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August 1984

UNC HSRC

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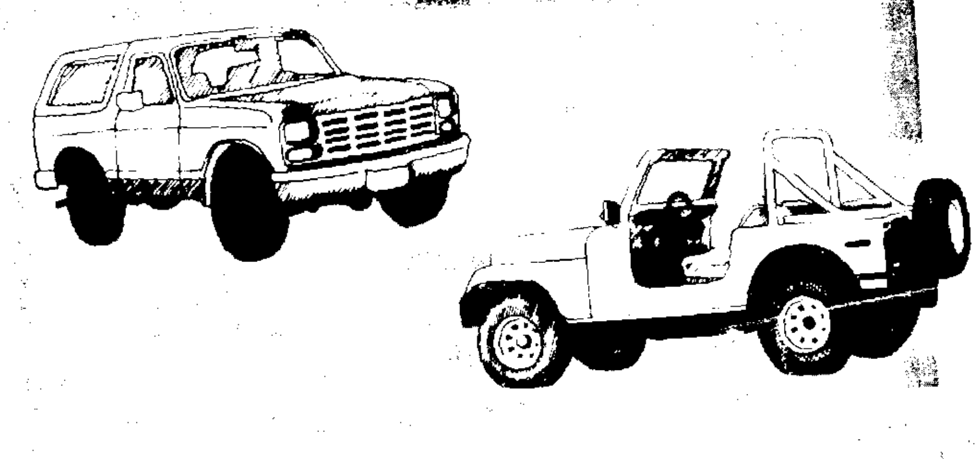

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Although many have contributed to this effort, the authors stand alone in accepting responsibility for the contents of this report and any shortcomings it may contain.

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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:

Utility Vehicle	Model Year	Comment
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:

Characters	Pattern
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:

Characters	Pattern
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 diver 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,

driver ages were grouped as follows: under 20, 20-24, 25-29, 30-34 and 35 and over years of age.

- Driver sex is encoded male or female and is important in examining possible age-sex interactions.

- Driver belt use is recorded by the officer at the scene. Belt usage is classified into one of seven possible categories: no belt, lap belt only, lap and shoulder belt, child restraint, unable to determine, not stated, and driver not present. In the subsequent analyses, "child restraint," "unable to determine," "not stated," and "driver not present" were eliminated from the computations and the remaining categories were combined into two groups -- "belted" (i.e., lap belt only or lap and shoulder belt) and "not belted" (i.e., no belt).

- Driver intoxication has four possible levels: (1) had not been drinking; (2) drinking - ability impaired; (3) drinking - unable to determine impairment; and (4) unknown. For the analysis dealing with alcohol involvement, the "unknowns" are discarded and categories (2) and (3) are treated as the "drinking" group.

- Driver injury was coded as follows (see ANSI D16.1, National Safety Council, 1976, pp. 10-11):

  K = killed

  A = incapacitating injury, that is, any injury other than a fatal injury which prevents the injured person from walking, driving or normally continuing the activities he was capable of performing before the injury occurred

  B = non-incapacitating injury other than K or A injury evident at the scene

  C = no visible sign of injury but complaint of pain or momentary unconsciousness

  O = not injured

  In all computations involving driver injury, cases which had been indicated by the investigating officer as "driver not present" or for which injury information was "not stated" were excluded.

Vehicle Registration Data

Two sources of exposure or denominator data were available for this study -- vehicle registration data and vehicle mileage data. The former was available for each of the various utility vehicle and pickup truck models; the latter was not nearly as detailed and thus was used mainly for certain overall comparisons.

As a result, the various rate comparisons made in the following analyses are largely based on vehicle registration data.

Registration data were obtained from R.L. Polk & Co., which, since 1975, has produced a detailed profile of vehicle registration counts by make, model, and model year for each state (as of July 1 each year) using copies of computerized registration files from the various states. This information is summarized in their publication, "National Vehicle Population Profile."

Registration frequencies for each of the years 1979 through 1982 for each of the utility vehicle, pickup truck, and car groups included in the accident file were obtained using the R.L. Polk & Co. description of vehicle make, model, model year, and body style. Most groups included several models. For example, the registration counts for the Ford Broncos included Bronco, Bronco wagon, and Bronco pickup utility, while those for the Blazer included the Blazer, Blazer K-10, GMC Jimmy, and GMC Jimmy K-1500. Similarly, the registration frequencies for the Ford pickup trucks included the F-100, F-100 Super Cab, F-150 and F-150 Super Cab, while those for the Chevrolet pickups included the C-10, K-10, GMC C-1500, and GMC K-1500. (Details of the composition of each study group and the resulting registration frequencies can be found in Appendix A.)

The vehicle registration counts for each of the constituents of each study group were summed across registration years to provide the total number of eacn group registered in North Carolina during 1979-1982. Dividing the total number of crashes for a particular comparison group during the four-year study period by the total number of registrations for that group then provided an annualized crash involvement rate.

In addition to the tabulations of the individual utility vehicle, pickup truck and passenger car size subgroups, registration frequencies were determined for "other" utility vehicles (i.e., Dodge Ram Charger, Plymouth Trail Duster, Jeep CJ-6, and Jeep Scrambler) and for "other" half-ton pickup trucks (i.e., Ford Courier, Dodge, Plymouth, International, Jeep, Mazda, Subaru, and Isuzu) so that registration-based rates could be computed for "all" utility vehicles and "all" pickup trucks.

Vehicle Mileage Data

Vehicle-specific mileage was extremely difficult data to obtain. The one source that was both relevant and available was the odometer data from a sample of North Carolina motor vehicle inspection receipts. This sample was drawn statewide during November 1979 and includes a variety of information on 122,004 cars, half-ton pickups, and utility vehicles appearing for periodic motor vehicle inspection. (See Appendix B for the field data form.)

Among the items of information recorded on the inspection receipt at the time of each vehicle's annual inspection were the previous inspection date and odometer reading, along with the current inspection date, odometer reading and license plate number. Using the license plate number, the critical VIN was determined by accessing the North Carolina vehicle registration file.

The paired odometer readings, one from the previous inspection and one from the current, together with the dates of these inspections enabled the calculation of average annual mileages for certain of the study groups. Unfortunately, in many cases part of the critical data was either missing or illegible. In addition, for many of the study groups (e.g., Jeep CJ-7, Bronco 78-82, International Scout), there was too little data from which to estimate average annual mileage with any degree of precision. Thus, the mileage data was useful only for certain global comparisons (i.e., utility vehicles vs half-ton pickups vs passenger cars).

CHAPTER III. RESULTS

Overall crash involvement rates per 10,000 registered vehicles per year by vehicle type for North Carolina during the years 1979-82 are displayed in Table 1. Also presented in square brackets are the results from Reinfurt et al. (1981) for those vehicle models that appear in both studies. It should be noted at the outset that some differences would be expected due to different accident and exposure years in the two sets of data, different model year ranges (i.e., 1972-78 for the earlier study; 1972-82 for the follow-up), changes in North Carolina between the two periods (e.g., increasing urbanization; different vehicle mix), etc.

It is interesting to note how very similar the trends are. Crash rates for single vehicle and multi-vehicle crashes for all utility vehicles and the leading utility vehicle models, for all half-ton pickup trucks and the leading models, and for passenger cars are given in Table 1. For example, the overall crash rate of utility vehicles in North Carolina was 487 per 10,000 registered vehicles, compared with 503 in the earlier study. The 6,804 which follows in parentheses indicates the number of utility vehicles involved in crashes during the period 1979-82. The corresponding accident sample size for utility vehicles was 3,823 in the original investigation. The corresponding denominator or exposure data is shown in Table A.1 in Appendix A. The single vehicle and multi-vehicle crash rates for all utility vehicles were 145 [145] and 342 [358], respectively.

As in the previous study, utility vehicles as a group had overall crash rates that were intermediate between those for pickup trucks and for passenger cars; the same is true for multi-vehicle crashes. However, utility vehicles had, by a considerable margin, the highest single vehicle crash rates among the three vehicle groups. And among the utility vehicles, the Jeep CJ-5 had an overall accident rate that was the highest among the utility vehicle models, followed by the Jeep CJ-7. The rates for the other models were relatively bunched (except for the Bronco 72-77) and were below the first two groups. For multi-vehicle crashes, the Blazer and the Jeep CJ-5 and CJ-7 had the highest rates. For single vehicle crashes, the Jeep CJ-5 again had the highest rate followed by the Jeep CJ-7, while the rates for the other models were reasonably similar.

Pickup trucks had considerably lower single vehicle crash rates than utility vehicles. The Ford and Chevrolet again had lower rates than the Datsun,

Table 1. Crash involvement rates (per 10,000 registered vehicles) by type of crash.[1] - North Carolina 1979-82

Type of Vehicle	Single Vehicle Rate		Multi-Vehicle Rate		Overall Rate		Overall (N)
Utility Vehicles	145	[145][2]	342	[358]	487	[503]	(6804)
Jeep CJ-5	214	[228]	366	[382]	580	[610]	(2404)
Jeep CJ-7	172		368		540		(1050)
Ford Bronco							
1972-77	105	[162]	206	[276]	311	[438]	(361)
1978-82	113		317		430		(432)
Chevrolet Blazer[3,4]	95	[95]	368	[447]	463	[542]	(1608)
International Scout	98		309		407		(437)
Toyota Land Cruiser	121		287		408		(264)
Pickup Trucks (1/2 ton)	59	[62]	279	[353]	338	[415]	(51,183)
Ford F-100, F-150	60	[72]	289	[397]	349	[470]	(18,401)
Chevrolet C-10, K-10[5]	54	[65]	277	[390]	331	[455]	(21,483)
Toyota	114	[138]	386	[582]	500	[720]	(3848)
Datsun	79	[85]	362	[461]	441	[546]	(3072)
Passenger Cars	81	[119]	463	[472]	544	[591]	(458,843)
Subcompact	107	[160]	501	[503]	608	[663]	(152,050)
Compact	83	[150]	466	[504]	549	[654]	(104,163)
Intermediate	75	[111]	477	[466]	552	[577]	(129,955)
Full-Size	47	[73]	385	[434]	432	[507]	(72,675)

[1]Excludes crashes with pedestrians, bicycles, trains, etc.
[2]Rate reported in Reinfurt, et al. (1981).
[3]Includes the GMC Jimmy, an essentially identical vehicle.
[4]Excludes 1972 models which had a different wheelbase.
[5]Includes the GMC C-1500 and K-1500 which are essentially identical to the Chevrolet C-10 and K-10.

while the Toyota had the highest rates of this group. For the passenger car groups, single vehicle crash rates increased as passenger car wheelbase length decreased.

As mentioned previously, vehicle mileage data was available from the sample of motor vehicle inspection receipts collected statewide in November 1979. After eliminating cases with only one odometer reading or only one date, the study file consisted of paired odometer readings for some 1154 utility vehicles, 12,198 half-ton pickups, and 69,713 passenger cars. The corresponding vehicle-specific estimated annual mileages for these vehicle groups are as follows:

Vehicle Group	Estimated Annual Mileage
Utility vehicles	10,529
Pickups	11,524
Cars	11,644

Since utility vehicles average approximately 1000 fewer miles per year than either half-ton pickup trucks or passenger cars, it is clear that the comparisons that follow based on registration rates are conservative.

Furthermore, it should be noted that sample size limitations precluded annual mileage estimation for several of the individual utility vehicle models. It is, however, of interest to note the difference in the estimates for the smaller utility vehicles compared with their larger counterparts. More specifically, the estimates are as follows:

Utility Vehicle Models	Estimated Annual Mileage
Smaller Models: Jeep CJ-5, Jeep CJ-7, Ford Bronco 72-77, and Toyota Land Cruiser	9,604
Larger Models: Ford Bronco 78-82, Chevrolet Blazer, and International Scout	11,688

Table 2 and Figure 1 show the numbers of rollovers per 10,000 registered vehicles. As was observed by both Snyder et al. (1980) and Reinfurt et al. (1981), the rollover rate for both single vehicle and multi-vehicle crashes was

Table 2. Rollover rates (per 10,000 registered vehicles) by type of crash.[1]
North Carolina 1979-82

Type of Vehicle	Single Vehicle Rate		Multi-Vehicle Rate		Overall Rate
Utility Vehicles	64.0	[55.5][2]	6.8	[6.2]	70.8
Jeep CJ-5	103.5	[95.8]	10.9	[9.5]	114.4
Jeep CJ-7	83.9		10.8		94.7
Ford Bronco					
1972-77	50.0	[68.6]	4.3	[8.5]	54.3
1978-82	42.8		3.0		45.8
Chevrolet Blazer[3,4]	29.6	[21.7]	3.8	[3.3]	33.4
International Scout	33.6		3.7		37.3
Toyota Land Cruiser	78.7		3.1		81.8
Pickup Trucks (1/2 ton)	14.0	[11.8]	1.3	[1.2]	15.3
Ford F-100, F-150	14.0	[12.8]	1.3	[1.1]	15.3
Chevrolet C-10, K-10[5]	11.6	[12.3]	1.0	[1.1]	12.6
Toyota	37.2	[38.0]	2.6	[7.4]	39.8
Datsun	22.4	[25.4]	3.4	[2.5]	25.8
Passenger Cars	12.7	[15.1]	0.9	[0.7]	13.6
Subcompact	25.2	[33.8]	1.8	[1.6]	27.0
Compact	12.1	[20.2]	0.8	[1.2]	12.9
Intermediate	6.5	[8.9]	0.5	[0.3]	7.0
Full-Size	3.6	[3.6]	0.3	[0.2]	3.9

[1]Excludes crashes with pedestrians, bicycles, trains, etc.
[2]Rate reported in Reinfurt, et al. (1981).
[3]Includes the GMC Jimmy, an essentially identical vehicle.
[4]Excludes 1972 models which had a different wheelbase.
[5]Includes the GMC C-1500 and K-1500 which are essentially identical to the Chevrolet C-10 and K-10.

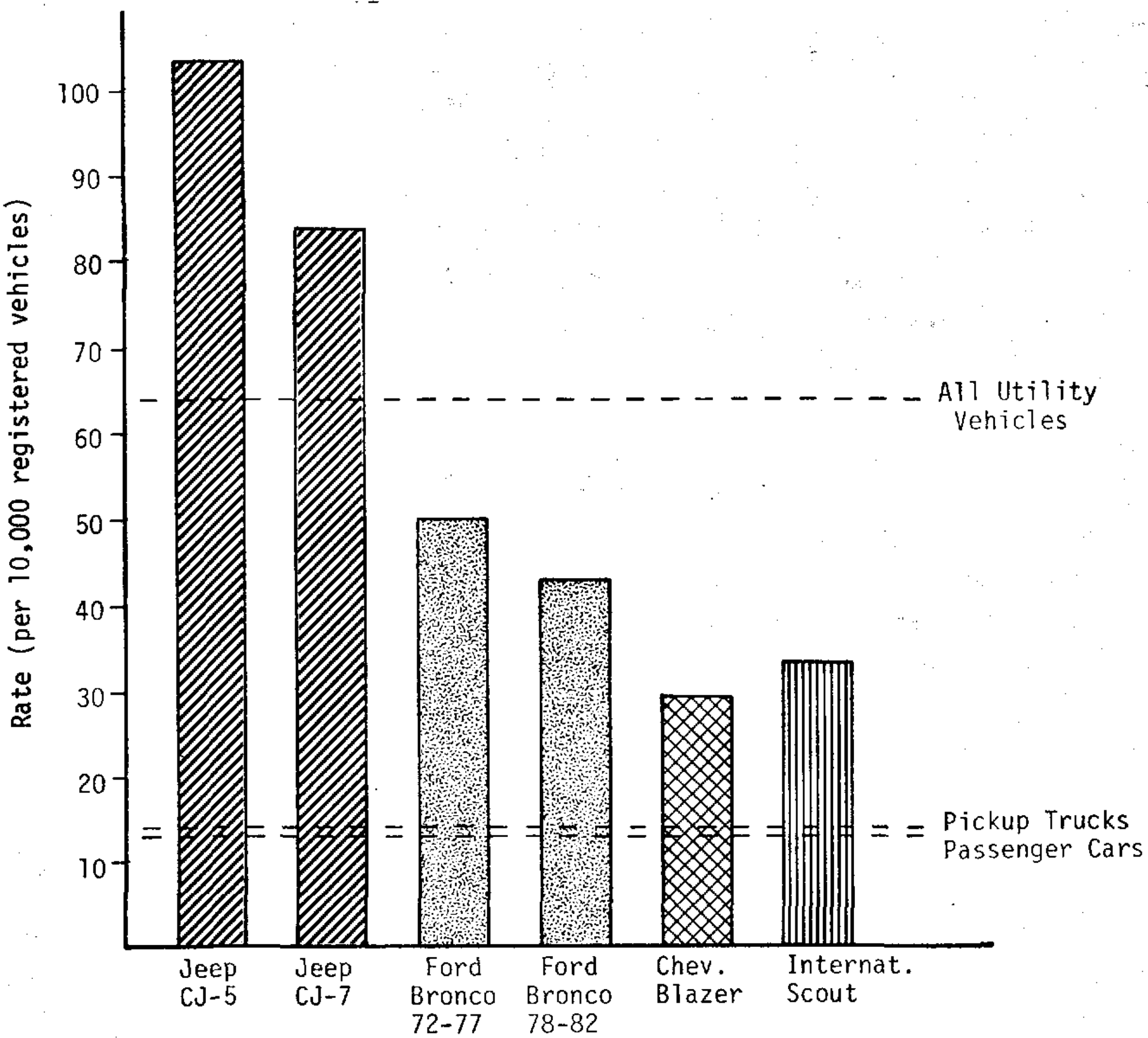

Figure 1. Single vehicle rollover rates (per 10,000 registered vehicles) for various utility vehicle models, compared with all utility vehicles, half-ton pickup trucks and passenger cars.

much higher for utility vehicles than for passenger cars or for pickup trucks (significant at $\alpha = 0.05$; see Appendix C for details on the statistical test procedure and results for single vehicle rollover rates). The data in Table 2 show that utility vehicle rollover rates were over four times higher than those for either passenger cars or half-ton pickups.

Among utility vehicles, single vehicle rates were highest for the Jeep CJ-5 followed by the Jeep CJ-7 and the Toyota Land Cruiser. As there were only 78 single vehicle crashes involving the Land Cruiser, this model was deleted from the more detailed analyses that follow. The remaining utility vehicle models had single vehicle crash rates that were less than half those of the Jeep CJ-5, with the Ford Bronco 72-77 highest in that group followed by the Bronco 78-82. Rates for the Blazer and Scout were similar and were lowest of the utility vehicle models. The statistical significance of these various differences is presented in Table C.1 of Appendix C.

Among half-ton pickups, again the Toyotas and Datsuns had single vehicle and multi-vehicle rollover rates that were higher than the Ford or Chevrolet pickup trucks and fairly similar to the Blazer and Scout utility vehicles. Among passenger cars, the rollover rates increased (six to seven fold) as wheelbase decreased for both single vehicle and multi-vehicle crashes.

Throughout this report, it should be kept in mind that when rather substantial and significant differences in, for example, single vehicle rollover rates or percentages are observed, it is not immediately obvious what the contributing sources for these differences might be. Common sense would indicate that the reason a vehicle rolls over is likely to be a combination of vehicle, driver and roadway factors (e.g., the vehicle's own resistance to overturn, the age, sobriety, and/or experience characteristics of the person who is driving the vehicle, the nature of driving that's being done such as pleasure driving vs. commuting, and the roadway and environmental conditions present at that time). Because of sample size and other data limitations, it was not possible to distinguish with precision among all of these various factors.

An examination is made later in this report, however, of the effects on these comparisons of each of the following factors, which are, from the literature, potentially the most powerful:

driver: age, sex, intoxication, violations
vehicle: speed, TAD damage severity
roadway/environmental: rural-urban, road condition, time of day

along with a selected subset of interactions:

driver age x sex
driver age x intoxication
driver age x speed
driver age x intoxication
driver intoxication x speed
rural/urban x speed

Sample size considerations precluded examining higher order interactions (see Appendix D for the statistical details).

In addition to the rates of rollover per 10,000 registered vehicles, the percentages of crash-involved vehicles that rolled over provide a most useful additional indication of the relative frequency of particular vehicles being in rollover-type crashes. This is a conditional probability that answers the question, "Given that vehicle type A is in a crash, what is the probability or likelihood that it will roll over?" This measure is perhaps much less dependent on the amounts and types of mileage that various vehicles accumulate and thus may well be a more straightforward descriptor of the rollover behavior of the vehicles being studied.

The percentages of vehicles in single vehicle and multi-vehicle crashes that rolled over are shown in Table 3. Clearly, the results parallel those shown in Table 2 for rollover rates, as was also the case in Reinfurt et al. (1981) which presented results for North Carolina (1973-78) and for Maryland (1974-78). The percentages of rollovers in single vehicle crashes were much higher than in multi-vehicle crashes.

The rollover percentages -- for both single vehicle and multi-vehicle crashes -- were generally two to three times higher for utility vehicles than for pickup trucks or passenger cars. Again, the Jeep CJ-5 and Ford Bronco 72-77 along with the Jeep CJ-7, had the highest rollover percentages, followed by the Bronco 78-82, Blazer and Scout.

As with the rates per 10,000 registered vehicles, the Toyota and Datsun pickups had rollover percentages that resembled the Bronco 78-82, Blazer and Scout, and that were between the rates for the Ford and Chevrolet pickups and those for the Jeep CJ-5, Jeep CJ-7, and Bronco 72-77. Not surprisingly, the rollover percentages for passenger cars decreased as the wheelbase length increased.

In multi-vehicle crashes, which tend to occur more in urban areas and at lower speeds, the percentage of vehicles that rolled over was relatively small -- generally less than one percent for pickup trucks and passenger cars. For utility vehicles, however, the overturn percent was about four to five times

Table 3. Percentages of crash-involved vehicles that rolled over by type of crash.[1] North Carolina 1979-82

Type of Vehicle	Single Vehicle Crash		Multi-Vehicle Crash	
Utility Vehicles	45.2	[36.6][2]	2.1	[1.7]
Jeep CJ-5	49.3	[40.2]	3.1	[2.6]
Jeep CJ-7	49.7		3.0	
Ford Bronco				
1972-77	48.3	[37.4]	2.2	[3.3]
1978-82	39.8		1.0	
Chevrolet Blazer[3,4]	31.8	[22.5]	1.1	[0.6]
International Scout	35.3		1.2	
Pickup Trucks (1/2 ton)	24.5	[18.7]	0.5	[0.3]
Ford F-100, F-150	24.1	[17.5]	0.5	[0.3]
Chevrolet C-10, K-10[5]	22.0	[18.1]	0.4	[0.3]
Toyota	33.1	[27.3]	0.7	[1.2]
Datsun	28.7	[30.2]	1.0	[0.6]
Passenger Cars	16.0	[12.6]	0.2	[0.2]
Subcompact	23.8	[20.0]	0.4	[0.3]
Compact	14.8	[13.5]	0.2	[0.2]
Intermediate	8.9	[8.1]	0.1	[0.1]
Full-Size	7.9	[5.0]	0.1	[0.0]

[1]Excludes crashes with pedestrians, bicycles, trains, etc.
[2]Percentage reported in Reinfurt, et al. (1981).
[3]Includes the GMC Jimmy, an essentially identical vehicle.
[4]Excludes 1972 models which had a different wheelbase.
[5]Includes the GMC C-1500 and K-1500 which are essentially identical to the Chevrolet C-10 and K-10.