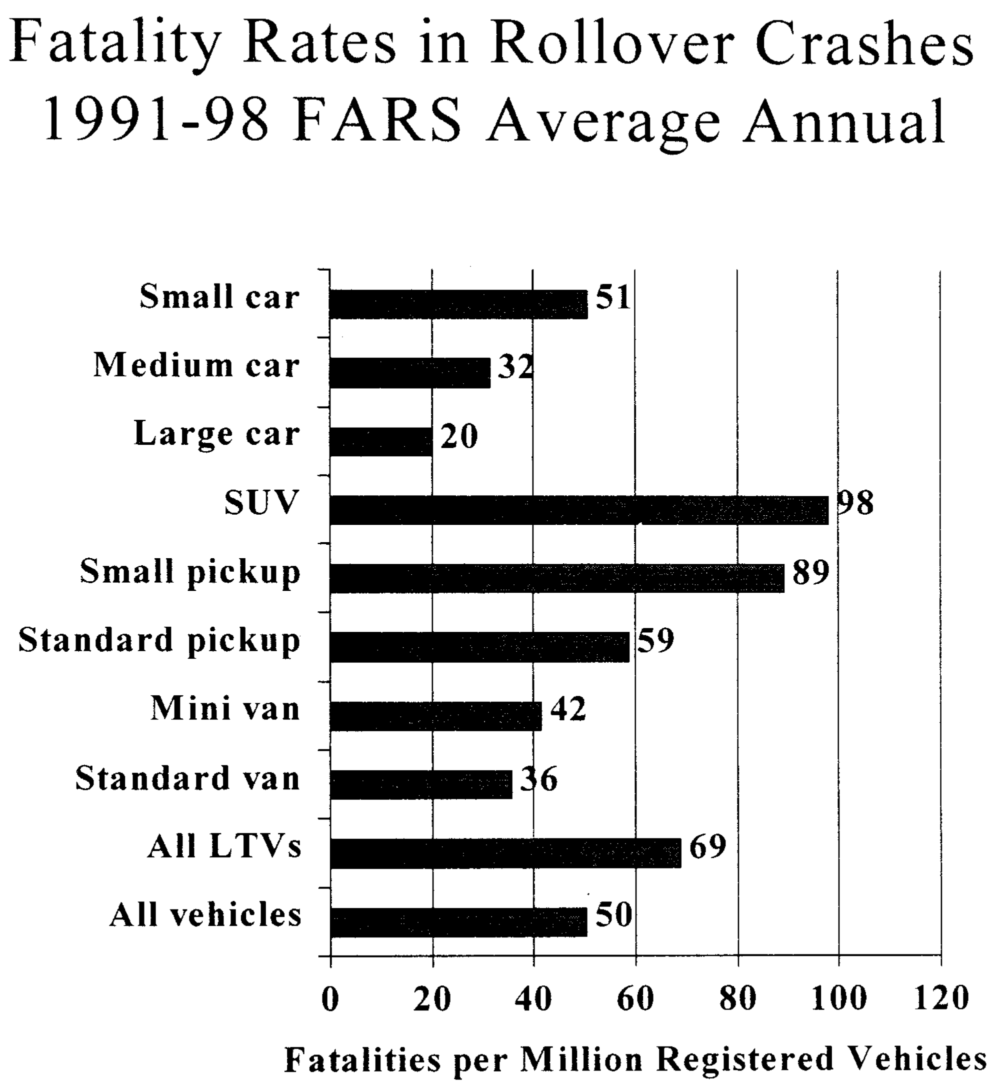

Figure 5 Fatality Rates in Rollover Crashes by Vehicle Types 1991-98 annual average

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However, NHTSA is aware that as we expand the areas in which we provide consumer information ratings, it is becoming more and more important to provide consumers with guidance on how to weigh ratings in different categories. For example, it is quite common for SUVs to receive five-star ratings in side impact NCAP, but our research indicates that these vehicles will have rollover ratings in the one- to three-star range. NHTSA can help consumers understand these differences by providing them with information on the frequency of various crash types, as we have been doing with the front and side impact NCAP ratings, and we plan to do for rollover crashes. In addition, NHTSA has been considering possible ways to provide consumers with a single summary rating of a vehicle's safety.

E. The Question of Electronic Stability Control

Continental Teves objected to the use of SSF to rate rollover resistance because the ratings would not reward manufacturers for equipping vehicles with Electronic Stability Control (ESC). It was also dissatisfied with language in the notice promising consumer information about ESC as part of the rating presentation after there is some evidence of its effectiveness. BMW, Toyota, Isuzu, Tenneco and the Alliance offered similar comments. All expressed confidence that the technology would reduce the number of on-road loss-of-control situations that often result in off-road tripped rollovers. The Alliance suggested that ESC may also reduce the risk of untripped rollover, and Continental believes that it may help drivers regain control after they leave the roadway. Many commented that ratings based on SSF would stifle and undercut advanced vehicle technology. The notice specifically asked commenters to share any data they may have on the effectiveness of stability control technologies in preventing single-vehicle crashes, but none did so.

The NCAP program rates the risk of rollover in the event of a single-vehicle crash. Most of these single-vehicle crashes involve hitting a curb or running off the road accidently and encountering soft soil, a ditch or something that trips the vehicle. To repeat, 95 percent of rollovers are tripped. Once a vehicle is in this situation and strikes a tripping mechanism, its chances of rolling over depend heavily on its SSF.

The promise of ESC is not that it can change what happens when a vehicle hits a tripping mechanism but that it may help the driver to avoid going off the roadway in the first place. ESC can apply one or more brakes automatically to keep the yaw rate of the vehicle proportional to its speed and lateral acceleration. Essentially, it corrects for vehicle understeer or oversteer, and some systems may override a driver's failure to brake when in fear of losing control. This benefit could minimize the driver's chances of compounding his or her driving errors in a panic situation. However, it cannot keep a vehicle from leaving the roadway if the vehicle is going too fast for the maneuver the driver is attempting.

Like frontal and side NCAP ratings, the Rollover Resistance Rating is concerned with vehicle attributes that affect the outcome of a crash. None of the present ratings attempt to describe the probability of a vehicle's involvement in a crash. For example, the frontal crashworthiness star rating does not reward manufacturers who equip vehicles with advanced braking systems. Also, the agency cannot rely on skid pad demonstrations to determine the effectiveness of a safety device in the hands of the public. Anti-lock brakes were once considered likely to reduce rollover crashes because they had the potential to reduce the number of vehicles exiting the road sideways as a result of rear brake lock-up. This expectation has not been realized in passenger cars according to years of crash statistics. There has actually been an increase in the rollover rate of passenger cars equipped with anti-lock brakes that researchers have not yet been able to explain.

The commenters suggest that NHTSA should abandon SSF as a basis for rollover rating because it does not reward ESC in the star rating and that without such a reward the use of the technology would be in doubt. The importance of SSF to rollover resistance is supported by abundant real-world evidence, while there is no data on the effectiveness of ESC. Based on the relative data available, it would not be appropriate to abandon SSF. We encourage manufacturers to assist us in determining the effectiveness of ESC by identifying optional ESC systems in VIN codes and sharing available data. We will continually monitor data on the real-world effectiveness of ESC and make appropriate changes based on that data. We do not expect that manufacturers will abandon ESC, since they express so much confidence in its ultimate effectiveness.

NHTSA wants to encourage technological applications that enhance vehicle stability, provide drivers with more control of their vehicle, and help prevent rollover and other crashes. For ESC in particular, it is reasonable to assume that it will help some drivers use the available traction to stay on the road in circumstances that would otherwise result in panic-driven errors and roadway departure. We have asked the National Academy of Sciences to recommend ways of combining the effect of ESC on exposure to single-vehicle crashes, with the effect of SSF on rollover resistance in a single-vehicle crash, as part of its Congressionally-mandated study of rollover consumer information. We do not expect that a recommendation can be implemented without some determination of ESC's real-world effectiveness, but in the meantime we will identify in our Buying a Safer Car brochure the vehicles for which ESC is available and provide an explanation of these systems. The identification of vehicles with ESC will start in the December 2000 issue of Buying a Safer Car. The April 2001 issue of Buying a Safer Car will also present Rollover Resistance Ratings.

The first presentation of Rollover Resistance Ratings will be on the NHTSA website. The website will also present Questions and Answers regarding rollover crashes including one discussing the effect of ESC and its relationship to the Rollover Resistance Ratings. Until the Rollover Resistance Ratings are integrated into Buying a Safer Car, the NHTSA website will provide a chart of rated vehicles which will include a column indicating the availability of ESC. The heading of that column will provide a link to the Q&A about ESC.

The Q&A section will include the following discussion:

Question: How does Electronic Stability Control affect rollover, and what is its relationship to the Rollover Resistance Ratings?

Answer: Most rollovers occur when a vehicle runs off the road and strikes a curb, soft shoulder, guard rail or other object that "trips" it. The Rollover Resistance Ratings estimate the risk of rollover in event of a single vehicle crash, usually when the vehicle runs off the road. Electronic Stability Control (which is offered under various trade names) is designed to assist drivers in maintaining control of their vehicles during extreme steering maneuvers. It senses when a vehicle is starting to spin out (oversteer) or plow out (understeer), and it turns the vehicle to the appropriate heading by automatically applying the brake at one or more wheels. Some systems also automatically slow the vehicle with further brake and throttle intervention. What makes Electronic Stability Control promising is the possibility that with its aid many drivers will avoid running off the road and having a single vehicle crash in first place. However, ESC cannot keep a vehicle on the road if its speed is simply too great for the available traction and the maneuver the driver is attempting or if road departure is a result of driver inattention. In these cases, a single vehicle crash will happen, and the Rollover Resistance Rating will apply as it does to all vehicles in the event of a single vehicle crash.

A similar discussion will accompany the rollover resistance ratings in the April issue of Buying a Safer Car.

F. Alternative Programs for Rollover Consumer Information Suggested by Commenters

Three commenters to the RFC presented ideas for consumer information programs to be used in place of the agency's proposal to use SSF to rate vehicles. The Alliance had four suggestions:

- Cause drivers to obey the speed limits, be alert and unimpaired, and use proper restraints, and provide driver training in off-road recovery and crash avoidance maneuvering.
- Improve the roadways with paved shoulders to eliminate road edge drop-offs and provide road edge rumble strips to help alert drivers.
- Promote Electronic Stability Control.
- Promote crashworthiness improvements including active restraint systems, tubular and side curtain air bags, new belt reminder systems, structural crashworthiness improvements, FMVSS 201 interior protection, new locks and latches and alternative glazings.

Ford and Suzuki commented that SSF should be used only to rate vehicle classes and should not be used to show distinctions between make/models in the same class. These commenters also believe that the program should not present the risk of rollover quantitatively.

The NADA recommended that NHTSA put more emphasis on the seat belt message in the context of rollover, including child safety restraints and suggested that manufacturers include in their vehicles' owners manuals material about crash avoidance driving practices. The manufacturers' association, the Alliance, on the other hand, wanted to see seat belt information only in a general sense, not specifically referring to rollover.

The major flaw with all of these suggestions is that they do not deliver what the consumer wants—definitive, comparative, information about the relative risk of rollover in specific vehicles. We have shown, in the previous sections of this notice and the notices that have preceded it, that we can link rollover risk to the SSF of specific make/models. Any rollover-specific consumer information product that NHTSA develops in the future will mention driving habits that contribute to rollover prevention and emphasize the importance of seat belt use. However, the focus of the present action is on allowing consumers to make an informed choice about the safety of the vehicles they purchase, both by class and by model.

G. Commenters Preference for a Minimum Standard Based on a Dynamic Test

Tab Turner, a plantiff's attorney, and Insurance Institute for Highway Safety, Consumers Union, and Advocates for Highway and Auto Safety, stated in their comments that, while they had no objection to using SSF to provide consumer information, an information program was not sufficient to address the rollover problem. They believe a federal motor vehicle safety standard, based on a dynamic track test of vehicles, is needed.

Notwithstanding the recent Transportation Recall Enhancement, Accountability, and Documentation Act (TREAD) [15] which requires the agency to issue ratings based on a dynamic test within two years, we believe that consumer information based on SSF is an appropriate way to proceed at this time to address rollover. Two issues are involved here: the issue of a minimum standard versus consumer information, and the issue of dynamic testing versus a static metric. Both of these issues were addressed at length in the RFC.

We agree that it would be desirable to have a standard to address a safety issue as significant as rollover resistance. However, as explained in the RFC, NHTSA previously decided not to set a vehicle rollover standard at a level that would effectively force nearly all light trucks to be redesigned to be more like passenger cars.[16] NHTSA also previously decided not to set a vehicle rollover standard at a level that would effectively force a redesign even of certain vehicle types like small pickups and small SUVs [17] because it would not be appropriate to prohibit the manufacture and sale of those vehicles without some predictable benefit commensurate with the cost of that action. However, we can still provide accurate and meaningful information about rollover resistance to allow the public to make fully informed choices when selecting a new vehicle.

IV. Rollover Information Dissemination using SSF in NCAP

The agency has decided to go forward with a pilot consumer information program on vehicle rollover resistance, using the SSF as a basis for the rating system. This program will be part of NCAP, which currently gives consumers information on frontal and side-impact crashworthiness. Today we are announcing the 2001 model year vehicles to be tested and how the information will be disseminated to the public.

There are two activities ongoing in NHTSA that may change this pilot program: the study by the National Academy of Science mandated by Congress in the Department's Fiscal Year 2001 appropriations bill [18] and the Congressional requirement contained in the TREAD Act that the agency develop a dynamic test for consumer information on rollover, conduct the tests, and determine how best to disseminate the test results to the public by November 1, 2002. Changes or additions to this program will be developed if necessary to conform to the requirements of these two statutes.

The rollover information program will operate just as the current frontal and side NCAP does. New models are selected for testing before the beginning of the model year. Selection is based primarily on production levels predicted by the manufacturers and submitted to the agency confidentially. Consideration is given also to vehicles scheduled for major changes, or new models with specific features that may affect their SSF's. The vehicles chosen for NCAP testing will be obtained and measured by NHTSA, as the vehicles become available. Vehicles are obtained with popular equipment, typical of a rental fleet, and the equipment with possible influence on SSF will be included in the vehicle description when the rating is reported. Two-wheel drive and four-wheel drive versions of a vehicle are treated as separate models, because a four-wheel drive option can have a significant effect on SSF. As provided for in the frontal and side NCAP, manufacturers can, at their option, pay for tests of vehicles, models, or configurations not included in NHTSA's test plan, if they wish to inform consumers about those vehicles through the program.[19] The SSF will be converted to a star rating according to the curve presented in Section III and Appendix I at the intervals specified in Section III. The rollover rating information will be available on the agency's website, and will be included in all NHTSA publications and press releases which use NCAP data. The brochures and the website presentation will explain the basis of the ratings, present the SSF measurements, and discuss the magnitude of rollover harm prevention provided by seat belt use.

As part of the presentation on rollover the following explanatory text will be used:

Description of Rollover Resistance Rating

- Most rollover crashes occur when a vehicle runs off the road and is tripped by a ditch, curb, soft soil, or other object causing it to roll over. These crashes are usually caused by driver behavior such as speeding or inattention. These are called single-vehicle crashes because the crash did not involve a collision with another vehicle. More than 10,000 people die each year in all rollover crashes.
- The Rollover Resistance Rating is an estimate of your risk of rolling over if you have a single-vehicle crash. It does not predict the likelihood of that crash. The Rollover Resistance Rating essentially measures vehicle characteristics of center of gravity and track width to determine how ''top-heavy'' a vehicle is. The more ''top-heavy'' the vehicle, the more likely it is to roll over. The lowest rated vehicles (1-star) are at least 3 times more likely to roll over than the highest rated vehicles (5-stars).
- The Rollover Resistance Ratings of vehicles were compared to 220,000 actual single-vehicle crashes, and the ratings were found to relate very closely to the real-world rollover experience of vehicles.

[15] P.L. 106–414, November 1, 2000.

[16] Denial of the Wirth petition, 52 FR 49033 (December 29, 1987).

[17] Termination to establish a minimum vehicle standard for rollover resistance based on TTR or CSV, 59 FR 33254 (June 28, 1994.)

[18] P.L. 106–346, October 23, 2000.

[19] The manufacturer pays for the vehicle and the test, however, actual vehicle leasing and testing is done by a testing laboratory under contract to NHTSA.

• While the Rollover Resistance Rating does not directly predict the risk of injury or death, keep in mind that rollovers have a higher fatality rate than other kinds of crashes.

Remember: Even the highest rated vehicle can roll over, but you can reduce your chance of being killed in a rollover by about 75% just by wearing your seat belt.

• Here are the Rollover Resistance Ratings:

In A Single-Vehicle Crash, a vehicle with a rating of:

Five Stars ★★★★★

Has a risk of rollover of less than 10%

Four Stars ★★★★

Has a risk of rollover between 10% and 20%

Three Stars ★★★

Has a risk of rollover between 20% and 30%

Two Stars ★★

Has a risk of rollover between 30% and 40%

One Star ★

Has a risk of rollover greater than 40%

As part of these ratings, the agency also has decided to note vehicles that are equipped with ''electronic stability control'' technology, which may reduce the risk of a vehicle getting into an incipient rollover situation.

Appendix II contains a preliminary list of vehicles we will measure and for which we will report SSF and star ratings. The vehicles will be tested as they become available to the test facility. As of today 24 vehicles have been tested; the results are available from the Auto Safety Hotline (888–327–4236) or on the NHTSA website at www.nhtsa.dot.gov. The remainder of the test results and star ratings for the 2001 model year will be available by April 30, 2001.

V. Rulemaking Analyses and Notices

Executive Order 12866

This notice was not reviewed under Executive Order 12866 (Regulatory Planning and Review). NHTSA has analyzed the impact of this decision and determined that it is not a ''significant regulatory action'' within the meaning of Executive Order 12866. The agency anticipates that providing information on rollover risk under NHTSA's New Car Assessment Program would impose no regulatory costs on the industry.

Authority: 49 U.S.C. 322, 30117, and 32302; delegation of authority is at 49 CFR 1.50 and 49 CFR 501.8.

Issued on: January 8, 2001.

Stephen R. Kratzke,

Associate Administrator for Safety Performance Standards.

Appendix I: Statistical Analysis in Response to Comments

Response to Comments of the Alliance of Automotive Manufacturers based on a Study by Exponent Failure Analysis Associates, Inc. titled: *The Relative Importance of Factors Related to the Risk of Rollover Among Passenger Vehicles*

Background

The agency has proposed expanding the New Car Assessment Program (NCAP), which tests vehicle performance in front and side crashes, to include information on rollover resistance. We proposed a rollover metric for consumer information based on the Static Stability Factor (SSF) and described the approach in a *Request for Comments, Notice for Rollover NCAP* (''the Notice,'' docket NHTSA 2000–6859, item 1, June 1, 2000). The Appendix to the Notice described a statistical analysis of four years of data (1994 to 1997) from six states (Florida, Maryland, Missouri, North Carolina, Pennsylvania, and Utah), and we provided more details of the analysis (definitions, programming statements, and computer output) in another submission to the Rollover NCAP docket (item 4). The Alliance of Automobile Manufacturers (''the Alliance'') reviewed the Notice and the supplemental material and submitted their comments to that docket (item 25).

Appendix 4 of their comments is a paper prepared for the Alliance by Exponent Failure Analysis Associates, Inc. (''the Exponent report'') on *The Relative Importance of Factors Related to the Risk of Rollover Among Passenger Vehicles* (Alan C. Donelson, Farshid Forouhar, and Rose M. Ray, in a paper dated August 30, 2000). The Exponent report critiqued our linear regression analysis of the summarized crash data and suggested an alternative approach based on logistic regression analysis of individual crash events. This paper is a comparison of the two approaches (the linear model from summarized data and the logistic model of individual crash events) in response to those comments.

Overview

The Exponent report listed four goals for their study (page 4 of that report), and we will address their conclusions in our response. The four goals were as follows:

(1) ''To evaluate the statistical study offered by NHTSA as a basis for comparative 'ratings' [emphasis in original] of rollover risk,''

(2) ''To gauge the strength of SSF as a predictor of rollover relative to the influence of non-vehicular factors,''

(3) ''To quantify the relationship between SSF and risk of rollover after adjusting for the influence of non-vehicular factors,'' and

(4) ''To estimate the magnitude and reliability of apparent changes in rollover risk with changes in SSF.''

The Exponent report offered three corrections to our vehicle group definitions, questioned the use of linear models of summarized data, and recommended logistic models of individual crash events as an improvement (their goals 1 and 2). In response, we have made the suggested corrections, used updated VIN-decoded data, added a year of data (the 1998 calendar year data are now available for all six states used in our original analysis), and refit the model. Details on the data definitions are included below in ''Available Data,'' and the results of are described in ''Refitting the Linear Model.'' We have also used our data to fit logistic regression models, and these results are described in ''Fitting Logistic Models.'' A comparison of the two approaches is provided in ''Comparing the Models.''

Our logistic models produced results that were similar to those produced by our linear model of summarized data and to the logistic models described in the Exponent report (which were based on a slightly different group of states, calendar years, and explanatory variables). That is, the choice of model form and data source do not affect our essential conclusion: the SSF is strongly related (both in terms of statistical significance and magnitude of effect) to rollover risk. However, there are some differences among the models in the estimated sensitivity of rollover risk to changes in the SSF.

Where we disagree most with the Exponent report is in the interpretation of the results. The authors of the Exponent report argue that the SSF plays a smaller role in rollover causation than do driver and other road-use factors (their goals 2 and 4). Goal 2 (gauging the relative strength of the SSF and non-vehicle factors) is so important to the authors that they used it as the title of their report. We believe that our analysis indicates that the SSF is very important in describing rollover risk, as measured by the fit of each model, the significance of the coefficient of the SSF term, and the magnitude of the coefficient of the SSF term. We do recognize that driver and other road-use variables are also important. Federal, state, and local education and enforcement programs are all aimed at the vulnerability of road users to human error, and we recognize that the driver plays a large role in causing or avoiding crashes. However, what we set out to address in the Notice is whether the SSF provides information that is useful to consumers—information they can use in selecting a vehicle, deciding whether to use seat belts and child seats, and adapting their driving style to a new vehicle. We describe this point in more detail below, in ''Interpreting the Analytical Results,'' using an example based on the relationship between crash severity, belt use, and injury severity.

In summary, we believe that our statistical models (both the linear model of summarized data and the logistic models of individual crash events) and the statistical models offered in the Exponent report support our conclusion that the SSF is a useful measure of rollover risk that will help the consumer choose a new vehicle and use it wisely.

Available Data

The analysis described in the Notice was based on single-vehicle crashes, which we defined to exclude crashes with another motor vehicle in transport or with a nonmotorist (such as a pedestrian or pedalcyclist), animal, or train. We eliminated vehicles without a driver and all vehicles that were parked, pulling a trailer, designed for certain special or emergency uses (ambulance, fire, police, or military), or on an emergency run at the time of the crash. Our only criterion for including a vehicle model in the analysis was a reliable measure of the SSF. The 100 vehicle groups we identified were described in the Notice, and the definitions for these groups were included in another submission to the same docket (item 4).

Exponent reviewed this information and pointed out three errors in the specifications of the vehicle groups (page 37). First, vehicle group 65 should have been defined as model years 1990–1995 (not 1988–1996). Second, vehicle group 66 should have been defined as model years 1996–1998 (not 1997–1998). And third, vehicle group 91 should have included model code ''SKI'' (not ''SCI''), as defined by the output from The Polk Company's PC VINA® software (PC VINA® for Windows User's Manual, October 20, 1998). We also found a typographical error in the specification of vehicle group 79: the number of drive wheels should have been specified as ''not equal to 4'' (rather than ''equal to 4''). We corrected these mistakes in the list and computer programs, and the corrected list of vehicles is included here as Tables 1 through 4.

Our understanding of some important differences in state crash reporting are included in Table 5. The Notice described our criteria for including a state in the analysis, which were as follows:

(1) Data availability (the state must participate in the agency's State Data System (SDS) and have provided the 1997 data),

(2) VIN reporting (the vehicle identification number (VIN) must be coded on the electronic file), and

(3) Rollover identification (we must be able to determine whether a rollover occurred, regardless of whether it was a first or subsequent event in the crash).

Six states (Florida, Maryland, Missouri, North Carolina, Pennsylvania, and Utah) met all three criteria. Two states (New Mexico and Ohio) met two of the three criteria; these states participate in the SDS and the VIN is available on the electronic file, but rollovers are identified only if they are reported as the first harmful event in the crash. We have made some use of all eight states in this updated analysis, but most of the analysis is based on the six states with the best rollover reporting. These are the six states that were the basis for the analysis described in the Notice.

For this analysis, we used the SDS data and the VIN-decoded data available on NHTSA's Research and Development Local Area Network (LAN). The National Center for Statistics and Analysis (NCSA, an office in R&D) recently rebuilt the 1997 VIN files for Maryland and Missouri, and the numbers of relevant cases differ slightly from those reported in the Notice. The major changes were a slightly more-conservative approach to dealing with mistakes in VIN transcription and some additional vehicle-make codes. We also expanded somewhat our definition of ''rollover'' in North Carolina (adding information from the four impact-type variables), which increased the number of rollovers in that state over what was reported in the Notice. The number of relevant vehicles identified for each state and calendar year are shown as Table 6. Note that Ohio reported a relatively small percentage of VINs in 1998 (about 29 percent of vehicles had a VIN on the electronic file), so case counts for the vehicles relevant to this study are low. Our analysis is not too sensitive to missing VIN information because it is based on internal comparisons of the crash data (specifically, on rollovers per single-vehicle crash); this would not be the case if we were basing our analysis on comparisons with an external source, such as rollovers per registered vehicle.

We added a calendar year of data (1998) for the six states used in the analysis described in the Notice. However, Pennsylvania no longer includes on the electronic file some environmental variables that we need for this analysis (specifically, CURVE and GRADE), so we could not use the 1998 Pennsylvania data in the analysis. The variables available for this analysis are shown as Table 7. We calculated the SSF to two decimal places (with observed values between 1.00 and 1.53), we defined NUMOCC as the count of occupants in each vehicle, and we defined all the other road-use factors as dichotomous variables (with ''0'' coded for ''no,'' and ''1'' coded for ''yes'').

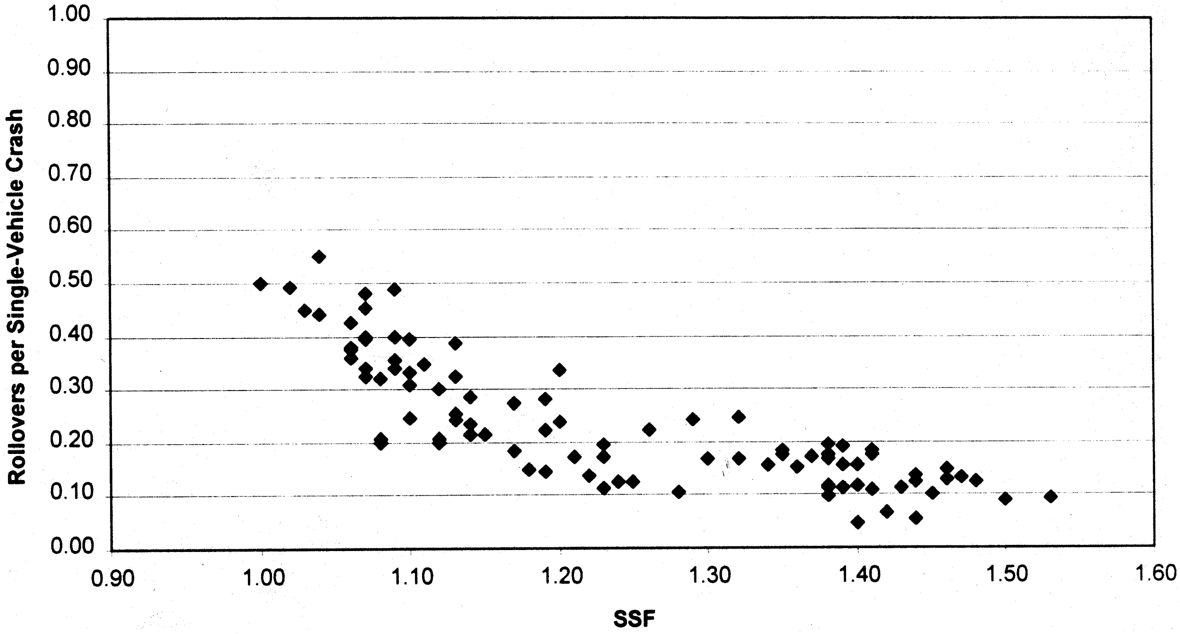
All eight states reported the following data: ROLL, SSF, DARK, STORM, FAST, HILL, CURVE, BADSURF, MALE, YOUNG, OLD, and DRINK. Speed limit is not reported in New Mexico, so we defined FAST based on the roadway function class after reviewing the relationship between these two variables among New Mexico cases in the 1994–1998 Fatality Analysis Reporting System (FARS) data. We assumed, based on our review of the FARS data, that (1) interstate and rural arterial roads had a speed limit of at least 55 mph, (2) local roads and urban arterial roads, collectors, and ramps had a speed limit of no more than 50 mph, and (3) the speed limit was unknown for all other roads. RURAL was unavailable for two states (Maryland and Missouri), BADROAD was unavailable for two states (Missouri and Pennsylvania), NOINSURE was unavailable for three states (Maryland, North Carolina, and Utah), and NUMOCC was unavailable for Missouri (where uninjured passengers need not be reported).

Refitting the Linear Model

We refit the linear model using the approach described in the Notice. There were 241,036 single-vehicle crashes available for this analysis (that is, involving a vehicle in one of the 100 vehicle groups, occurring between 1994 and 1998, and occurring in the six states we studied in preparing the Notice (Florida, Maryland, Missouri, North Carolina, Pennsylvania, and Utah), and 48,996 of these (20.33 percent) involved rollover. We eliminated the 1998 Pennsylvania data because CURVE and GRADE are not available on the electronic file, and this left 227,194 single-vehicle crashes, of which 45,880 (20.19 percent) involved rollover.

We summarized the data for each vehicle group in each state, which produced 599 summary records (there were no reported single-vehicle crashes involving vehicle group 54 in Utah). As with the earlier analysis, we eliminated any summary record that was based on fewer than 25 cases because we thought estimates based on smaller samples were too unreliable. This left us with 518 summary records, representing the experiences of 226,117 single-vehicle crashes, including 45,574 (20.16 percent) rollovers. Figure 1 shows the rollover rate (rollovers per single-vehicle crash) as a function of the SSF plotted for each of the 100 vehicle groups. These data have not been adjusted for differences in vehicle use or state reporting practices, but they do show a strong tendency for lower rollover rates with higher values of the SSF.

Figure 1: Rollovers per Single-Vehicle Crash Estimated from Six States (Not Adjusted for Differences in Road Use or State Reporting)



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We used the 1994–1998 General Estimates System (GES) for a comparison with the six-state rollover rate for the study vehicles as a group. The five years of GES data include 9,910 sampled vehicles that we identified as being in one of the 100 vehicle groups (based on decoding the VIN with the PC VINA® software for those states that include the VIN on their police reports) involved in a single-vehicle crash, and 2,377 of these rolled over. Weighting the GES data to reflect the sample scheme (but not adjusting for missing VIN data) produces estimates of 1,185,474 single-vehicle crashes per year, of which 236,335 (19.94 percent) involved rollover. That is, the six states in our study have a rollover rate for police-reported crashes that is essentially the same as the national estimate produced from the GES data (with the qualification that the GES estimate is based on data from just those states that include the VIN on the police report).

We defined the dependent variable ROLL as the fraction of single-vehicle crashes that involved rollover. The independent (explanatory) variables in the six-state combined model were those available in all six states. They were expressed as the fraction of single-vehicle crashes that involved each of the following ten situations: DARK, STORM, FAST, HILL, CURVE, BADSURF, MALE, YOUNG, OLD, and DRINK. We also defined dummy variables for five states (DUMMY__FL, DUMMY__MD, DUMMY__NC, DUMMY__PA, and DUMMY__UT, with Missouri used as the baseline case) to capture state-to-state differences in reporting thresholds and definitions. These variables have the value ''1'' if the crash occurred in that state (for example DUMMY__MD = 1 for all Maryland crashes), and they have the value ''0'' otherwise (for example, DUMMY__MD = 0 for all crashes in Florida, Missouri, North Carolina, Pennsylvania, and Utah). These are the fourteen variables we used in the earlier analysis (described in the Notice), plus the variable OLD.

We ran the stepwise linear regression analysis against these 518 summary records to describe the natural logarithm of rollovers per single-vehicle crash, which we call LOGROLL, as a function of a linear combination of the explanatory variables. (To avoid losing information on vehicle models with a low risk of rollover, we set ROLL to 0.0001 if there were no rollovers represented by the summary record.) We used the option that gives more weight to data points that are based on more observations, so vehicle groups with more crashes count for more in the analysis. Each data point was weighted by the number of single-vehicle crashes it represented, but the weighting was capped at 250. That is, data points based on more than 250 observations were weighted by 250. Our rationale was that we wanted the model to fit well across the full range of SSF values, so we did not want to over-weight the data for the most-common models on the road.

We ran a preliminary model using the SSF and the five state dummies to estimate LOGROLL. The model had an R^2 of 0.73, and the coefficient of the SSF term (-2.8634) was highly significant (the t-statistic indicates that the probability that the coefficient is really zero is less than 0.0001); the details are included as Table 8a. Thus, it appears that the SSF is very useful in understanding rollover risk. We then performed a stepwise linear regression (using forward variable selection and a significance level of 0.15 for entry and removal from the model) on the six-state data; this is the same approach we used for the analysis described in the Notice. The stepwise regression procedure with the SSF chose three variables that describe the driving situation (DARK, FAST, and CURVE), three variables that describe the driver (MALE, YOUNG, and DRINK), and all five state dummy variables. The F-statistic for the model as a whole was 311, and the probability of a value this high by chance alone is less than 0.0001. The model had an R^2 of 0.88 and the coefficient of the SSF term (-3.3760) was highly significant; more details on the fit of the model are included as Table 8b. Note that adding the road-use variables increased both the model R^2 (from 0.73 to 0.88) and the absolute value of the coefficient of the SSF term (from -2.8634 to -3.3760). That is, the effect of the SSF on rollover risk is estimated to be even greater after adjusting for differences in road use.

We used the results of the model to adjust the observed number of rollovers per single-vehicle crash to account for differences among vehicle groups in their road-use characteristics in single-vehicle crashes. For each of the 518 summary records, we used the regression results and the typical road use to estimate what LOGROLL would have been if road use for that vehicle group had been the typical road use observed for all the vehicles in the study. The approach is the one used in the Notice. We used an intermediate step to account for differences in road use and adjust the data towards the average experience for the study vehicles:

ADJ__LOGROLL$_i$
=LOGROLL$_i$
BETA__DARK $\times$ (DARK$_i$ $-$ MEAN__DARK)
$-$ BETA__FAST $\times$ (FAST$_i$ $-$ MEAN__FAST)
$-$ BETA__CURVE $\times$ (CURVE$_i$ $-$ MEAN__CURVE)
$-$ BETA__MALE $\times$ (MALE$_i$ $-$ MEAN__MALE)
$-$ BETA__YOUNG $\times$ (YOUNG$_i$ $-$ MEAN__YOUNG)

− BETA__DRINK × (DRINK$_i$ − MEAN__DRINK)
− BETA__DUMMY—FL × DUMMY__FL$_i$
− BETA__DUMMY__MD × DUMMY__MD$_i$
− BETA__DUMMY__NC × DUMMY__NC$_i$
− BETA__DUMMY__PA × DUMMY__PA$_i$
− BETA__DUMMY__UT × DUMMY__UT$_i$
+ MEAN__DUMMIES,

where:

ADJ__LOGROLL$_i$ is the estimate of what LOGROLL would have been for each summary record if all vehicles were used the same way,
LOGROLL$_i$ is the value of LOGROLL observed for each summary record,
BETA__DARK through BETA__DRINK are the coefficients (Beta-values) of the road-use variables, DARK through DRINK, that were produced by the model (as shown in Table 8b),
BETA__DUMMY__FL through BETA__DUMMY__UT are the coefficients of the state dummy variables, DUMMY__FL through DUMMY__UT, that were produced by the model,
DARK$_i$ through DRINK$_i$ are the values of the road-use variables observed for each summary record,
DUMMY__FL$_i$ through DUMMY__UT$_i$ are the values of the state dummy variables for each summary record (with no more than one of these equal to ''1,'' and all the rest equal to ''0''),
MEAN__DARK through MEAN__DRINK are the average values of the road-use variables observed in the study data (with MEAN__DARK=0.4314, MEAN__FAST=0.4807, MEAN__CURVE=0.3315, MEAN__MALE = 0.6276, MEAN__YOUNG=0.3987, and MEAN__DRINK=0.1509), and
MEAN__DUMMIES is the average state adjustment in the study data.

MEAN__DUMMIES was calculated for these 226,117 single-vehicle crashes from the coefficient of the state dummy variables and the number of cases in each state as follows:

(1.2253 × number of Florida cases
+0.6933 × number of Maryland cases
+0.0000 × number of Missouri
+0.6969 × number of North Carolina cases
+1.2449 × number of Pennsylvania cases
+0.8622 × number of Utah cases)
/Total number of cases
=0.8019,

The adjusted rollover rate for each vehicle group is then estimated by:

ADJ__ROLL=e$^{(\text{ADJ__LOGROLL})}$.

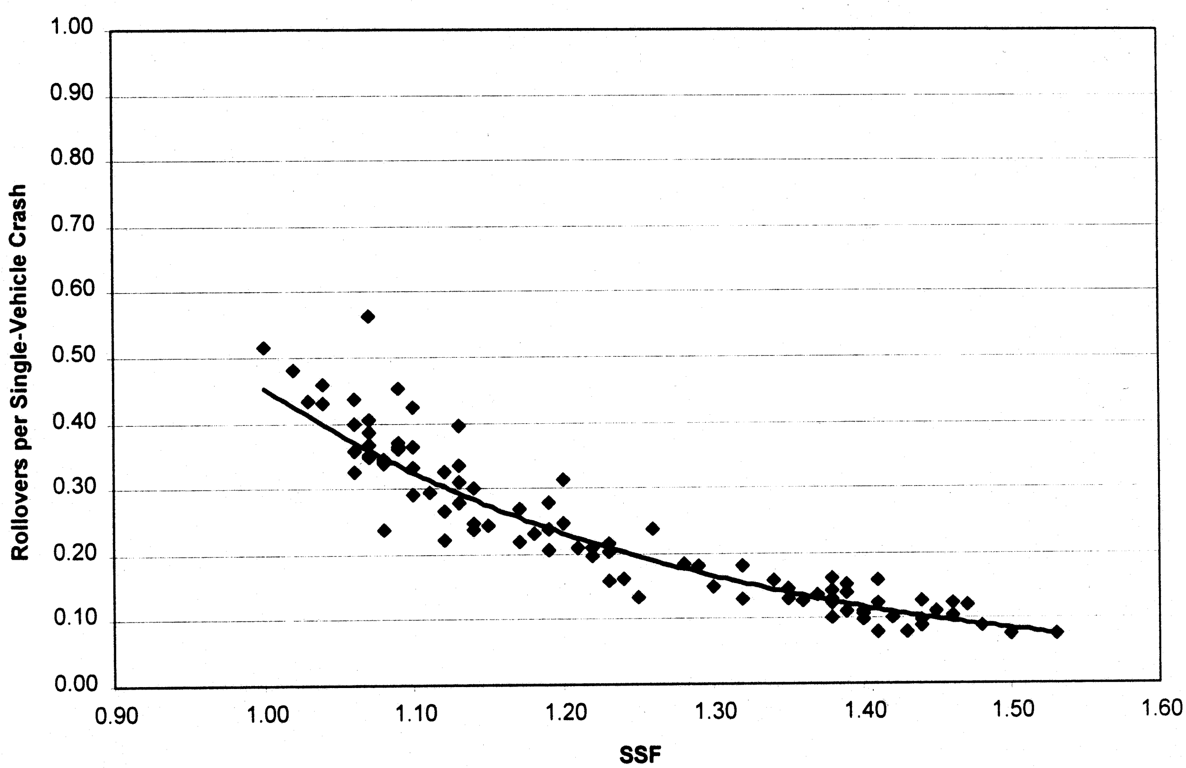
This is our estimate of what the rollover rate would have been if all vehicle groups were used in the same way, and it reflects the average use patterns of all vehicles in the study. The adjusted rollover rates are shown in Figure 2.

The average adjusted number of rollovers per single-vehicle crash for all the study vehicles in the six states is 0.1982, which is essentially the same as the rollover rate in the original study data (0.2016) and the rollover rate estimated from the GES data (0.1994) for these 100 vehicle groups. A linear model fit through the adjusted data is described by the equation:

LOGROLL = 2.5861—3.3760 × SSF.

The model has an R^2 of 0.85, and the coefficient of the SSF term was highly significant. Details on the fit of the model through the adjusted rollover rates are included as Table 8c.

Figure 2: Rollovers per Single-Vehicle Crash Estimated from Six States (Adjusted to National Average Road Use and for Differences in State Reporting)



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Exponentiating both sides of the equation produces an estimate that the number of rollovers per single-vehicle crash is approximated by the curve:

ROLL = 13.28 × e$^{(-3.3760 \times \text{SSF})}$.

The estimated rollover rates for the SSF values between 0.95 and 1.55 are shown in Table 19 in the column labeled ''Model 1,'' and the estimates for the observed range (SSF values from 1.00 to 1.53) are shown as Figure 2. This model form has very useful properties. The increase in the SSF that is associated with halving the number of rollovers per single-vehicle crash is estimated as 0.21. For example, the number of rollovers per single-vehicle crash under average conditions is estimated as:

0.44 for a SSF of 1.01
0.23 for a SSF of 1.22, and

0.11 for a SSF of 1.43.

Thus, rollover risk drops by a half when the SSF increases from 1.01 to 1.22, and it drops in half again when the SSF increases from 1.22 to 1.43.

The SSF is both highly significant in the model and very important in describing rollover risk (the estimated rollover risk increases by a factor of 6.0 over the observed range of the data, from a SSF of 1.00 to 1.53). This means that changes in the SSF (or changes in how vehicles with low SSF values are used) has the potential for large reductions in rollover risk.

Fitting Logistic Models

The Exponent report questioned the validity of using a linear regression analysis of summarized data, though they noted the advantages of this approach for describing the data. They suggested using a logistic regression analysis with the SSF and road-use variables, and they also suggested (as a way of dealing with potential cross-correlations) an approach that uses crash-risk scenarios in place of the road-use variables. They provided results from the states they used in their analysis, and we did a similar analysis of the eight states available to us. The data for two states, New Mexico and Ohio, were not combined with the data from the other six states because a rollover is reported in New Mexico or Ohio only if it is considered to have been the first harmful event in the crash. However, we did look briefly at these data because we were curious about how the rollover definition affects the analysis. We wanted to see how the risk of a rollover occurring as the first harmful event in a single-vehicle crash varies as a function of the SSF as reported in these two states.

We ran a logistic regression analysis for each state to model rollover as a function of the SSF and the road-use variables. For each state, we used the explanatory variables available for the linear regression analysis plus other variables that were available in each state, as described in Table 7. The fits of the models are summarized in Tables 9a through 16a. Each model seems to fit the data well. The coefficient of the SSF term varies from (−3.0800) in North Carolina to (−4.3908) in Florida. The values for New Mexico (−3.0809) and Ohio (−4.3642) fall in this range, which suggests that the choice between ‘‘all rollovers’’ and ‘‘first harmful event rollovers’’ may not be critical for a basic understanding of the sensitivity of rollover risk to the SSF (though the choice is important in determining the absolute level of rollover risk). In all cases, the coefficient of the SSF term was highly significant; the probability of a chi-square this large by chance alone (the smallest chi-square values were 209 for New Mexico and 416 for Utah) was estimated as less than 0.0001.

We then combined the data from the six states that have the best rollover reporting (that is, data that were not limited to first-harmful-event rollovers) and used them together in a logistic model, using the explanatory variables they have in common. We used the approach Charles Kahane described in his study of the safety effects of vehicle size. He used dummy variables to capture reporting differences in a logistic model of state data, and the results are included in Relationships between Vehicle Size and Fatality Risk in Model Year 1985–93 Passenger Cars and Light Trucks (Charles J. Kahane, Evaluation Division, Office of Plans and Policy, National Highway Traffic Safety Administration, DOT HS 808 570, January 1997). The results of the six-state combined model are shown as Table 17a. The model fits the data well, and the SSF is highly significant in the model (with a chi-square value of 7,230).

The coefficient of the SSF term in the logistic model for each state and for the six-state combined model describes the relationship between the rollover rates for any two values of the SSF, and we can use this relationship to estimate the rollover rate under average road-use conditions for each value of the SSF. We used the method that Ellen Hertz described in her study of the safety effects of vehicle weight. She estimated injury risk based on a logistic model of state data, and the results are included in A Collection of Recent Analyses of Vehicle Weight and Safety (T.M. Klein, E. Hertz, and S. Borener, Mathematical Analysis Division, National Center for Statistics and Analysis, Research and Development, National Highway Traffic Safety Administration, DOT HS 807 677, May 1991). We defined:

BETASSF = the coefficient of the SSF term in the logistic model for a state,

$ROLL_{SSF}$ = the rollover rate at a specific value of the SSF, and

$ODDS_{SSF}$ = the odds of rollover at a specific value of the SSF.

We choose a SSF of 1.00 as the basis for the calculations. The relationship between $ROLL_{1.00}$ and any other $ROLL_{SSF}$ can be calculated for each state as follows:

$ROLL_{SSF} = ODDS_{SSF} / (1 + ODDS_{SSF})$

where

$ODDS_{SSF} = e^{((SSF - 1.00) \times BETASSF)} \times ROLL_{1.00} / (1 - ROLL_{1.00})$.

The results of the logistic analysis of the Florida data are shown in Table 9a, including an estimate that:

BETASSF = (−4.3908),

so all we need for rollover rate estimates across the range of the SSF is an estimate of $ROLL_{1.00}$ in Florida. We estimated ROLL1.00 using the following approach. For each state, we defined:

$ODDS_{ALL}$ = odds of rollover for the study vehicles as a group,

$LOGODDS_{ALL}$ = the natural logarithm of $ODDS_{ALL}$, and

MEANSSF = the average SSF for the study vehicles.

The model says that:

LOGODDS = T + (BETASSF × SSF),

where

T = a linear function of the explanatory variables,

and we solved for the ‘‘average’’ value of T such that:

$LOGODDS_{ALL} = T + (BETASSF \times MEANSSF)$.

That is, we assumed that the results of the logistic model apply to the average rollover rate and SSF value for the vehicles as a group, and this means that:

$T = LOGODDS_{ALL} - (BETASSF \times MEANSSF)$.

The rollover rate for all the vehicles included in the Florida study was 0.2044 and their average SSF was 1.2894, which means that:

$T = \log_e(0.2044/0.7956) - (-4.3908 \times 1.2894)$ and

T = 4.3025 at the average rollover odds and SSF values.

We call this specific value of the function T, ‘‘T0.’’ Then, after controlling for other factors, $LOGODDS_{SSF}$ is estimated as:

$LOGODDS_{SSF} = T0 + (BETASSF \times SSF)$,

and at SSF=1.00 in Florida, this is calculated as:

$LOGODDS_{1.00} = 4.3025 - (4.3908 \times 1.00)$,

so

$LOGODDS_{1.00} = (-0.0883)$.

$ROLL_{1.00}$ is estimated from the $LOGODDS_{1.00}$ as:

$e^x/(1 + e^x)$,

where x is the $LOGODDS_{1.00}$, so the rollover rate at a SSF value of 1.00 is estimated as 0.4778 rollovers per single-vehicle crash. The rollover rate for all other values of the SSF can be estimated using:

$ODDS_{SSF} = e^{((SSF - 1.00) \times BETASSF)} \times ROLL_{1.00} / (1 - ROLL_{1.00})$

and

$ROLL_{SSF} = ODDS_{SSF}/(1 + ODDS_{SSF})$.

We used this approach for each state and for the six-state combined model. The average rollover rate and SSF for each state and for the six-state combined data are shown in Table 18, along with the estimated rollover rates for a SSF of 1.00. For example, the rollover risk for the six-states combined is estimated as 0.4031 at an SSF of 1.00, and it is shown in the column for the results of the models based on ‘‘individual variables.’’ (The results of the models based on ‘‘crash scenarios’’ are described below.) The results for each value of the SSF are shown in the column labeled ‘‘Model 2’’ in Table 19.

As a check of the six-state combined model, we calculated the average rollover risk for each value of the SSF based on the individual state models. For example, we calculated the average rollover rate for a vehicle with a SSF of 1.00 by taking the average of the estimates for these six states (that is, Florida, Maryland, Missouri, North Carolina, Pennsylvania, and Utah), weighted by the size of each state (as measured by the number of single-vehicle crashes involving any study vehicle in each state). The result is an estimated risk of 0.4101 rollovers per single-vehicle crash for an SSF of 1.00, and the same procedure was applied to each value of the SSF from 0.95 to 1.55. The results are shown as the column labeled ‘‘Model 3’’ in Table 19.

The Exponent report also suggested using an approach they called a ‘‘crash scenario analysis’’ to address possible interactions among the explanatory variables. This idea is interesting and conceptually simple. The single-vehicle crashes from each state are categorized into cells defined by the possible combinations of the road-use variables. For example, the Florida logistic analysis used 14 road-use variables: DARK, STORM, RURAL, FAST, HILL, CURVE, BADROAD, BADSURF, MALE, YOUNG, OLD, NOINSURE, DRINK, and NUMOCC. NUMOCC is the count of occupants in each vehicle, and the other 13 variables take on the value ''0'' or ''1'' (indicating ''no'' or ''yes''). This produces a large number of possible combinations of the variable values:

$2^{13} \times$ the number of levels of NUMOCC.

Converting NUMOCC into a dichotomous variable (for example, one that identifies vehicles with at least three occupants) yields 14 dichotomous variables, which means 214 combinations of these variables, or 16,384 cells for the various crash scenarios. In practice, not all combinations will occur (there were 2,034 non-zero cells in the Florida data), and some non-zero cells have very low counts (there were 267 cells in the Florida data with at least 25 observations). The rollover rate for each cell can be calculated from these data, and this is a measure of the risk associated with that scenario. This rate can be used in place of all the road-use explanatory variables (for example, in place of the 14 original road-use variables in the Florida analysis). The Exponent report recommends a refinement to this calculation so that the scenario-risk variable for each specific vehicle reflects the rollover rate for all other vehicles in its cell. For example, in a cell with 100 vehicles and 20 rollovers, the scenario-risk variable (SCENRISK) will be calculated as:

20/(100 − 1) for each nonrollover vehicle and as

(20 − 1)/(100 − 1) for each rollover vehicle.

Using a crash-scenario variable is an interesting idea, even though the analytical results in the Exponent report seem to show that the individual-variable and crash-scenario logistic models produced very similar results. The standardized estimates for the coefficients of the SSF term produced by the two approaches (and our own results) are shown in Table 20. We attempted to duplicate the crash-scenario analysis based on the description provided in the Exponent report. The concept seems clear and logical, and we made the following decisions in implementing it for this analysis. First, we reviewed the output from the logistic regression on individual variables for each state and selected those for which the probability of a greater chi-square value was less than 0.20. We reasoned that using a large number of variables to define the crash scenarios would tend to produce many cells with small sample sizes, and that the variables with smaller chi-square values would be missed less. A review of Tables 9a through 16a shows that this eliminated only one variable in Florida (DARK), but it eliminated five variables in Utah (STORM, HILL, MALE, YOUNG, and OLD). Second, we converted NUMOCC into MANYOCC (with value ''1'' meaning three or more occupants, and ''0'' meaning one or two occupants). Again, the purpose of this was to reduce the number of cells with small sample counts, while retaining the essential information.

Third, we tabulated the number of single-vehicle crashes (SVACCS) and the number of rollovers (ROLLACCS) for each combination of DARK, STORM, RURAL, FAST, HILL, CURVE, BADROAD, BADSURF, MALE, YOUNG, OLD, NOINSURE, DRINK, and MANYOCC that had been selected for inclusion in each state. We eliminated any combination (that is, any crash scenario) with fewer than 25 observations. The results are summary data describing the experience of all vehicles in each crash scenario. Fourth, we merged the crash-scenario summary data for each state back onto the original data (that is, the data for each individual single-vehicle crash), so that each crash was linked to a count of the total number of single-vehicle crashes and the total number of rollovers that occurred in its crash scenario (its cell). We defined the scenario-risk variable, SCENRISK, as the rollover rate for all other vehicles in that crash scenario in that state. The calculation was as follows:

SCENRISK = (ROLLACCS − ROLL)/(SVAACCS − 1).

Recall that ROLL is coded as ''1'' if the vehicle rolled over and ''0'' if it did not, so this equation produces an estimate of the rollover rate for all vehicles in the crash scenario except for the one case under study; this was the method recommended by the Exponent report. This scenario-specific rollover rate is calculated for each vehicle on the file and is then available as an explanatory variable for a logistic model.

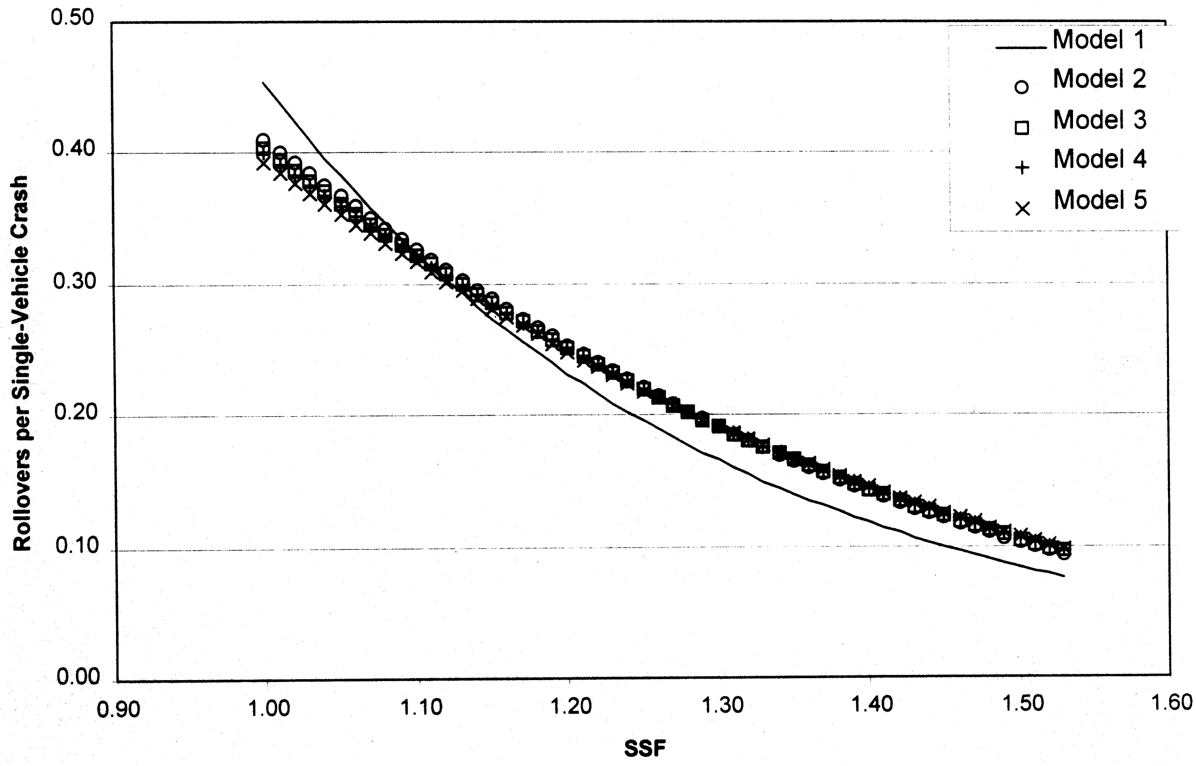
We ran a logistic regression analysis against the data for each state and for the six-state combined data to model rollover risk as a function of two variables: the SSF and SCENRISK. The fits of the models are summarized in Tables 9b through 17b. Each table shows the number of crash scenarios with at least 25 observations and the total number of crashes in these more-frequent scenarios. Each model seems to fit the data well. The coefficient of the SSF term in the crash-scenario logistic model for each state describes the relationship between any two values of the SSF. We applied the approach we used for the individual-variable logistic model to estimate the rollover risk for each value of the SSF and to combine the values across states. The rollover rates at a SSF of 1.00 are shown in Table 18, and the estimated rollover rates as a function of the SSF are shown in Table 19. The column labeled ''Model 4'' shows the results for the six-state model, and the column labeled ''Model 5'' shows the average of the individual models for the six states. Note that the individual-variable and the crash-scenario approaches produce very similar numbers. This is consistent with the results reported in the Exponent report (and summarized in Table 20, using the standardized estimates of the coefficients).

Comparing the Models

The rollover rates estimated across the range of SSF values for the six states combined are shown in Table 19 for all five statistical models (the linear model of summarized data and the four versions of the logistic model), and the estimates for the observed values of the SSF are plotted in Figure 3. The five models are as follows:

Model 1: Linear model of the summarized data,
Model 2: Logistic model of the six-state combined data, based on individual variables,
Model 3: Average of the logistic models for the six states, based on individual variables,
Model 4: Logistic model of the six-state combined data, based on crash scenarios, and
Model 5: Average of the logistic models for the six states, based on crash scenarios.

Figure 3: Rollovers per Single-Vehicle Crash Estimated from Six States: Comparison of the Summary and Logistic Approaches



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There are important similarities between the estimates produced by the two approaches: both the linear model of summarized data and the logistic models suggest a strong relationship (in terms of statistical significance and in terms of the magnitude of the effect) between the SSF and rollover risk. The average slope across the range of the observed SSF values (from 1.00 to 1.53) shown in Figure 3 is −0.713 for the linear model; the logistic models produce estimates of a slightly smaller effect, with average slopes between −0.598 and −0.555. Both types of models agree in estimating a large increased risk for vehicles with a low SSF. The four logistic models produce very similar results, and each suggests that rollover risk is very sensitive to the SSF (only slightly less so than estimated from the results of the linear model of the summarized data).

Figure 3 shows that the greatest absolute differences in the rollover rate estimates are at the lowest values of the SSF. The values of the rollover rate estimated for a SSF of 1.00 were as follows:

Model 1 = 0.4551 (linear model of the summarized data),
Model 2 = 0.4101 (logistic model of the six-state combined data with individual variables),
Model 3 = 0.4031 (average of the logistic models for the six states with individual variables),
Model 4 = 0.3999 (logistic model of the six-state combined data with crash scenarios), and
Model 5 = 0.3929 (average of the logistic models for the six states with crash scenarios),

The results of the four logistic models are almost indistinguishable in Figure 3: the crash-scenario approach produces results that are only slightly different from the individual-variable approach (the former are a little lower at a SSF of 1.00 and little higher at an SSF of 1.53), and the average of the logistic models for the six states produces results that are only slightly different from the logistic model of the six-state combined data (the former are a little lower at a SSF of 1.00 and little higher at an SSF of 1.53).

The results of our logistic analyses seem to differ only slightly from those described in the Exponent report, and much of the difference may be the result of our decision to omit wheelbase from the models. We did not include wheelbase as an explanatory variable because we could not identify any physical reason for an effect on rollover risk. However, we reran each analysis with the addition of wheelbase to test the sensitivity of the results to this decision. In every case, adding wheelbase to the model produced a higher estimate of the effect of the SSF on rollover risk and a higher estimate of rollover risk for the lowest values of the SSF. This occurred for all 18 models (those estimated using both the individual-variable and crash-scenario approaches for each of the eight states and for the six-state combined data), despite a negative value for the coefficient of the wheelbase term in each model. That is, the coefficient of the SSF term was negative in each of the original models, it became more negative in the presence of wheelbase, and wheelbase itself had a negative coefficient in each model in which it was included.

Adding wheelbase seemed to produce results closer to those in the Exponent report. That report does not include the estimates of the variable coefficients, but it does include the standardized coefficients. These are shown in our Table 20, along with the corresponding values from our analysis. For example, when we ran the logistic regression analysis on the Florida data and used wheelbase as one of the explanatory variables, we obtained values of (−0.392) and (−0.374) for the standardized coefficients from the individual-variable and crash-scenario models, respectively. These are higher than the values we obtained without wheelbase, (−0.349) and (−0.327), and they are very close to the values in the Exponent report, (−0.383) and (−0.381). Adding wheelbase to our models produced higher estimates of the coefficient for the SSF term and higher estimated rollover rates for vehicles with lower SSF values. For example, the six-state models that included wheelbase produced estimates that the coefficients of the SSF term are (−3.9525) and (−3.7918) and the estimated rollover rates for a SSF of 1.00 are 0.4338 and 0.4228 for the individual-variable and crash-scenario approaches, respectively.

There is also one important difference between the linear analysis of summary data and the logistic analysis of individual crashes. We limited the summary data to those based on at least 25 observations and we capped the weighting at 250 to avoid over-emphasizing the more-popular vehicles. However, the logistic regression analysis on individual crashes uses all observations equally. When we removed the two thresholds from the linear analysis, we obtained slightly lower estimates of the effect of the SSF on rollover risk, and the relationship between the adjusted rollover rates and the SSF is described by:

$ROLL = 10.99_e{}^{(-\ 3.2356 \times SSF)}$

This model produces an estimate of 0.4323 rollovers per single-vehicle crash at an SSF of 1.00, which is closer to the estimates from our logistic models (and essentially the same as the estimates from the logistic models that include wheelbase as an explanatory variable).

Interpreting the Analytical Results

Many of the comments in the Exponent report reflect an interest in evaluating the relative strength of the driver and vehicle contributions to rollover risk. We agree that this is an interesting question, but it is not the one we set out to address. Our perspective is that of a person choosing a new vehicle who wants to know how his choice of vehicle will affect his risk of being involved in a rollover. We are interested in eliminating the confounding effects of road use so we can isolate the effect of the vehicle on rollover risk. The importance of road-use factors does not preclude a role for vehicle-specific information.

Also, a factor can be important without suggesting an easy remedy. Consider two factors that increase the risk of rollover given a single-vehicle crash: driver age (specifically, the effect of young, inexperienced drivers) and curved roads. We do have some influence over their effect on rollover risk: better driver training and better road design can help reduce rollovers even among young drivers on curved roads. However, some additional risk is a given for people who are still gaining on-road experience, and curved roads are a necessity in many places. So, while driver and other road-use factors are important to understanding rollover risk, this is not the same as saying that all rollovers can be prevented by driver and other road-use remedies. Vehicle design plays an important role in understanding and mitigating rollover risk even among young drivers on curved roads by making vehicles more-forgiving of driver and road limitations, and our analysis describes the magnitude of that effect.

Another comparison may help clarify why we believe that the SSF can be useful even though driver and other road-use factors are such valuable predictors of rollover risk. Using the same approach Exponent used for SSF and other factors involved in rollover, one can statistically demonstrate that seat belt use is insignificant in preventing injuries from a crash. The 1998–1999 National Automotive Sampling System (NASS) data include 7,631 investigated unbelted drivers of light passenger vehicles that were towed from a frontal nonrollover crash (Table 22), and weighting these data to reflect the sampling plan produces an annual average estimate of 171,284 drivers involved each year. An estimated 11,569 of these were seriously injured (that is, they died or received an injury rated as three or higher on the Abbreviated Injury Scale). The overall risk of serious injury was 6.75 percent, but the risk varied greatly as a function of the change in vehicle velocity during the impact (that is, the delta V). For delta V less than 10 mph, the risk of serious injury was 0.76 percent.

If all 171,284 drivers in these towaway crashes had been injured at the same rate as those in the lowest delta V range, we would have seen:

$0.0076 \times 171{,}284 = 1{,}302$ serious injuries

among unbelted drivers in frontal crashes. Half of these (601 serious injuries) could have been prevented if the drivers had used a lap-and-shoulder belt. Thus, we have the following:

171,284 serious injuries among unbelted drivers, of which 1,202 would have occurred if delta V was low, of which 601 would have occurred if belts were used.

According to the logic proposed by Exponent, we would interpret the results as follows:

99.30 percent of serious injuries are attributable to high crash speeds, and 0.35 percent are attributable to neglecting to use belts.

Clearly this is nonsense. Belt use will prevent serious injury even among those in higher-speed crashes (half of the 11,569 serious injuries that did occur among unbelted drivers at any crash speed could have been prevented by belt use, for a reduction of 5,784 serious injuries from belt use). More importantly, belts offer a practical solution, while there is no practical way to reduce all crash speeds to less than 10 mph.

Note that this is comparable to the approach that the Exponent report used in arguing that the value of the SSF in understanding rollover risk was in the range of 3–8 percent. They estimated the relative risk of the lowest-risk scenario, estimated how many rollovers could be prevented if all single-vehicle crashes occurred with the risk of the lowest-risk scenario, and relegated the importance of the SSF to a fraction of the small amount of risk that remained. The lowest-risk scenario that they use as their standard appears to be (based on the table on page 31 of their report) crashes that did not involve a vehicle defect and that did involve a mature driver who had not been drinking or engaged in risky driving, on a straight, urban road with a speed limit of 50 mph or less, and for which the first harmful event was a collision with a traffic unit in a single-vehicle crash; the bulk of these crashes may be collisions with pedestrians and pedalcyclists, which would tend to be reported because of the injuries to the non-motorists.

These are crashes with almost no chance of rollover, and so they are essentially irrelevant to a rollover-prevention program. Also note that some of these factors can be addressed by the driver (driving more carefully and when fully sober), but others are beyond the control of the driver (roads are curved, through rural areas, and with speed limits of 55 mph so traffic can move efficiently through all parts of the country). Young drivers gain experience through driving, and they eventually become mature drivers; in the meantime, they also benefit from more-stable vehicles. It is difficult to see how Exponent's the low-risk scenario could be used as an alternative to the SSF as the basis for a rollover safety program.

The approach described in the Exponent report (comparing the risk associated with the SSF to all the risks associated with road-use factors) would suggest, in our example based on NASS data, that reducing delta V should be a higher safety priority than increasing belt use. (To use an extreme example to make a point, using the approach described in the Exponent report for a study of air crashes would suggest that preventing gravity is more important than regular maintenance of the airplane.) However, belt use programs have been successful because the remedy is simple and cost-effective and because the importance of delta V does not reduce the importance of belt use in preventing injury. We believe a similar argument can be made for focusing on the SSF, while agreeing that driver and other road-use variables may be the basis for other safety improvements.

Conclusion

The Exponent report acknowledged the potential advantages of multiple linear analysis, and their recommendation is relevant here:

Multiple regression analysis can have some value as an explanatory tool for describing factors related to vehicle rollover. Linear regression analysis, however, must only be used in this heuristic way and only when prior research has demonstrated that linear regression produced essentially the same results as did a rigorous and valid statistical analysis. [page 28]

Table 19, Figure 3, and the sensitivity analyses described above suggest that the linear and logistic regression approaches produce essentially the same results. The Exponent report recommended a logistic approach and concluded that the linear approach based on summarized data overstated the value of the SSF in understanding rollover risk. This does not seem to be the case. The linear approach produces estimates of rollover risk that are a little more conservative (in the sense that they are lower) than those from the logistic models for most observed values of the SSF and for most vehicles on the road today. The Exponent report included much lower estimates for rollover risk across the range of SSF values, but this was not a result of the logistic approach. Rather, it was the result of tying the estimates to the low-risk scenario (where rollover is unlikely).

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Table 1: Passenger Cars Used in the Analysis

Vehicle Group	Make / Model	Model Years	SSF
1	Dodge Neon, Plymouth Neon	95-98	1.44
2	Ford Crown Victoria	92-97	1.42
3	Ford Escort	91-96	1.38
4	Ford Escort, Mercury Tracer	97-98	1.37
5	Ford Mustang	88-93	1.38
6	Ford Probe	93-97	1.41
7	Ford Taurus, Mercury Sable	88-95	1.45
8	Lincoln Town Car	90-96	1.44
9	Buick Century, Chevrolet Celebrity, Oldsmobile Cutlass Ciera / Ciera, Pontiac 6000	88-96	1.38
10	Buick Regal, Pontiac Grand Prix	88-96	1.41
11	Chevrolet Lumina	95-98	1.34
12	Buick Lesabre, Pontiac Bonneville	92-96	1.39
13	Buick Park Avenue, Oldsmobile 98	91-96	1.38
14	Buick Skylark / Somerset, Oldsmobile Cutlass Calais / Calais, Pontiac Grand Am	88-91	1.35
15	Buick Skylark, Oldsmobile Achieva, Pontiac Grand Am	92-97	1.38
16	Chevrolet Camaro, Pontiac Firebird	88-92	1.53
17	Chevrolet Camaro, Pontiac Firebird	93-98	1.50
18	Buick Roadmaster, Chevrolet Caprice	91-96	1.40
19	Buick Skyhawk, Chevrolet Cavalier, Pontiac Sunbird	88-94	1.32
20	Chevrolet Corsica	88-96	1.30
21	Chevrolet Geo Metro, Suzuki Swift	89-94	1.32
22	Chevrolet Geo Metro, Suzuki Swift	95-98	1.29
23	Saturn SL	90-95	1.39
24	Saturn SL	96-98	1.35
25	Chevrolet Geo Prizm	89-92	1.38
26	Honda Civic	92-95	1.48
27	Honda Civic	96-98	1.43
28	Honda Accord	90-93	1.47
29	Mazda Protégé	95-98	1.40
30	Nissan Maxima	89-94	1.44
31	Nissan Sentra	91-94	1.46
32	Nissan Sentra	95-98	1.40
33	Toyota Camry	92-96	1.46
34	Toyota Corolla	89-92	1.36
35	Toyota Tercel	91-94	1.41
36	Toyota Tercel	95-98	1.39

Table 2: Sport Utility Vehicles Used in the Analysis

Vehicle Group	Make / Model	Model Years	Drive Wheels	SSF
37	Dodge Ramcharger	88-93	4	1.13
38	Ford Bronco	88-96	4	1.13
39	Ford Bronco II	88-90	2	1.04
40	Ford Bronco II	88-90	4	1.04
41	Ford Explorer	91-94	2	1.07
42	Ford Explorer	91-94	4	1.08
43	Ford Explorer	95-98	2	1.06
44	Ford Explorer	95-98	4	1.06
45	Chevrolet S-10 Blazer, GMC S-1500 Jimmy	88-94	2	1.10
46	Chevrolet S-10 Blazer, GMC S-1500 Jimmy	88-94	4	1.10
47	Chevrolet Blazer, GMC Jimmy	95-98	2	1.09
48	Chevrolet Blazer, GMC Jimmy	95-98	4	1.09
49	Chevrolet V10/K10/K1500 Blazer	88-91	4	1.09
50	Chevrolet K1500 Blazer / Tahoe, GMC Yukon	92-98	4	1.12
51	Chevrolet V1500/V2500 Suburban, GMC V1500/V2500 Suburban	88-91	4	1.10
52	Chevrolet K1500/K2500 Suburban, GMC K1500/K2500 Suburban	92-98	4	1.08
53	Chevrolet Geo Tracker, Suzuki Sidekick	89-98	4	1.13
54	Honda CR-V	97-98	4	1.19
55	Honda Passport, Isuzu Rodeo	91-97	4	1.06
56	Isuzu Trooper	88-91	4	1.02
57	Isuzu Trooper	92-94	4	1.07
58	Jeep Cherokee	88-97	4	1.08
59	Acura SLX, Isuzu Trooper	95-98	4	1.09
60	Jeep Grand Cherokee	93-98	4	1.07
61	Jeep Wrangler	88-96	4	1.20
62	Nissan Pathfinder	88-95	4	1.07
63	Nissan Pathfinder	96-98	4	1.10
64	Suzuki Samurai	88-95	4	1.09
65	Toyota 4Runner	90-95	4	1.00
66	Toyota 4Runner	96-98	4	1.06

Table 3: Passenger Vans Used in the Analysis

Vehicle Group	Make / Model	Model Years	Drive Wheels	SSF
67	Dodge Caravan / Grand Caravan, Plymouth Voyager / Grand Voyager	88-95	2	1.21
68	Chrysler Town & Country, Dodge Caravan / Grand Caravan, Plymouth Voyager / Grand Voyager	96-98	2	1.23
69	Dodge B-150 Ram Wagon	88-98	2	1.09
70	Ford Aerostar	88-98	2	1.10
71	Ford E-150 Clubwagon	88-91	2	1.11
72	Ford E-150 Clubwagon	92-97	2	1.11
73	Ford Windstar	95-98	2	1.24
74	Chevrolet Astro, GMC Safari	88-98	2	1.12
75	Chevrolet Lumina APV, Oldsmobile Silhouette, Pontiac Transport	90-96	2	1.12
76	Chevrolet Venture, Oldsmobile Silhouette, Pontiac Transport	97-98	2	1.18
77	Chevrolet G10/G20 Sportsvan, GMC G1500/G2500 Rally van	88-95	2	1.08
78	Mazda MPV	89-97	2	1.17
79	Toyota Previa	91-97	2	1.23

Table 4: Pickup Trucks Used in the Analysis

Vehicle Group	Make / Model	Model Years	Drive Wheels	SSF
80	Dodge Dakota	97-98	2	1.25
81	Dodge Ram 1500	94-98	2	1.22
82	Dodge D-150 Ram	88-93	2	1.28
83	Ford F-150	88-96	2	1.19
84	Ford F-150	88-96	4	1.15
85	Ford F-150	97-98	2	1.18
86	Ford Ranger	88-92	2	1.13
87	Ford Ranger	88-92	4	1.03
88	Ford Ranger, Mazda B-series	93-97	2	1.17
89	Ford Ranger, Mazda B-series	93-97	4	1.07
90	Chevrolet C-1500, GMC C-1500 / Sierra	88-98	2	1.22
91	Chevrolet K-1500, GMC K-1500 / Sierra	88-98	4	1.14
92	Chevrolet S-10, GMC S-15 / Sonoma	88-93	2	1.19
93	Chevrolet S-10, GMC S-15 / Sonoma	88-93	4	1.19
94	Chevrolet S-10, GMC S-15 / Sonoma, Isuzu Hombre	94-98	2	1.14
95	Chevrolet S-10, GMC S-15 / Sonoma	94-98	4	1.14
96	Nissan Pickup	88-97	2	1.20
97	Nissan Pickup	88-97	4	1.11
98	Toyota Pickup	89-94	2	1.23
99	Toyota Pickup	89-94	4	1.07
100	Toyota Tacoma	95-98	2	1.26

Table 5: State File Characteristics that Affect the Estimated Rollover Rate

STATE and Reporting Threshold	Vehicle Form	Single-Vehicle Crash	Rollover
FLORIDA Threshold is $500 property damage, injury, or fatality	Completed for parked vehicles, phantom vehicles, pedalcycles, and trains	Identified by (1) eliminating vehicle forms for phantom and parked vehicles, (2) selecting crashes with a single vehicle form that meet this criterion, and (3) eliminating crashes for which either the first harmful event or the subsequent event is listed as a collision with a pedestrian, pedalcycle, train, or animal	Identified from the first harmful event in the crash, subsequent event in the crash, and impact point for the vehicle
MARYLAND Threshold is $500 property damage, injury, or fatality	Completed for parked vehicles	Identified by (1) eliminating vehicle forms for parked vehicles, (2) selecting crashes with a single vehicle form that meet this criterion, (3) eliminating crashes for which either the first harmful event or the subsequent event is listed as a collision with a pedestrian, pedalcycle, other nonmotorized conveyance, train, or animal, and (4) eliminating vehicles for which the most harmful event is listed as a collision with a pedestrian, pedalcycle, other nonmotorized conveyance, train, or animal	Identified from the first harmful event in the crash, subsequent event in the crash, most harmful event for the vehicle, initial impact point for the vehicle, and main impact point for the vehicle
MISSOURI Threshold is $500 property damage, injury, or fatality	Completed for parked vehicles, pedalcycles, horses with riders, and other non-motorized transport devices	Identified by (1) eliminating vehicle forms for parked vehicles, (2) selecting crashes with a single vehicle form that meet this criterion, and (3) eliminating crashes for which the accident type is listed as a collision with a pedestrian, pedalcycle, train, or animal	Identified from the accident type for the crash
NEW MEXICO Threshold is $500 property damage, injury, or fatality	Completed for parked vehicles	Identified by (1) eliminating vehicle forms for parked vehicles, (2) selecting crashes with a single vehicle form that meet this criterion, and (3) eliminating crashes for which the first harmful event is listed as a collision with a pedestrian, pedalcycle, train, or animal	Identified from the first harmful event in the crash

Table 5 (continued): State File Characteristics that Affect the Estimated Rollover Rate

STATE and Reporting Threshold	Vehicle Form	Single-Vehicle Crash	Rollover
NORTH CAROLINA Threshold is $500 property damage, injury, or fatality	Completed for parked vehicles, pedalcycles, and pedestrians	Identified by (1) eliminating vehicle forms for parked vehicles, (2) selecting crashes with a single vehicle form that meet this criterion, (3) eliminating crashes for which the first harmful event is listed as a collision with a pedestrian, pedalcycle, train, or animal, and (4) eliminating vehicles for which the most harmful event is listed as a collision with a pedestrian, pedalcycle, train, or animal	Identified from the rollover identifier for the vehicle and from four impact point variables
OHIO Threshold is $150 property damage, injury, or fatality	Completed for parked vehicles, pedalcycles, animals with riders, and animals with buggies	Identified by (1) eliminating vehicle forms for parked vehicles, (2) selecting crashes with a single vehicle form that meet this criterion, and (3) eliminating crashes for which the first harmful event is listed as a collision with a pedestrian, pedalcycle, train, animal, or other non-vehicle	Identified from the first harmful event in the crash
PENNSYLVANIA Threshold is all crashes	Completed for illegally parked vehicles, trains, pedalcycles, trolleys, and horses with buggies	Identified by (1) eliminating vehicle forms for illegally parked vehicles, (2) selecting crashes with a single vehicle form that meet this criterion, and (3) eliminating crashes for which the most harmful event is listed as a collision with a pedestrian or animal	Identified from the most harmful event in the crash and the events file (vehicle-event level)
UTAH Threshold is $750 property damage, injury, or fatality	Completed for parked vehicles	Identified by (1) eliminating vehicle forms for parked vehicles, (2) selecting crashes with a single vehicle form that meet this criterion, and (3) eliminating crashes for which the first, second, or third event is listed as a collision with a pedestrian, pedalcycle, train, or animal	Identified from the first, second, and third events in the crash

Table 6: Single-Vehicle Crashes of Relevant Vehicles

State		Calendar Year of State Data					
		1994	**1995**	**1996**	**1997**	**1998**	**Total**
Florida	FL	6,174	8,295	9,552	10,766	10,832	45,619
Maryland	MD	3,795	4,296	5,079	4,957	4,974	23,101
Missouri	MO	6,001	7,464	8,988	8,957	9,620	41,030
New Mexico	NM	1,591	2,018	2,365	2,454	2,190	10,618
North Carolina	NC	8,555	10,674	12,880	13,609	12,866	58,584
Ohio	OH	11,031	12,333	12,347	13,334	4,990	54,035
Pennsylvania	PA	9,303	11,143	13,530	14,885	13,842	62,703
Utah	UT	1,499	1,731	1,955	2,338	2,476	9,999

Table 7: Data Elements Available for the Analysis

Variable	Definition	Data Elements Available in Each State (X)							
		FL	MD	MO	NM	NC	OH	PA	UT
ROLL	Did the single-vehicle crash involve rollover?	X	X	X	(1)	X	(1)	X	X
SSF	What was the Static Stability Factor?	X	X	X	X	X	X	X	X
DARK	Was it dark when the crash occurred?	X	X	X	X	X	X	X	X
STORM	Was the weather inclement?	X	X	X	X	X	X	X	X
RURAL	Did the crash occur in a rural area?	X			X	X	X	X	X
FAST	Was the speed limit 50 mph or greater?	X	X	X	(2)	X	X	X	X
HILL	Did the crash occur on a grade, dip, or summit?	X	X	X	X	X	X	X	X
CURVE	Did the crash occur on a curve?	X	X	X	X	X	X	X	X
BADROAD	Were there potholes or other bad road conditions?	X	X		X	X	X		X
BADSURF	Was the road wet or icy or have another bad surface condition?	X	X	X	X	X	X	X	X
MALE	Was the driver male?	X	X	X	X	X	X	X	X
YOUNG	Was the driver under 25 years old?	X	X	X	X	X	X	X	X
OLD	Was the driver 70 years or older?	X	X	X	X	X	X	X	X
NOINSURE	Was the driver uninsured?	X		X	X		X	X	
DRINK	Was drinking or illegal drug use noted for the driver?	X	X	X	X	X	X	X	X
NUMOCC	How many occupants were in the vehicle?	X	X		X	X	X	X	X

"(1)" indicates "rollover reported on the file only if it was the first-harmful event in the crash"
"(2)" indicates "roadway function class was used as a proxy for speed limit in the analysis"

Table 8a: Linear Model of the Logarithm of the Rollover Rate as a Function of the SSF and State in Six States

Summary records = 518; R-squared = 0.7278; *F*-statistic = 227.671

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	T for H0: Parameter=0	Probability > |T|
INTERCEPT	1	1.4130	0.1251	11.297	0.0001
SSF	1	-2.8634	0.0959	-29.857	0.0001
DUMMY_FL	1	0.5583	0.0472	11.820	0.0001
DUMMY_MD	1	0.3269	0.0495	6.610	0.0001
DUMMY_NC	1	0.5993	0.0463	12.930	0.0001
DUMMY_PA	1	0.6974	0.0476	14.641	0.0001
DUMMY_UT	1	1.0245	0.0571	17.952	0.0001

Table 8b: Best Linear Model of the Logarithm of the Rollover Rate as a Function of the SSF in Six States

Summary records = 518; R-squared = 0.8809; *F*-statistic = 311.229

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	T for H0: Parameter=0	Probability > |T|
INTERCEPT	1	0.8509	0.1946	4.372	0.0001
SSF	1	-3.3760	0.0756	-44.652	0.0001
DARK	1	-0.4585	0.2057	-2.229	0.0262
FAST	1	1.6119	0.1924	8.378	0.0001
CURVE	1	1.5718	0.2454	6.406	0.0001
MALE	1	-1.2844	0.1064	-12.070	0.0001
YOUNG	1	0.9581	0.0990	9.680	0.0001
DRINK	1	1.7178	0.2814	6.104	0.0001
DUMMY_FL	1	1.2253	0.0713	17.187	0.0001
DUMMY_MD	1	0.6933	0.0885	7.836	0.0001
DUMMY_NC	1	0.6969	0.0364	19.125	0.0001
DUMMY_PA	1	1.2449	0.0639	19.466	0.0001
DUMMY_UT	1	0.8622	0.0508	16.961	0.0001

Table 8c: Best Linear Model of the Logarithm of the Adjusted Rollover Rate as a Function of the SSF in Six States

Observations = 518; R-squared = 0.8478; *F*-statistic = 2873.526

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	T for H0: Parameter=0	Probability > |T|
INTERCEPT	1	2.5861	0.0795	32.515	0.0001
SSF	1	-3.3760	0.0630	-53.605	0.0001

Table 9a: Individual-Variable Logistic Model of Rollover as a Function of the SSF in Florida

Observations = 37,300; Concordant = 75.4%; Discordant = 24.3%; Tied = 0.3%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	2.9420	0.1331	488.3685	0.0001		
SSF	1	-4.3908	0.0999	1931.1873	0.0001	-0.3491	0.012
DARK	1	-0.0334	0.0297	1.2674	0.2603	-0.0092	0.967
STORM	1	-0.1083	0.0522	4.2950	0.0382	-0.0237	0.897
RURAL	1	0.6207	0.0308	405.0068	0.0001	0.1681	1.860
FAST	1	1.1120	0.0292	1454.0623	0.0001	0.2933	3.040
HILL	1	-0.0562	0.0382	2.1664	0.1411	-0.0110	0.945
CURVE	1	0.6265	0.0321	380.9064	0.0001	0.1420	1.871
BADROAD	1	0.1697	0.0506	11.2535	0.0008	0.0251	1.185
BADSURF	1	-0.1450	0.0471	9.4892	0.0021	-0.0354	0.865
MALE	1	-0.1234	0.0297	17.2843	0.0001	-0.0323	0.884
YOUNG	1	0.3567	0.0285	156.2179	0.0001	0.0960	1.429
OLD	1	-0.4538	0.1004	20.4109	0.0001	-0.0469	0.635
NOINSURE	1	0.2198	0.0319	47.4223	0.0001	0.0510	1.246
DRINK	1	0.1519	0.0351	18.7156	0.0001	0.0357	1.164
NUMOCC	1	0.1612	0.0134	144.7564	0.0001	0.0830	1.175

Table 9b: Crash-Scenario Logistic Model of Rollover as a Function of the SSF in Florida

Observations = 29,370; Scenarios = 267; Concordant = 75.3%; Discordant = 24.3%; Tied = 0.3%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	2.6144	0.1411	343.4742	0.0001		
SSF	1	-4.1227	0.1125	1343.9588	0.0001	-0.3271	0.016
SCENRISK	1	5.3457	0.1099	2367.7499	0.0001	0.4048	209.714

Table 10a: Individual-Variable Logistic Model of Rollover as a Function of the SSF in Maryland

Observations = 18,874; Concordant = 68.6%; Discordant = 30.8%; Tied = 0.6%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	2.1597	0.1907	128.2880	0.0001		
SSF	1	-3.7203	0.1441	666.9999	0.0001	-0.2948	0.024
DARK	1	-0.3142	0.0651	23.3129	0.0001	-0.0719	0.730
STORM	1	0.0675	0.0436	2.4004	0.1213	0.0186	1.070
FAST	1	0.7651	0.0430	317.1410	0.0001	0.2005	2.149
HILL	1	0.2328	0.0436	28.5448	0.0001	0.0614	1.262
CURVE	1	0.3927	0.0437	80.7210	0.0001	0.1054	1.481
BADROAD	1	0.3401	0.0828	16.8675	0.0001	0.0426	1.405
BADSURF	1	0.0923	0.0546	2.8613	0.0907	0.0248	1.097
MALE	1	0.0020	0.0443	0.0020	0.9643	0.0005	1.002
YOUNG	1	0.3525	0.0428	67.7455	0.0001	0.0949	1.423
OLD	1	0.0389	0.1325	0.0863	0.7690	0.0037	1.040
DRINK	1	0.1431	0.0568	6.3513	0.0117	0.0295	1.154
NUMOCC	1	0.1392	0.0222	39.2952	0.0001	0.0646	1.149

Table 10b: Crash-Scenario Logistic Model of Rollover as a Function of the SSF in Maryland

Observations = 16,553; Scenarios = 142; Concordant = 67.4%; Discordant = 31.9%; Tied = 0.7%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	1.9412	0.1956	98.4856	0.0001		
SSF	1	-3.5760	0.1521	552.9069	0.0001	-0.2831	0.028
SCENRISK	1	5.5869	0.3108	323.1908	0.0001	0.2125	266.909

Table 11a: Individual-Variable Logistic Model of Rollover as a Function of the SSF in Missouri

Observations = 34,937; Concordant = 68.0%; Discordant = 31.2%; Tied = 0.7%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	2.0259	0.1722	138.4234	0.0001		
SSF	1	-3.8283	0.1325	834.5754	0.0001	-0.2879	0.022
DARK	1	0.0377	0.0352	1.1499	0.2836	0.0103	1.038
STORM	1	-0.1178	0.0541	4.7493	0.0293	-0.0284	0.889
FAST	1	0.8503	0.0414	422.6698	0.0001	0.2219	2.340
HILL	1	0.0159	0.0340	0.2194	0.6395	0.0044	1.016
CURVE	1	0.2996	0.0345	75.3110	0.0001	0.0792	1.349
BADSURF	1	-0.0352	0.0486	0.5262	0.4682	-0.0095	0.965
MALE	1	-0.1444	0.0351	16.8717	0.0001	-0.0392	0.866
YOUNG	1	0.2448	0.0344	50.5767	0.0001	0.0666	1.277
OLD	1	-0.3333	0.1253	7.0745	0.0078	-0.0316	0.717
NOINSURE	1	0.2680	0.0385	48.5743	0.0001	0.0607	1.307
DRINK	1	-0.0563	0.0559	1.0162	0.3134	-0.0096	0.945

Table 11b: Crash-Scenario Logistic Model of Rollover as a Function of the SSF in Missouri

Observations = 34,959; Scenarios = 76; Concordant = 67.6%; Discordant = 31.6%; Tied = 0.8%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	1.4063	0.1653	72.3498	0.0001		
SSF	1	-3.6441	0.1290	798.0744	0.0001	-0.2742	0.026
SCENRISK	1	8.9135	0.3578	620.4768	0.0001	0.2456	999.000

Table 12a: Individual-Variable Logistic Model of Rollover as a Function of the SSF in New Mexico

Observations = 9,154; Concordant = 77.4%; Discordant = 22.4%; Tied = 0.3%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	0.7299	0.2724	7.1784	0.0074		
SSF	1	-3.0809	0.2133	208.5949	0.0001	-0.2331	0.046
DARK	1	-0.0242	0.0577	0.1762	0.6746	-0.0066	0.976
STORM	1	0.1299	0.0882	2.1693	0.1408	0.0277	1.139
RURAL	1	1.8164	0.0733	614.1228	0.0001	0.4988	6.150
FAST	1	0.3412	0.0597	32.6510	0.0001	0.0911	1.407
HILL	1	0.1229	0.0615	3.9975	0.0456	0.0295	1.131
CURVE	1	0.1793	0.0613	8.5486	0.0035	0.0427	1.196
BADROAD	1	-0.5813	0.5341	1.1847	0.2764	-0.0177	0.559
BADSURF	1	0.0497	0.0795	0.3906	0.5320	0.0120	1.051
MALE	1	-0.0654	0.0570	1.3169	0.2511	-0.0175	0.937
YOUNG	1	0.2841	0.0572	24.6576	0.0001	0.0769	1.329
OLD	1	-0.2411	0.1766	1.8638	0.1722	-0.0251	0.786
NOINSURE	1	0.1633	0.0774	4.4520	0.0349	0.0310	1.177
DRINK	1	0.3537	0.0740	22.8347	0.0001	0.0754	1.424
NUMOCC	1	0.1647	0.0282	34.0232	0.0001	0.0823	1.179

Table 12b: Crash-Scenario Logistic Model of Rollover as a Function of the SSF in New Mexico

Observations = 7,156; Scenarios = 73; Concordant = 77.9%; Discordant = 21.8%; Tied = 0.3%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	0.8547	0.2980	8.2271	0.0041		
SSF	1	-3.0129	0.2406	156.8274	0.0001	-0.2278	0.049
SCENRISK	1	5.8555	0.1996	860.6319	0.0001	0.5645	349.164

Table 13a: Individual-Variable Logistic Model of Rollover as a Function of the SSF in North Carolina

Observations = 55,434; Concordant = 73.1%; Discordant = 26.5%; Tied = 0.4%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	1.2711	0.1103	132.8526	0.0001		
SSF	1	-3.0800	0.0813	1435.4357	0.0001	-0.2390	0.046
DARK	1	0.0480	0.0235	4.1522	0.0416	0.0130	1.049
STORM	1	-0.4030	0.0376	114.6765	0.0001	-0.0976	0.668
RURAL	1	0.7457	0.0299	620.7173	0.0001	0.2025	2.108
FAST	1	0.5310	0.0295	324.1840	0.0001	0.1431	1.701
HILL	1	0.0282	0.0233	1.4626	0.2265	0.0075	1.029
CURVE	1	0.6787	0.0230	873.3881	0.0001	0.1817	1.971
BADROAD	1	0.4013	0.0525	58.4725	0.0001	0.0426	1.494
BADSURF	1	0.0159	0.0339	0.2219	0.6376	0.0042	1.016
MALE	1	-0.1018	0.0241	17.8176	0.0001	-0.0273	0.903
YOUNG	1	0.4292	0.0230	348.6563	0.0001	0.1165	1.536
OLD	1	-0.3667	0.0802	20.8821	0.0001	-0.0360	0.693
DRINK	1	0.6928	0.0331	437.7642	0.0001	0.1214	1.999
NUMOCC	1	0.0286	0.0119	5.7343	0.0166	0.0144	1.029

Table 13b: Crash-Scenario Logistic Model of Rollover as a Function of the SSF in North Carolina

Observations = 51,823; Scenarios = 276; Concordant = 72.9%; Discordant = 26.7%; Tied = 0.4%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	1.1053	0.1045	111.8042	0.0001		
SSF	1	-2.9751	0.0817	1325.3747	0.0001	-0.2309	0.051
SCENRISK	1	5.8457	0.0921	4032.6846	0.0001	0.4086	345.746

Table 14a: Individual-Variable Logistic Model of Rollover as a Function of the SSF in Ohio

Observations = 48,108; Concordant = 68.6%; Discordant = 29.6%; Tied = 1.9%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	1.4519	0.2621	30.6806	0.0001		
SSF	1	-4.3642	0.2013	469.9953	0.0001	-0.3257	0.013
DARK	1	-0.1452	0.0502	8.3810	0.0038	-0.0399	0.865
STORM	1	-0.2342	0.0658	12.6878	0.0004	-0.0631	0.791
RURAL	1	0.0474	0.0674	0.4954	0.4815	0.0118	1.049
FAST	1	0.8290	0.0661	157.1036	0.0001	0.2202	2.291
HILL	1	-0.0607	0.0507	1.4331	0.2313	-0.0161	0.941
CURVE	1	0.2178	0.0515	17.8613	0.0001	0.0556	1.243
BADROAD	1	-0.7001	0.3838	3.3269	0.0682	-0.0391	0.497
BADSURF	1	0.0430	0.0644	0.4470	0.5038	0.0118	1.044
MALE	1	-0.0036	0.0506	0.0051	0.9432	-0.0010	0.996
YOUNG	1	0.2777	0.0489	32.2650	0.0001	0.0749	1.320
OLD	1	-0.5707	0.2355	5.8740	0.0154	-0.0496	0.565
NOINSURE	1	0.1361	0.1431	0.9034	0.3419	0.0123	1.146
DRINK	1	-0.0091	0.0777	0.0136	0.9073	-0.0017	0.991
NUMOCC	1	0.0546	0.0232	5.5513	0.0185	0.0247	1.056

Table 14b: Crash-Scenario Logistic Model of Rollover as a Function of the SSF in Ohio

Observations = 50,290; Scenarios = 83; Concordant = 68.0%; Discordant = 30.0%; Tied = 2.0%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	1.1495	0.2357	23.7752	0.0001		
SSF	1	-4.3136	0.1912	509.1057	0.0001	-0.3217	0.013
SCENRISK	1	22.4584	1.2514	322.0866	0.0001	0.2334	999.000

Table 15a: Individual-Variable Logistic Model of Rollover as a Function of the SSF in Pennsylvania

Observations = 39,362; Concordant = 69.7%; Discordant = 29.9%; Tied = 0.4%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	1.7465	0.1216	206.3426	0.0001		
SSF	1	-3.0793	0.0906	1155.4773	0.0001	-0.2453	0.046
DARK	1	0.0138	0.0264	0.2717	0.6022	0.0038	1.014
STORM	1	-0.2369	0.0340	48.5499	0.0001	-0.0615	0.789
RURAL	1	0.7553	0.0272	772.1106	0.0001	0.2067	2.128
FAST	1	0.4987	0.0262	363.5505	0.0001	0.1285	1.647
HILL	1	0.3054	0.0250	148.9803	0.0001	0.0835	1.357
CURVE	1	0.2721	0.0259	110.4628	0.0001	0.0718	1.313
BADSURF	1	0.2260	0.0329	47.1891	0.0001	0.0623	1.254
MALE	1	-0.0926	0.0265	12.1816	0.0005	-0.0247	0.912
YOUNG	1	0.1955	0.0262	55.7071	0.0001	0.0523	1.216
OLD	1	-0.4441	0.0847	27.5095	0.0001	-0.0461	0.641
NOINSURE	1	0.0055	0.1398	0.0015	0.9689	0.0003	1.005
DRINK	1	0.1015	0.0364	7.7846	0.0053	0.0207	1.107
NUMOCC	1	0.0060	0.0148	0.1649	0.6847	0.0027	1.006

Table 15b: Crash-Scenario Logistic Model of Rollover as a Function of the SSF in Pennsylvania

Observations = 43,092; Scenarios = 264; Concordant = 69.4%; Discordant = 30.2%; Tied = 0.4%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	1.3045	0.1074	147.4610	0.0001		
SSF	1	-2.9574	0.0824	1287.8470	0.0001	-0.2365	0.052
SCENRISK	1	4.8066	0.1058	2064.5693	0.0001	0.3074	122.311

Table 16a: Individual-Variable Logistic Model of Rollover as a Function of the SSF in Utah

Observations = 6,753; Concordant = 73.7%; Discordant = 26.0%; Tied = 0.2%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	3.0214	0.2616	133.3965	0.0001		
SSF	1	-4.0534	0.1988	415.8912	0.0001	-0.3297	0.017
DARK	1	0.0795	0.0596	1.7795	0.1822	0.0203	1.083
STORM	1	-0.0149	0.0878	0.0288	0.8651	-0.0038	0.985
RURAL	1	1.1669	0.0744	246.0926	0.0001	0.2832	3.212
FAST	1	0.6116	0.0705	75.2753	0.0001	0.1513	1.843
HILL	1	0.0207	0.0592	0.1219	0.7270	0.0056	1.021
CURVE	1	0.1068	0.0604	3.1263	0.0770	0.0285	1.113
BADROAD	1	-0.1441	0.0935	2.3757	0.1232	-0.0239	0.866
BADSURF	1	-0.4951	0.0840	34.7391	0.0001	-0.1356	0.609
MALE	1	-0.0032	0.0564	0.0032	0.9548	-0.0009	0.997
YOUNG	1	0.0503	0.0569	0.7806	0.3770	0.0138	1.052
OLD	1	-0.0157	0.1698	0.0085	0.9265	-0.0014	0.984
DRINK	1	0.5768	0.1086	28.1849	0.0001	0.0813	1.780
NUMOCC	1	0.1796	0.0236	58.0417	0.0001	0.1161	1.197

Table 16b: Crash-Scenario Logistic Model of Rollover as a Function of the SSF in Utah

Observations = 5,864; Scenarios = 53; Concordant = 73.4%; Discordant = 26.4%; Tied = 0.2%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	2.6307	0.2557	105.8240	0.0001		
SSF	1	-4.0590	0.2046	393.6800	0.0001	-0.3307	0.017
SCENRISK	1	4.7170	0.2110	499.9490	0.0001	0.4223	111.828

Table 17a: Individual-Variable Logistic Model of Rollover as a Function of the SSF in Six States

Observations = 204,134; Concordant = 71.4%; Discordant = 28.2%; Tied = 0.4%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	1.5459	0.0569	737.2266	0.0001		
SSF	1	-3.6054	0.0424	7230.1063	0.0001	-0.2837	0.027
DARK	1	-0.0006	0.0124	0.0028	0.9581	-0.0002	0.999
STORM	1	-0.1813	0.0170	114.2240	0.0001	-0.0453	0.834
FAST	1	0.9229	0.0124	5497.0390	0.0001	0.2544	2.517
HILL	1	0.1274	0.0125	104.2731	0.0001	0.0336	1.136
CURVE	1	0.5243	0.0123	1831.8179	0.0001	0.1368	1.689
BADSURF	1	-0.0155	0.0159	0.9484	0.3301	-0.0041	0.985
MALE	1	-0.0924	0.0124	55.3414	0.0001	-0.0247	0.912
YOUNG	1	0.3230	0.0120	724.7098	0.0001	0.0873	1.381
OLD	1	-0.3720	0.0408	83.3029	0.0001	-0.0368	0.689
DRINK	1	0.2604	0.0165	249.7817	0.0001	0.0521	1.298
DUMMY_FL	1	1.1667	0.0214	2965.0082	0.0001	0.2486	3.211
DUMMY_MD	1	0.7735	0.0267	841.2490	0.0001	0.1237	2.167
DUMMY_NC	1	0.7988	0.0192	1728.8262	0.0001	0.1969	2.223
DUMMY_PA	1	1.2124	0.0200	3665.7178	0.0001	0.2783	3.361
DUMMY_UT	1	1.5232	0.0305	2502.1393	0.0001	0.1512	4.587

Table 17b: Crash-Scenario Logistic Model of Rollover as a Function of the SSF in Six States

Observations = 203,816; Scenarios = 654; Concordant = 71.6%; Discordant = 27.9%; Tied = 0.4%

Variable	Degrees of Freedom	Parameter Estimate	Standard Error	Wald Chi-Square	Probability > Chi-Square	Standardized Estimate	Odds Ratio
INTERCEPT	1	1.7339	0.0523	1101.0809	0.0001		
SSF	1	-3.4555	0.0413	7011.2375	0.0001	-0.2722	0.032
SCENRISK	1	5.6540	0.0511	12221.2738	0.0001	0.3435	285.433

Table 18: Baseline Values from the Logistic Models

State	Average of Study Vehicles		Rollover Rate for SSF=1.00	
	Rollover Rate	SSF	Individual Variables	Crash Scenarios
Florida	0.2044	1.2894	0.4778	0.4585
Maryland	0.1601	1.2928	0.3617	0.3520
Missouri	0.1235	1.2715	0.2849	0.2748
New Mexico	0.2475	1.2406	0.4084	0.4044
North Carolina	0.2077	1.2953	0.3943	0.3869
Ohio	0.0395	1.2658	0.1161	0.1147
Pennsylvania	0.2458	1.2648	0.4241	0.4163
Utah	0.3615	1.2331	0.5930	0.5933
Weighted average of six states (FL, MD, MO, NC, PA, UT)	0.2019	1.2803	0.4031	0.3929
Six-state model (FL, MD, MO, NC, PA, UT)	0.2019	1.2803	0.4101	0.3999

Table 19: National Rollover Rates Estimated from the Linear and Logistic Models

SSF	MODEL 1: Linear Model Based on the Summary Data for Six States	Logistic Models Using Individual Variables		Logistic Models Using Crash Scenarios	
		MODEL 2: Six States Combined	MODEL 3: Average of the Six State Models	MODEL 4: Six States Combined	MODEL 5: Average of the Six State Models
0.95	0.5374	0.4543	0.4458	0.4420	0.4334
0.96	0.5195	0.4454	0.4372	0.4335	0.4252
0.97	0.5023	0.4365	0.4286	0.4250	0.4171
0.98	0.4856	0.4277	0.4201	0.4166	0.4090
0.99	0.4695	0.4188	0.4116	0.4082	0.4009
1.00	0.4539	0.4101	0.4031	0.3999	0.3929
1.01	0.4388	0.4014	0.3947	0.3916	0.3849
1.02	0.4243	0.3928	0.3864	0.3834	0.3770
1.03	0.4102	0.3842	0.3781	0.3753	0.3692
1.04	0.3966	0.3757	0.3699	0.3672	0.3614
1.05	0.3834	0.3673	0.3618	0.3592	0.3537
1.06	0.3707	0.3590	0.3537	0.3513	0.3460
1.07	0.3584	0.3507	0.3457	0.3435	0.3385
1.08	0.3465	0.3425	0.3378	0.3357	0.3310
1.09	0.3350	0.3345	0.3300	0.3281	0.3236
1.10	0.3238	0.3265	0.3223	0.3205	0.3163
1.11	0.3131	0.3186	0.3147	0.3130	0.3091
1.12	0.3027	0.3108	0.3071	0.3056	0.3019
1.13	0.2926	0.3032	0.2997	0.2984	0.2949
1.14	0.2829	0.2956	0.2924	0.2912	0.2879
1.15	0.2735	0.2882	0.2852	0.2841	0.2811
1.16	0.2645	0.2808	0.2780	0.2771	0.2743
1.17	0.2557	0.2736	0.2710	0.2703	0.2677
1.18	0.2472	0.2665	0.2641	0.2635	0.2611
1.19	0.2390	0.2595	0.2574	0.2568	0.2547
1.20	0.2311	0.2526	0.2507	0.2503	0.2484
1.21	0.2234	0.2459	0.2441	0.2439	0.2421
1.22	0.2160	0.2393	0.2377	0.2376	0.2360
1.23	0.2088	0.2328	0.2314	0.2314	0.2300
1.24	0.2019	0.2264	0.2252	0.2253	0.2241
1.25	0.1952	0.2201	0.2191	0.2193	0.2183

Table 19 (continued): National Rollover Rates Estimated from the Linear and Logistic Models

SSF	MODEL 1: Linear Model Based on the Summary Data for Six States	Logistic Models Using Individual Variables		Logistic Models Using Crash Scenarios	
		MODEL 2: Six States Combined	MODEL 3: Average of the Six State Models	MODEL 4: Six States Combined	MODEL 5: Average of the Six State Models
1.26	0.1887	0.2140	0.2132	0.2134	0.2126
1.27	0.1824	0.2080	0.2074	0.2077	0.2070
1.28	0.1764	0.2021	0.2016	0.2021	0.2016
1.29	0.1705	0.1964	0.1960	0.1966	0.1962
1.30	0.1649	0.1907	0.1906	0.1912	0.1910
1.31	0.1594	0.1852	0.1852	0.1859	0.1858
1.32	0.1541	0.1799	0.1800	0.1807	0.1808
1.33	0.1490	0.1746	0.1749	0.1756	0.1759
1.34	0.1440	0.1695	0.1699	0.1707	0.1711
1.35	0.1392	0.1645	0.1650	0.1659	0.1663
1.36	0.1346	0.1596	0.1602	0.1611	0.1617
1.37	0.1302	0.1548	0.1556	0.1565	0.1572
1.38	0.1258	0.1501	0.1510	0.1520	0.1528
1.39	0.1217	0.1456	0.1466	0.1476	0.1486
1.40	0.1176	0.1412	0.1423	0.1433	0.1444
1.41	0.1137	0.1368	0.1381	0.1391	0.1403
1.42	0.1099	0.1326	0.1340	0.1350	0.1363
1.43	0.1063	0.1285	0.1300	0.1310	0.1324
1.44	0.1028	0.1246	0.1261	0.1272	0.1286
1.45	0.0994	0.1207	0.1223	0.1234	0.1249
1.46	0.0961	0.1169	0.1186	0.1197	0.1213
1.47	0.0929	0.1132	0.1150	0.1161	0.1178
1.48	0.0898	0.1097	0.1115	0.1126	0.1143
1.49	0.0868	0.1062	0.1081	0.1092	0.1110
1.50	0.0839	0.1028	0.1048	0.1059	0.1078
1.51	0.0811	0.0995	0.1016	0.1026	0.1046
1.52	0.0784	0.0964	0.0985	0.0995	0.1015
1.53	0.0758	0.0933	0.0955	0.0965	0.0985
1.54	0.0733	0.0903	0.0925	0.0935	0.0956
1.55	0.0709	0.0873	0.0896	0.0906	0.0928
Average slope*	-0.713	-0.598	-0.580	-0.572	-0.555

* The Average Slope was calculated for the observed range of SSF values for our vehicles in the state data (1.00 to 1.53), as the difference in the estimated rollover rates divided by the difference in the SSF values.

Table 20: Standardized Estimate for the Coefficients Produced by the Logistic Models of Rollover as a Function of the SSF

State	Exponent: Individual Variables	Exponent: Crash Scenarios	NHTSA: Individual Variables, without Wheelbase	NHTSA: Crash Scenarios, without Wheelbase	NHTSA: Individual Variables, with Wheelbase	NHTSA: Crash Scenarios, with Wheelbase
Alabama	-0.282	-0.282				
Florida	-0.383	-0.381	-0.349	-0.327	-0.392	-0.374
Idaho	-0.308	-0.318				
Maryland	-0.303	-0.310	-0.295	-0.283	-0.320	-0.310
Missouri			-0.288	-0.274	-0.312	-0.304
New Mexico			-0.233	-0.228	-0.239	-0.236
North Carolina	-0.287	-0.292	-0.239	-0.231	-0.269	-0.266
Ohio			-0.326	-0.322	-0.343	-0.342
Pennsylvania	-0.271	-0.284	-0.245	-0.236	-0.266	-0.260
Utah			-0.330	-0.331	-0.368	-0.369

Table 21: Coefficients of the SSF Variable from the Logistic Models

State	Model without Wheelbase		Model with Wheelbase	
	Individual Variables	Crash Scenarios	Individual Variables	Crash Scenarios
Florida	−4.3908	−4.1227	−4.9284	−4.7108
Maryland	−3.7203	−3.5760	−4.0387	−3.9206
Missouri	−3.8283	−3.6441	−4.1553	−4.0384
New Mexico	−3.0809	−3.0129	−3.1559	−3.1185
North Carolina	−3.0800	−2.9751	−3.4710	−3.4260
Ohio	−4.3642	−4.3136	−4.6001	−4.5838
Pennsylvania	−3.0793	−2.9574	−3.3352	−3.2562
Utah	−4.0534	−4.0590	−4.5195	−4.5338
Six-state model (FL, MD, MO, NC, PA, UT)	−3.6054	−3.4555	−3.9525	−3.7918

Table 22: Risk of Serious Injury Among Unbelted Drivers of Towed Light Vehicles in Frontal Nonrollover Crashes (1988-1999 NASS Investigated Cases and Annualized National Estimates)

Delta V (in mph)	Investigated Cases		Annualized Estimates		
	All Involved Drivers	Drivers with Serious Injury	All Involved Drivers	Drivers with Serious Injury	Percent with Serious Injury
00-09	517	8	24,196	183	0.76
10-19	3,758	305	107,038	3,342	3.12
20-29	2,343	623	33,564	4,573	13.63
30-39	718	381	4,822	2,370	49.15
40-49	207	146	1,198	726	60.58
50 +	88	73	465	374	80.46
Total	7,631	1,536	171,284	11,569	6.75

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Appendix II: List of Test Vehicles for MY2001 Rollover Resistance Ratings

NHTSA expects to measure the Static Stability Factor and provide rollover resistance ratings for each of the following model year 2001 vehicles. For pickups and SUVs, the agency plans to measure and report separately on both two-wheel-drive and four-or all-wheel-drive variants of each model, where applicable. In no case will a two-wheel-drive measurement be applied to a four-or all-wheel-drive variant, or vice versa. The agency may need to make substitutions for some of the models listed depending on availability. The list is arranged largely alphabetically within each vehicle category, and passenger cars are sorted by class according to the classifications used in the NHTSA NCAP frontal and side crash test programs. The order in which vehicles will be tested will be determined by the test laboratory and will depend primarily on model availability.

The following class abbreviations are used:

LPC = light passenger car
CPC = compact passenger car
MPC = medium passenger car
HPC = heavy passenger car
SUV = sport utility vehicle
LT = light truck

BILLING CODE 4910–59–C

MANUFACTURER	MAKE	MODEL	TWINS	CLASS	STYLE
PASSENGER CARS					
Ford	Ford	Focus		LPC	4DR
Hyundai	Hyundai	Accent		LPC	4DR
Toyota	Toyota	Corolla	Prizm	LPC	4DR
Toyota	Toyota	Echo		LPC	4DR
GM	Chevrolet	Cavalier	Sunfire	CPC	4DR
DC	Dodge	Neon	Neon	CPC	4DR
Honda	Honda	Civic		CPC	4DR
VW	Volkswagen	Jetta		CPC	4DR
GM	Chevrolet	Impala		MPC	4DR
DC	Dodge	Stratus	Sebring	MPC	4DR
Ford	Ford	Taurus	Sable	MPC	4DR
Honda	Honda	Accord		MPC	4DR
GM	Pontiac	Grand Am 4dr	Alero	MPC	4DR
Toyota	Toyota	Camry		MPC	4DR
Ford	Ford	Crown Victoria	Grand Marquis	HPC	4DR
Ford	Lincoln	LS		HPC	4DR
VANS					
GM	Chevrolet	Astro	Safari	Van	
GM	Chevrolet	Venture	Silhouette; Montana	Van	ext. whlbs.
DC	Dodge	Caravan	Voyager	Van	
DC	Dodge	Grand Caravan	Town & Country	Van	
DC	Dodge	Ram Van/Wagon		Van	
Ford	Ford	Econoline Club Wagon	Econoline Van	Van	
Ford	Ford	Windstar		Van	
Honda	Honda	Odyssey		Van	
Mazda	Mazda	MPV		Van	
Ford	Nissan	Quest	Villager	Van	
Toyota	Toyota	Sienna		Van	
***SUVs** (will include 2WD and 4WD or AWD versions of each model listed, if applicable)*					

MANUFACTURER	MAKE	MODEL	TWINS	CLASS	STYLE
GM	Chevrolet	Blazer	Jimmy/Envoy; Bravada	SUV	4DR
GM	Chevrolet	Suburban	Yukon XL	SUV	
GM	Chevrolet	Tahoe	Yukon	SUV	4DR
GM	Chevrolet	Tracker	Vitara	SUV	4DR
DC	Dodge	Durango		SUV	
DC	Chrysler	PT Cruiser		SUV	
Ford	Ford	Escape	Mazda Tribute	SUV	4DR
Ford	Ford	Expedition	Navigator	SUV	
Ford	Ford	Explorer	Mountaineer	SUV	4DR
Honda	Honda	CR-V		SUV	
Isuzu	Honda	Passport	Rodeo	SUV	
DC	Jeep	Cherokee		SUV	
DC	Jeep	Grand Cherokee		SUV	
DC	Jeep	Wrangler		SUV	4WD only
Toyota	Lexus	RX300		SUV	
Mitsubishi	Mitsubishi	Montero Sport		SUV	
Nissan	Nissan	Pathfinder	Infiniti QX4	SUV	
Nissan	Nissan	Xterra		SUV	
GM	Pontiac	Aztek		SUV	
Subaru	Subaru	Forester		SUV	AWD only
Toyota	Toyota	4Runner		SUV	
Toyota	Toyota	RAV4		SUV	
***PICK-UPs** (will include 2WD and 4WD versions of each model listed in most cases)*					
GM	Chevrolet	S-10 ExCab	Sonoma; Hombre	LT	

MANUFACTURER	MAKE	MODEL	TWINS	CLASS	STYLE
GM	Chevrolet	Silverado ExCab	GMC Sierra	LT	
DC	Dodge	Dakota ExCab		LT	
DC	Dodge	Ram ExCab		LT	
Ford	Ford	F-150		LT	
Ford	Ford	Ranger	Mazda B-Series	LT	
Nissan	Nissan	Frontier QuadCab		LT	
Toyota	Toyota	Tacoma ExCab		LT	
Toyota	Toyota	Tundra ExCab		LT	

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