American Motors Corporation
Vehicle Environmental and Safety Affairs
14250 Plymouth Road
Detroit, Michigan 48232
(313) 493-3046

FILE

January 21, 1987

PRM-M.P.-006

Miss Diane K. Steed
Administrator
National Highway Traffic Safety Administration
400 Seventh St., S.W.
Washington, D.C. 20590

ATTENTION: Docket No. PRM M.P.

Dear Miss Steed:

The National Highway Traffic Safety Administration (NHTSA) has been requested by a petition dated September 16, 1986, to initiate rulemaking and other actions related to the rollover risk of passenger cars, utility vehicles, and pick-up trucks. The petition suggests that a May 1986 study prepared by A.B. Kelley and Leon Robertson "...isolates the cause of rollover when measured against many other factors...addresses many questions which have heretofore been unresolved, and provides a basis for setting an objective and practicable safety standard." The recommended basis for a safety standard is a stability factor defined as one-half the track width divided by the height of the center of gravity (T/2h). The petition specifically recommends that vehicles be required to have a T/2h value of 1.2 or greater.

American Motors Corporation (AMC) encourages NHTSA to carefully and comprehensively review the issues raised in the petition. NHTSA should determine if a sound scientific basis for rulemaking or other action exists, prior to proceeding further. In particular, the Kelley/Robertson report should be objectively reviewed for scientific validity since this study is the principal basis of the petition.

AMC believes that the Kelley/Robertson report presents a severely flawed analysis that is not sound science. The data used in the study are inadequate and not representative of either the vehicle population at risk or rollover accidents. Further, these data contain notable errors. For example, about seventy-five percent of the Blazer accident data were omitted because vehicle identification numbers were not used to identify vehicles. The report

SAFETY IS A SNAP

utilized linear regression as the analysis method. The appropriateness of this method was not demonstrated and this method was applied in a manner that does not adequately control for confounding factors. Importantly, the analysis uses an inadequate measure, rollovers per-crash. This measure expresses the likelihood of a rollover given a crash and is not sensitive to the effects of pre-crash factors or types of crashes. Clearly, the Kelley/Robertson report does not demonstrate that T/2h is a valid predictor of rollover risk. Thus, T/2h is not established as an objective and valid criterion for rulemaking or determination of defect as the petition asserts. A more detailed critique of the Kelley/Robertson report is attached.

Objective stability criteria would be an aid to manufacturers and the public. Rollover accidents are extremely complex events that involve many environmental and human factors in addition to vehicle factors. We are not aware of any objective criteria that correlate rollover risk with vehicle design geometry. Static ratios like T/2h have not been shown to be good predictors of dynamic vehicle behavior.

AMC would welcome the development of objective criteria based on an in-depth and scientifically sound understanding of the role that human, vehicle, and environmental factors play in crash causation and injury production. Such criteria could assist manufacturers in the design of vehicles with improved in-use stability and could also aid consumers in determining the relative real-world rollover risk of a specific vehicle. However, scientifically valid research has not yet developed such criteria and it is unclear that such criteria can be developed.

The petition also requests NHTSA to advise vehicle owners regarding rollover risk. NHTSA presently requires that a label be placed on utility vehicles providing information on vehicle characteristics. Additional information is provided by manufacturers in owner's manuals. AMC has developed information on how to operate a four-wheel-drive vehicle that is part of the glovebox material for new vehicles. Further, the 1982 version of the consumer information packet was sent to registered owners of vehicles in use as well. AMC has supported, and continues to support, the effective dissemination of product information to consumers. The scientific literature does not provide clear guidance on the most effective ways to communicate safety information. In fact, there is a lack of evidence showing the effectiveness of consumer warnings in reduction of risk. AMC recommends that NHTSA carefully consider the consumer information aspects of the petition. Manufacturers should be advised if a method of information dissemination is identified that would enhance communication with our consumers.

In conclusion, AMC supports the concept of developing objective criteria that would correlate vehicle design with real-world rollover accident risk. At this time, AMC is not aware of such criteria. A criterion based on T/2h value is not supported by sound science.

Sincerely yours,

James A. Carlson

James A. Carlson, Director
Vehicle, Safety and Health
Regulatory Affairs

JAC/js

Attachment: "Critique of Robertson/Kelley Report"

6990E/1668

APPENDIX A

CRITIQUE OF ROBERTSON/KELLEY REPORT

Robertson and Kelley (1986) have written a report that alleges there is a firm mathematical relationship between rollovers per crash and vehicle stability (where vehicle stability is defined as T/2H = one half the track width divided by the height of the center of gravity).

Robertson and Kelley use rollovers per crash as their primary comparative risk measure. The crash data are obtained from the 1981-1984 Fatal Accident Reporting System (FARS) data. Vehicle stability data for 14 vehicles are from two sources (Snyder et al. 1980 and Rice et al. 1978). The authors claim to establish a mathematical relationship between rollovers per crash and vehicle stability using linear regression analysis. They support the strength of the relationship they developed by constructing twenty regression equations, each containing rollover/crash as the dependent variable, T/2H as one independent variable, and one of twenty driver or environmental confounding factors as a second independent variable. Robertson and Kelley purport to control for the effect of various factors on rollovers/registered vehicle by an analysis using mileage data.

Major problems exist in the Robertson/Kelley Report: use of an inappropriate rollover risk measure, inadequate selection and careless use of data, minimal and improperly executed control for the effect of confounding factors on the rollover risk measures, and an inadequate analytical method.

ROLLOVER RISK MEASURE

The rollover risk measure used by Robertson and Kelley is rollovers per crash, a proportion. Inherent in the use of this measure is the assumption that the rollovers in the numerator are drawn from a set of crashes in the denominator that represents the complete set of events that could result in a rollover. This assumption is false and leads to errors in comparing vehicles.

The denominator in rollovers per crash may not contain equivalent sets of crashes for all vehicles. This is because different vehicle types are involved in different types of crashes and events, and not all the events are reported as crashes. Often such events are not represented in the mass accident data bases. The denominator of the primary comparative risk measure used is all crashes. This is the main exposure measure used by Robertson and Kelley. They also use registered vehicle data as an exposure measure for some analyses.

In order to have a reasonable comparison of vehicle-specific risks, the exposure measure used in calculating the risks (either in rates or proportions) must account for the differences in quality and quantity of vehicle exposure. Otherwise the effects of the vehicles' use and user characteristics remain in the calculated risk. Both exposure measures used by Robertson and Kelley are inadequate because they do not account for the use or user characteristics of the vehicles being studied.

DATA PROBLEMS

The Robertson/Kelley Report is replete with data problems and errors. Major problems include the following: the FARS data base is not representative of all crashes in the United States, important variables are not included in the analysis, others are included that are irrelevant or misleading, the data used cannot be reproduced, oversights occurred in selecting the data, and the data set used is a sample of convenience.

DATA NOT REPRESENTATIVE

While FARS data are available for hundreds of vehicle types, the authors identified T/2H data for fourteen vehicles and used only those vehicles as the study population. The fourteen vehicles are not representative of the fleet of vehicles on the road in the United States. Thus, the fourteen vehicles are a sample of convenience.

One could argue that a representative sample is not needed, but rather only a good range of variation in observations. This argument holds only if the vehicles are selected to represent essentially the entire ranges of stabilities for utility vehicles and for passenger cars and if they are selected without reference to rollover frequency. There is no substantiation in the report that the vehicles selected cover the ranges of stabilities for utility vehicles and for passenger cars. If the vehicles were selected because they had unusually high or low rollover frequencies, the sample could be seriously biased.

Single T/2H Value for Several Vehicles

In the FARS file one make/model variable code often represents more than one configuration of a vehicle. This is true for the make/model #1206, Ford LTD, Galaxy, Custom (National Highway Traffic Safety Administration 1982, p. 86).

Figure A-1 lists the vehicles represented in make/model code #1206. Robertson and Kelley use only one T/2H value to represent all nine of these vehicles. Clearly, one T/2H value cannot accurately represent a range of vehicles including sedans and station wagons.

Figure A-1

FARS 1981-1984

MAKE MODEL CODE 1206

FORD LTD, GALAXY, CUSTOM

Includes

XL	S
Landau	500, 500XL
Ranch Wagon	Crown Victoria
Country Squire	Brougham

FARS DATA

The FARS data base represents a census of all motor vehicle accidents in the United States in which a fatality occurred. Fatal accidents, however, comprise less than one percent of all motor vehicle accidents in the United States (National Safety Council 1984, p. 40). Thus, while FARS is the most comprehensive source available for studying fatalities, it does not include over 99 percent of the accidents in this country which may provide insight into vehicle rollovers.

VIN Removed From Data Base

The FARS data used by Robertson and Kelley are taken from the 1981-1984 FARS data tapes. Robertson and Kelley did not look at individual years of data. Rather, the data from 1981-1984 annual tapes were aggregated into one composite tape. In preparing the composite tape, Robertson and Kelley filtered out those variables not of interest to them. An important variable which was excluded in their filtering process was the Vehicle Identification Number (VIN). This is important because without the VIN it is impossible to confirm the make and model of vehicles included in the data base used for analysis.

Toronado and Blazer Data

The FARS data used by Robertson and Kelley are not reproducible. An attempt was made to reproduce the number of pre-1979 Toronados reported by Robertson and Kelley. This was not possible to do, even though the exact variables used by Robertson and Kelley were applied to the FARS data base. This is a straightforward procedure performed by accessing the FARS tapes obtained by the University of Michigan from the National Highway Traffic Safety Administration.

Figure A-2 shows in its first column the number of crashes of pre-1979 Toronados obtained from the 1981-1984 FARS data tapes where there was a death in the Toronado. These crashes are sorted by single-vehicle and multi-vehicle crashes, and first harmful event equals overturn and first harmful event other than overturn. The second column shows the number of pre-1979 Toronados reported by Robertson and Kelley in their data tabulations. Robertson and Kelley report 67 percent more pre-1979 Toronado crashes than are actually in the FARS file.

An attempt was also made to reproduce the Blazer data reported by Robertson and Kelley. An anomaly in the data is revealed when the number of accidents by year individually for 1981, 1982, 1983, and 1984 are printed out. The number of accidents of Blazers dropped sharply in the FARS data base from 1981 to 1982, 1983, and 1984.

Figure A-3 shows in its first column the number of crashes of Blazers from the 1981-1984 FARS tapes where the death occurred in the Blazer. These crashes are sorted by multi-vehicle and single-vehicle crashes, and first harmful event equals overturn or not overturn. The second column shows the number of Blazer crashes reported by Robertson and Kelley in their data tabulations. The total numbers are fairly close, but the notable point is the drop in counts from 1981 to subsequent years. This drop is not obvious in the Robertson/Kelley data because they did not examine their data by year, but only in the aggregate.

To further understand what occurred, the FARS code books were checked. In 1981, the number of Blazer accidents, coded as variable number 103, case number 2071, was 413. The FARS code books for 1982, 1983, and 1984, however, list the numbers of Blazers involved in fatal crashes as only 9, 12, and 13, respectively (The University of Michigan 1982, p. 22; 1983, p. 25; 1984, p. 53; 1985, p. 45).

Figure A-2

TORONADOS: 1981-1984 FARS

Pre-1979

	FARS	Robertson/Kelley
Single Vehicle		
1981		
Rollover	3	
Other	13	
1982		
Rollover	0	
Other	12	
1983		
Rollover	1	
Other	2	
1984		
Rollover	1	
Other	0	
Rollover Total	5	12
Other Total	27	37
Multi-Vehicle		
1981		
Rollover	0	
Other	16	
1982		
Rollover	0	
Other	10	
1983		
Rollover	0	
Other	6	
1984		
Rollover	0	
Other	8	
Rollover Total	0	1
Other Total	40	70
Total Crashes	72	120

Figure A-3

BLAZERS: 1981-1984 FARS

	FARS	Robertson/Kelley
Single Vehicle		
1981		
Rollover	54	
Other	105	
1982		
Rollover	2	
Other	4	
1983		
Rollover	1	
Other	2	
1984		
Rollover	1	
Other	4	
Rollover Total	58	52
Other Total	115	105
Multi-Vehicle		
1981		
Rollover	0	
Other	43	
1982		
Rollover	0	
Other	1	
1983		
Rollover	0	
Other	2	
1984		
Rollover	0	
Other	3	
Rollover Total	0	0
Other Total	49	43
Total Crashes	222	200

The Blazer accidents in those three years apparently were coded differently than in 1981. Because Robertson and Kelley aggregated their data for 1981-1984, they were apparently unaware of this change. Robertson and Kelley did not use about 75 percent of the Blazer accidents over the study analysis period.

Omitted Variables

In their analysis, Robertson and Kelley did not use all of the FARS data available to them, specifically variables that would have been relevant in studying rollovers per crash. Examples of these available but unused FARS variables include vehicle maneuver, variable 138; vehicle speed, variable 124; and driver behavior, variable 223.

Misleading Variables

Robertson and Kelley used variables that could be considered misleading. For example, the variables, prior convictions and prior crashes, were used by Robertson and Kelley. Whether a driver has a prior conviction or a prior crash has very little to do with the occurrence of a rollover once a crash has been initiated. Such variables are used by Robertson and Kelley, allegedly to control for the effect of confounding factors.

Aggregated Variables

In the controlling procedure in which Robertson and Kelley used FARS data in their regression analysis they convert multi-category variables into bifurcated variables. For example, one of Robertson's and Kelley's variables is off- versus on-road. The relevant variable in the FARS code book includes nine different categories: on-roadway, shoulder, median, roadside, outside right-of-way, off roadway - location unknown, in parking lane, gore, and unknown. Robertson and Kelley aggregated these in some fashion to achieve a two-category variable. How they did this is not documented in their report. Some categories may have been combined, or some eliminated. Elimination of categories with small observations may not be justified, even though there are very few observations. It may be that such categories represent the specific conditions in which utility vehicles are most likely to be used (for example, snow, ice, or sand on the road).

Uneven Counts

Another problem with the data used by Robertson and Kelley is that the number of vehicles of each type varies widely. About 2,000 vehicles are in the Pinto, Nova, and LTD classes, while 200 or less are in the Blazer, Bronco, Pacer, and Toronado classes. The differences in counts, in particular the small numbers of rollovers in some cases, have the consequence that the standard errors of the rollover percentages vary among the vehicles. A rigorous analysis would weight the data correspondingly. This could change the results of Robertson's and Kelley's analyses. This could become especially important if the classes are further subdivided in an attempt to control for certain factors.

For example, see figure A-4 which is a summary of Robertson's and Kelley's data tabulations and which shows the numbers of each vehicle in the report.

ANALYTICAL METHOD

RAW ROLLOVER RATES

The first figure presented in the Robertson/Kelley Report is unadjusted rollover rates, rollovers per registered vehicle. The

Figure A-4

1. Frequency
2. Percent
3. Row PCT
4. Col PCT

EVENT	VEH: NOVA (1.58)	BLAZER (1.21)	MUST (1.47)	PINTO (1.33)	LTDETC (1.57)	BRONCO	FIRE (1.63)	TOTAL
1 Single-Vehicle Rollover-Initiated Crashes	178 1.43 13.43 9.06	52 0.42 3.92 26.00	79 0.63 5.96 9.73	161 1.29 12.15 8.29	122 0.98 9.21 5.88	74 0.59 5.58 41.11	80 0.64 6.04 6.44	1325 10.63
2 Single-Vehicle Not Rollover-Initiated Crashes	877 7.04 17.27 44.63	105 0.84 2.07 52.50	407 3.27 8.01 50.12	621 4.98 12.23 31.96	916 7.35 18.04 44.17	74 0.59 1.46 41.11	689 5.53 13.57 55.48	5078 40.75
3 Multi-Vehicle Rollover-Initiated Crashes	1 0.01 5.56 0.05	0 0.00 0.00 0.00	1 0.01 5.56 0.12	0 0.00 0.00 0.00	0 0.00 0.00 0.00	1 0.01 5.56 0.56	3 0.02 16.67 0.24	18 0.14
4 Multi-Vehicle Not Rollover-Initiated Crashes	909 7.29 15.04 46.26	43 0.34 0.71 21.50	325 2.61 5.38 40.02	1161 9.31 19.21 59.75	1036 8.31 17.14 49.95	31 0.25 0.51 17.22	470 3.77 7.78 37.84	6043 48.48
TOTAL	1965 15.76	200 1.60	812 6.51	1943 15.59	2074 16.64	180 1.44	1242 9.96	12465 100.00

(CONTINUED)

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TABLE OF EVENT BY VEH

EVENT (FREQUENCY / PERCENT / ROW PCT / COL PCT)	VEH: CORON (1.27)	BEET (1.35)	GREM (1.34)	PACER (1.41)	CONCORD (1.40)	TORON (1.38)	CJ	TOTAL
1 Single-Vehicle Rollover-Initiated Crashes	27 0.22 2.04 8.01	175 1.40 13.21 10.69	28 0.22 2.11 6.02	5 0.04 0.38 4.31	43 0.34 3.25 6.89	12 0.10 0.91 10.00	289 2.32 21.81 38.53	1325 10.63
2 Single-Vehicle Not Rollover-Initiated Crashes	151 1.21 2.97 44.81	466 3.74 9.18 28.47	182 1.46 3.58 39.14	42 0.34 0.83 36.21	199 1.60 3.92 31.89	37 0.30 0.73 30.83	313 2.51 6.16 41.73	5078 40.75
3 Multi-Vehicle Rollover-Initiated Crashes	0 0.00 0.00 0.00	9 0.07 50.00 0.55	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	1 0.01 5.56 0.83	2 0.02 11.11 0.27	18 0.14
4 Multi-Vehicle Not Rollover-Initiated Crashes	159 1.28 2.63 47.18	987 7.92 16.33 60.29	255 2.05 4.22 54.84	69 0.55 1.14 59.48	382 3.06 6.32 61.22	70 0.56 1.16 58.33	146 1.17 2.42 19.47	6043 48.48
TOTAL	337 2.70	1637 13.13	465 3.73	116 0.93	624 5.01	120 0.96	750 6.02	12465 100.00

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TABLE 1 OF EVENT BY VEH
CONTROLLING FOR LAND=URBAN

method used in obtaining these data is simply the division of numbers of rollovers by numbers of registered vehicles. These numbers were derived without any control for those factors that might affect the risk measure presented.

The differences in the rates shown are actually a result of a combination of many human, vehicle, and environmental factors. It is not possible to say how much any set of factors contributed to the rate shown for an individual vehicle. Comparisons among vehicles should not be made with raw, uncontrolled data.

CONTROL

When analyzing rollover experience of vehicles it is necessary to control for a variety of factors that influence rollovers. A wide range of factors influence the frequency of crashes and the type of crash. The type of crash is a determinant of rollover. Key factors influencing rollovers include vehicle maneuvers and environmental factors. Given a crash, one would not expect certain factors to play a role in influencing whether a rollover occurs. Such factors would include driver sex, prior convictions, or age. Such factors are precrash factors and influence the occurrence of a crash. Crash-type factors are those that influence rollover. Control for precrash factors on rollover percent, therefore, has little effect. What needs to be addressed is the effect of precrash factors on crashes and the effect of crash types on rollover. Robertson and Kelley attempt to address, through a regression analysis, the effect of precrash factors on rollovers per crash. This adds almost no information to the issue of comparative rollover risk of vehicles.

REGRESSION ANALYSIS

Robertson and Kelley perform a regression analysis to establish a preliminary relationship between rollover percent, the dependent variable, and the stability ratio. They extend this analysis by adding to the regression equation 20 driver and environmental factors, one at a time. The result is 20 new regression equations with rollover percent as the dependent variable and T/2H and one other factor as the independent variables.

This analysis is presented as the control for the effect of the 20 factors. There are inadequacies associated with this analysis: (1) the control factors are of questionable relevance, (2) linear regression may not be the best method to use in doing the analysis, (3) more than one confounding factor should have been considered simultaneously, (4) the theory that rollover *percent* is a *function* of T/2H is not supported by the data, and (5) the importance of stability decreases as other factors are added to the regression equation.

Inadequate Control

Robertson and Kelley perform a regression analysis in which rollover percent is a function of the stability factor, T/2H. They present this as a control for the effect of 20 confounding factors: 10 are environmental factors and 10 are driver factors. As discussed above, the driver factors are a priori of questionable relevance for rollover causation. Therefore, it is not surprising that *none of them* has a *significant* effect. The environmental factors are more relevant as is confirmed by the significance of some of them. However, these factors classify the environment only in a very crude way. "Urban" and "rural" environments cover wide ranges of differing driving conditions. Nevertheless, the simple dichotomous factor urban/rural is highly significant and reduces the apparent role of stability dramatically. One would expect that a more refined classification would show an even stronger environmental effect and a further reduction of the apparent effect of stability.

Linear Regression

The method used by Robertson and Kelley in their analysis is linear regression. In this analysis, an attempt is made to draw the best fitting line among the points that represent rollover percents and stability. There is no assurance that linear regression is the best method to use. In fact, viewing the distribution of the points on Robertson and Kelley's graph on their page 16 suggests that a straight line is not the best explanation of the relationship between those two variables. Figure A-5 is a copy of Robertson's and Kelley's page 16.

In addition, the line's poor predictive power is exemplified by its predicted value of the rollover percent for Firebirds. It is predicted to be negative.

Stability Importance Decreases When Other Factors are Considered

In their regression analysis Robertson and Kelley use 20 confounding factors (driver and environmental) as explanatory variables. However, they consider only one variable at a time in conjunction with vehicle stability. That is, they develop 20 separate regression equations. They ignore in their regression analysis the possibility of adding a second confounding factor to the regression equation. This is not an ideal way of doing this analysis because these 20 factors and others interact simultaneously at the time of a crash.

Even more important, however, is that Robertson and Kelley completely ignore the use of multi- versus single-vehicle crashes as an independent variable in any of their regressions, even though all the necessary data were available. Multi- versus single-vehicle accidents could have been added either as a single variable in combination with stability or as an additional variable in combination with stability in each of the 20 other equations.

Figure A-5
Corrected by author on 8/6/86

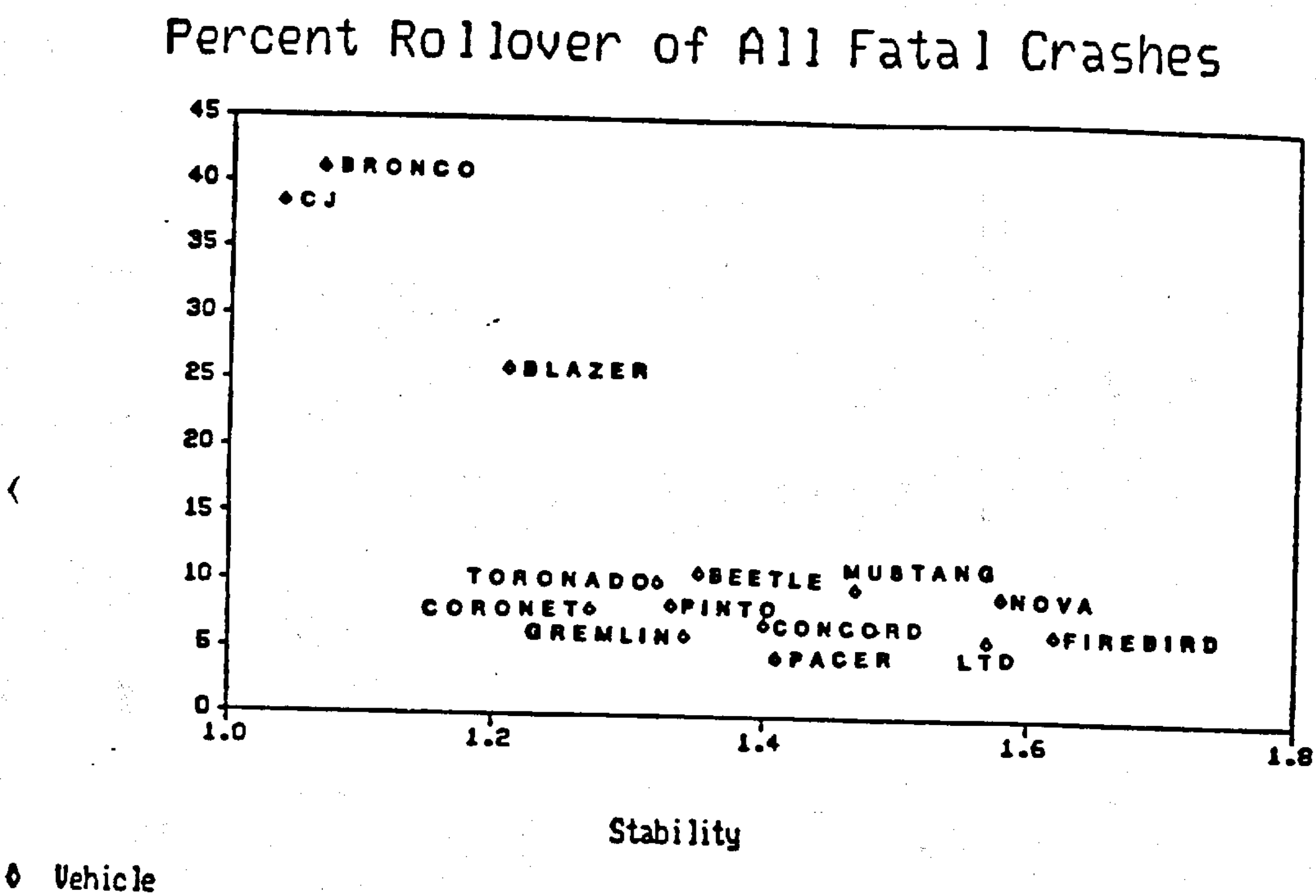


FIGURE 4

Percent Rollover = 91.9 - 57.5 (T/2/H)

Percent variance explained = 63

It could be argued that it is useless to study the confounding variables in combination. However, Robertson's data on page 18 indicate that when the variables are taken in combination, in more than half the cases, the coefficient on the stability variable decreases, indicating a decline in importance of stability as other factors are accounted for.

Sample of Convenience

Robertson and Kelley use a sample of convenience in selecting their data. ". . . convenience sampling . . . is particularly useful testing theoretical propositions. If a theoretical statement is correct, it will hold for any group of subjects. It does not matter if the subjects are randomly selected" (Hy et al. 1983, p. 92). This implies that one should be able to develop a regression analysis using the same variables that Robertson and Kelley use (rollover percent and T/2H) and test their theory with different data or a subset of their data. This was done using the 11 passenger cars in the report. The equation for the resulting line is:

$$\text{Rollover percent} = 14.17 - 4.39\ (T/2H)$$

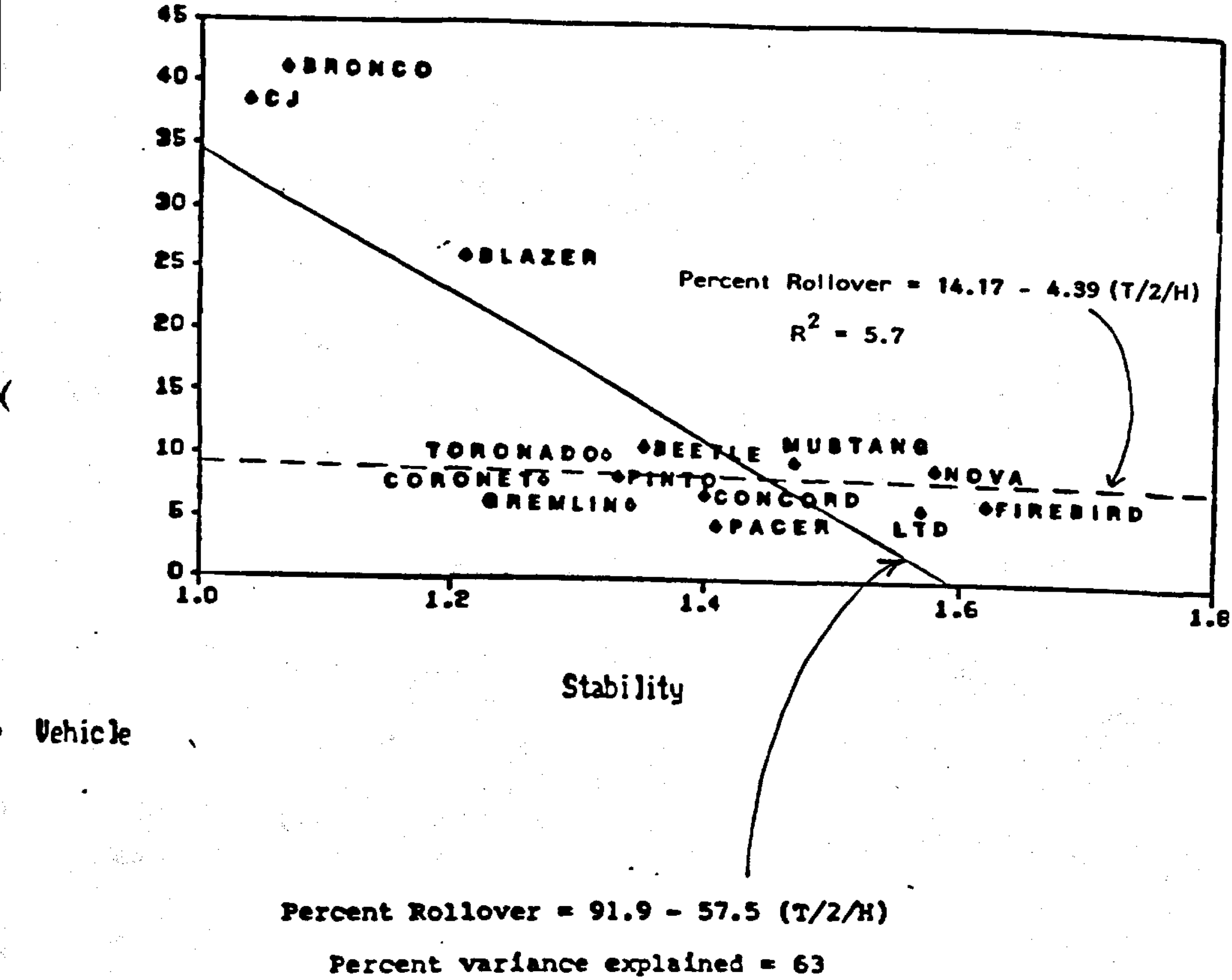
$$R^2 = .057$$

Figure A-6 shows both Robertson's and Kelley's original line and the line estimated with 11 points.

There are two interesting things about this line. First, note that the slope of -4.39 is almost flat, indicating that there is very little change in rollover percent for a change in T/2H. In this particular case, as T/2H varies from 1.01 to 1.62, the estimated rollover percent decreases from 9.74 to 7.06, a decrease of only 2.7 percentage points. Second, the R^2 is very low at .057, indicating that the rollover percent does not vary significantly with stability. Robertson's and Kelley's theory is that rollover percent is a

Figure A-6

Percent Rollover of All Fatal Crashes



function of T/2H. The theory does not appear to hold for sets of data other than that chosen by Robertson and Kelley.

Mileage Control

Robertson and Kelley note that they control for the effect of vehicle mileage under different driving conditions on rollover rates by estimating the number of miles a utility vehicle would have to be driven in order for their high rollover rates to be due to those different driving conditions. This is not what Robertson and Kelley actually do. The numbers they develop are the miles that passenger cars would have to be driven under normal passenger car exposure conditions in order for passenger cars to have the same number of crashes as utility vehicles. Their analysis is conceptually flawed and mislabeled.

IMPLICATIONS OF THE REPORT

There are major errors through the Robertson/Kelley Report. However, there is an interesting outcome of their regression analysis. Their basic regression equation is:

$$\text{Rollover percent} = 91.9 - 57.5\ (T/2H)$$

$$R^2 = .63$$

The slope of the regression line, -57.5, indicates that, with an increase in T/2H of .1, rollover percent will decrease by only 5.75 percentage points.

On page 18 of the report, Robertson and Kelley also report regression results for stability and other factors. As previously noted, the magnitude of the stability coefficient decreases when other factors are considered. For example, the stability coefficient for the regression equation that considered stability and two-lane versus four-lane roads is -45.7. This indicates that if the stability ratio for a vehicle (T/2H) were to be increased by .1, the rollover percent would decrease by 4.57 percentage points.

If a regression is performed using the Robertson and Kelley data with the stability ratio as one independent variable and multi-vehicle versus single-vehicle crash involvement as the second independent variable, the stability coefficient decreases to -33.3. This indicates that an increase in the stability ratio of .1 would produce a decrease of 3.3 percentage points in the rollover percent.

CONCLUSION

The Robertson and Kelley Report was the first utility vehicle rollover report to relate rollover percent and stability by means of regression analysis. However, their analysis is severely flawed. First, the data they use are inadequate. For example, the data are not reproducible, and the Blazer data do not represent the full range of Blazer accidents that have actually been experienced. In addition, VIN data were eliminated by Robertson and Kelley from the data set used in their analysis. Therefore, no means were available for checking vehicle make and model. In addition, the regression analysis in which confounding factors were added to the regression equation does not adequately represent conditions at the time of a crash.

The analytical method used by Robertson and Kelley is inadequate in that there is no indication that linear regression is the best way of relating these variables to one another. An inadequate controlling procedure was carried out. Had *multi-vehicle* and single-vehicle crashes been added to the regression equation, the coefficient of stability would change to -33.3. This indicates that an increase in T/2H of .1 (e.g., from 1.1 to 1.2) would result in a rollover percentage decrease of only 3.3 percentage points.

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