

individual test vehicles and the nominal vehicle group SSF values, the nominal SSFs were retained for the present statistical analyses because they represent vehicles produced over a wide range of years in many cases and provide a simple comparison between the risk model presented in this document and that discussed in the previous notices.

The check marks under the various test maneuver names indicate which vehicles tipped up during the tests. Eleven of the twenty-five vehicles tipped up in the Fishhook maneuver conducted in the heavy condition. The heavy condition represented a five-occupant load for all vehicles except the six mentioned above that were limited to a four-occupant load by the vehicle seating positions and GVWR. All eleven were among the sixteen test vehicles with SSFs less than 1.20. None of the vehicles with higher SSFs tipped up in any test maneuver. The fishhook test under the heavy load clearly had the greatest potential to cause tip-up. The groups of vehicles that tipped up in other tests were subsets of the larger group of eleven that tipped up in the fishhook heavy test. There were seven vehicles in the group that tipped up in the J-Turn heavy test, six of which also tipped up in the Fishhook light test. The J-Turn light test had the least potential to tip up vehicles. Only three vehicles tipped up, all of which had tipped up in every other test.

VI. Rollover Risk Model

In its study of our rating system for rollover resistance (Transportation Research Board Special Report 265), the National Academy of Sciences (NAS) recommended that we use logistic regression rather than linear regression for analysis of the relationship between rollover risk and SSF. Logistic regression has the advantage that it operates on every crash data point directly rather than requiring that the crash data be aggregated by vehicle and state into a smaller number of data points. For example, we now have state data reports of about 293,000 single-vehicle crashes of the hundred vehicle make/models (together with their corporate cousins) whose single-vehicle crashes we have been tracking in six states. The logistic regression analysis of this data would have a sample size of 293,000, producing a narrow confidence interval on the repeatability of the relationship between SSF and rollover rate. In contrast, the linear regression analysis operates on the rollover rate of the hundred vehicle make/models in each of the six states. It produces a maximum sample size of only 600 (100

vehicles times six states) minus the number of samples for which fewer than 25 crashes were available for determining the rollover rate (a data quality control practice). Confidence limits computed for a data sample size of 600 will be much greater than those based on a sample size of 293,000. On average, each sample in the linear regression analysis was computed from over 400 crash report samples. However, ordinary techniques to compute the confidence intervals of linear regression results do not take into account the actual sample size represented by aggregated data. The statistical model created to combine SSF and dynamic test information in the prediction of rollover risk was computed by means of logistic regression as recommended by the NAS. Logistic regression is well suited to the correlation with crash data of vehicle properties that include both continuous variables like SSF and binary variables like tip-up or no tip-up in maneuver tests.

We had previously considered logistic regression during the development of the SSF based rating system (66 FR 3388, January 12, 2001, p.3393), but found that it consistently under-predicted the actual rollover rate at the low end of the SSF range where the rollover rates are high. The NAS study acknowledged this situation and gave the example of another analysis technique (non-parametric) that made higher rollover rate predictions at the low end of the SSF scale. In the NPRM, we discussed our plan to first examine ways to improve the fit of the logistic regression model to the actual rollover rates in the simpler model with SSF as the only vehicle attribute before expanding the logistic regression model to predict rollover rates using maneuver test results and SSF as vehicle attributes. In this way, the addition of maneuver test results is more likely to have an effect that reflects the additional information they represent on rollover causation.

Appendix II discusses the details of seeking a mathematical transformation of SSF to improve the accuracy of logistic regression models. We found that logistic regression on the transformation "Log(SSF-0.9)" rather than on SSF directly computed a risk model whose predictions of rollovers per single-vehicle crash more closely matched the relationship between vehicle SSF and actual rollover rates observed in state crash data. We sought to optimize the accuracy of the predictions in the SSF range between 1.0 and 1.25 that includes the vehicles with the highest rollover rates, even at the expense of accuracy in predicting

the low rollover rates at high end of the SSF scale. The risk model that resulted from this exercise is equivalent to the SSF-based rating system used for 2001–2003 NCAP rollover resistance ratings except that it was computed using logistic regression rather than linear regression as the statistical technique. Figure 3 compares the logistic regression model and linear regression model formerly used for NCAP ratings. The linear regression model is not in the form of a straight line because it also operated on a transformation of SSF (Log(SSF) in this case). The logistic regression model is the more accurate at lower half of the SSF range, and the linear regression model is the more accurate at the upper half of the SSF range. The two curves are quite similar.

A good logistic regression risk model using SSF only was the starting point for models using dynamic variables together with SSF. The dynamic maneuver test results (tip-up or no tip-up in each maneuver/load combination in Table 1) were used as four binary dynamic variables in the logistic regression analysis. The dynamic variables were entered in addition to SSF to describe the vehicle. The same driver and road variables from state crash reports discussed above were used. The state crash report data for twenty four of the vehicles used in the logistic regression analysis with dynamic maneuver test variables was a subset of the database of 293,000 single-vehicle crashes described above. One extra vehicle was added for the maneuver tests that was not among the 100 vehicle groups we had studied previously, but state crash report data from the same years and states was obtained for it. However, the database with SSF and dynamic maneuver test was much smaller than the 293,000 sample size available for the logistic regression model with SSF only. Its sample size was 96,000 single-vehicle crashes of 25 vehicles including 20,000 rollovers. Appendix II contains a more detailed discussion.

First, we tried each dynamic variable separately in conjunction with SSF. The models using variables for performance in the Fishhook heavy and J-Turn heavy maneuvers predicted a greater rollover risk for those vehicles that tipped up in the maneuver test. However, the models using variables for performance in the Fishhook light and J-Turn light maneuvers predicted a greater rollover risk for vehicles that did *not* tip up.

We do not believe vehicles that tip up in the least severe maneuvers are actually safer than those that do not tip up. A more rational interpretation is that the numbers of vehicle tipping up