

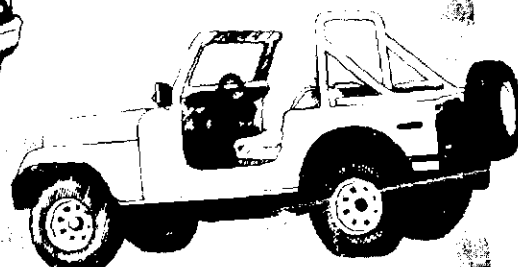
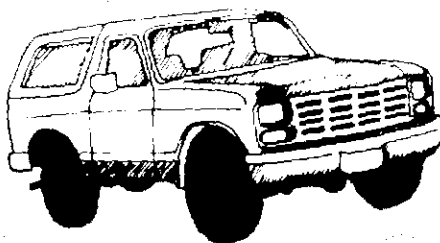
# A FURTHER LOOK AT UTILITY VEHICLE ROLLOVERS

Donald W. Reinfurt  
Jane C. Stutts  
Elizabeth G. Hamilton

August 1984

**UNC** **HSRC**

University of North Carolina  
Highway Safety Research Center



A FURTHER LOOK AT UTILITY VEHICLE ROLLOVERS

Donald W. Reinfurt  
Jane C. Stutts  
Elizabeth G. Hamilton

Highway Safety Research Center  
University of North Carolina

August 1984

This work was supported by the Insurance Institute for Highway Safety. The opinions, findings, and conclusions expressed in this publication are those of the authors and do not necessarily reflect the views of the Insurance Institute for Highway Safety.

## ACKNOWLEDGEMENTS

Data for this study was provided by the North Carolina Division of Motor Vehicles. The authors express appreciation to the DMV staff both for their contribution to this effort and for their longstanding support of HSRC research activities.

We are also grateful to our Secretarial Staff, Ms. Teresa Parks and Ms. Peggy James, and to Mr. Robert Gray and Ms. Lauren Marchetti, who were responsible for the graphics work. The final appearance of this report has benefitted greatly from their combined dedication and skills.

Of special mention is the statistical input provided by Dr. George Chi in the development of Appendix D. In addition, Dr. Chi provided valuable feedback on the overall report.

Although many have contributed to this effort, the authors stand alone in accepting responsibility for the contents of this report and any shortcomings it may contain.

## TABLE OF CONTENTS

	<u>Page</u>
ACKNOWLEDGEMENTS . . . . .	i
LIST OF TABLES . . . . .	v
LIST OF FIGURES . . . . .	vii
I. INTRODUCTION . . . . .	1
II. THE DATA . . . . .	3
Background . . . . .	3
Accident Data . . . . .	5
Vehicle Registration Data . . . . .	7
Vehicle Mileage Data . . . . .	8
III. RESULTS . . . . .	11
IV. DISCUSSION . . . . .	39
REFERENCES . . . . .	43
APPENDIX A. Vehicle Group Registration Counts and Description . . . . .	45
APPENDIX B. North Carolina Accident Report Form and Motor Vehicle Inspection Form . . . . .	51
APPENDIX C. Statistical Tests for Differences in Proportions and Differences in Rates . . . . .	55
APPENDIX D. Mantel-Haenszel-Type Statistical Analysis Procedures . . . . .	63
APPENDIX E. Single Vehicle Rollover Distributions for the Utility Vehicle Groups . . . . .	69

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	Crash involvement rates (per 10,000 registered vehicles) by type of crash . . . . .	12
2	Rollover rates (per 10,000 registered vehicles) by type of crash . . . . .	14
3	Percentages of crash-involved vehicles that rolled over by type of crash . . . . .	18
4	Single vehicle serious (A) or fatal (K) driver injury rates (per 10,000 registered vehicles) . . . . .	20
5	Percentages of drivers in single vehicle crashes with serious (A) or fatal (K) injuries . . . . .	21
6	Serious (A) or fatal (K) driver injury rates (per 10,000 registered vehicles for single vehicle, rollover crashes . . . . .	23
7	Percentages of serious (A) or fatal (K) driver injuries in single vehicle, rollover crashes . . . . .	26
8	Percentages of vehicles in single vehicle crashes that overturned in road . . . . .	27
9	Serious (A) or fatal (K) driver injuries by belt usage status . . . . .	30
10	Single vehicle crash-involved driver age distribution . . . . .	34
11	Crude and age-standardized single vehicle rollover percentages . . . . .	36
12	Single vehicle rollover rate significance tests controlling for certain driver, vehicle, and roadway/environmental factors and their interactions . . . . .	38
A.1	Total registration counts for vehicle groups in North Carolina 1979-82 . . . . .	46
A.2	Description of vehicle groups -- makes and models . . . . .	47
C.1	Single vehicle rollover rate comparisons . . . . .	59
C.2	Single vehicle (A+K) driver injury rate comparisons . . . . .	60
C.3	(A+K) driver injury rate comparisons for single vehicle, rollover crashes . . . . .	61
D.1	Basic data table . . . . .	64

LIST OF TABLES

<u>Table</u>		<u>Page</u>
E.1	Single vehicle rollovers by driver age . . . . .	70
E.2	Single vehicle rollovers by driver sex . . . . .	71
E.3	Single vehicle rollovers by driver intoxication . . . . .	72
E.4	Single vehicle rollovers by driver violations . . . . .	73
E.5	Single vehicle rollovers by accident speed . . . . .	74
E.6	Single vehicle rollovers by TAD severity . . . . .	75
E.7	Single vehicle rollovers by rural-urban location . . . . .	76
E.8	Single vehicle rollovers by pavement condition . . . . .	77
E.9	Single vehicle rollovers by time-of-day . . . . .	78

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Single vehicle rollover rates (per 10,000 registered vehicles) for various utility vehicle models, compared with all utility vehicles, half-ton pickup trucks and passenger cars . . . . .	15
2	Percentages of drivers in single vehicle crashes with serious injuries for various utility vehicle models, compared with all utility vehicles, half-ton pickup trucks and passenger cars . . . . .	22
3	Serious driver injury rates (per 10,000 registered vehicles) in single vehicle rollover crashes for various utility vehicle models, compared with all utility vehicles, half-ton pickup trucks and passenger cars . . . . .	24
4	Percentages of vehicles in single vehicle crashes that overturned in road for various utility vehicle models compared with all utility vehicles, half-ton pickup trucks and passenger cars . . . . .	28
5	Driver serious injury percentages by belt usage status for the leading utility vehicle models compared with all utility vehicles, half-ton pickup trucks and passenger cars . . . . .	31
6	Utility vehicle rollover percentages by driver age for single vehicle crashes . . . . .	35
B.1	North Carolina Accident Report Form . . . . .	52
B.2	North Carolina Motor Vehicle Inspection Receipt Form . . . . .	54

## CHAPTER I. INTRODUCTION

A variety of utility vehicles, similar to the small multi-purpose military vehicles known as "Jeeps," have become increasingly numerous on the highways since the 1970's. The most popular utility vehicle models are the AMC Jeep CJ-5 and Jeep CJ-7, Ford Bronco, Chevrolet Blazer, and International Scout. It has been alleged that utility vehicles are especially susceptible to rollover compared to other four-wheeled motor vehicles. Because of their "high rollover accident rates," the U.S. Army stopped selling surplus military vehicles of this type to the public (DOT, 1971). With the crash experience of the military vehicles as background, Reinfurt and others (1981) examined the crash experience of certain utility vehicles and contrasted it with the experience of other motor vehicles. The current study updates and expands the previous work using more recent crash data.

With respect to the literature in this area, Snyder and others (1980) reported on the on-road crash experience of non-military utility vehicles based on 1975-78 accident data from Arizona, Maryland, Michigan, New Mexico, New York, North Carolina, Texas and Washington, as well as with data from the Fatal Accident Reporting System (FARS) file for 1977. Among other things, they concluded that utility vehicles "experience rollover at a rate that is at least five times higher than that experienced by the average passenger car." Their study also indicated that certain utility vehicle models were more likely to overturn than others, and that the Jeep CJ-5 was the least stable of those studied.

The 1981 study by Reinfurt and others compared the rollover experience of utility vehicles with that of half-ton pickup trucks and also passenger cars. Accident data from North Carolina (1973-78) and Maryland (1974-78) and FARS data (1978-79) provided the data base for this investigation. Again, single vehicle rollover crashes were much more prevalent among utility vehicles; the Jeep CJ-5 rate exceeded that of either the Ford Bronco or the Chevrolet Blazer in all three data files investigated.

Smith (1982) examined the incidence of single vehicle fatal rollover crashes involving utility vehicles using data from the FARS file for the years 1978-80. Her findings show that "in single vehicle fatal accidents involving a utility vehicle, the Jeep CJ-5 and the Toyota Land Cruiser are more likely to have rolled over than any other vehicle type. Also occupant fatalities resulting from utility vehicle accidents which involve a rollover occur more

frequently in Jeeps (excluding the Wagoneer and Cherokee) and the Land Cruiser as opposed to the other vehicle types."

The present investigation follows the results of Reinfurt et al. (1981) with more recent data and includes additional utility vehicle models. This data base allows the study to focus on the leading utility vehicle models -- AMC Jeep CJ-5 and Jeep CJ-7, Ford Bronco, Chevrolet Blazer, and International Scout -- that represent the vast majority of the utility vehicles currently in use. The model years considered were as follows:

<u>Utility Vehicle</u>	<u>Model Year</u>	<u>Comment</u>
Jeep CJ-5	1972-1982	
Jeep CJ-7	1976-1982	1976 first year of production
Ford Bronco	1972-1977 1978-1982	wheelbase lengthened in 1978
Chevrolet Blazer	1973-1982	1972 model was smaller
International Scout	1975-1980	1980 last year of production

Results were not obtained separately for the Jeep CJ-6, Jeep Scrambler, Toyota Land Cruiser, Plymouth Trail Duster, or Dodge Ramcharger because there were not sufficient numbers of them on the highways to obtain reliable crash experience results. They were, however, included in the results for the "All Utility Vehicles" group.

As in Reinfurt et al. (1981), the crash experience of a number of leading small (half-ton) pickup truck models was used for comparison purposes as small pickups and utility vehicles should have reasonably similar exposure. The pickup models studied were again the Ford F-100 and F-150, Chevrolet C-10 and K-10, and the smaller Toyotas and Datsuns. In addition, because much is known about the rollover experience of passenger cars (Garrett, 1969), passenger cars by wheelbase length groups (subcompact, compact, intermediate and full-size) were studied.

## CHAPTER II. THE DATA

### Background

As in Reinfurt *et al.* (1981), the rollover accident and injury experience of drivers of utility vehicles, half-ton pickup trucks, and passenger cars is the focus of the current study. In the earlier work, statewide police-reported accident data for North Carolina (1973-1978) and Maryland (1974-1978) was utilized along with national data from FARS (Fatal Accident Reporting System) for 1978-1979. As the results were so very consistent between North Carolina and Maryland across virtually every comparison -- single vehicle vs. multi-vehicle crashes, rollover rates, serious driver injury rates, etc. -- this follow-up study uses data only from North Carolina crashes for the period 1979-1982.

Several sources of exposure or "denominator" data are examined in this study. Mileage information is generally accepted as one of the best measures of exposure to risk of crashes but is also perhaps most difficult to obtain on a vehicle-specific basis. Such data were available using paired odometer readings from the statewide motor vehicle inspection program. These data had been collected during November 1979 for a different project, but they were made available for analysis in this report and provided useful information on annual mileage exposure differences for the various classes of vehicles. A second source of exposure data consisted of vehicle registrations compiled by R. L. Polk & Co. and published in their National Vehicle Population Profile. Due to various limitations in the mileage data, crash rates are primarily based on registration counts for the period 1979-1982.

As in the previous study, the primary purpose of this investigation was to contrast the rollover crash experience of the leading utility vehicle models. Because half-ton pickup trucks would be expected to be used for similar purposes and would also have reasonably similar vehicle characteristics such as wheelbase length, they were used as a primary comparison group. In addition, passenger cars classified by size (subcompact, compact, intermediate and full-size) were also used as a comparison group partly because more is known about the rollover tendencies of passenger cars and also because of the familiarity of the driving population with these vehicles.

To define the various study groups, the unique Vehicle Identification Number (VIN) was used. For passenger cars, the subgroups were defined by wheelbase length (subcompact < 102 inches; compact 102-111 inches; intermediate

112-120 inches; and full-size > 120 inches). Determinations of wheelbase lengths were made from the VIN's using R. L. Polk's VINA program.

Because of limited sample sizes of the various utility vehicle subgroups, it was important not to unnecessarily discard any vehicles from the data base in the VIN-decoding process. VINA uses a series of tests that a candidate VIN must pass before it attempts to decode the VIN. Some of these tests are important to this study while others are not. An example of the latter is that the program will reject an entire VIN if the production sequence number contains some alphabetic characters. Clearly this should not affect this study other than reducing the sample size. As a result, an alternative package called VINDICATOR was utilized which is less restrictive than VINA but still requires the essential criteria to be met.

As a further step in retaining legitimate utility vehicles for further study, unique VIN patterns were utilized to identify those utility vehicles that were rejected by the VINDICATOR package. Thus, for example, the Jeep CJ-5 VIN for model years 1972-80 was a 13-character string with the following pattern:

<u>Characters</u>	<u>Pattern</u>
1-5	J--83
6-7	Alpha characters
8-13	Numeric production number sequence

while the Jeep CJ-5 VIN for model years 1981-82 was a 17-character string with the following pattern:

<u>Characters</u>	<u>Pattern</u>
1-7	IJC--85
8-11	Alpha/numeric characters
12-17	Numeric production number sequence

Those vehicles that satisfied both the VIN pattern check (as illustrated above) and had compatible make designations were then retained in the study group.

In similar fashion, the pickup truck study file was developed first using the VINDICATOR package and secondarily the unique VIN patterns. The makes and models of utility vehicles and pickup trucks are provided in Appendix A.

Accident Data

Crash data were based on the nearly 600,000 reported accidents occurring in North Carolina during the years 1979 to 1982\*. All accidents involving any of the three vehicle types -- utility vehicles (multi-purpose vehicles usually designed for both on-road and off-road use), half-ton pickup trucks, and passenger cars -- were identified. Excluded from the study file were crashes with pedestrians, bicycles, mopeds, motorcycles, trains, farm equipment, etc.

As indicated, the study file was created from the state's accident files by utilizing the VINDICATOR package coupled with VIN patterns as a means for identifying crashes involving the utility vehicle and half-ton pickup truck groups of interest. As certain models (e.g., the Plymouth Trail Duster utility vehicle and the Subaru pickup truck) were involved in very few crashes during the study period, they were not treated separately but were combined into the All Utility Vehicle or All Pickup Truck groups. Thus, the resulting study file consisted of accidents involving the leading utility vehicle models (Jeep CJ-5, Jeep CJ-7, Ford Bronco, Chevrolet Blazer, and International Scout) and, as previously, four groups of half-ton pickup trucks (Ford F-100 and F-150, Chevrolet C-10 and K-10, Toyota, and Datsun).

Because the Ford Bronco underwent a major design change in 1978, this vehicle is grouped for 1972-77 and 1978-82. Note also that the Chevrolet Blazer and GMC Jimmy are combined into a single group called the "Blazer" as they are essentially identical. The Chevrolet C-10 and K-10 and the GMC C-1500 and K-1500 pickup trucks are similarly grouped. A detailed listing of the resulting vehicle groups along with information on the model years included and the corresponding registration counts is provided in Appendix A. All the passenger cars, utility vehicles, and pickup trucks considered were 1972 or later models.

The variables extracted from the accident files for subsequent analysis included the following officer-reported factors: crash type (including rollover and non-collision overturn-in-road), location (rural-urban), road condition (e.g., dry, wet), accident speed, TAD severity (i.e., vehicle damage rating reflecting the seriousness of the crash), and time of day, along with driver age, sex, belt use, intoxication, and corresponding injury. The study variables are described in the following:

---

\*In North Carolina, any motor vehicle crash resulting in death or injury or total property damage in excess of \$200 must be reported to the State on a form supplied by the N.C. Division of Motor Vehicles (see Appendix B).

- Crash type (i.e., single vehicle vs. multi-vehicle) was created by counting the number of vehicles involved in each accident. Thus, excluding those crashes involving pedestrians, bicycles, motorcycles, trains, etc., a multi-vehicle accident was defined as a collision of a motor vehicle with at least one other motor vehicle while a single vehicle accident involved only one motor vehicle.
- Rollover is one of the events coded under the variable, "point of initial contact" (see Appendix B). Whenever a crash involves a rollover, the officer is instructed to indicate this by writing a "25" in the corresponding Point(s) of Initial Contact box.
- Non-collision overturn-in-road is one of the accident types coded on the North Carolina collision report. Because it applies to non-collision events only, any overturn-in-road analysis should apply only to single vehicle crashes. It should be noted that, since there is no separate code for overturn-off-the-road, it could be that some off-road rollovers are recorded by the officers as overturns in the road. Although this should not occur differentially among the various utility vehicle or pickup truck models or the car size groups, caution might be exercised in interpreting the data concerning the "overturn-in-road" variable.
- Road condition is rather straightforward and describes the roadway surface condition at the time of the crash. The components of this variable are dry, wet, muddy, snowy, icy or other.
- Accident speed is based on the officer's judgment of the speed of the vehicle(s) at the point of impact. For single vehicle crashes, it is the estimated speed at which, for example, the vehicle was traveling when it rolled over. For multi-vehicle crashes, it is a speed derived from the estimated impact speeds of the first two vehicles involved in the crash. For rear-end crashes, it is the difference of the two speeds; for all other crashes, it is the maximum of the two speeds.
- TAD severity provides an indication of the forces involved in the crash. Using a pictorial vehicle damage rating scale referred to as the TAD scale, officers in North Carolina rate the degree of vehicle damage on a seven-point scale with a low severity rating (1 or 2) reflecting minor damage and a high rating (6 or 7) major vehicle damage.
- Time of day is the time (in hours and minutes) at which the crash occurred.
- Driver age was one of a number of driver variables that were examined. It is the actual age of the driver on the date of the accident as recorded on the accident report form. To simplify later analysis and with particular interest in the young driver,