

of the transformation  $\text{Log}(\text{SSF}-0.90)$  instead of SSF alone in the logistic regression gave us a risk model with the benefits of logistic regression recommended by the NAS and a goodness of fit with the actual rollover rate data at least equivalent to that of the linear regression model we have been using.

Figure II.8 shows the best logistic regression model (margin = 0.90) and the linear regression model we have been using. In this presentation, the driver and road variables of the crashes for each SSF were the same so that the differences in predicted rollover rates along each line were a purely a function of SSF differences, and the risk curve is continuous. The common scenario of driver and road variables represented the average conditions for the entire 293,000 single vehicle crashes (only 20% of which resulted in rollover). The linear regression model represents the same scenario.

The line in Figure II.8 representing the linear regression model is described by the equation:

$$\text{Roll Rate} = 13.28e^{(-3.376 \times \text{SSF})}$$

The line in Figure II.8 representing the logistic regression model is described by the following equation:

$$\text{Roll Rate} = \frac{1}{1 + e^{(2.7546 + 1.1814 \times \ln(\text{SSF}-0.90))}}$$

#### B. Adding Dynamic Maneuver Test Results to the Logistic Regression Model

The dynamic maneuver test results (tip-up or no tip-up in each maneuver/load combination in Table 1 of the main body of the notice) were used as four binary variables in the logistic regression analysis. They 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 tests 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.

The risk models combining SSF and dynamic maneuver test results ("dynamic results" for short) are computed in the same way as the logistic regression curve in Figure II.7. The logistic regression analysis of the database of 96,000 state reports of single

vehicle crashes along with the dynamic results and SSF of each crashed vehicle provides a mathematical relationship between all of the vehicle, driver and road variables and a prediction of whether rollover will occur in a single vehicle crash described by any combination of the variables. Next, for the number of sets of driver and road variables that define the average crash scenario of the 293,000 single vehicle crash database, predictions of rollover or no rollover in the crash are made at each combination of SSF and dynamic results. The proportion of crashes that are predicted to result in rollover is plotted at each SSF and dynamic result. Continuous curves predicting rollover rate versus SSF for each combination of dynamic results is the form of the model. Since all of the predictions were made with the same driver and road scenario, the changes in rollover rate along each SSF curve or between dynamic results are functions of vehicle attributes.

Figure II.9 illustrates the form of the model with dynamic results. It shows the predicted rollover rate as a function of SSF and whether or not the vehicle tipped-up in the Fishhook maneuver with 5 occupant loading (fishhook heavy or FH). It predicts a rollover rate that is strongly dependant on SSF but higher for vehicles that tip-up in this severe maneuver than for vehicles that do not tip up in the test.

The intent of using dynamic results from four tests was to provide tests with a range of severity to best discriminate between vehicles on the basis of dynamic performance. The Fishhook heavy maneuver was the most severe, and the J-turn light was the least severe. The expectation was that tip-up in the least severe maneuver would predict a greater rollover risk than tip-up in the most severe maneuver.

Figures II.10, II.11 and II.12 show logistic regression models using each of the other maneuvers as a single variable for dynamic results. In Figure II.10, vehicles that tip-up in J-turn heavy are predicted to have a slightly greater rollover risk than those that do not tip. However, in the Fishhook light and J-turn light maneuvers, the logistic regression models of Figures II.11 and II.12 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 in these maneuvers were too few to establish a definitive correlation. Only three vehicles tipped up in the J-turn light maneuver, and six vehicles tipped up in the Fishhook light maneuver. Only one more vehicle tipped up in the J-turn heavy maneuver than in the Fishhook light, and the

prediction of the model with J-turn heavy was consistent with expectations that tip-up in the test predicts greater rollover risk. However, the extra vehicle in the J-turn heavy tip-up group was the Ford Ranger 2 WD with a very large sample size of over 8,000 single vehicle crashes (nearly 10 percent of the entire data base).

Next we computed a logistic regression using both dynamic results variables, Fishhook heavy and J-turn heavy, that were observed to have a directionally correct result when entered into the model individually. The result was that the variable, J-turn heavy, was rejected by the logistic regression program as not statistically significant in the presence of the Fishhook heavy variable. In other words, the predictions based on tip-up in the Fishhook heavy maneuver do not change whether or not the vehicle also tips up in the J-turn heavy maneuver.

Figure II.13 shows the final model that uses only Fishhook heavy of the dynamic results variables. The printout of the SAS logistic regression procedure that establishes the coefficients of the model has been docketed separately. This model has a risk prediction for vehicles that tip up in the dynamic maneuver tests based on the greatest number of vehicles possible in our 25 vehicle data base. All 11 vehicles that tipped up in any maneuver are represented on the tip-up curve, and the 14 vehicles without tip-up are represented on the other curve. The logistic regression model based on SSF only for 100 vehicles is included for reference. It is very similar to the risk model with dynamic result variables for vehicles that tip up in the Fishhook heavy maneuver. This result is not surprising because the SSF only model was optimized for best fit in the 1.00 to 1.25 SSF range that included all vehicles tipping up in dynamic maneuver tests. The SSF only model was based on a vehicle sample that included 10 of the 11 vehicles that tipped up in the dynamic tests, but the sample included 90 additional vehicles. The fact that the prediction based on the SSF of 100 vehicles closely matches the prediction based on 11 vehicles that tipped up in the dynamic tests suggests that the small sample has produced a robust prediction although the predictive power of tip-up in the dynamic test may not be great.

In Figure II.13, the equation of the line representing the SSF only model (from the 100 vehicle database) is:

$$\text{Roll Rate} = \frac{1}{1 + e^{(2.7546 + 1.1814 \times \ln(\text{SSF}-0.90))}}$$

The equations for the final model representing a combination of SSF with dynamic scores for each of the dynamic results (tip-up and no tip-up) are:

$$\text{Roll Rate} = \frac{1}{1 + e^{(2.6968 + 1.1686 \times \ln(\text{SSF}-0.90))}} \text{ for tip - up in FH}$$

$$\text{Roll Rate} = \frac{1}{1 + e^{(2.8891 + 1.1686 \times \ln(\text{SSF}-0.90))}} \text{ for no tip - up}$$