A FURTHER LOOK AT UTILITY VEHICLE ROLLOVERS

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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), 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:

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*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 is one of the accident types coded on the North Carolina collision report (see top of page 52). Because it applies to non-collision events only, any such overturn analysis should apply only to single vehicle crashes. It should be noted that the earlier study (Reinfurt and others, 1981) examined non-collision overturn-in-road, whereas, due to a change in the collision report on January 1, 1979, the present investigation addresses any non-collision overturn.

- 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,

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

  0 = 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 each 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.

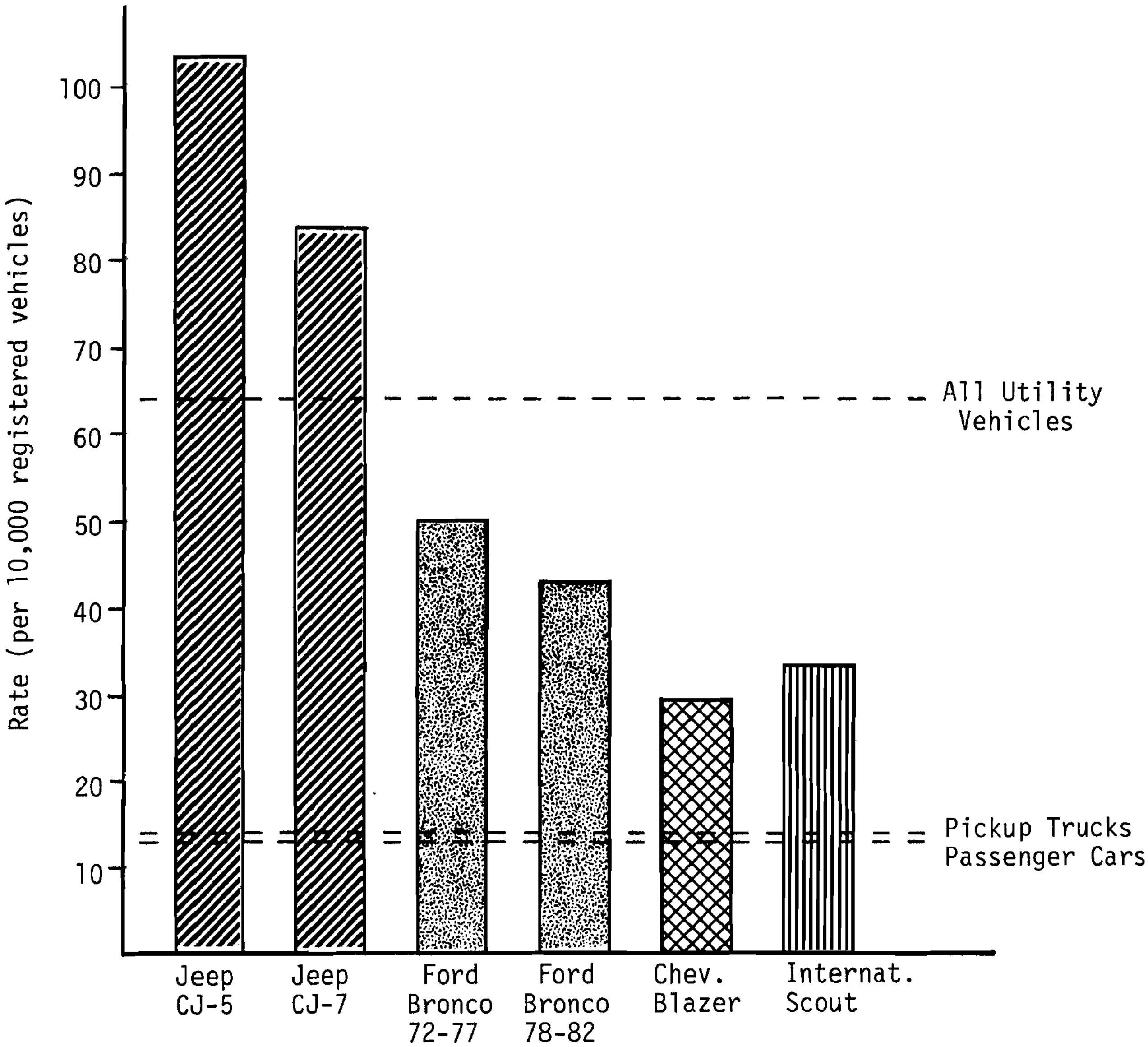

Figure 1. Single vehicle rollover rates (per 10,000 registered vehicles) for various utility vehicle models, compared with all utility vehicles, half-ton pickup trucks and passenger cars.

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.

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 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. Thus, this conditional probability of overturn is of primary interest in this investigation.

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

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.

for pickup trucks or passenger cars. Again, the Jeep CJ-5 and Ford Bronco 71-77 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 higher than for pickups or cars. Even higher were the multi-vehicle overturn percentages for the Jeep CJ-5 and the Jeep CJ-7.

As Tables 2 and 3 indicate, however, rollovers in single vehicle crashes were much more frequent than in multi-vehicle crashes -- higher by a factor of 21 for utility vehicles, 49 for pickup trucks, and 80 for passenger cars. Therefore, the remainder of this study focuses on single 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 <u>or</u> 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 sex 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).

The numbers of serious (A) or fatal (K) driver injuries per 10,000 registered vehicles in single vehicle crashes are presented in Table 4. Utility vehicles had serious or fatal driver injury rates that were approximately three times higher than the rates for either half-ton pickups or passenger cars, which is consistent with the findings in the earlier study. Among the utility vehicles, the Jeep CJ-5 and Jeep CJ-7 had significantly higher serious or fatal driver injury rates; the rates for the other utility vehicle models were similar and lower -- ranging from 8.6 to 13.0.

As in the earlier study, the Toyota and Datsun pickup truck rates were higher than those for the Ford and Chevrolet pickups but similar to those for the Broncos, Blazers, and Scouts. The serious or fatal driver injury rates for passenger cars decreased as wheelbase increased with a three-fold range from highest (subcompact) to lowest (full-size).

The corresponding percentages of drivers in single vehicle crashes with serious or fatal injuries (as shown in Table 5 and Figure 2) resemble those seen in the rate comparisons, although the differences among and within the three vehicle types are not as large. In brief, these percentages are highest for the Jeep CJ-5 and the Jeep CJ-7 (19.2 and 19.9 percent, respectively) followed by the other utility vehicle models and all pickup truck models (ranging from 9.5 to 13.5 percent). The percentages again decrease as wheelbase increases for passenger cars.

Note that, although the results in Tables 4 and 5 closely resemble those obtained in Reinfurt _et al_. (1981), the serious or fatal driver injury rates and percentages are generally slightly higher in this investigation. This is due to a change in the injury section of the North Carolina police accident report form on January 1, 1979, which resulted in relatively more serious (A) injuries being reported than before the form change.

Table 6 and Figure 3 present the numbers of serious (A) or fatal (K) driver injuries in single vehicle rollover crashes per 10,000 registered vehicles. Here, there was a considerably higher rate for utility vehicle drivers compared

Table 4. Single vehicle serious (A) or fatal (K) driver injury rates (per 10,000 registered vehicles).[1] North Carolina 1979-82

Type of Vehicle	(A+K) Driver Injury Rate	
Utility Vehicles	23.2	[19.6][2]
Jeep CJ-5	40.1	[37.4]
Jeep CJ-7	32.9	
Ford Bronco		
1972-77	12.9	[11.3]
1978-82	10.9	
Chevrolet Blazer[3,4]	8.6	[9.8]
International Scout	13.0	
Pickup Trucks (1/2 ton)	6.6	[4.6]
Ford F-100, F-150	6.2	[5.4]
Chevrolet C-10, K-10[5]	6.1	[5.5]
Toyota	12.0	[10.5]
Datsun	11.8	[7.2]
Passenger Cars	7.9	[7.8]
Subcompact	11.7	[12.6]
Compact	8.3	[9.8]
Intermediate	6.5	[6.8]
Full-Size	3.9	[4.1]

[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.

Table 5. Percentages of drivers in single vehicle crashes with serious (A) or fatal (K) injuries.[1]
North Carolina 1979-82

Type of Vehicle	Percent (A+K) Injury	
Utility Vehicles	16.5	[13.4][2]
Jeep CJ-5	19.2	[16.3]
Jeep CJ-7	19.9	
Ford Bronco		
1972-77	12.7	[6.7]
1978-82	10.2	
Chevrolet Blazer[3,4]	9.5	[10.5]
International Scout	13.5	
Pickup Trucks (1/2 ton)	11.8	[8.1]
Ford F-100, F-150	11.1	[8.1]
Chevrolet C-10, K-10[5]	11.9	[9.3]
Toyota	10.9	[8.0]
Datsun	15.6	[8.7]
Passenger Cars	10.3	[7.0]
Subcompact	11.3	[8.0]
Compact	10.4	[6.8]
Intermediate	9.1	[6.5]
Full-Size	9.0	[6.0]

[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.

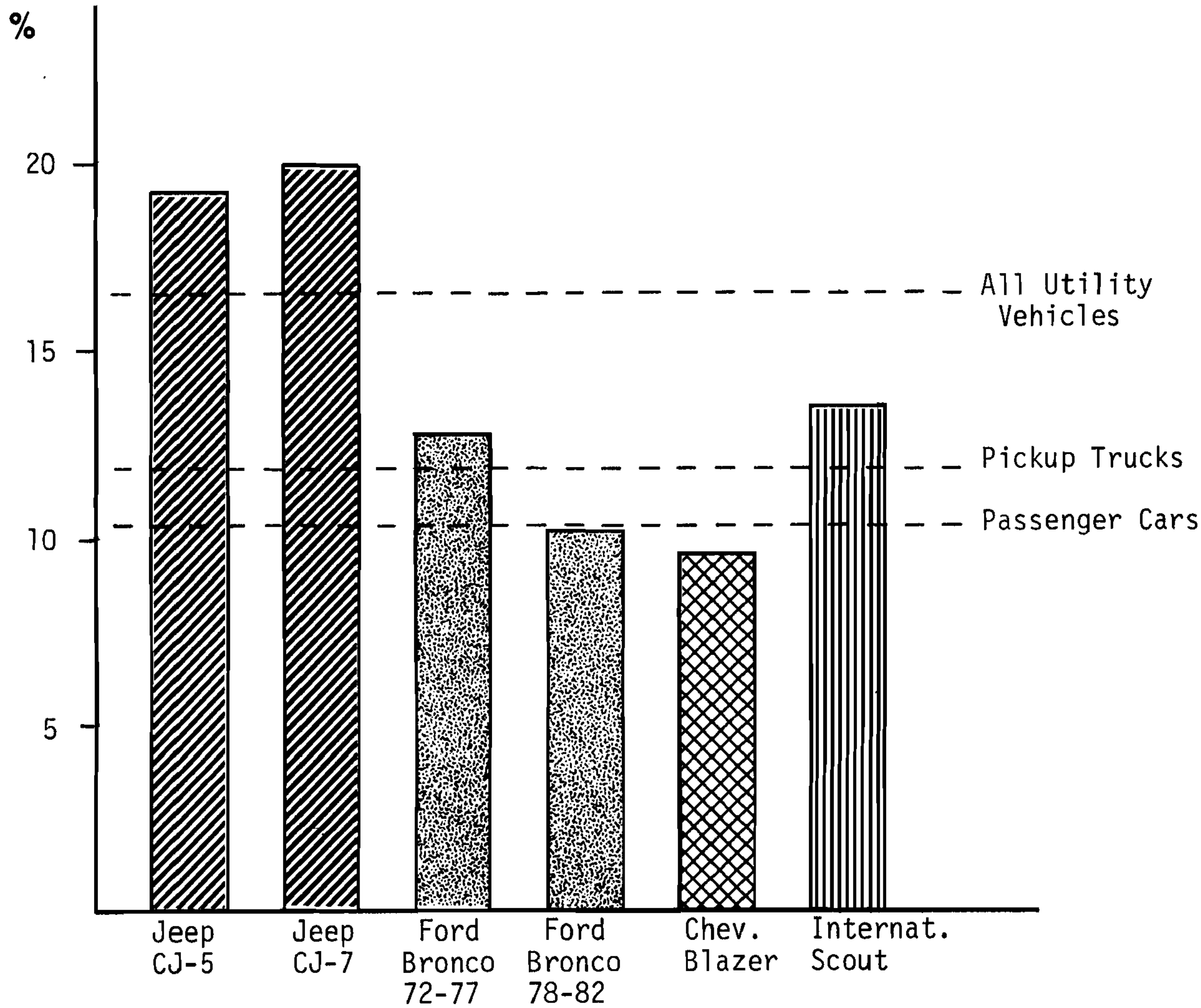

Figure 2. Percentages of drivers in single vehicle crashes with serious injuries for various utility vehicle models, compared with all utility vehicles, half-ton pickup trucks and passenger cars.

Table 6. Serious (A) or fatal (K) driver injury rates (per 10,000 registered vehicles) for single vehicle, rollover crashes.[1] North Carolina 1979-82

Type of Vehicle	(A+K) Driver Injury Rate	
Utility Vehicles	14.0	[10.0][2]
Jeep CJ-5	24.6	[21.0]
Jeep CJ-7	22.1	
Ford Bronco		
1972-77	8.6	[5.6]
1978-82	7.0	
Chevrolet Blazer[3,4]	3.7	[2.2]
International Scout	5.6	
Pickup Trucks (1/2 ton)	2.3	[1.5]
Ford F-100, F-150	2.1	[1.8]
Chevrolet C-10, K-10[5]	2.2	[1.6]
Toyota	4.7	[6.3]
Datsun	3.4	[1.7]
Passenger Cars	2.1	[2.0]
Subcompact	3.8	[4.1]
Compact	2.2	[2.8]
Intermediate	1.2	[1.1]
Full-Size	0.6	[0.8]

[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.

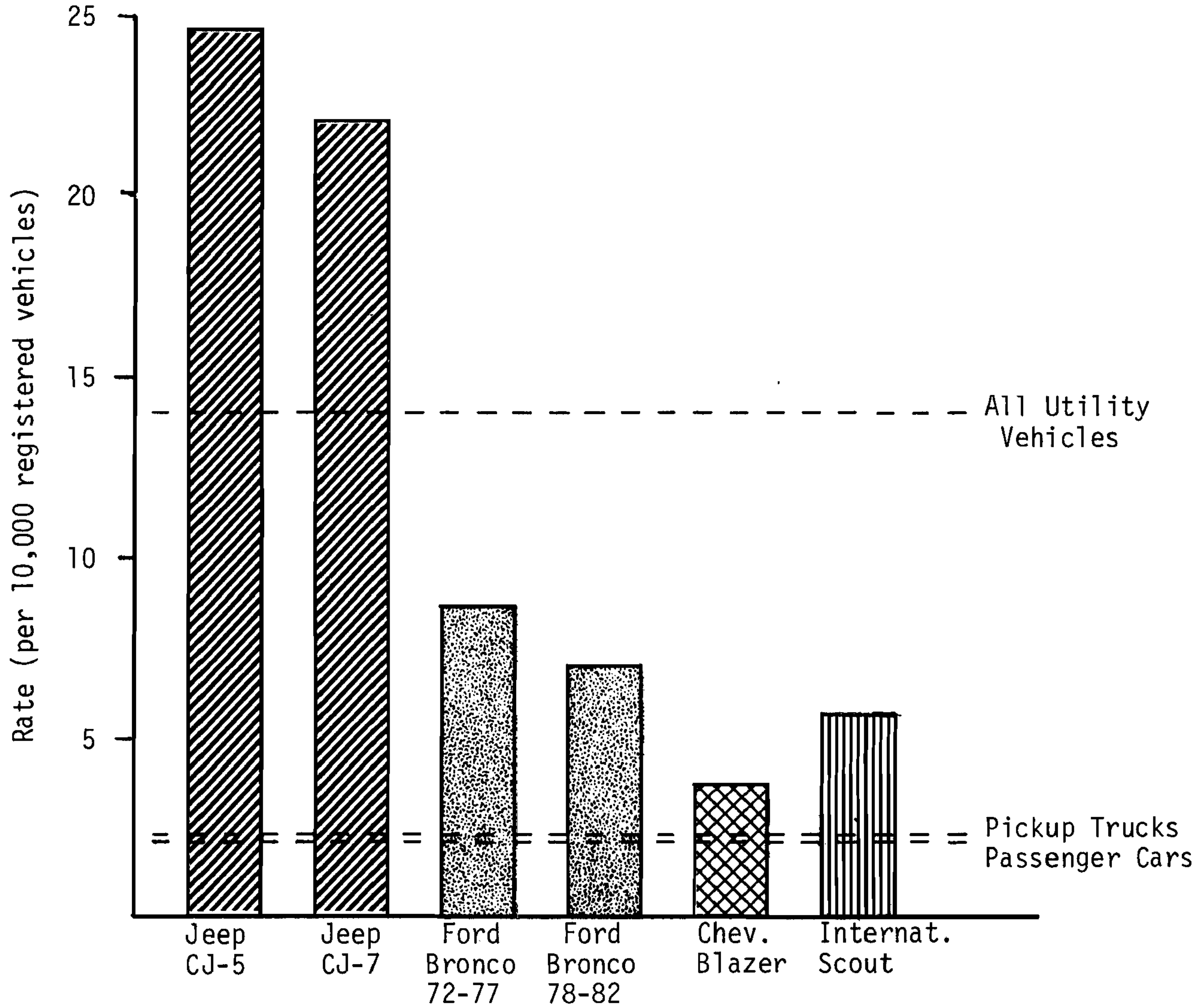

Figure 3. Serious driver injury rates (per 10,000 registered vehicles) in single vehicle rollover crashes for various utility vehicle models, compared with all utility vehicles, half-ton pickup trucks and passenger cars.

to the other two vehicle types -- an approximately six-fold difference. The Jeep CJ-5 and Jeep CJ-7 had rates that were nearly three-fold higher than those for the other leading utility vehicle models (significant at $\alpha = 0.05$; see Table C.3 in Appendix C). Ford Bronco 72-77 had a single vehicle (A+K) driver injury rate that was significantly higher than that of the Chevrolet Blazer, which was the lowest of the utility vehicle models.

Again, the Toyota and Datsun pickup rates were slightly higher than those of the Ford and Chevrolet pickups but very similar to the Blazer utility vehicle. Among passenger cars, the serious injury rates decreased with increasing car size, with an approximately six-fold difference between subcompact and full-size cars.

The percentages of drivers with serious (A) or fatal (K) injuries in single vehicle rollover crashes are presented in Table 7. Here, again, the percentages have a narrower range than the rates, but the same relative ordering obtains. The (A+K) driver injury percentages are relatively similar ranging from 12.9 percent to 19.9 percent across car sizes, pickup truck models, and also the Ford Bronco models, Chevrolet Blazer and International Scout. Only the Jeep CJ-5 and Jeep CJ-7 utility vehicles had (A+K) percentages out of this range -- 24.6 and 27.0 percent, respectively. The lack of a trend across car sizes may be a function of the severity of a single vehicle crash in which the forces were sufficient to cause the larger wheelbase cars to overturn. That is, single vehicle crashes in which an intermediate or full-size car overturns are probably more severe, in general, and hence more likely to have a higher risk of serious driver injuries.

Table 8 contains the percentages of vehicles in single vehicle crashes in North Carolina where the investigating officer indicated "non-collision overturn". This measure is of particular interest in that it deals with rollovers where other objects such as trees, guardrails, median barriers, etc., are not involved. As seen in Table 8, utility vehicles were more than four times as likely to be reported as overturned in non-collision crashes as half-ton pickup trucks and over nine times as likely as passenger cars. Among utility vehicles, the Jeep CJ-7 percentage was 8.4 followed by the Jeep CJ-5 at 7.2 and the Ford Bronco 72-77 at 4.1 percent. The Jeep CJ-5 and CJ-7 non-collision overturn percentages were significantly higher than those of the Chevrolet Blazer and the International Scout, while the Jeep CJ-7 percentage was also significantly higher than the Ford Bronco 78-82 (see Figure 4). Blazers, Scouts, and the newer Broncos had non-collision overturn percentages that were

Table 7. Percentages of serious (A) or fatal (K) driver injuries in single vehicle, rollover crashes.[1] North Carolina 1979-82

Type of Vehicle	Percent (A+K) Injury	
Utility Vehicles	22.5	[17.4][2]
Jeep CJ-5	24.6	[21.0]
Jeep CJ-7	27.0	
Ford Bronco		
1972-77	17.2	[7.6]
1978-82	16.3	
Chevrolet Blazer[3,4]	12.9	[10.9]
International Scout	16.7	
Pickup Trucks (1/2 ton)	17.5	[13.3]
Ford F-100, F-150	15.8	[15.4]
Chevrolet C-10, K-10[5]	19.9	[14.1]
Toyota	13.0	[16.5]
Datsun	15.7	[8.1]
Passenger Cars	16.9	[13.5]
Subcompact	15.5	[12.3]
Compact	18.7	[13.9]
Intermediate	19.8	[13.4]
Full-Size	17.6	[22.1]

[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.

Table 8. Percentages of vehicles that overturned in non-collision crashes[1]
North Carolina 1979-82

Type of Vehicle	Percent Non-Collision Overturn	
Utility Vehicles	5.7	[9.1] [2]
Jeep CJ-5	7.2	[12.2]
Jeep CJ-7	8.4	
Ford Bronco		
1972-77	4.1	[8.2]
1978-82	2.7	
Chevrolet Blazer [3,4]	2.4	[2.0]
International Scout	1.9	
Pickup Trucks (1/2 ton)	1.3	[1.8]
Ford F-100, F-150	1.2	[1.7]
Chevrolet C-10, K-10 [5]	0.9	[1.5]
Toyota	1.8	[3.8]
Datsun	2.6	[5.3]
Passenger Cars	0.6	[0.8]
Subcompact	0.9	[1.4]
Compact	0.6	[0.8]
Intermediate	0.4	[0.4]
Full-Size	0.3	[0.5]

[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.

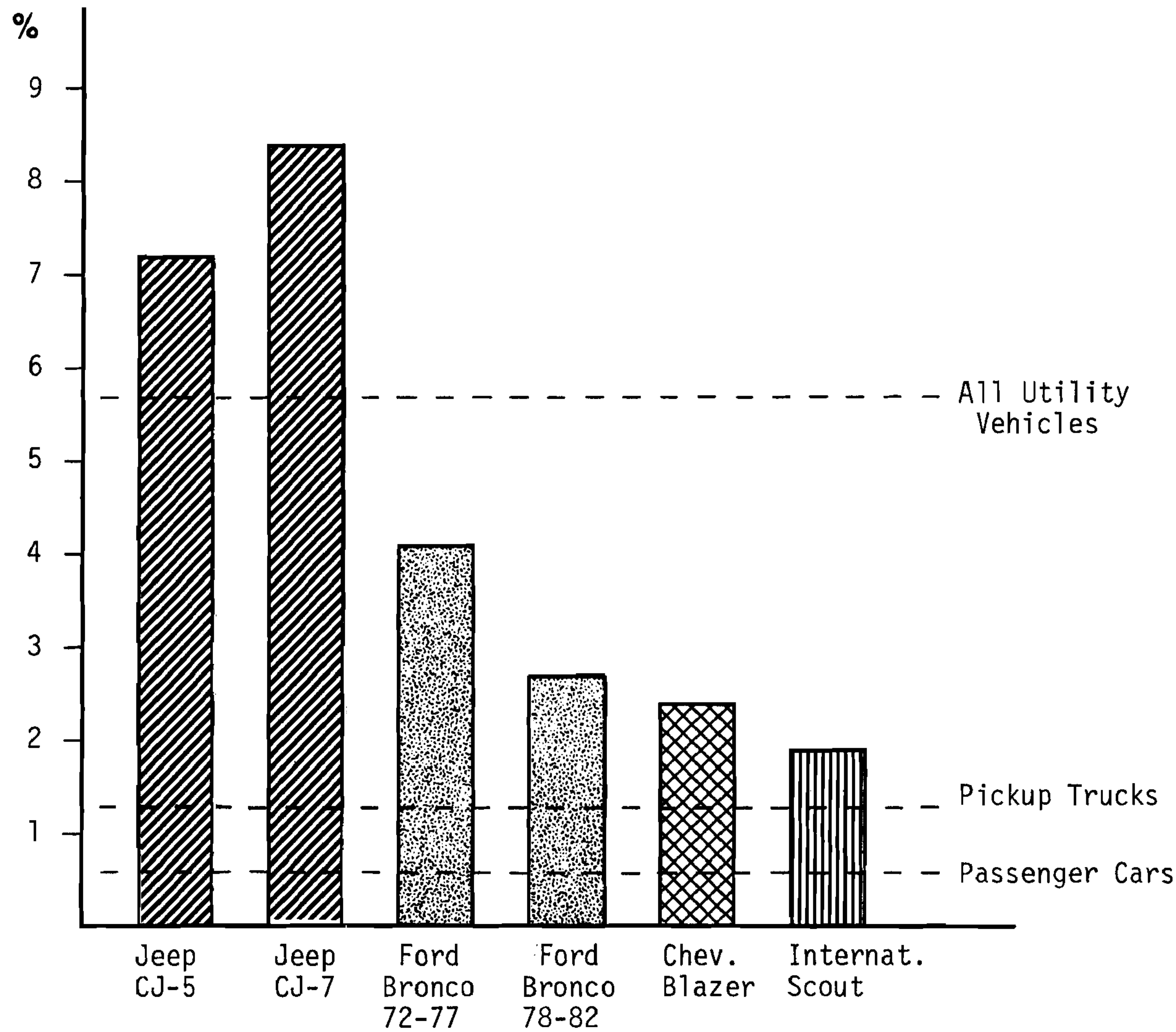

Figure 4. Percentages of vehicles in non-collision crashes that overturned for various utility vehicle models, compared with all utility vehicles, half-ton pickup trucks and passenger cars.

similar to those of the Toyota and Datsun pickups. The percentages for passenger cars were still lower, but the subcompact cars were nearly three times more likely to overturn in non-collision crashes than the full-size cars.

It should be noted that, except for the Chevrolet Blazer, the non-collision overturn percentages were lower for 1979-82 than for 1973-78. This evidently reflects a change in the North Carolina police accident report form on January 1, 1979. Prior to that time, non-collision overturn was coded regardless of whether or not it was the first in a series of harmful events involved in the crash sequence. Subsequently, if it was the most harmful event rather than the first, it would not be used in the analysis. In either case, however, it should not differentially affect any particular model, and thus the outcomes of the comparisons, which are relatively the same for the two time periods, should be valid.

Another variable of interest is reported seat belt usage. Table 9 and Figure 5 present various findings concerning belt usage and the percentage of serious (A) or fatal (K) driver injuries within belt-usage categories for all crashes. As is clear, driver belt usage rates were fairly low in all three vehicle classes but highest in the utility vehicle class (12.8%) followed by passenger cars (10.0%) and, much lower, pickup trucks (5.7%). The percentages wearing belts were highest for the Jeep CJ-5 and the Jeep CJ-7 drivers.

Consistent with a vast array of previous research on seat belts, there was a substantially lower incidence of (A+K) injuries among the belted drivers of all vehicles than among the unbelted drivers. Also, the (A+K) percentage for belted and unbelted utility vehicle drivers was about double that of their pickup and passenger car counterparts.

As expected, the percentage of drivers with serious or fatal injuries increased as passenger car wheelbase decreased, i.e., there was a two-fold increase for both belted and unbelted drivers from full-size to subcompact cars.

As indicated in Table 9, it should be noted that the 5.9 percent (A+K) for the Ford Bronco 72-77 is based on one serious injury in only 17 single vehicle crashes involving belted drivers. Likewise the zero percent (A+K) for the Ford Bronco 78-82 arises from no serious injuries among 39 belted drivers. Thus, caution should be observed in interpreting these two results. In the remaining cases, the highest serious or fatal driver injury rates are found among both belted and unbelted drivers of the Jeep CJ-5 and Jeep CJ-7.

Table 9. Serious (A) or fatal (K) driver injuries by belt usage status.[1]
North Carolina 1979-82

Type of Vehicle	Belted % (A+K)	Belted No. Belted	Belted % Belted	Not Belted % (A+K)	Not Belted No. Not Belted	Not Belted % Not Belted	Total
Utility Vehicles	3.4	820	(12.8)[2]	7.5	5559	(87.1)	6379
Jeep CJ-5	4.3	324	(14.3)	10.7	1947	(85.7)	2271
Jeep CJ-7	3.6	195	(19.9)	11.0	783	(80.1)	978
Ford Bronco							
1972-77	5.9[6]	17	(5.1)	8.5	318	(94.9)	335
1978-82	0.0	39	(9.7)	3.6	363	(90.3)	402
Chevrolet Blazer[3,4]	0.8	133	(8.8)	3.1	1373	(91.2)	1506
International Scout	2.1	48	(11.7)	4.2	361	(88.3)	409
Pickup Trucks (1/2 ton)	1.5	2723	(5.7)	3.9	44647	(94.3)	47370
Ford F-100, F-15	1.5	874	(5.2)	3.7	16040	(94.8)	16914
Chevrolet C-10, K-10[5]	0.8	1082	(5.4)	3.6	18809	(94.6)	19891
Toyota	2.1	243	(6.8)	4.8	3354	(93.2)	3597
Datsun	2.9	205	(7.1)	5.1	2663	(92.9)	2868
Passenger Cars	1.7	42320	(10.0)	3.9	380677	(90.0)	422997
Subcompact	2.4	14983	(10.6)	5.3	126296	(89.4)	141279
Compact	1.8	10153	(10.5)	3.9	86499	(89.5)	96652
Intermediate	1.4	11471	(9.6)	3.1	107768	(90.4)	119239
Full-Size	0.7	5713	(8.7)	2.7	60114	(91.3)	65827

[1]Excludes crashes with pedestrians, bicycles, trains, etc.

[2]Belt %: $12.8 = \frac{820}{6379} \times 100$

[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.

[6]Note the small n's: $5.9 = \frac{1}{17} \times 100$ and $0.0 = \frac{0}{39} \times 100$

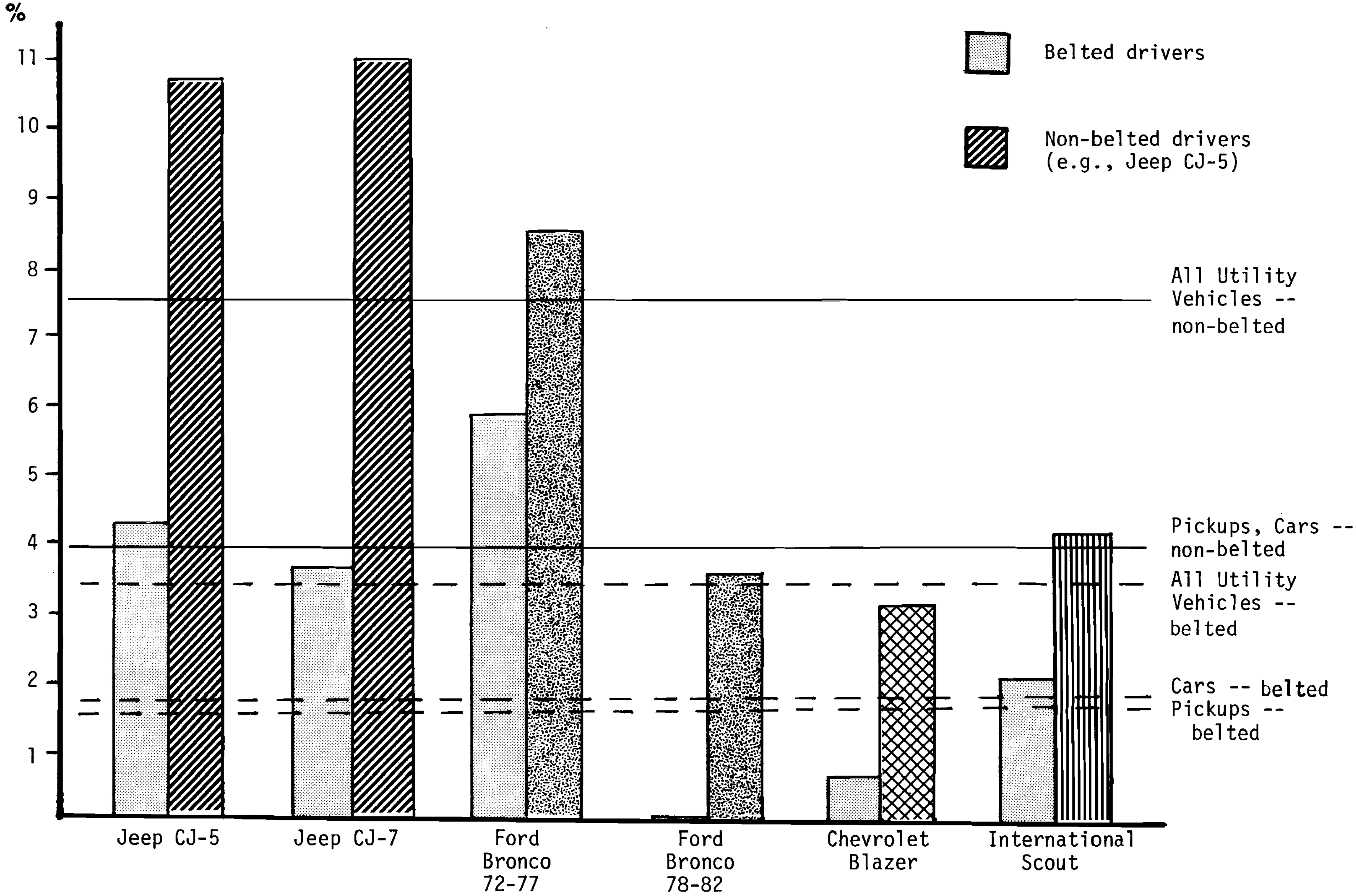

Figure 5. Driver serious injury percentages by belt usage status for the leading utility vehicle models compared with all utility vehicles, half-ton pickup trucks and passenger cars.

The percentage reduction in serious or fatal driver injuries resulting from seat belt usage was measured by

$$E = \text{Effectiveness} = \frac{(\text{Unbelted A+K \%}) - (\text{Belted A+K \%})}{(\text{Unbelted A+K \%})}$$

This value exceeded 50 percent in all cases excepting the Datsun pickup (43.1%) and the Ford Bronco 72-77 (with its small sample size). The observed effectiveness ranges for serious or fatal injury reduction at 50 percent or better is consistent with the literature. Overall effectiveness estimates were 54.7, 61.5, and 56.4 percent for utility vehicles, pickup trucks, and passenger cars, respectively.

Both the results presented here and those in Reinfurt et al. (1981) have shown by the use of several related measures that in single vehicle crashes utility vehicles have higher involvement rates, more frequent serious driver injuries, higher rollover rates, and more frequent serious driver injuries in rollover crashes. Among the utility vehicle models, the Jeep CJ-5 and Jeep CJ-7 are consistently the most extreme. Again the question should be raised, "To what extent might these differences be attributable to vehicle characteristics as opposed to other characteristics such as driving factors or patterns of vehicle use?"

Although perhaps this question cannot be fully answered from an analysis of the available accident data, many of the most probable factors can be explored. Throughout the previous results, the analyses controlled for accident type (single vehicle crashes). What effect does driver age have on the differential rollover rates or percentages for the various leading utility vehicle models? Driver intoxication? Reported driver violations? Accident speed or severity? Rural vs urban crash site? Condition of the road pavement? And what about the interacting effects of certain variables on rollover outcomes?

Clearly such analyses are limited by the type, quantity, and quality of data available. With this in mind, the following is an investigation of single vehicle rollover percentages for each of the leading utility vehicle models controlling for those driver-vehicle-highway/environmental factors (and their interactions) that the literature has shown to be most likely to make a difference. These include the following:

driver: age, sex, intoxication, violations
vehicle: speed, TAD damage rating severity
highway/environment: rural-urban, pavement condition, time of day

Two statistical analysis procedures were considered. The first calculates, for example, age-standardized rollover percentages (or rates for crash-involved vehicles) for each utility vehicle model (see Reinfurt, et al., 1981, page 37). The second uses Mantel-Haenszel-type statistics for comparing indices or ratios calculated within each of the age strata and then summed across strata (see Appendix D for the statistical details). As the latter makes better use of the full information in each table, and as tests for significance are ready outputs to the procedure, it is the method of choice. However, both procedures will be illustrated for driver age in order to compare the results with those found in the previous report.

Single vehicle rollover percentages may be differentially influenced by the ages of the drivers of the utility vehicle models being studied. Thus, it is useful to know if the age distribution for crash-involved drivers of the various utility vehicle models differs considerably. If so, perhaps the rollover differences are mainly a reflection of driver age differences. Table 10 presents the crash-involved driver age distributions for three vehicle types and for the leading utility vehicle models. It shows that the crash-involved drivers of utility vehicles were somewhat younger than their pickup or passenger car counterparts and that the Jeep CJ-5 and Jeep CJ-7 drivers were the youngest of all drivers. As younger drivers have not only more than their share of crashes on a mileage basis but more serious crashes as well, some of the rollover differences between, for example, the Jeep CJ-5 and All Utility Vehicles may be primarily a function of driver age.

Driver age-specific registration counts were not available to compare utility vehicle rollover rates (per 10,000 registered vehicles) for examining the effect of these differential driver ages. However, it was possible to compare rollover percentages by driver age groups (see Figure 6). As shown in the figure, the rollover percentages for the Jeep CJ-5 exceeded those of the reference population of All Utility Vehicles in virtually every age category, while those of the Chevrolet Blazer were consistently lower across age groups. This suggests that age is not an important factor for any particular utility vehicle model involved in rollover crashes.

To quantify this effect, the age-standardized rollover percentages using the age distribution for all utility vehicle drivers as a reference population show only minimal changes, suggesting again only a marginal age effect (if any). More specifically, the age-adjusted rollover percentage for the Jeep CJ-5, for example, is given by

Table 10. Single vehicle crash-involved driver age distribution.[1]
North Carolina 1979-82

Type of Vehicle	Driver Age: Under 20	20-24	25-29	30-34	Over 34	Total No. of Drivers
Utility Vehicles	29.0	30.7	16.6	10.6	13.1	1978
Jeep CJ-5	32.8	35.6	16.0	8.3	7.3	873
Jeep CJ-7	34.2	31.5	17.9	10.2	6.2	324
Ford Bronco						
1972-77	26.7	24.2	20.8	15.8	12.5	120
1978-82	20.2	29.3	14.7	11.0	24.8	109
Chevrolet Blazer[2,3]	23.4	24.3	16.5	13.1	22.7	321
International Scout	20.2	21.2	12.5	11.5	34.6	104
Pickup Trucks (1/2 ton)	20.5	22.1	15.7	11.6	30.1	8477
Passenger Cars	28.5	26.3	14.8	9.5	20.9	65423

[1]Table entries are row percentages; excludes "not stated" driver age and "driver not present" as well as crashes with pedestrians, bicycles, trains, etc.
[2]Includes the GMC Jimmy, an essentially identical vehicle.
[3]Excludes 1972 models which had a different wheelbase.

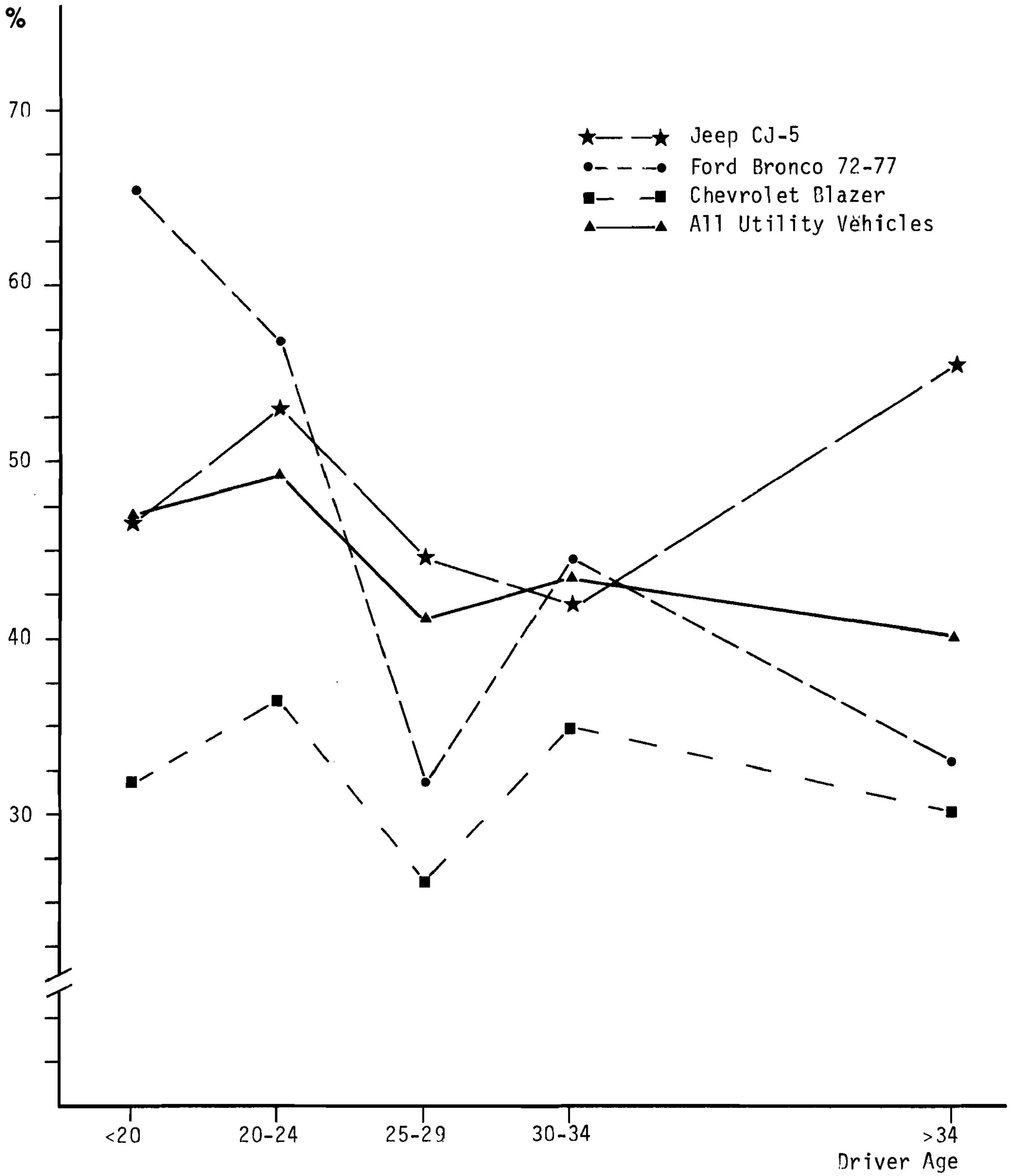

Figure 6. Utility vehicle rollover percentages by driver age for single vehicle crashes.

$$r_{J(adj)} = \sum_{i=1}^{5} r_{Ji}\, p_{Ui} ,$$

where

$r_{J(adj)}$ = standardized Jeep CJ-5 single vehicle rollover percentage;

r_{Ji} = Jeep CJ-5 single vehicle rollover percentage for age group i with

i = 1 under 20 years of age,
= 2 20-24,
= 3 25-29,
= 4 30-34,
= 5 35 and over; and

p_{Ui} = proportion of single vehicle crashes in age group i for the All Utility Vehicle (U) group.

Thus,

$$r_{J(adj)} = 46.6\ (0.29) + 53.3\ (0.31) + 44.9\ (0.17) + 42.2\ (0.10) + 55.6\ (0.13)$$

$$= 49.1$$

compared to a crude rate of 49.3 percent of single vehicle crashes involving the Jeep CJ-5 resulting in overturn. See Table 11 for the results for the other utility vehicle models.

Table 11. Crude and age-standardized single vehicle rollover percentages. North Carolina 1979-82

Type of Vehicle	r	r(adj)
Utility Vehicles	45.2%	
Jeep CJ-5	49.3	49.1
Jeep CJ-7	49.7	51.5
Ford Bronco		
1972-77	48.3	50.9
1978-82	39.8	41.4
Chevrolet Blazer	31.8	32.5
International Scout	35.3	39.3

The alternative and preferred procedure for controlling for the effect that variables such as driver age have on the single vehicle rollover percentages is described in detail in Appendix D. Briefly, the procedure compares the observed single vehicle rollover percentage for a given utility vehicle model (e.g., Jeep CJ-5) within each stratum of the control variable (e.g., for age, those drivers under 20) with the expected percentage of crashes resulting in rollovers based on that of the reference population (i.e., the All Utility Vehicle group) for that stratum. This comparison is done through the use of an index that is the ratio of the observed percentage to the expected percentage. The index within each stratum is weighted (to account for stratum size) and then summed across strata to provide the overall index, I. In this example, confidence intervals are then constructed for I to determine whether or not the observed Jeep CJ-5 single vehicle rollover percentage of 49.3 (see Table 11) is significantly higher than that of the reference population (45.2) having controlled for age.

Table 12 presents the results of these analyses. The rows provide a listing of the variables that were controlled for and the columns identify the specific utility vehicle model. The single vehicle rollover percentages for the Jeep CJ-5 (49.3) and Jeep CJ-7 (49.7) remained elevated ($\alpha = 0.05$ and $\alpha = 0.1$, respectively) after controlling for each of the variables shown in Table 12 (excepting driver violation for the Jeep CJ-7) On the other hand, the corresponding percentage for the Chevrolet Blazer (31.8) was significantly lower ($\alpha = 0.05$), as was also generally ($\alpha = 0.1$) the International Scout (35.3) except for the two-way interactions where a relatively small sample size posed certain limitations. In no cases were the single vehicle rollover percentages for the Ford Bronco 72-77 and Ford Bronco 78-82 (48.3 and 39.8, respectively) significantly different from the All Utility Vehicle group (45.2).

Clearly there are other factors that could have been examined, while there are others for which no data was available. Nevertheless, it would appear that the potentially most important variables have been controlled for in the single vehicle rollover percentage comparisons, with the findings being basically consistent with those observed using the raw percentages.

Table 12. Single vehicle rollover percentage significance tests controlling for certain driver, vehicle and roadway/environmental factors and their interactions.

Factor	U.V. Model	Jeep CJ-5	Jeep CJ-7	Bronco 72-77	Bronco 78-82	Chev. Blazer	Internat. Scout
Driver	Age	++	++	ns	ns	--	ns
	Sex	++	+	ns	ns	--	--
	Intoxication	++	+	ns	ns	--	-
	Violation	++	ns	ns	ns	--	--
Vehicle	Speed	++	+	ns	ns	--	--
	TAD Damage Severity	++	++	ns	ns	--	-
Roadway	Rural-Urban	++	+	ns	ns	--	--
	Road Condition	++	+	ns	ns	--	--
	Time of Day	++	++	ns	ns	--	--
Interactions:							
	Age x Sex	++	++	ns	ns	--	ns
	Age x Intoxication	++	++	ns	ns	--	-
	Age x Speed	++	++	ns	ns	--	ns
	Sex x Intoxication	++	+	ns	ns	--	ns
	Speed x Intoxication	++	+	ns	ns	--	ns
	Rural-Urban x Speed	++	+	ns	ns	--	-

++ Significantly higher ($\alpha = 0.05$) -- Significantly lower ($\alpha = 0.05$)
+ Significantly higher ($\alpha = 0.1$) - Significantly lower ($\alpha = 0.1$)
ns Non-significant at $\alpha > 0.1$

CHAPTER IV. DISCUSSION

The current study is a follow-up to a 1981 report by Reinfurt, Li, Popkin, O'Neill, Burchman, and Wells in which the relative involvement in rollover crashes of utility vehicles, pickup trucks, and passenger cars was investigated using crash data from North Carolina (1973-78), Maryland (1974-78) and the Fatal Accident Reporting System (1978-79). Highlights of the results of the earlier study were that smaller vehicles generally had higher rates of rollover involvement than larger vehicles. Among the passenger cars, there were very pronounced relationships with car size -- smaller cars had four to five times higher involvement rates in rollover crashes than larger cars. Similarly, among half-ton pickup trucks, smaller imported models were involved in rollover crashes at least twice as frequently as larger domestic models. Among utility vehicles, size was also a factor; the largest utility vehicle studied -- the Chevrolet Blazer -- had a much lower rollover rate than the smaller utility vehicles. Among the smaller utility vehicles, the Jeep CJ-5 had a generally worse experience than the pre-1978 Ford Bronco, although both were about the same size. In virtually every category of comparison -- crash involvement rates (particularly single vehicle), serious (A+K) driver injuries, rate of overturn, serious driver injuries in rollover crashes, serious injuries for belted and unbelted drivers -- the Jeep CJ-5 had the least favorable results of the various vehicles studied.

This follow-up study offered the opportunity to examine more recent crash data for North Carolina (1979-82) that included several additional utility vehicle models for which data were previously inadequate or nonexistent. These include the Jeep CJ-7, Ford Bronco 1978-82, and the International Scout. (The Toyota Land Cruiser crash data continued to be rather sparse.) Also, this report estimated vehicle-specific mileage exposure from newly available data.

As previously, rollovers occurred approximately ten times as often in single vehicle crashes as in multi-vehicle crashes. Thus, this follow-up investigation focused on single vehicle accidents in the North Carolina data files. (Maryland data was not used in this study as previously the results were consistent between North Carolina and Maryland across virtually every comparison.) Among the vehicle groups, utility vehicles had, by a considerable margin, the highest involvement rate in single vehicle rollover crashes; pickups and cars were similar and considerably lower. These findings are consistent with those in both Snyder _et al_. (1980) and Reinfurt _et al_. (1981).

Within vehicle types, the higher rollover rates were observed with the smaller vehicles -- Jeep CJ-5, Jeep CJ-7, and Toyota Land Cruiser utility vehicles; Toyota and Datsun pickups; and subcompact automobiles. Again, there was a five- to six-fold difference in rollover rates between the largest and smallest cars. The smaller imported pickups -- Toyota and Datsun -- had single vehicle rollover rates that were more than double those of the domestic pickups. The Jeep CJ-5 and Jeep CJ-7 had rates that were over double those of the larger utility vehicle models -- Chevrolet Blazer and International Scout -- with the Ford Bronco (72-77 and 78-82) having rates which were intermediate.

In virtually every category of comparison -- crash involvement rates (overall and single vehicle), serious (A+K) driver injury rates, rate of overturn (single vehicle and multi-vehicle), serious driver injuries in rollover crashes, percentages of vehicles in non-collision crashes that overturned, serious injuries for belted and unbelted drivers -- the Jeep CJ-5 and the Jeep CJ-7 had the least favorable results of the various vehicles studied, generally by a factor of two or more. The fact that the Jeep CJ-5 and the Jeep CJ-7 are usually sold as open-top vehicles undoubtedly contributed to their injury and fatality experience.

The remaining vehicle models tended to fall into one of several groups with similar within-group performance on these variables. In order of improving performance, these groups were as follows:

I. Jeep CJ-5 and Jeep CJ-7 utility vehicles

II. Ford Bronco 1972-77 and Ford Bronco 1978-82 utility vehicles

III. Chevrolet Blazer and International Scout utility vehicles; Toyota and Datsun half-ton pickups; subcompact cars

IV. Ford F-100 and F-150 and Chevrolet C-10 and K-10 half-ton pickups; compact cars

V. Intermediate and full-size cars

To what extent were these differences attributable to other factors involved in the crashes? To address this question, an analysis was carried out that controlled the single vehicle rollover percentage comparisons for each of the following factors as well as selected interactions:

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

Even after controlling for these variables, the previous conclusions held.

As indicated previously, registration data was used as the primary exposure measure. However, a sample of mileage data was examined which indicated that utility vehicles averaged approximately 1000 fewer miles per year than either half-ton pickups or passenger cars. This being the case, the results based on registration rates are, if anything, conservative.

The other measure examined (e.g., the percentage of Jeep CJ-5's that rolled over in single vehicle crashes) was much less affected by exposure differences because it only considers the outcomes for vehicles that were in crashes; that is, the percentage of single vehicle crashes for the particular utility vehicle in question that resulted in a rollover. Using this criterion, utility vehicles and especially the Jeep CJ-5 and the Jeep CJ-7 again fared rather poorly.

The literature (Garrett, 1969) has indicated that the track width and center of gravity of a vehicle are most important factors with respect to rollovers. Thus, it is not surprising to find in this study (as well as its predecessor) that utility vehicles, with higher centers of gravity and narrower track widths than passenger cars and half-ton pickup trucks, were more likely to be involved in rollover crashes. This finding was especially true for the smaller utility vehicles. It may be that many utility vehicle drivers are aware of the different handling characteristics of these vehicles and adjust their driving practices accordingly. However, the results of this study confirm those found in Reinfurt et al. (1981) that many drivers still are either not aware of some of these vehicles' handling characteristics or, if they are aware, do not or cannot adjust their driving practices to the extent necessary to avoid rollovers.

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APPENDIX A.

Vehicle Group Registration Counts and Description

Table A.1. Total registration counts for vehicle groups in North Carolina 1979-82

Type of Vehicle	No. of Registrations
Utility Vehicles	139,850
Jeep CJ-5	41,434
Jeep CJ-7	19,427
Ford Bronco	
1972-77	11,597
1978-82	10,050
Chevrolet Blazer[1,2]	34,758
International Scout	10,728
Other	11,856
Pickup Trucks (1/2 ton)	1,515,031
Ford F-100, F-150	527,271
Chevrolet C-10, K-10[3]	648,503
Toyota	76,932
Datsun	69,726
Other	192,599
Passenger Cars	8,433,747
Subcompact	2,501,334
Compact	1,896,668
Intermediate	2,353,039
Full-Size	1,682,706

[1]Includes the GMC Jimmy, an essentially identical vehicle.
[2]Excludes 1972 models which had a different wheelbase.
[3]Includes the GMC C-1500 and K-1500 which are essentially identical to the Chevrolet C-10 and K-10.

Table A.2. Description of vehicle groups -- makes and models.

Vehicle Type	Make	Model Name	Model Year(s)
Utility Vehicles			
	Jeep	CJ-5	1972-1982
	Jeep	CJ-7	1976-1982
	Ford	Bronco	1972-1982
		Bronco Pickup Utility	"
		Bronco Wagon	"
	Chevrolet	Blazer	1973-1982
		Blazer K-10	"
		(GMC) Jimmy	"
		(GMC) Jimmy K-1500	"
	International	Scout II	1975-1980
		Scout II Traveler	1976-1980
		Scout II SS2	1976-1979
Other Utility Vehicles			
	Jeep	CJ-6	1972-1975
		Scrambler	1981-1982
	Toyota	Land Cruiser	
		FJ55L	1970-1979
		FJ40L	1970-1980
		FJ40	1981-1982
		FJ60	1981-1982
	Plymouth	Trailduster	1974-1981
	Dodge	Ramcharger	1974-1982
Pickup Trucks (1/2 ton)			
	Ford	F-100	1972-1982
		F-100 Super Cab	1977-1979
		F-150	1975-1982
		F-150 Super Cab	1977-1982
	Chevrolet	C-10	1972-1982
		K-10	"
		S-10	1982
		Luv	1972-1982
		(GMC) C-1500	"
		(GMC) K-1500	"
		(GMC) S-1500	1982

Table A.2. (Con't)

Vehicle Type	Make	Model Name	Model Year(s)
	Toyota	RN[1] 14, 22, 22L, 23L, 27, 28, 32L, 34, 34L, 37L, 38, 38L, 42L, 44, 44L, 47L, 48, 48L	1972-1982
		LN 40	1981
		LN 44	1982
	Datsun	PL-521	1972
		620: Short Bed	1972-1979
		Long Bed	1975-1979
		King Cab	1976-1979
		720: Short Bed	1980-1982
		Long Bed	"
		King Cab	"
Other Pickup Trucks (1/2 ton)			
	Ford	Courier	1972-1980
		Courier Short Bed	1981-1982
		Courier Long Bed	"
	Dodge	D-50	1979-1982
		D-100	1972-1979
		D-150	1978-1982
		W-150	"
	Plymouth	Arrow	1979-1982
	Jeep	J-10	1974-1982
	International	Scout II Pickup	1975-1978
		Scout II Terra	1976-1980
		150	1975
	Mazda	RE	1974-1977
		B1600	1972-1976
		B1800: Standard Bed	1978
		Long Bed	1977-1978
		B2000: Short Bed	1979-1982
		Long Bed	"
		B2200: Long Bed	1982
	Subaru	Brat	1978-1980
		Brat DL	1981-1982
		Brat GL	"

[1]Each model produced during some portion of the study period.

Table A.2. (Con't)

Vehicle Type	Make	Model Name	Model Year(s)
	Isuzu	R14: Standard Bed	1981-1982
		L14: Standard Bed	"
		Long Bed	"
Passenger Cars			
	Subcompact	(<102 inch wheelbase)	
	Compact	(102-111 inch wheelbase)	
	Intermediate	(112-120 inch wheelbase)	
	Full-Size	(>120 inch wheelbase)	

APPENDIX B.

North Carolina Accident Report Form and
Motor Vehicle Inspection Receipt Form

ACCIDENT SEQUENCE CODES

1. VEHICLE MANEUVER/ PEDESTRIAN ACTION:
VEHICLE
1. Stopped in travel lane
2. Parked out of travel lanes
3. Parked in travel lanes
4. Going straight ahead
5. Changing lanes or merging
6. Passing
7. Making right turn
8. Making left turn
9. Making U turn
10. Backing
11. Slowing or stopping
12. Starting in roadway
13. Parking
14. Leaving parked position
15. Avoiding object in road
16. Other
PEDESTRIAN
17. Crossing at intersection
18. Crossing not at intersection
19. Coming from behind parked vehicle
20. Walking with traffic
21. Walking against traffic
22. Getting on or off vehicle
23. Standing in road
24. Working in road
25. Playing in road
26. Lying in road
27. Other in road
28. Not in road

2. ACCIDENT TYPE:
RAN OFF ROAD
1. Right
2. Left
3. Straight ahead
NON-COLLISION
4. Overturn
5. Other
COLLISION OF MOTOR VEHICLE WITH
6. Pedestrian
7. Parked vehicle
8. Train
9. Bicycle
10. Moped
11. Animal
12. Fixed object
13. Other object
COLLISION OF MOTOR VEHICLE WITH ANOTHER MOTOR VEHICLE
14. Rear end, slow or stop
15. Rear end, turn
16. Left turn, same roadway
17. Left turn, different roadways
18. Right turn, same roadway
19. Right turn, different roadways
20. Head on
21. Sideswipe
22. Angle
23. Backing

3. OBJECT STRUCK (excluding another motor vehicle in traffic)
1. None
2. Parked vehicle
3. Bicycle, moped
4. Pedestrian
5. Animal
6. Tree
7. Utility pole (with or without light)
8. Luminaire pole (non-breakaway)
9. Luminaire pole (breakaway)
10. Official highway sign (non-breakaway)
11. Official highway sign (breakaway)
12. Commercial sign
13. Guardrail end on shoulder
14. Guardrail face on shoulder
15. Guardrail end in median
16. Guardrail face in median
17. Shoulder barrier end (Non-Guardrail)
18. Shoulder barrier face (Non-Guardrail)
19. Median barrier end (Non-Guardrail)
20. Median barrier face (Non-Guardrail)
21. Bridge rail end
22. Bridge rail face
23. Overhead part of underpass
24. Pier on shoulder of underpass
25. Pier in median of underpass
26. Abutment (supporting wall of underpass)
27. Curb, median or traffic island
28. Catch basin or culvert on shoulder
29. Catch basin or culvert in median
30. Ditch bank
31. Mailbox
32. Fence or fence post
33. Construction barrier
34. Crash cushion
35. Other object (describe)

4. DISTANCE
1. In road
2. Right of road, 0-10 ft.
3. Right of road, 11-30 ft.
4. Right of road, over 30 ft.
5. Left of road, 0-10 ft.
6. Left of road, 11-30 ft.
7. Left of road, over 30 ft.

5. TRAILER TYPE:
NON-SEMI TRAILERS
BT = Boat
CT = Camper
UT = Utility
HE = Horse
HS = House trailer (mobile home)
TV = Towed vehicle
OT = Other
SEMI TRAILERS
TN = Tanker
VN = Van (enclosed trailer)
FB = Flat-bed or platform
OS = Other semi

DMV-349 (Rev. 1/79)

TRAFFIC ACCIDENT REPORT – Send To: N. C. Division of Motor Vehicles Raleigh, N. C. 27697

LOCATION

Date: ______ 19___ (Month Day Year) Day of Week: ______ Time: ___ (24 Hour Clock)

Local Use | Do not write in these spaces — DMV Report No.: | Date Received by DMV: | Patrol Area

Accident Occurred in ______ County ☐ In ☐ Near Incorporated City or Town of ______

Outside City or Town ______ Miles ☐ ☐ ☐ ☐ (N E S W) of City or Town Limits

On ______ Hwy. No. (I., U.S., N.C., R.P., R.U.). If within corporate limit or no hwy. no., identify by street name. If ramp or service road, indicate on line.

RR. Crossing No.: ______

___ • ___ Miles ☐ ☐ ☐ ☐ (N E S W) At or from ______ Use Hwy. No., Street Name, or Adjacent County or State Line ______ Toward ______ Use Hwy. No., Street Name, Incorporated Town, or Adjacent County or State Line

Feet (0 ft. if intersec.)

ACCIDENT SEQUENCE

1. VEHICLE MANEUVER/ PEDESTRIAN ACTION		2. ACCIDENT TYPE			3. OBJECT STRUCK AND 4. DISTANCE			
		FIRST HARMFUL EVENT	MOST HARMFUL EVENT: Repeat code if same as for FIRST HARMFUL EVENT		Vehicle 1		Vehicle 2	
Veh. 1	Veh. 2 or Ped.		Veh. 1	Veh. 2 or Ped.	Object	Distance	Object	Distance

No of Units Involved

VEHICLE NO. 1

Driver: First Middle Last Name
Address:
City: ______ State: ______ Zip Code: ______
Same Address as on Driver's License? Yes ☐ No ☐ Driver's Phone No.:
Race/Sex: ______ Driver's Lic.: ______ State: ______
Date of Birth: Month Day Year Specify Restriction:
Veh. Year: ______ Veh. Make: ______ Veh. Type: ______ Trailer Type: ______
Lic. Plate No.: ______ State: ______ Year: ______
VIN:
Owner:
Address:
City: ______ State: ______ Zip Code: ______
TAD (Parts Damaged): ______ Estimated Damage: $ ______
Vehicle Drivable? ☐ Yes ☐ No
Removed to:
Address:
By: ______ Authority: ______

☐ VEHICLE NO. 2 ☐ PEDESTRIAN ☐ OTHER

Driver: First Middle Last Name
Address:
City: ______ State: ______ Zip Code: ______
Same Address as on Driver's License? Yes ☐ No ☐ Driver's Phone No.:
Race/Sex: ______ Driver's Lic.: ______ State: ______
Date of Birth: Month Day Year Specify Restriction:
Veh. Year: ______ Veh. Make: ______ Veh. Type: ______ Trailer Type: ______
Lic. Plate No.: ______ State: ______ Year: ______
VIN:
Owner:
Address:
City: ______ State: ______ Zip Code: ______
TAD (Parts Damaged): ______ Estimated Damage: $ ______
Vehicle Drivable? ☐ Yes ☐ No
Removed to:
Address:
By: ______ Authority: ______

Other Property Damaged: ______ Estimated Damage: $ ______ Owner Name: ______ Address: ______

INJURY SECTION INSTRUCTIONS: Give Injury Class, Belt Usage, Race/Sex and Age of all Occupants in the space corresponding to the seat occupied (see codes at bottom). Names and addresses are necessary for persons who were injured.

Seat	Inj. Cl.	Belt Use	Race Sex	Age	Injured Names and Addresses (First Name … Last Name)	Seat	Inj. Cl.	Belt Use	Race Sex	Age	Injured Names and Addresses (First Name … Last Name)
Left Front					DRIVER 1	Left Front					DRIVER 2, PEDESTRIAN, OTHER
Center Front						Center Front					
Right Front						Right Front					
Left Rear						Left Rear					
Center Rear						Center Rear					
Right Rear						Right Rear					

Total No. Occupants: ______ Total No. Injured: ______ Total No. Occupants: ______ Total No. Injured: ______

Ambulance Requested? ☐ Yes ☐ No. If Yes, Ambulance Arrived At: ___ (24 Hour Clock)

Injured Taken To: ______ (Treatment Facility and City or Town)

MARKS > ADDED BY < ______ (Initial)

Injury Class

K – Killed
A – Incapacitating (Injury obviously serious enough to prevent carrying on normal activities for at least 24 hours; e.g., massive loss of blood, broken bone)
B – Nonincapacitating (injury other than K or A evident at the scene)
C – No visible sign of injury but complaint of pain or momentary unconsciousness
O – No injury

Belt Use

1. None or not used
2. Lap only
3. Lap and shoulder
4. Child restraint system
9. Unable to determine

Figure B.1 North Carolina Traffic Accident Report Form (front).

1. LOCALITY
1. Rural (< 30% developed)
2. Mixed (30% to 70% developed)
3. Urban (> 70% developed)

2. PREDOMINANT DEVELOPMENT TYPE
1. Farms, woods, pastures
2. Residential
3. Commercial
4. Institutional
5. Industrial

3. ROAD FEATURE
1. Bridge
2. Underpass
3. Driveway, public
4. Driveway, private
5. Alley intersection
6. Intersection of roadways
7. Non-intersection median crossing
8. End or beginning of divided highway
9. Interchange ramp
10. Interchange service road
11. Railroad crossing
12. Tunnel
13. Other (write in narrative)
14. No special feature

4. ROAD CHARACTER
1. Straight, level
2. Straight, hillcrest
3. Straight, grade
4. Straight, bottom (sag)
5. Curve, level
6. Curve, hillcrest
7. Curve, grade
8. Curve, bottom (sag)

5. ROAD CLASS
1. Interstate
2. U.S. route
3. N.C. route
4. State secondary route
5. Local street
6. Other public road
7. Private road, property or driveway

6. NUMBER OF LANES
Enter "O" if parking lot

7. ROAD CONFIGURATION
1. Undivided, one-way
2. Undivided, two-way
3. Divided

8. ROAD SURFACE
1. Concrete
2. Grooved concrete
3. Smooth asphalt
4. Coarse asphalt
5. Gravel
6. Sand
7. Soil
8. Other (write in narrative)

9. ROAD DEFECTS
1. Loose material on surface
2. Holes, deep ruts
3. Low shoulders
4. Soft shoulders
5. Other defects
6. Under construction
7. No defects

10. ROAD CONDITION
1. Dry
2. Wet
3. Muddy
4. Snowy
5. Icy
6. Other (write in narrative)

11. LIGHT CONDITION
1. Daylight
2. Dusk
3. Dawn
4. Darkness (street lighted)
5. Darkness (street not lighted)

12. WEATHER
1. Clear
2. Cloudy
3. Raining
4. Snowing
5. Fog, smog, smoke, dust
6. Sleet or hail

13. TRAFFIC CONTROL
1. Stop sign
2. Yield sign
3. Stop and go signal
4. Flashing signal with stop sign
5. Flashing signal without stop sign
6. RR gate and flasher
7. RR flasher
8. RR crossbucks only
9. Human control
10. Other (write in narrative)
11. No control present

14. VISION OBSTRUCTION
1. None
2. Vehicle window(s) obscured
3. Trees, crops, brush, etc.
4. Building(s)
5. Embankment
6. Sign(s)
7. Hillcrest
8. Parked vehicle(s)
9. Moving vehicle(s)
10. Blinded, headlights
11. Blinded, sunlight
12. Blinded, other lights
13. Other (write in narrative)

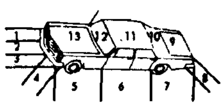
15. PHYSICAL CONDITION
1. Normal
2. Ill
3. Fatigued
4. Asleep
5. Impairment due to medicine or drugs
6. Other physical impairment
7. Restriction not complied with
8. Condition not known

16. INTOXICATION
1. Had not been drinking
2. Drinking – ability impaired
3. Drinking – unable to determine impairment
4. Unknown

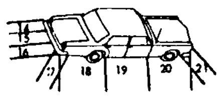
17. CHEMICAL TEST GIVEN

18. VEHICLE DEFECTS
(List one or more)
1. Defective brakes
2. Defective headlights
3. Defective rear lights
4. Defective steering
5. Defective tires
6. Other defects
7. Not known if defective
8. No defects detected

POINT(S) OF INITIAL CONTACT Write in Codes	
VEH. 1	VEH. 2

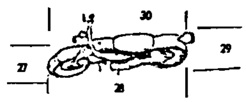


O. – No Contact



Underneath:
22. Front
23. Center
24. Rear

25. Rollover
26. Unknown



Motorcycle, Bicycle or Moped

ROADWAY INFORMATION					DRIVER 1	DRIVER 2 OR PED.		VEH. 1	VEH. 2
1. Locality		8. Road Surface							
2. Development Type		9. Road Defects		14. Vision Obstruction			18. Vehicle Defects		
3. Road Feature		10. Road Condition		15. Physical Condition			19. Speed Limit (for each vehicle)		
4. Road Character		11. Light Condition		16. Intoxication			20. Estimated Original Traveling Speed		
5. Road Class		12. Weather		17. Chemical Test Given	☐ Yes ☐ No ☐ Refused	☐ Yes ☐ No ☐ Refused	21. Estimated Speed at Impact		
6. Number of Lanes		13. Traffic Control Operating ☐ Yes ☐ No Visible ☐ Yes ☐ No					22. Tire Impressions Before Impact (ft.)		
7. Road Configuration							23. Distance Traveled After Impact (ft.)		

INDICATE NORTH

Vehicle 1 was Traveling ☐ ☐ ☐ ☐ on
N E S W

Vehicle 2 was Traveling ☐ ☐ ☐ ☐ on
N E S W

DESCRIBE WHAT HAPPENED:

WITNESSES: Name ________ Address ________ Phone No. ________
Name ________ Address ________ Phone No. ________

ARRESTS: Name ________ Charge(s) ________ (Cit. No.) ________
Name ________ Charge(s) ________ (Cit. No.) ________

Sign Here: ________
Officer's Rank and Name — Number — Department — Date of Report

VIOLATION INDICATED (Check as many violations as apply)

Driver 1 2		Driver 1 2		Driver 1 2	
☐ ☐	1. No violation indicated	☐ ☐	9. Minimum speed law	☐ ☐	17. Improper or no signal
☐ ☐	2. DUI/alcohol	☐ ☐	10. Pass stopped school bus	☐ ☐	18. Improper vehicle equipment
☐ ☐	3. DUI/drugs	☐ ☐	11. Passing on hill	☐ ☐	19. Safe movement violation
☐ ☐	4. Yield	☐ ☐	12. Passing on curve	☐ ☐	20. Following too closely
☐ ☐	5. Stop sign	☐ ☐	13. Other improper passing	☐ ☐	21. Improper backing
☐ ☐	6. Traffic signal	☐ ☐	14. Improper lane change	☐ ☐	22. Improper parking
☐ ☐	7. Exceeding speed limit	☐ ☐	15. Use of improper lane	☐ ☐	23. Unable to determine
☐ ☐	8. Exceeding safe speed	☐ ☐	16. Improper turn	☐ ☐	24. Other ________

RESERVED FOR CITY OR OTHER USE

RESERVED FOR STATE USE

	Driver 1	Driver 2
24. Direction		
25. Violation		
26. Mis. Action		
27. Charges		
28. Investigating Agency:		

Figure B.1 (cont.) North Carolina Traffic Accident Report Form (back).

NORTH CAROLINA DIVISION OF MOTOR VEHICLES

RECEIPT AND STATEMENT COVERING VEHICLE INSPECTION

OWNER U.N.C. Administration

ADDRESS South Campus

CITY Chapel Hill, NC 27514

LICENSE PLATE	MAKE OF VEHICLE	YEAR	VEHICLE IDENTIFICATION NUMBER
ABC-123	Ply.	78	HL45D8F123456

MILEAGE	TYPE OF VEHICLE
35,678	☑ AUTO ☐ TRUCK ☐ TRAILER ☐ STA. WAGON ☐ BUS ☐ MOTORCYCLE

COPY FROM PREVIOUS INSPECTION CERTIFICATE

MILEAGE	Month of Previous Inspection
24,342	☐ JAN ☐ FEB ☐ MAR ☐ APRIL ☐ MAY ☐ JUNE ☐ JULY ☐ AUG ☐ SEPT ☐ OCT ☑ NOV ☐ DEC

SAFETY EQUIPMENT	APPROVED INITIALLY	DISAPPROVED INITIALLY	CORRECTED DURING INSPECT.	REINSPECTED & APPROVED
HEADLIGHTS	✓			
BEAM INDICATOR LIGHT	✓			
PARKING LIGHTS	✓			
LICENSE PLATE LIGHT	✓			
TAIL LIGHTS		✓	✓	
STOP LIGHTS	✓			
CLEARANCE LIGHTS	✓			
DIRECTIONAL SIGNALS	✓			
FOOT BRAKE	✓			
EMERGENCY BRAKE	✓			
STEERING MECHANISM	✓			
WINDSHIELD WIPER	✓			
HORN	✓			
TIRES	✓			
REAR VIEW MIRRORS	✓			
EXHAUST EMISSION CONTROLS	✓			
EXHAUST SYSTEM	✓	Defective	If defective, do not reject vehicle, inform operator of condition.	

INSPECTION FEE 3.65 ☑
CERTIFICATE FEE .60 ☑ REPAIR CHARGE MADE $ 1.50

STATION NO.	DATE	MECHANIC'S SIGNATURE
1111	11/13/79	John J. Doe

INSPECTION NO. 123456 CERTIFICATE

REINSPECTION DATE	MECHANIC'S SIGNATURE

DISAPPROVED EQUIPMENT MAY BE REPAIRED BY THE OWNER OR AT A FIRM OF THE OWNER'S CHOICE AND BE REINSPECTED FREE OF CHARGE WITHIN 30 DAYS UPON PRESENTATION OF THIS RECEIPT TO THE SAME STATION CONDUCTING THE ORIGINAL INSPECTION; HOWEVER, THE INSPECTION DEADLINE IS NOT EXTENDED. OPERATION WITHOUT CURRENT "INSPECTION CERTIFICATE" OR DEFECTIVE EQUIPMENT SUBJECTS THE OPERATOR TO ARREST ACTION.

YOUR SAFETY IS ON THE LINE! A385402

MOORE BUSINESS FORMS, INC. RALEIGH, N.C. M

Figure B.2 North Carolina Motor Vehicle Inspection Receipt Form.

APPENDIX C.

Statistical Tests for Differences in Proportions and Differences in Rates

Differences in Two Proportions

Are the differences in, for example, the single vehicle rollover percentages for the Jeep CJ-5 and the Chevrolet Blazer significantly different? With adequately large (N > 30) samples of independent observations in each group, and assuming that the underlying distributions are binomial (i.e., an observation is either a rollover or not a rollover), this question can be answered with the following z-test (see Council, Reinfurt, Campbell, Roediger, Carroll, Dutt and Dunham, 1980, page 74):

$$z^* = \frac{p_J - p_B}{\left[p\,(1-p)\,\left(\frac{1}{N_J} + \frac{1}{N_B}\right)\right]^{1/2}}$$

where

p_J = proportion of single vehicle Jeep CJ-5 crashes with rollovers

p_B = proportion for the Chevrolet Blazer

p = pooled rollover estimate

$$= \frac{N_J p_J + N_B p_B}{N_J + N_B}$$

with

N_J = number of Jeep CJ-5's in single vehicle crashes

N_B = number for the Chevrolet Blazer

Then reject the null hypothesis, H_0, of equal proportions if

$z^* > z_c$ where z_c is the critical value from N(0,1) such that $Pr\,[\,z^* > z_c \mid H_0] = \alpha/2$ where α = Type I error

From the data in Table 2

$$p_J = \frac{429}{871} = 0.493$$

$$p_B = \frac{103}{324} = 0.318$$

$$p = \frac{871\ (0.493) + 324\ (0.318)}{871 + 324} = 0.446$$

so that

$$z^* = \frac{0.493 - 0.318}{[(0.446)(0.554)(\frac{1}{871} + \frac{1}{324})]^{\frac{1}{2}}} = 5.42$$

For $\alpha = 0.05$, $z_C = 1.96$. Since $z^* = 5.42 > 1.96 = z_C$, we would conclude that the two utility vehicle models have different single vehicle rollover percentages.

Differences in Two Rates

Are the differences in, for example, the single vehicle rollover rates (per 10,000 registered vehicles) for the Jeep CJ-5 and the Chevrolet Blazer significantly different? Here the rollover involvements with given exposures are assumed to follow Poisson distributions. Then, following the derivation presented in Dutt and Reinfurt (1977), confidence intervals for the ratio of the two rates, ρ , can be determined as follows.

Let

$$\omega = \frac{r_J\ v_J}{r_B\ v_B} \mathrel{\hat{=}} \frac{n_J}{n_B}$$

where

r_J = single vehicle rollover rate for the Jeep CJ-5

v_J = no. of registered Jeep CJ-5's

n_J = no of single vehicle Jeep CJ-5 rollovers

and similarly r_B, v_B and n_B for the Chevrolet Blazer where $r_J > r_B$.

Then a 100 (1- α) percent confidence interval (θ_L, θ_U) for

$$\theta = \frac{\omega}{1 + \omega}$$

is given by

$$\frac{n}{n + z_c^2}\left[\hat{\theta} + \frac{z_c^2}{2n} \pm z_c\left(\frac{\hat{\theta}(1-\hat{\theta})}{n} + \frac{z_c^2}{4n^2}\right)^{1/2}\right]$$

where

$$n = n_J + n_B$$

z_c is the critical value from N(0,1) such that

$$\Pr[\, z^* > z_c \mid H_o] = \alpha/2$$

$$\hat{\theta} = \frac{\hat{\omega}}{1 + \hat{\omega}} = \frac{n_J/n_B}{1 + n_J/n_B} = \frac{n_J}{n}$$

Thus the lower confidence limit, ρ_L, for ρ, the ratio of the single vehicle rollover rates, is given by

$$\rho_L = \frac{v_B}{v_J}\left(\frac{\theta_L}{1-\theta_L}\right)$$

and similarly for the upper limit, ρ_U. Reject H_o: $r_J = r_B$ if the interval does not contain unity, i.e.

$$1 \notin (\rho_L, \rho_U)$$

Illustrating using the data in Table 2 for the Jeep CJ-5 and the Chevrolet Blazer,

$$\hat{\omega} = \frac{n_J}{n_B} = \frac{429}{103} = 4.165$$

$$n = n_J + n_B = 532$$

$$z_c = 1.96 \text{ for } \alpha = 0.05$$

$$\hat{\theta} = \frac{\hat{\omega}}{1 + \hat{\omega}} = 0.806$$

Thus

$$\theta_L = \frac{532}{532 + (1.96)^2} \left[0.806 + \frac{(1.96)^2}{2\,(532)} - 1.96 \left(\frac{(0.806)(0.194)}{532} + \frac{(1.96)^2}{4\,(532)^2} \right)^{1/2} \right]$$

$$= 0.77$$

$$\theta_U = 0.84$$

so that

$$\rho_L = \frac{v_B}{v_J} \left(\frac{\theta_L}{1-\theta_L} \right) = \frac{34,758}{41,434} \left(\frac{0.77}{1-0.77} \right) = 2.81$$

$$\rho_U = 4.40$$

Table C.1 summarizes the results of the various pairwise comparisons between the various utility vehicle groups with respect to differences in single vehicle rollover rates. Thus, for example, from the first row, the All Utility

Table C.1. Single vehicle rollover rate comparisons.

		All U.V. (64.0)	Jeep CJ-5 (103.5)	Jeep CJ-7 (83.9)	Bronco 72-77 (50.0)	Bronco 78-82 (42.8)	Blazer (29.6)	Scout (33.6)
All U.V.	(64.0)		-[1]	-	0[2]	+[3]	+	+
Jeep CJ-5	(103.5)			+	+	+	+	+
Jeep CJ-7	(83.9)				+	+	+	+
Bronco 72-77	(50.0)					0	+	0
Bronco 78-82	(42.8)						+	0
Blazer	(29.6)							0
Scout	(33.6)							

[1] - indicates that the single vehicle rollover rate for All Utility Vehicles (64.0) is significantly ($\alpha = 0.05$) lower than the 103.5 rate for the Jeep CJ-5

[2] 0 indicates that the All Utility Vehicle rate of 64.0 and the Ford Bronco 72-77 rate of 50.0 are not significantly different

[3] + indicates that the All Utility Vehicle rate of 64.0 is significantly higher than the 42.8 rate for the Bronco 78-82

Vehicle rate (at 64.0) is significantly ($\alpha = 0.05$) below (-) the rates for the Jeep CJ-5 (at 103.5) and the Jeep CJ-7 (at 83.9), no different (0) from the Ford Bronco 72-77 (at 50.0), and higher than (+) the rates for the Ford Bronco 78-82 (at 42.8), Chevrolet Blazer (at 29.6) and the International Scout (at 33.6).

Table C.2 provides the results of the comparisons of serious (A) or fatal (K) driver injury rates in single vehicle crashes. Likewise, Table C.3 displays

Table C.2. Single vehicle (A+K) driver injury rate comparisons.

		All U.V. (23.2)	Jeep CJ-5 (40.1)	Jeep CJ-7 (32.9)	Bronco 72-77 (12.9)	Bronco 78-82 (10.9)	Blazer (8.6)	Scout (13.0)
All U.V.	(23.2)		-[1]	-	+[3]	+	+	+
Jeep CJ-5	(40.1)			0[2]	+	+	+	+
Jeep CJ-7	(32.9)				+	+	+	+
Bronco 72-77	(12.9)					0	0	0
Bronco 78-82	(10.9)						0	0
Blazer	(8.6)							0
Scout	(13.0)							

[1] - indicates that the single vehicle (A+K) driver injury rate for All Utility Vehicles (23.2) is significantly ($\alpha = 0.05$) lower than the 40.1 rate for the Jeep CJ-5

[2] 0 indicates that the Jeep J-5 rate of 40.1 and the Jeep CJ-7 rate of 32.9 are not significantly different

[3] + indicates that the All Utility Vehicle rate of 23.2 is significantly higher than the 12.9 rate for the Bronco 72-77

the results of comparing the rates of (A+K) driver injuries in single vehicle, rollover crashes.

Table C.3. (A+K) driver injury rate comparisons for single vehicle, rollover crashes.

		All U.V. (14.0)	Jeep CJ-5 (24.6)	Jeep CJ-7 (22.1)	Bronco 72-77 (8.6)	Bronco 78-82 (7.0)	Blazer (3.7)	Scout (5.6)
All U.V.	(14.0)		-[1]	-	0[2]	0	+[3]	+
Jeep CJ-5	(24.6)			0	+	+	+	+
Jeep CJ-7	(22.1)				+	+	+	+
Bronco 72-77	(8.6)					0	+	0
Bronco 78-82	(7.0)						0	0
Blazer	(3.7)							0
Scout	(5.6)							

[1] - indicates that the single vehicle rollover (A+K) driver injury rate for All Utility Vehicles (14.0) is significantly ($\alpha = 0.05$) lower than the 24.6 rate for the Jeep CJ-5

[2] 0 indicates that the All Utility Vehicle rate of 14.0 and the Ford Bronco 72-77 rate of 8.6 are not significantly different

[3] + indicates that the All Utility Vehicle rate of 14.0 is significantly higher than the 3.7 rate for the Chevrolet Blazer

APPENDIX D.

Mantel-Haenszel-Type Statistical Analysis Procedures

Basically, in this application, the procedure compares the observed single vehicle rollover percentage (or rate for crash-involved vehicles) for a given utility vehicle model (e.g., Jeep CJ-5) within each stratum of the control variable of interest (e.g., for age, those drivers under 20) with the expected percentage based on that of the reference population (i.e., the All Utility Vehicle group) for that stratum. This comparison is made using an index, I_j, which is the ratio of the observed percentage to the expected percentage. The index, I_j, within each stratum, j, is weighted to account for stratum size and then summed across strata to provide the overall index, I. For this example, confidence intervals are then constructed for I to determine whether or not the observed Jeep CJ-5 rollover percentage of 49.3 (from Table 3) is significantly higher than that of the reference population (45.2) having controlled for the effect of driver age.

More specifically for this example if driver age is dichotomized into two categories -- young and old -- and there are, for simplicity, only three utility vehicle groups, then the within stratum data can be represented as in Table D.1.

Table D.1. Basic data table.

Factor i	U.V. Group j	Rollover k=1	Not a Rollover k=2	Margin Total
Young (i=1)	1	n_{111}	n_{112}	n_{11*}
	2	n_{121}	n_{122}	n_{12*}
	3	n_{131}	n_{132}	n_{13*}
Margin Total		n_{1*1}	n_{1*2}	n_{1**}
Mature (i=2)	1	n_{211}	n_{212}	n_{21*}
	2	n_{221}	n_{222}	n_{22*}
	3	n_{231}	n_{232}	n_{23*}
Margin Total		n_{2*1}	n_{2*2}	n_{2**}
Total		n_{**1}	n_{**2}	n_{***}

Paralleling the derivation of the Mantel-Haenszel Test given in Elandt-Johnson and Johnson (1980), page 251, the index for utility vehicle type j is given by

$$I_j = \sum_{i=1}^{2} \left(\frac{n_{i*1}}{n_{**1}} \right) \frac{n_{ij1}}{E(n_{ij1})}$$

Now

$$E(n_{ij1}) = E\left(n_{ij1} \,\middle|\, \begin{array}{l} \text{rollover proportion and utility vehicle group} \\ \text{are independent; } n_{i**},\ n_{i*1} \text{ and } n_{ij*} \text{ given} \end{array} \right)$$

$$= \frac{n_{ij*}\, n_{i*1}}{n_{i**}}$$

so that

$$I_j = \sum_{i=1}^{2} \left(\frac{n_{i**}}{n_{**1}} \right) \frac{n_{ij1}}{n_{ij*}} \tag{1}$$

Thus

$$V_j = \mathrm{var}(I_j) = \sum_{i=1}^{2} \left(\frac{n_{i**}}{n_{**1} n_{ij*}} \right)^2 \mathrm{var}\,(n_{ij1})$$

$$= \sum_{i=1}^{2} \left(\frac{n_{i**}}{n_{**1} n_{ij*}} \right)^2 \left[\frac{n_{i*1} n_{i*2}}{n_{i**}^2 (n_{i**}-1)} \quad (n_{i**} n_{ij*} - n_{ij*}^2) \right]$$

$$= \sum_{i=1}^{2} \left(\frac{n_{i*1}}{n_{**1}} \right)^2 \left[\frac{n_{i*2}}{n_{i*1} n_{ij*}\ (n_{i**}-1)} \quad (n_{i**} - n_{ij*}) \right] \tag{2}$$

Thus 100 $(1-\alpha)$ percent confidence intervals $(I_{Lj},\ I_{Uj})$ are given by

$$\begin{aligned} I_{Lj} &= I_j - z_c V_j^{1/2} \\ I_{Uj} &= I_j + z_c V_j^{1/2} \end{aligned} \tag{3}$$

where

z_c is the critical value from N(0,1) such that $Pr[\,|z^*| > z_c |\, H_0] = \alpha/2$

Reject H_0 if $1 \notin (I_{Lj}, I_{Uj})$.

For the example comparing the Jeep CJ-5 single vehicle rollover percentage with that for All Utility Vehicles controlling for driver age, Table E.1 is summarized in the basic data table shown below. Thus for the Jeep CJ-5, using (1),

$$I_1 = \left(\frac{1157}{878}\right)\left(\frac{292}{583}\right) + \left(\frac{776}{878}\right)\left(\frac{127}{272}\right) = 1.07$$

Age Group i	Utility Vehicle Group j	Rollover (k=1)	Not a Rollover (k=2)	Subtotal
Young (i=1)	Jeep CJ-5	292	291	583
	Jeep CJ-7	97	114	211
	Bronco 72-77	37	23	60
	Bronco 78-82	25	28	53
	Blazer	52	99	151
	Scout	19	22	41
	Other	35	23	58
Subtotal		557	600	1157
Mature (i=2)	Jeep CJ-5	127	145	272
	Jeep CJ-7	62	44	106
	Bronco 72-77	21	37	58
	Bronco 78-82	18	33	51
	Blazer	49	114	163
	Scout	17	43	60
	Other	27	39	66
Subtotal		321	455	776
Total		878	1055	1933

and from (2)

$$V_1 = \left(\frac{557}{878}\right)^2 \left[\frac{600}{(557)(583)(1156)} \quad (1157-583)\right]$$

$$+ \left(\frac{321}{878}\right)^2 \left[\frac{455}{(321)(272)(775)} \quad (776-272)\right]$$

$$= 0.000822$$

For $\alpha = 0.05$, $z_c = 1.96$ so that from (3)

$$I_{L1} = 1.07 - 1.96\ (0.029) = 1.01$$

$$I_{U1} = 1.07 + 1.96\ (0.029) = 1.13$$

and because $1 \notin (1.01, 1.13)$ we conclude that, having controlled for driver age (<25 vs. ≥ 25), the Jeep CJ-5 single vehicle rollover percentage is still significantly higher than that for All Utility Vehicles.

APPENDIX E.

Single Vehicle Rollover Distributions for the Utility Vehicle Groups

Table E.1 Single vehicle rollovers by driver age.

Vehicle Type	Driver Age	No. of Rollovers	%	Total	(Col. %)
Jeep CJ-5	< 20	131	46.6	281	(32.9)
	20-24	161	53.3	302	(35.3)
	25-29	62	44.9	138	(16.1)
	30-34	30	42.3	71	(8.3)
	> 34	35	55.6	63	(7.4)
Jeep CJ-7	< 20	51	46.8	109	(34.4)
	20-24	46	45.1	102	(32.2)
	25-29	29	52.7	55	(17.3)
	30-34	20	64.5	31	(9.8)
	> 34	13	65.0	20	(6.3)
Ford Bronco 72-77	< 20	21	65.6	32	(27.1)
	20-24	16	57.1	28	(23.7)
	25-29	8	32.0	25	(21.2)
	30-34	8	44.4	18	(15.3)
	> 34	5	33.3	15	(12.7)
Ford Bronco 78-82	< 20	10	45.5	22	(21.2)
	20-24	15	48.4	31	(29.8)
	25-29	3	23.1	13	(12.5)
	30-34	5	41.7	12	(11.5)
	> 34	10	38.5	26	(25.0)
Chevrolet Blazer	< 20	24	32.0	75	(23.9)
	20-24	28	36.8	76	(24.2)
	25-29	13	26.0	50	(15.9)
	30-34	14	35.0	40	(12.7)
	> 34	22	30.1	73	(23.3)
International Scout	< 20	11	55.0	20	(19.8)
	20-24	8	38.1	21	(20.8)
	25-29	3	23.1	13	(12.9)
	30-34	5	41.7	12	(11.9)
	> 34	9	25.7	35	(34.6)
All Utility Vehicles	< 20	265	47.0	564	(29.2)
	20-24	292	49.2	593	(30.7)
	25-29	130	41.0	317	(16.4)
	30-34	89	43.6	204	(10.5)
	> 34	102	40.0	255	(13.2)

Table E.2 Single vehicle rollovers by driver sex.

Vehicle Type	Driver Sex	No. of Rollovers	%	Total	(Col. %)
Jeep CJ-5	M	366	50.3	728	(86.0)
	F	50	42.0	119	(14.0)
Jeep CJ-7	M	139	50.4	276	(88.5)
	F	18	50.0	36	(11.5)
Ford Bronco 72-77	M	50	51.6	97	(83.6)
	F	8	42.1	19	(16.4)
Ford Bronco 78-82	M	38	42.7	89	(86.4)
	F	5	35.7	14	(13.6)
Chevrolet Blazer	M	83	32.3	257	(84.0)
	F	18	36.7	49	(16.0)
International Scout	M	25	30.1	83	(82.2)
	F	11	61.1	18	(17.8)
All Utility Vehicles	M	757	46.2	1638	(85.8)
	F	116	43.0	270	(14.2)

Table E.3 Single vehicle rollovers by driver intoxication.

Vehicle Type	Driver Intoxication	No. of Rollovers	%	Total	(Col. %)
Jeep CJ-5	Yes	131	48.3	271	(35.0)
	No	244	48.5	503	(65.0)
Jeep CJ-7	Yes	54	53.5	101	(35.2)
	No	90	48.4	186	(64.8)
Ford Bronco 72-77	Yes	15	41.7	36	(32.7)
	No	40	54.1	74	(67.3)
Ford Bronco 78-82	Yes	15	45.5	33	(35.5)
	No	23	38.3	60	(64.5)
Chevrolet Blazer	Yes	25	28.7	87	(30.0)
	No	71	35.0	203	(70.0)
International Scout	Yes	7	24.1	29	(31.2)
	No	27	42.2	64	(68.8)
All Utility Vehicles	Yes	267	44.1	606	(34.4)
	No	528	45.8	1154	(65.6)

Table E.4 Single vehicle rollovers by driver violations.

Vehicle Type	Driver Violations	No. of Rollovers	%	Total	(Col. %)
Jeep CJ-5	None	128	46.2	277	(32.3)
	Speeding	156	53.6	291	(34.0)
	Other	140	48.4	289	(33.7)
Jeep CJ-7	None	37	40.2	92	(28.5)
	Speeding	71	60.2	118	(36.5)
	Other	53	46.9	113	(35.0)
Ford Bronco 72-77	None	18	43.9	41	(34.7)
	Speeding	21	60.0	35	(29.7)
	Other	19	45.2	42	(35.6)
Ford Bronco 78-82	None	13	37.1	35	(33.0)
	Speeding	11	52.4	21	(19.8)
	Other	19	38.0	50	(47.2)
Chevrolet Blazer	None	28	28.9	97	(30.9)
	Speeding	37	41.6	89	(28.3)
	Other	38	29.7	128	(40.8)
International Scout	None	13	34.2	38	(37.6)
	Speeding	14	48.3	29	(28.7)
	Other	9	26.5	34	(33.7)
All Utility Vehicles	None	258	41.7	619	(31.9)
	Speeding	331	53.5	619	(31.9)
	Other	297	42.2	703	(36.2)

Table E.5 Single vehicle rollovers by accident speed.

Vehicle Type	Accident Speed	No. of Rollovers	%	Total	(Col. %)
Jeep CJ-5	< 30	38	39.6	96	(11.3)
	30-49	206	48.0	429	(50.4)
	≥ 50	171	52.5	326	(38.3)
Jeep CJ-7	< 30	16	48.5	33	(10.4)
	30-49	71	44.9	158	(49.8)
	≥ 50	70	55.6	126	(39.8)
Ford Bronco 72-77	< 30	3	27.3	11	(9.2)
	30-49	20	38.5	52	(43.3)
	≥ 50	35	61.4	57	(47.5)
Ford Bronco 78-82	< 30	1	9.1	11	(10.5)
	30-49	22	45.8	48	(45.7)
	≥ 50	20	43.5	46	(43.8)
Chevrolet Blazer	< 30	11	24.4	45	(14.4)
	30-49	37	27.2	136	(43.6)
	≥ 50	52	39.7	131	(42.0)
International Scout	< 30	6	50.0	12	(12.1)
	30-49	17	31.5	54	(54.6)
	≥ 50	12	36.4	33	(33.3)
All Utility Vehicles	< 30	78	35.9	217	(11.2)
	30-49	407	43.0	946	(49.1)
	≥ 50	385	50.3	765	(39.7)

Table E.6 Single vehicle rollovers by TAD severity.

Vehicle Type	TAD Severity	No. of Rollovers	%	Total	(Col. %)
Jeep CJ-5	Minor[1]	187	42.6	439	(58.1)
	Major[2]	177	56.0	316	(41.9)
Jeep CJ-7	Minor	76	45.5	167	(59.9)
	Major	64	57.1	112	(40.1)
Ford Bronco 72-77	Minor	24	37.5	64	(61.5)
	Major	24	60.0	40	(38.5)
Ford Bronco 78-82	Minor	20	37.7	53	(58.2)
	Major	16	42.1	38	(41.8)
Chevrolet Blazer	Minor	40	25.3	158	(57.0)
	Major	46	38.7	119	(43.0)
International Scout	Minor	19	33.9	56	(62.9)
	Major	12	36.4	33	(37.1)
All Utility Vehicles	Minor	394	39.4	1001	(58.7)
	Major	363	51.5	705	(41.3)

[1]Minor: TAD 1-3
[2]Major: TAD 4-7

Table E.7 Single vehicle rollovers by rural-urban location.

Vehicle Type	Location	No. of Rollovers	%	Total	(Col. %)
Jeep CJ-5	Rural	379	54.1	701	(80.7)
	Urban	50	29.8	168	(19.3)
Jeep CJ-7	Rural	143	55.2	259	(79.2)
	Urban	20	29.4	68	(20.8)
Ford Bronco 72-77	Rural	56	56.0	100	(84.0)
	Urban	1	5.3	19	(16.0)
Ford Bronco 78-82	Rural	37	43.0	86	(79.6)
	Urban	6	27.3	22	(20.4)
Chevrolet Blazer	Rural	101	39.3	257	(79.3)
	Urban	2	3.0	67	(20.7)
International Scout	Rural	32	38.1	84	(82.4)
	Urban	4	22.2	18	(17.6)
All Utility Vehicles	Rural	801	50.7	1579	(79.9)
	Urban	93	23.5	396	(20.1)

Table E.8 Single vehicle rollovers by pavement condition.

Vehicle Type	Pavement Condition	No. of Rollovers	%	Total	(Col. %)
Jeep CJ-5	Dry	273	49.6	551	(63.5)
	Wet	62	48.1	129	(14.9)
	Other	92	49.2	187	(21.6)
Jeep CJ-7	Dry	112	52.8	212	(64.6)
	Wet	14	31.8	44	(13.4)
	Other	37	51.4	72	(22.0)
Ford Bronco 72-77	Dry	43	51.2	84	(70.0)
	Wet	7	35.0	20	(16.7)
	Other	8	50.0	16	(13.3)
Ford Bronco 78-82	Dry	28	38.4	73	(68.2)
	Wet	9	45.0	20	(18.7)
	Other	6	42.9	14	(13.1)
Chevrolet Blazer	Dry	74	33.5	221	(68.2)
	Wet	13	27.7	47	(14.5)
	Other	16	28.6	56	(17.3)
International Scout	Dry	19	33.3	57	(55.9)
	Wet	4	28.6	14	(13.7)
	Other	13	41.9	31	(30.4)
All Utility Vehicles	Dry	595	46.1	1290	(65.4)
	Wet	117	40.2	291	(14.7)
	Other	181	46.1	393	(19.9)

Table E.9 Single vehicle rollovers by time-of-day.

Vehicle Type	Time-of-Day	No. of Rollovers	%	Total	(Col. %)
Jeep CJ-5	1:00 am - 5:59 am	86	45.3	190	(22.0)
	Commuting[1]	106	50.0	212	(24.6)
	9:00 am - 3:59 pm	97	56.1	173	(20.1)
	7:00 pm - 9:59 pm	64	50.8	126	(14.6)
	10:00 pm - 12:59 am	70	43.5	161	(18.7)
Jeep CJ-7	1:00 am - 5:59 am	34	45.9	74	(22.8)
	Commuting	39	55.7	70	(21.5)
	9:00 am - 3:59 pm	32	43.2	74	(22.8)
	7:00 pm - 9:59 pm	25	55.6	45	(13.8)
	10:00 pm - 12:59 am	33	53.2	62	(19.1)
Ford Bronco 72-77	1:00 am - 5:59 am	8	47.1	17	(14.3)
	Commuting	17	53.1	32	(26.9)
	9:00 am - 3:59 pm	13	41.9	31	(26.0)
	7:00 pm - 9:59 pm	7	36.8	19	(16.0)
	10:00 pm - 12:59 am	13	65.0	20	(16.8)
Ford Bronco 78-82	1:00 am - 5:59 am	10	34.5	29	(27.1)
	Commuting	11	47.8	23	(21.5)
	9:00 am - 3:59 pm	12	52.2	23	(21.5)
	7:00 pm - 9:59 pm	2	18.2	11	(10.3)
	10:00 pm - 12:59 am	8	38.1	21	(19.6)
Chevrolet Blazer	1:00 am - 5:59 am	6	11.5	52	(16.1)
	Commuting	28	30.1	93	(28.9)
	9:00 am - 3:59 pm	29	37.2	78	(24.2)
	7:00 pm - 9:59 pm	20	45.5	44	(13.7)
	10:00 pm - 12:59 am	19	34.6	55	(17.1)
International Scout	1:00 am - 5:59 am	3	16.7	18	(17.9)
	Commuting	11	42.3	26	(25.7)
	9:00 am - 3:59 pm	10	35.7	28	(27.7)
	7:00 pm - 9:59 pm	3	37.5	8	(7.9)
	10:00 pm - 12:59 am	9	42.9	21	(20.8)
All Utility Vehicles	1:00 am - 5:59 am	164	40.2	408	(20.8)
	Commuting	225	46.3	486	(24.8)
	9:00 am - 3:59 pm	211	47.8	441	(22.5)
	7:00 pm - 9:59 pm	129	48.0	269	(13.7)
	10:00 pm - 12:59 am	159	44.5	357	(18.2)

[1]Commuting: 6:00 am - 8:59 am
4:00 pm - 6:59 pm