U.S. Department
of Transportation

**National Highway
Traffic Safety
Administration**

Memorandum

Subject: SAE Paper on Rollover Risk Evaluation
Using CARDfile

Date: MAY 4 1987

From: Michael M. Finkelstein
Associate Administrator for
Research and Development

Reply to
Attn of:

To: Distribution

Attached for review is a draft copy of a paper entitled "Analysis of the Relationship Between Vehicle Rollover Stability and Rollover Risk, Using NHTSA CARDfile Accident Database". It presents the results from a statistical analysis of rollover risk which was performed on the Crash Avoidance Research Datafile. This paper may have bearing on Rulemaking's action regarding the petition submitted by Senator Timothy Wirth.

The paper is to be presented at the SAE Government/Industry meeting May 18-21, 1987. Due to the fast approaching deadline, we request your indulgence by getting your comments to us by Thursday, May 12, 1987.

Attachment

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DRAFT

Analysis of the Relationship Between Vehicle Rollover Stability and Rollover Risk Using the NHTSA CARDfile Accident Database

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Abstract

Statistical confirmation of the important relationship between vehicle rollover stability, as defined by the ratio of half track width to center of gravity height, and rollover risk, has been established using data extracted from the automated police accident reports of three states. A consistent and robust relationship between this measure of stability and single vehicle crashes involving rollover was found by means of linear regression analysis techniques. Tests for the effect of a variety of factors on rollover rate, including driver traits, and environmental factors, further substantiate the tendency for this type of crash to be associated with vehicles possessing a low rollover stability index.

Introduction

As part of its current research program in crash avoidance, NHTSA has undertaken an investigation of the relationship between rollover frequency in single vehicle accidents and a commonly accepted measure of vehicle rollover stability, i.e., the ratio of the half-track width to the center of gravity height. This study is motivated by the fact that rollover is a particularly grave accident type, both because of its high potential for producing serious injury and fatality and because of its high frequency in certain types of vehicles. The seriousness of the rollover problem is apparent from a brief examination of accident data. For example, based on 1981 data from the National Accident Sampling System (NASS) for police reported tow away passenger car accidents, as cited by Clark[1], there were approximately 2,628,000 injuries associated with passenger vehicle accidents of all types. Of these, approximately 8.6 percent or 226,025 of the injured (moderately or above) were involved in rollover accidents. Moreover, of the total of 294,000 people involved in rollover accidents, that were reported to the police, a total of 6,576 were killed. This represents nearly a quarter of the 26,545 people killed in passenger vehicles for all accident types in 1981. Obviously it is important to determine the degree to which vehicle design factors, such as the rollover stability index, are involved in rollover risk. This knowledge can then be applied to the development of effective countermeasures and consumer information advisories.

To carry out this study, a newly created accident datafile (CARDfile) has been utilized. This database has been constructed from information derived from police accident reports obtained from a selected sample of states. Due to the large size of this accident datafile and the particular structure of its data elements, it is more suited to crash avoidance applications than either the NCSS or the Fatal Accident Reporting System (FARS) databases, which are traditionally used by NHTSA. A more detailed description of this accident file will be found in a later section of this paper.

Previous studies of rollover accident data [2-9] suggest that vehicles with reduced roll stability, such as those that fall into the general category of light trucks and utility vehicles, also appear to have the highest rollover frequency. Since the popularity and market share of these types of vehicles has been increasing significantly in recent years, it is important to verify this apparent relationship through a rigorous statistical examination of the accident data. This requires that confounding factors which are associated with the driver or vehicle usage, and which may result in increased risk of rollover, also be taken into account. The determination of the extent of the relationship between rollover risk and rollover stability by means of an analysis of the CARDfile accident database is the primary objective of this study.

Crash Avoidance Research Data File: CARDfile

The selection of a database for the statistical study of accidents is a critical first step in the analysis process. This is because the choice of a data base may influence or obscure the outcome of the study. For example, the FARS database which consists solely of fatal accidents, is not well suited for the analysis of rollover risk, due to the extreme bias of this file toward crash worthiness factors, e.g., roof crush, restraint usage, etc. Although the FARS database has been used to estimate rollover risk [4] the results may be questioned for this obvious reason. A more suitable database for the study of rollover accidents would be any, or a combination of, the large state police automated accident files. These datafiles contain all police reported accidents, regardless of the degree of damage or injury severity level. These files, especially when combined in a standard data format, also provide sufficiently large numbers of observations to allow statistically significant conclusions to be drawn relative to the involvement of specific makes/models in certain types of crashes. This was the underlying philosophy of the recently developed CARDfile. [10,11]

CARDfile is an accident database, developed by NHTSA, to specifically support efforts in problem identification and to assist research in areas pertaining to crash avoidance. In addition to the advantages of large sizes, and the inclusion of the complete spectrum of accident severities, it also contains an array of variables associated with the pre-crash conditions and vehicle movements. The file itself is an adaptation, to a common data format, of accident data from six separate states, i.e., Indiana, Maryland, Michigan, Pennsylvania, Texas and Washington.

Accident records from the most recent three years from each state make up the total CARDfile dataset. Table 1 provides a numerical summary of the overall file contents relative to each contributing state. Obviously the large numbers of crashes contained in this file is a significant advantage in crash avoidance studies, as compared with other accident databases.

The structure of the CARDfile is similar to that of FARS in that it is divided into three inter-related subfiles, i.e., Accident File, Vehicle File, and Driver File. The Accident File contains information relating to the pre-crash movement of the vehicles, the accident type, and crash-site environmental conditions. The Vehicle File contains information relating primarily to the identification of the specific vehicle involved in the accident. The Driver File contains specific information about driver characteristics such as age, sex, impairment, etc., that may influence the frequency or injury severity of a certain accident category. A summary of the data elements in of each of the CARDfile subfiles is presented in Table 2.

In order to draw conclusions of national scope from the CARDfile database, its statistical representativeness to the national accident experience must be established. Salvatore, et.al.[12] have conducted a comparative analysis of CARDfile against NASS, and have concluded that for those variables evaluated across all six states, there is a ninety percent or greater agreement, on the average, with the national accident record. Of the items that differed by more than ten percent, the majority pertained to the highway description.

CARDfile Datasets for Rollover Analysis

The structure of the CARDfile database is such that data from any of the six states or any of the three accident years, may be considered individually or in any desired combination. This allows validation studies of statistical models to be conducted by comparison of results using subsets of the total database, as well as by comparing results from independent states. For the purpose of the rollover study, data was selected from the states of Texas and Maryland for the accident years of 1984 and 1985. The size of this combined database was large enough to allow for meaningful statistical projections, without entailing excessive computer processing time. As an independent check on the results from this combined database, a second dataset was constructed using Washington data for the accident years of 1983 through 1985. Finally, for some analyses these two data set were merged to form a single large datafile. After constructing the datasets, a number of specific vehicle make/models were selected for analysis of their rollover frequency. A series of nineteen foreign and domestic passenger cars along with eight utility vehicles were chosen for investigation. These vehicles were selected such that they would span, without significant gaps, the complete range of rollover stability factors from large American passenger cars to utility vehicles. In addition to this basic set of twenty seven vehicles, a number of so called "sister vehicles" were also included. These are vehicles such as the Chevrolet Citation and Oldsmobile Omega, which for all practical purposes have identical chassis designs, even though they carry different make/model designations. With the inclusion of these vehicles, a total of forty vehicle make/models are contained in the study sample. A complete listing of the vehicles chosen for this study, together with important geometrical and center of gravity (c.g.) data is included in Tables A1a, A1b, and A1c, in the appendix of this paper.

Once the vehicle make/models were defined, a census of the contents of the individual and combined data set was performed. It is noteworthy that even though the relative size of the Maryland and Texas data files differ by a factor of three, the percentage of rollover to single vehicle accidents (RO/SVA) for the selected vehicles is nearly identical for the two files, i.e., 11.2 percent for Texas and 10.2 percent for Maryland. Table 3 summarizes the contents of the individual and combined data sets in terms of the RO and SVA values. A detailed listing of the contents of the Texas, Maryland and Washington data sets by individual vehicle make/model designation is contained in Tables A2a, A2b, A2c, in the appendix.

Univariate Regression Analysis of Rollover Propensity

Using the databases described above, a series of univariate regression analyses were carried out to determine the extent to which rollover risk is correlated with the rollover stability factor, for the given sample of vehicles. To perform this analysis, a measure of rollover risk must be selected. Possible candidates for this risk measure include, (1) Rollovers per mile traveled, (2) Rollovers per Vehicle Registration, (3) Rollovers per Accident, and (4) Rollovers per Single Vehicle Accident. None of these measures is perfectly ideal. For example, rollovers per mile traveled suffers from the difficulty in establishing mileage values for specific vehicles. In addition, Jones [3] has demonstrated that this measure is unreliable for cars with highly different handling characteristics. Likewise, rollovers per vehicle registration is not particularly well suited as a risk metric because vehicle registration per se does not afford an opportunity for rollover. Also, given that the vast majority of vehicle rollovers are single vehicle accidents, the use of rollovers per accident, regardless of accident type, will be influenced by uncontrolled traffic exposure variables. An example of this is second party driver error in multiple vehicle accidents. Since our objective is to focus on specific vehicle factors which may influence rollover, it appears that the most suitable risk measure for this purpose is rollovers per single vehicle accident and more precisely percent RO/SVA.

The regression analyses were performed using conventional Statistical Analysis System (SAS) statistical software installed at the National Institutes of Health (NIH) computer facility. Linear regression models were computed for each of the four base state/accident years separately, i.e., MD84, MD85, TX84, and TX85, and for the collected or combined dataset as well. Figures 1-4 show the linear regression curves for the separate state/accident years. Figure 5 shows the regression curve for the combined data set, and Figure 6 is a plot of the corresponding regression residuals. The corresponding R-squared statistics and coefficient estimates are reported in Table 4.

The value of R-squared, which is the square of the correlation coefficient, is a measure of the linear relationship between the rollover risk and the rollover stability factor, estimated by the data sample. Another interpretation for R-squared is the explained variance, i.e., the amount of variation in the rollover risk due to changes in the rollover stability factor. High values for R-squared, of course, imply a good model fit. It can be observed from the values reported in Table 4 that a robust relationship is revealed between rollover risk and the rollover stability factor, especially when the combined data sets are utilized.

As an independent validation of the linear regression model determined for the Maryland and Texas data, a similar regression was performed on the accident data from Washington for the accident years of 1983-1985. The regression curve for this data is illustrated in Figure 7, and the R-squared values and coefficient estimates are also shown in Table 4. As can be observed, there is remarkable agreement between the regression equations which describe these independent data sets, especially when the Washington data is compared with the combined Maryland and Texas data. Likewise, the high R-squared value of 0.84 obtained for both of these datasets indicates a clear relationship between rollover risk and rollover stability factor.

For the sake of completeness, a linear regression analysis was also performed on the total combined database, consisting of the merged Maryland, Texas, and Washington datafiles. As shown in Table 3, this combined dataset contains approximately 40,000 single vehicle accidents and 5,000 rollover accidents, for the vehicle sample used. The corresponding regression curve is illustrated in Figure 8, together with a plot of the regression residuals in Figure 9. The R-square value for this model was 0.86.

Lastly, linear regressions were also performed of rollover accidents per 100,000 registered vehicles, and single vehicle accidents per 100,000 registered vehicles, both against the rollover stability factor. The results of these regressions are shown in the last two rows of Table 4. It is evident that a reasonably strong correlation exists between RO/100,000 registered vehicles and the rollover stability factor.

(R-squared = 0.66) although it is much less than for RO/SVA for the reasons discussed earlier. However, there is practically no correlation between SVA/100,000 registered vehicle and the rollover stability factor (R-squared = 0.007). This demonstrates that within the class of single vehicle accidents, the vehicle parameter defined as the rollover stability factor, exerts an influence on only one specific accident type, i.e., vehicle rollover.

Effect of Vehicle Size on Rollover Risk

Some past investigations have suggested that vehicle size is a principal vehicle parameter in determining rollover risk. Size is defined either in terms of gross vehicle weight or, more typically, in terms of wheelbase. This conclusion has been examined using linear regression analysis of the CARDfile database. The results indicate that there is,in fact, a high correlation between rollover risk, as measured by percent RO/SVA, and wheelbase. However, upon further examination, it appears that this correlation is explainable in terms of the covariance that exists between vehicle track width and wheelbase .i.e., longer vehicles tend to have wider tracks and vice versa. This covariance is illustrated in Table 5, which is a matrix of correlation coefficients of rollover risk and various geometric vehicle variables, including wheelbase. As can be seen, the wheelbase and track width are closely related with a correlation coefficient of 0.81. Moreover, if the wheelbase is normalized by the c.g. height, then this variable is even more highly correlated with the rollover stability factor, having a coefficient 0.93. This is also illustrated by the linear regression curve shown in Figure 10. Obviously then, one would expect that the rollover risk would correlate equally well with either the rollover stability factor or the normalized wheelbase. This is indeed the case, as is shown in Figure 11.

Effects of Driver and Environmental Factors

A number of variables associated with driver characteristics and environmental factors have also been investigated to determine the extent to which they influence rollover risk. Table 6 lists the nineteen different driver and environmental variables that were examined. All of these factors are recorded both in the Texas and Maryland state datafiles with the one exception of Factor 5, "urban land use". Therefore, this variable was considered separately, utilizing only the Maryland state database, as will be discussed later. The remaining variables were evaluated using the combined Maryland and Texas datafiles.

As a preliminary step to conducting the multivariate regression analysis, a survey of the combined dataset contents was conducted for each of the nineteen variables. The results are expressed as a percent of the dataset content for each variable and are broken out for both rollover and single vehicle accidents. The results of this survey are shown in bar chart form in Figure 12.

From this dataset survey, a subset of the variables were selected for detailed analysis using multivariate regression analysis techniques. This variable subset, including the rollover stability factor, is given in Table 7. The combined dataset from Texas and Maryland for the accident years of 1984 and 1985 was utilized to conduct the multivariate analysis. A standard "step down" multivariate regression technique was employed. This procedure consists of a stepped process wherein the variable with the least statistical significance, as determined by its "t" statistic, is eliminated from the linear regression model, prior to proceeding to the next step. At the end of this procedure, only those variables that have true statistical significance are retained.

The results of the stepped multivariate regression analysis are given in Table 8. For the Texas and Maryland combined dataset, only three variables were shown to be significant in influencing the rollover risk, i.e. rollover stability factor, percent drivers under 25 years old, and percent male drivers. It is noteworthy however, that the R-squared value for this multivariate model has improved only slightly over the value obtained from the univariate analysis, i.e., 0.92 as opposed to 0.84.

To test the consistency of the multivariate regression model, a second regression analysis was carried out using only data from Maryland for the accident years of 1984 and 1985. A similar stepped analysis procedure was performed and the results are contained in Table 9. In this second procedure, only the vehicle rollover stability factor and driver sex remained as consistent influencing factors, while the drive age was replaced with alcohol/drug involvement. The R-squared value again has increased only modestly over that obtained from the univariate analysis, i.e., 0.81 as opposed to 0.70. It is not yet clear, what factors account for this inconsistency in the regression model between the two datasets. However, it is obvious that the overwhelming influence on rollover risk is still due to the vehicle rollover stability factor, as was found in the univariate analysis.

Finally, a third multivariate regression analysis was performed using the Maryland data for 1984 and 1985. The reason for conducting this analysis was to evaluate the significance of "rural land use" as a variable. As noted at the beginning of this section, this variable is not coded in the Texas data, and hence can only be evaluated with the Maryland data file. Although this variable was found to be statistically significant, we shall not repeat the stepped regression table here for the sake of conciseness. Instead we present only the final regression equation and its R-squared value;

$$\%RO/SVA = 32.0 - 39.9\,(X1) + 0.24\,(X4) + 0.4\,(X5) - 0.26\,(X10)$$

$$\text{R-Squared} = 0.88$$

Conclusions

An analysis of single vehicle accident data has shown that a high degree of correlation exists between the risk of vehicle rollover and the vehicle rollover stability factor. This correlation has been substantiated by statistical regression analyses conducted on independent state accident datasets contained in the NHTSA CARDfile. Various driver and environmental factors were also evaluated as to their influence on rollover risk by means of multivariate stepped regression analysis techniques. Although drivers sex was shown to be consistently significant across all data sets, the overwhelming variable in explaining rollover rate variations as a function of vehicle make/model designation, is the vehicle rollover stability factor.

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Appendix

Tables A1a, A1b and A1c of this appendix contain summary data on vehicle geometric and c.g. characteristics by make/model designation for the vehicles used in this study. In these tables, the wheelbase is denoted by L, the c.g. height by H and the track width by T. The numbers in the "source" column refer to the list of references from which this data was obtained.

Tables A2a, A2b and A2c likewise contain the RO/SVA count by state and accident year for each make/model designation as derived from the CARDfile database.

Table 1 — Summary of CARDFILE State Crash Experience (1983—1985)

State	No. Crashes	No. Vehicles
Indiana	480,399	854,571
Maryland	384,450	717,284
Michigan	1,023,366	1,724,288
Pennsylvania	414,210	694,854
Texas	1,341,415	2,326,103
Washington	338,307	617,093
Totals	3,982,117	6,934,193

Table 2 — CARDFILE Data Elements

Accident	Vehicle	Driver
Day of Crash	Crash Type	Age
Month of Crash	Make/Model	Sex
Year of Crash	Model Year	Alcohol/Drug Use
Time of Crash	Vehicle Type	Restraint Use
Number of Vehicles	Component Failures	Helmet Use
Crash Severity	Precrash Stability	Driver Error
Precrash Movement	Avoidance Action	
Light Conditions	Injury Severity	
Weather Conditions		
Road Surface		
General Land Character		
Primary Impact		
Location of Impact		
Relation to Intersection		
Intersection Signaling		
Roadway Alignment		
Roadway Profile		
Roadway Separation		

Table 3 — Contents of CARDFile Data Sets

ROLLOVER AND SINGLE VEHICLE ACCIDENTS			
STATE/YR.	RO	SVA	RO/SVA
MD 84	368	3,346	0.110
MD 85	307	3,156	0.097
TX 84	1,323	11,195	0.118
TX 85	1,174	11,085	0.106
WA 83–85	1,738	11,055	0.157

$$Y = A0 + A1 \bullet X$$

Table 4 — Univariate Regression Analysis for Various Data Sets

RESULTS TABLE — UNIVARIATE REGRESSION ANALYSIS						
Data Set	Y	X	A1	A2	R-SQUARED	MIN. OBS
MD 84	PERCENT — RO/SVA	T/2H	97.8	−63.7	0.81	7
MD 85			77.8	−49.7	0.58	7
TX 84			123.7	−81.0	0.84	7
TX 85			111.3	−72.5	0.80	7
MD (84+85)			89.6	−56.3	0.70	21
TX (84+85)			117.2	−76.6	0.86	21
MD+TX (84+85)			112.5	−73.6	0.84	21
WA (83–85)			114.0	−74.0	0.84	21
MD+TX (84+85)	PERCENT— RO/100,000 REG. VEH.	T/2H	962.9	−617.9	0.66	21
MD+TX (84+85)	PERCENT— SVA/100,000 REG. VEH.	T/2H	638.2	243.3	0.007	21

Table 5 – Corelation Coefficients for Geometric Vehicle Parameters

	RO/SVA	H	T	L	T/2H	L/H
RO/SVA	1.00	0.75	0.52	0.65	−0.92	−0.94
H	0.75	1.00	0.05	−0.09	−0.82	−0.80
T	−0.52	0.05	1.00	0.81	0.52	0.45
L	−0.65	−0.09	0.81	1.00	0.52	0.66
T/2H	−0.92	−0.82	0.52	0.52	1.00	0.93
L/H	−0.94	−0.80	0.45	0.66	0.93	1.00

Table 6 — Definition of Exposure Factors

FACTOR NO.	DEFINITION
1	AVERAGE DRIVER AGE
2	LOCATION OF INITIAL IMPACT WAS ON ROAD SHOULDER
3	LOCATION OF INITIAL IMPACT WAS ON THE ROAD
4	LAND USE AT THE CRASH SITE IS RURAL
5	LAND USE AT THE CRASH SITE IS UBRAN
6	ROADWAY HAS RISE OR DROP AT ACCIDENT SITE
7	DARK AT TIME OF CRASH
8	ROADWAY IS CURVED AT CRASH SITE
9	VEHICLE WAS TRACKING PRIOR TO CRASH
10	ROADWAY WAS WET
11	ROADWAY WAS SNOW COVERED
12	WEATHER INVOLVED RAIN OR SNOW AT TIME OF ACCIDENT
13	DRIVER WAS LESS THAN 25 YEARS OLD
14	INDICATION OF ALCOHOL OR DRUG USE BY DRIVER
15	NO RESTRAINTS IN USE BY DRIVER
16	DRIVER WAS MALE
17	NO EVIDENCE OF COMPONENT FAILURE CITED
18	ACCIDENT OCCURRED AT DUSK OR DAWN
19	SLEEP OR GROSS INATTENTIVENESS CITED

Table 7 — Independent Variables — Multivariate Regression Analysis

VARIABLE	DEFINITION
X1	ROLL STABILITY FACTOR — T/2H
X2	PERCENT DRIVERS UNRESTRAINED
X3	PERCENT DRIVERS UNDER 25 YEARS OLD
X4	PERCENT MALE DRIVERS
X5	PERCENT ACCIDENTS WITH DRUG/ALCOHOL INVOLVEMENT
X6	PERCENT ACCIDENTS OCCURING ON CURVES
X7	PERCENT ACCIDENTS WHERE ROAD SURFACE HAD SNOW OR ICE
X8	PERCENT ACCIDENTS WHERE WEATHER INVOLVED RAIN, SNOW OR ICE
X9	PERCENT ACCIDENTS OCCURING ON GRADES
X10	PERCENT ACCIDENTS OCCURRING OR RURAL ROADS

Table 8 – Stepped Multivariate Analysis – MD+TX (84+85)

STEP NO.	XI	Ao	AI	R–SQUARE	t	Prob.>t
1	X1	78.3	−64.6	0.93	−10.3	0.0001
	X2		−0.05		−0.33	0.74
	X3		0.21		3.47	0.0016
	X4		0.24		2.77	0.0095
	X5		−0.29		−1.51	0.140
	X6		0.17		0.77	0.45
	X7		0.19		0.63	0.53
	X8		0.03		0.20	0.85
	X9		−0.10		−0.60	0.55
2	X1	78.8	−64.8	0.93	−10.5	0.0001
	X2		−0.05		−0.33	0.740
	X3		0.21		3.50	0.0013
	X4		0.25		2.80	0.008
	X5		−0.30		−1.56	0.130
	X6		0.17		0.78	0.44
	X7		0.20		0.70	0.49
	X9		−0.10		−0.61	0.55
3	X1	74.7	−64.0	0.93	−11.40	0.0001
	X3		0.20		3.80	0.0007
	X4		0.30		3.50	0.0016
	X5		−0.33		−2.0	0.05
	X6		0.20		1.18	0.25
	X7		0.20		0.70	0.49
	X9		−0.10		−1.30	0.20
4	X1	75.7	−65.3	0.93	−12.30	0.0001
	X3		0.20		3.95	0.0004
	X4		0.27		3.70	0.0008
	X5		−0.30		−2.10	0.040
	X6		0.20		1.40	0.18
	X9		−0.10		−1.10	0.30
5	X1	78.4	−66.5	0.92	−12.8	0.0001
	X3		0.20		4.3	0.0002
	X4		0.24		3.5	0.0013
	X5		−0.30		−1.8	0.077
	X6		0.10		0.9	0.40
6	X1	84.6	−69.2	0.92	−16.0	0.0001
	X3		0.20		8.0	0.0001
	X4		0.20		3.4	0.0016
	X5		−0.2		−1.60	0.11
7	X1	82.4	−67.7	0.92	−15.70	0.0001
	X3		0.20		4.60	0.0001
	X4		0.20		3.00	0.0054

Table 8 — Stepped Multivariate Analysis — MD (84+85)

STEP NO.	Xi	Ao	Ai	R—SQUARE	t	Prob.>t
1	X1	61.1	−54.4	0.83	−6.2	0.0001
	X2		−0.03		−0.30	0.80
	X3		0.05		0.70	0.50
	X4		0.20		1.90	0.08
	X5		0.50		2.40	0.20
	X6		−0.10		−0.50	0.60
	X7		0.05		0.20	0.80
	X8		−0.20		−0.90	0.40
	X9		0.30		1.40	0.20
2	X1	61.8	−55.0	0.83	−6.7	0.0001
	X2		−0.03		−0.26	0.80
	X3		0.05		0.71	0.50
	X4		0.20		1.90	0.07
	X5		0.50		2.50	0.02
	X6		−0.10		−0.51	0.61
	X8		−0.20		−0.90	0.40
	X9		0.30		1.40	0.20
3	X1	58.5	−54.4	0.83	−6.50	0.0001
	X3		0.04		0.60	0.54
	X4		0.20		2.0	0.05
	X5		0.40		2.70	0.01
	X6		0.03		0.15	0.90
	X8		−0.20		−1.20	0.20
	X9		0.20		1.30	0.20
4	X1	59.0	−54.8	0.83	−7.00	0.0001
	X3		0.04		0.60	0.50
	X4		0.20		2.00	0.04
	X5		0.40		2.80	0.009
	X8		−0.20		−1.20	0.20
	X9		0.20		1.40	0.20
5	X1	57.8	−53.9	0.83	−7.0	0.0001
	X4		0.20		2.2	0.04
	X5		0.40		3.2	0.004
	X8		−0.20		−1.3	0.20
	X9		0.30		1.6	0.10
6	X1	46.5	−49.1	0.82	−7.3	0.0001
	X4		0.30		2.9	0.006
	X5		0.40		3.0	0.005
	X9		0.2		1.2	0.30
7	X1	56.4	−51.1	0.81	−7.80	0.0001
	X4		0.30		2.90	0.007
	X5		0.40		2.90	0.007

Table 10· Stepped Multivariate Analysis — MD (84+85)

STEP NO.	Xi	Ao	Ai	R-SQUARE	t	Prob.>t
1	X1	61.1	-54.4	0.83	-6.2	0.0001
	X2		-0.03		-0.30	0.80
	X3		0.05		0.70	0.50
	X4		0.20		1.90	0.08
	X5		0.50		2.40	0.20
	X6		-0.10		-0.50	0.60
	X7		0.05		0.20	0.80
	X8		-0.20		-0.90	0.40
	X9		0.30		1.40	0.20
2	X1	61.8	-55.0	0.83	-6.7	0.0001
	X2		-0.03		-0.26	0.80
	X3		0.05		0.71	0.50
	X4		0.20		1.90	0.07
	X5		0.50		2.50	0.02
	X6		-0.10		-0.51	0.61
	X8		-0.20		-0.90	0.40
	X9		0.30		1.40	0.20
3	X1	58.5	-54.4	0.83	-6.50	0.0001
	X3		0.04		0.80	0.54
	X4		0.20		2.0	0.05
	X5		0.40		2.70	0.01
	X6		0.03		0.15	0.90
	X8		-0.20		-1.20	0.20
	X9		0.20		1.30	0.20
4	X1	59.0	-54.8	0.83	-7.00	0.0001
	X3		0.04		0.60	0.50
	X4		0.20		2.00	0.04
	X5		0.40		2.80	0.009
	X8		-0.20		-1.20	0.20
	X9		0.20		1.40	0.20
5	X1	57.8	-53.9	0.83	-7.0	0.0001
	X4		0.20		2.2	0.04
	X5		0.40		3.2	0.004
	X8		-0.20		-1.3	0.20
	X9		0.30		1.6	0.10
6	X1	46.5	-49.1	0.82	-7.3	0.0001
	X4		0.30		2.9	0.006
	X5		0.40		3.0	0.005
	X9		0.2		1.2	0.30
7	X1	56.4	-51,1	0.81	-7.80	0.0001
	X4		0.30		2.90	0.007
	X5		0.40		2.90	0.007

Table A1.B — Vehicle Data — Imported Passenger Cars

VEHICLE GEOMETRIC AND ROLL STABILITY DATA							
Veh. No.	Make/Model	Year	L—IN.	H—IN.	T/2—IN.	T/2H	SOURCE
9	AUDI 4000	ALL	99.8	20.4	26.9	1.32	5,9
10	DATSUN Z,ZX	ALL	91.3	19.4	27.2	1.40	5,9
11	DATSUN B210	ALL	92.1	20.3	24.2	1.19	5,9
12	RENAULT LE CAR	ALL	95	20.9	24.5	1.17	5,9
13	HONDA CIVIC	<83	94.5	20.7	26.3	1.27	5,9
14	TOYOTA COROLLA	<79	93.3	20.7	25.5	1.23	5,9
15	VW BEETLE	<80	94.5	22.5	26.6	1.18	5,9
16	VW RABBIT	ALL	94.5	21.1	27.0	1.28	5,9
17	MAZDA GLC	<80	91.1	20.5	24.6	1.20	5,9

Table A1.C — Vehicle Data — Domestic Passenger Cars

	VEHICLE GEOMETRIC AND ROLL STABILITY DATA						
Veh. No.	Make/Model	Year	L–IN.	H–IN.	T/2–IN.	T/2H	SOURCE
		81–84	121.4	21.7	30.8	1.42	5,9
18	CAD. DEVILLE/BROUGHAM	80–81	104.9	21.0	28.9	1.38	9,4
19	CHEV. CITATION						
	OLDS. OMEGA						
	BUICK SKYLARK						
	PONTIAC PHOENIX	79	97.3	19.8	27.0	1.36	1,5
20	CHEV. CHEVETTE	73	98.0	18.2	28.8	1.57	1,5
21	CHEV. CORVETTE	ALL	108.0	18.7	29.4	1.57	5,9
22	CHEV. CAMERO						
	PONTIAC FIREBIRD	78–81	108.0	21.7	30.4	1.40	5,9
23	CHEV. MALIBU						
	OLDS. CUTLASS						
	CHEV. MONTE CARLO						
	BUICK CENTURY/REGAL						
	PONTIAC LEMANS	77–81	112.7	20.8	30.0	1.44	5,9
24	CHRYSLER CORDOBA						
	DODGE DIPLOMAT						
	DODGE MIRADA						
	CHRYSLER LEBARON	79–81	100.4	20.0	28.3	1.41	8,8
25	FORD MUSTANG						
	MERCURY CAPRI	79–81	114.0	21.2	28.4	1.34	5,9
26	FORD LTD						
	MERCURY MARQUIS	80	108.0	19.8	26.7	1.36	
27	AMC CONCORD						