An Overview of the ON-ROAD CRASH EXPERIENCE OF UTILITY VEHICLES

(Highlights of the Technical Report)

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16. Abstract

The purpose of this study was to investigate the on-road crash experience, safety, and stability of utility vehicles. Selected for study among the off-road, multi-purpose passenger vehicles were the JEEP, Blazer, Bronco (pre-1978) Jimmy, Ramcharger, Trail Duster, Scout, LandCruiser, and Thing.

Data studied included more than 12,000 fatal and non-fatal utility vehicle crashes in the states of Arizona, Colorado, Maryland, Michigan, New York, New Mexico, North Carolina, Texas, and Washington. Also, FARS data, R. L. Polk & Company vehicle registration data, and data from Collision Performance and Injury Report (CPIR) files were examined. Selected vehicles were subjected to physical measurement of the height of the center of gravity. Applicability of Federal Motor Vehicle Safety Standards was reviewed.

Major conclusions are that: utility vehicles experience a rollover rate 5 to 11½ times higher than passenger cars; the JEEP and pre-1978 Bronco overturn at least twice as often as Blazer; rollover and ejection in open-cab vehicles appear to be major fatal injury factors; death and injury rates are about twice as high in JEEPS as in Blazers.

The study findings raise serious questions concerning the safety and stability of these vehicles, which are exempted from or not covered by several of the Federal Motor Vehicle Safety Standards required for passenger cars. Complete technical documentation is presented in the HSRI report number UM-HSRI-80-14—*On-Road Crash Experience of Utility Vehicles* from which this overview was excerpted.

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ON-ROAD CRASH EXPERIENCE OF UTILITY VEHICLES*

ackground

The *objectives* of this study were to describe the n-road crash experience of the class of vehicles nerally known as utility vehicles, and to describe e magnitude of injury and fatality problems for cupants of these vehicles.

Utility vehicles are *defined* as multi-purpose passger vehicles designed for both on-road and off-ad use.

Today's four-wheel-drive utility vehicles largely olved from the "Jeep" of World War II. Current hicles commonly have four-wheel drive and (in me models) open, convertible, or detachable roofs. comparison with ordinary passenger cars, utility hicles have a higher center of gravity, a stiffer spension system, often a shorter wheelbase, and pically are capable of both on- and off-road operaon. The specific vehicle types studied included: MC JEEP, Kaiser and Willys Jeep, Ford Bronco re-1978), International Scout, and Toyota Land ruiser—classified as the "smaller" vehicles; Chevlet Blazer, GMC Jimmy, Plymouth Trail Duster, d Dodge Ramcharger—classified as the "larger" hicles.

Indications of the seriousness of the utility vehicle cident *problem* have been reported by the U.S. rmy. They found that 66 percent of the 1,102 151 Jeep crashes occurring between July 1974 d July 1976 were rollovers. Unstable handling aracteristics of the M151 caused the U.S. Departnt of Transportation in 1971 to refuse to sanction the sale of military surplus Jeeps in a driveable condition to the general public.

The military crash experience with Jeeps, coupled with a dramatic rise in utility vehicle popularity (utility vehicles are estimated to comprise one percent of all registered vehicles on the road today) has raised concerns about the crash experience and safety aspects of these vehicles used by the civilian population. This study confirms that serious problems exist relative to occupant safety and vehicle stability in the on-road driving environment.

Data Sources and Methods

Primary data sources consisted of police-reported accident data, clinical accident investigation reports, and vehicle registration data. State files containing computerized reports of crashes occurring for selected years between 1975-1978 were obtained from Arizona, Maryland, Michigan, New Mexico, New York, North Carolina, Texas, and Washington. The Fatal Accident Reporting Systems (FARS)* file for 1977, which contains virtually all U.S. fatal traffic accidents in that year, was analyzed (about 42,700 fatal accident reports).

Vehicle registration data published by the R. L. Polk and Company were obtained to estimate the number of utility vehicles registered for the years 1975, 1976, and 1977. Those data were used to determine the utility vehicle population in each study state as a percentage of all registered passenger vehicles.

Clinical data were obtained through a detailed review of police reports and photographic records of utility vehicle fatal accidents occurring in the

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* This study, *On-Road Crash Experience of Utility Vehicles* eport No. UM-HSRI-80-14), was conducted by the Highway ety Research Institute, and sponsored in part by The Inance Institute for Highway Safety, Washington, D.C. The opinions, findings and conclusions expressed in this publiion are those of the authors and do not necessarily reflect the ws of the Insurance Institute for Highway Safety nor the hway Safety Research Institute.

* FARS—a fatal accident data collection system maintained by the National Center for Statistics and Analysis, National Highway Traffic Safety Administration, U.S. Department of Transportation.

sources included examination of records pertaining to product liability litigation involving utility vehicle accidents. Finally, physical measurements were conducted by HSRI on selected vehicles in order to compare the stability (rollover) thresholds of selected utility vehicles to those of passenger cars.

Analyses of State and National Accident Data Files

To establish how frequently utility vehicles were involved in accidents compared to ordinary passenger cars and to compare the incidence of death and severity of injury as a consequence of utility vehicle accident involvement, the vehicle registration and on-road accident data for five states (Maryland, Michigan, North Carolina, Texas, and Washington) were compared.

In terms of *accident involvement*, Table 1 shows that in five study states, utility vehicles were relatively less frequently involved in accidents than were passenger cars. Also shown is the ratio of utility vehicle registrations to passenger car registrations.

TABLE 1

UTILITY VEHICLE CRASHES IN RELATION TO PASSENGER CAR CRASHES: SELECTED STATES

State	Number of Utility Vehicle Crashes	Utility Vehicle Crashes as a Percent of All Passenger Car Crashes %	Utility Vehicle Registrations as a Percent of All Passenger Car Registrations %
Maryland* (1975-1977)	1,336	0.3	0.5
Michigan (1976-1977)	6,599	0.7	1.3
North Carolina* (1975-1978)	3,691	0.6	0.9
Texas (1976-1977)	6,225	0.5	0.8
Washington (1976)	1,456	0.9	1.1

* Excludes crashes with pedestrians, pedalcyclists, motorcycles, and trains in this and in subsequent tables.

These data (Table 1) show that utility vehicles in all five states are involved in proportionately fewer total crashes than their frequency in the population would suggest; i.e., utility vehicles are underrepresented in total crashes, relative to passenger cars.

at least one person was killed. Rates of vehicle involvement in fatal crashes are 43.2 per 100,000 registered utility vehicles and 30.9 per 100,000 registered passenger cars.

While Table 1 compares the frequency of involvement in all types of crashes for utility vehicles and passenger cars, Table 2 shows that utility vehicles are involved in fatal crashes almost 40 percent more often than passenger cars.

TABLE 2

FATAL CRASHES AND TOTAL REGISTRATIONS: UTILITY VEHICLES AND PASSENGER CARS (ALL STATES, 1977)

Vehicle Type	Crashes %	Registrations %
Utility Vehicles	1.36	0.98
Passenger Cars	98.64	99.02
Total	100.00	100.00
Number	35,790	115,238,923

In summary, utility vehicles are less likely than passenger cars to be involved in an on-road crash of any kind, but almost 40 percent more likely to be involved in a crash that results in a fatality.

The *death rate*—the likelihood of occupant death in a crash-involved vehicle—is higher for utility vehicles than passenger cars. On a national basis for 1977, at least one occupant was killed in a utility vehicle in 31.8 fatal crashes per 100,000 registered utility vehicles. The corresponding rate for passenger cars is 18.5. Therefore, the death rate for utility vehicle crashes is 71.9 percent higher than the rate for passenger car crashes.

Comparative death rates for selected states are shown in Table 3. For each state, the total number

TABLE 3

TRAFFIC DEATH RATES (NUMBER KILLED PER THOUSAND CRASHES): SELECTED STATES

	Michigan 1976-77	Washington 1976	Texas 1976-77
	All Occupants		
Utility Vehicles	4.7	6.9	6.3
Passenger Cars	2.2	3.0	3.3
	Drivers		
Utility Vehicles	2.0	3.4	3.6
Passenger Cars	1.5	2.0	2.1
	Number of Crashes		
Utility Vehicles	6,599	1,456	3,649
Passenger Cars	498,240	153,331	663,940

Additional study findings concerning fatal injury re: (1) in both utility vehicles and passenger cars, raffic death rates in rural crashes are considerably igher than are those for urban crashes; (2) regardess of whether a urban or rural area, the *total traffic eath rates* in utility vehicles are higher than are ne rates in passenger cars; (3) in urban areas, difrences in *driver death rates* between utility vehicles nd passenger cars are negligible; (4) death rates in ngle-vehicle crashes for utility vehicles and pasenger cars are higher than for other types of rashes; (5) death rates in single-vehicle crashes are igher in utility vehicles than in passenger cars; nd (6) utility vehicles are more likely than passenger ars to be involved in single-vehicle crashes.

The rate of serious (disabling) injury is greater in ility vehicles than in passenger cars, for both rivers and passengers, as shown in Table 4.

TABLE 4

NUMBER OF DISABLING INJURIES PER THOUSAND CRASHES: SELECTED STATES

	Michigan 1976-77	Washington 1976
	All Occupants	
ility Vehicles	61.8	73.9
ssenger Cars	32.2	34.0
	Drivers	
ility Vehicles	33.3	40.4
ssenger Cars	17.9	21.8

Some utility vehicle models appear to be safer an others. The data indicate that the larger utility hicles have a lower serious injury rate, whereas e smaller vehicles are associated with the highest rious injury rates.

Utility vehicles are much more likely than passen- r cars to crash in rural areas. Within rural areas, lity vehicles crash more often than passenger rs when snow or ice is on the road surface, when rkness prevails, or when there is a curve in the ad.

Among crashed vehicles, utility vehicle drivers : on the average younger than passenger car vers and more frequently male.

In *summary*, death rates and serious injury rates substantially higher in utility vehicle crashes n in passenger car crashes. In part, these differes result from the fact that, compared to passen- cars, proportionately more utility vehicle crashes single-vehicle and occur in rural areas.

To examine accident, driver, and vehicle factors in fatal utility vehicle crashes, the utility vehicle case reports and post-crash photos were obtained from law enforcement agencies in the states of Arizona (for 1978), New Mexico (for Aug.-Dec. 1977, and all of 1978), and New York (for 1977). Factors examined included crash configuration, cab type, roll-bar presence, seat belt usage, occupant ejection, and tire type (whether original equipment, overwide, oversize, etc.). This review indicated that rollover and ejection of unrestrained occupants frequently occurred in fatal utility vehicle crashes. Typically, unrestrained occupants received critical or fatal injuries either through contact with the vehicle interior or ejection from the vehicle (often with the vehicle rolling onto them).

Vehicle Rollover

A specific study of rollover accidents was made using data from the states of Maryland, Michigan, North Carolina, Texas, and Washington, to determine if rollover collisions were a significant problem.

The ratio of utility vehicle rollovers to passenger car rollovers ranged from a low of 5.3 to 1 (North Carolina) to a high of 11.5 to 1 (Michigan), as shown in Table 5.

TABLE 5

PERCENT OF CRASHES INVOLVING ROLLOVER: UTILITY VEHICLES AND PASSENGER CARS

	Rollovers %		
	Utility Vehicles	Passenger Cars	Ratio
Maryland	9.7	1.0	9.7
Michigan	12.7	1.1	11.5
North Carolina	11.7	2.2	5.3
Texas	5.6	0.7	8.0
Washington	10.1	1.6	6.3

Rollover as a first event was reported in almost 30 percent of fatal crashes involving utility vehicles. Obviously, not all types of vehicles have the same overturn rate. Michigan data for 1976, shown in Table 6, shows the overturn rate for various types of vehicles.

Analyses of Michigan and Washington state accident data indicate that the smaller utility vehicles such as Bronco (pre-1978) and JEEP overturn more often than the larger utility vehicles such as Blazer.

INVOLVING ROLLOVER, BY VEHICLE TYPE: MICHIGAN, 1976

Vehicle Type	Percent Overturn Accidents %
All Passenger Cars	1.1
Full Size	0.6
Intermediate	1.4
Compact	2.3
Sports Car	3.5
Pick-up or Panel Trucks	2.9
Straight Trucks	3.1
Utility Vehicles	12.7
All Vehicles	1.7

Rollover is substantially more prevalent in single-vehicle crashes than in other types of crashes, as is shown in Table 7.

TABLE 7

PERCENT OF VEHICLES THAT OVERTURNED IN SINGLE-VEHICLE CRASHES: SELECTED STATES

	Michigan %	Texas %	Washington %	Maryland %	North Carolina %
Utility Vehicles	39	41	36	45	37
Passenger Cars	7	6	12	10	14

Rollover rates for *all* crashes are substantially lower than the rates shown for single-vehicle crashes. This implies that rollover is coded infrequently in multiple-vehicle crashes.* Data from selected states (not reproduced here) confirm this. Compared to passenger cars, vehicle rollover is *high* in utility vehicles, especially in single-vehicle crashes and in rural areas.

Injury Mechanisms

Occupant ejection is more likely to occur in utility vehicle crashes than in passenger car crashes. For example, 15 percent of utility vehicle occupants were ejected in single-vehicle crashes in Maryland in single-vehicle crashes than in multiple-vehicle crashes. Total driver ejection is much more frequent in open-topped vehicles, such as the JEEP, than in most other models of utility vehicles or passenger cars.

Little difference in seat belt usage is noticed between drivers of utility vehicles and passenger cars. In Washington, 17 percent of the utility vehicle drivers were reported to have been wearing seat belts at the time of the crash, compared with 16 percent of the passenger car drivers. Seat belt restraint systems, including some types of single-belt upper-torso systems, do not prevent occupant flailing, partial ejection, or injury to the unrestrained extremities. Injuries to upper extremities and the hand have occurred as a result of open-vehicle occupants using the roll-bar as a grip during vehicle overturn, or as a result of entrapment of the hand and forearm between the side of the open vehicle and the ground during rollover.

Rollover Stability Measurements

To establish the lateral acceleration (in g's) required to roll over five different models of utility vehicles, the vehicles were measured for wheelbase, track width, and height of center of gravity. Vehicles measured included a 1975 Chevrolet Blazer with fiberglass top, a 1979 JEEP CJ-5 with canvas top and roll-bar, a 1979 JEEP CJ-7 with canvas top and roll-bar, a 1973 Ford Bronco Ranger with a steel top, and a highly modified 1968 Ford Bronco. For purposes of comparison, the same measurements were available for several makes of passenger cars. The rollover limit of the five utility vehicles ranged from 1.01 to 1.21 g, compared to a range of 1.32 to 1.62 g for passenger cars. In general, the smaller the stability envelope of a vehicle (wheelbase times track width) the lower its rollover limit. Utility vehicles with short wheelbases and narrow tracks can be overturned solely by the side forces generated by the tires during unusual maneuvers, whereas larger utility vehicles generally overturn only if they are tripped by a road surface irregularity, curb, or other surface texture change.

Product Liability

Accident cases in litigation provided some information regarding alleged safety defects in utility vehicles. Rollover resulting in collapse of roll-bars, and steering and brake failures have been the most

* A new approach to coding rollovers was used in the 1978 FARS. Rollover, in the 1978 FARS, is coded regardless of when the event occurs during a crash. In 1977, rollover was coded only if associated with the first harmful event. Using an interim version (#36) of the 1978 FARS, 181 of 773 (23%) of the on/off road vehicles were coded as overturning in the first event. And, an additional 22 percent of the 773 vehicles overturned subsequent to the first harmful event. Thus, 45 percent of the on/off road vehicles were coded as overturning at some point during the crash. It remains to be seen if many states will adopt the 1978 FARS codes for rollover. Note that the FARS definition of an on/off road vehicle differs slightly from the definition of utility vehicle used in this study.

deral Standards

Many federal standards that apply to passenger s do not apply to utility vehicles. Although a S. General Accounting Office report (July 1978) s critical of delays in the promulgation of stan- ds to improve light truck (including utility vehicle) ety, nothing substantial has yet appeared. Of the standards that now apply to passenger cars, only currently apply without exception to utility icles. These are: FMVSS 205—Glazing Mate- s; FMVSS 207—Seating Systems; FMVSS 209 Seat Belt Assemblies; FMVSS 210—Seat Belt sembly Anchorages; FMVSS 211—Wheel Nuts, cs, Hub Caps; FMVSS 213—Child Seating tems.

jor Conclusions:*

The major conclusions of this study of on-road ity vehicle crash involvement are:

Crash Involvement

Based upon 1977 data for all states, utility vehicles are *involved in fatal crashes* almost 40 percent more often than passenger cars. The proportion of 1977 total crashes in which at least one occupant was killed is 72 percent higher for utility vehicles than passenger cars (31.8 utility vehicle fatal crashes per 100,000 registered vehicles vs. 18.5 passenger car fatal crashes per 100,000 registered vehicles).

Utility vehicles *crash* in rural areas proportionately more often than passenger cars, accounting for about 36 percent of the difference in overall death rates between utility vehicles and passenger cars. Higher average travel speed, curves, and ice or snow on the road surface have been shown to be major factors in the rural environment that are associated with an increase in crashes among utility vehicles.

Utility vehicle *drivers involved in crashes* generally are younger and more often male than their counterparts in passenger cars. The importance of these factors in contributing to total crashes or fatal crashes has not yet been established.

Rollover and Occupant Ejection

As a group, utility vehicles are much more

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least *five times* (and up to 11½ times in Michigan) higher than that experienced by passenger cars (Maryland, Michigan, North Carolina, Texas, and Washington). Among utility vehicles, some models have a higher rate of rollover than do others.

2. Based on the *height of the center of gravity*, utility vehicles as a class are more likely to overturn, and within the utility vehicle class those with a small stability envelope (JEEP, Jeep, pre-1978 Bronco, Scout, Land Cruiser) are more likely to overturn than those with a larger stability envelope (Blazer, Ramcharger, Jimmy, Trail Duster). The JEEP and the Bronco (pre-1978) overturn during a crash at least twice as often as the Blazer. Further, among those vehicles with the smaller stability envelope, the tire side forces may be sufficient to initiate the overturn, whereas utility vehicles with a larger stability envelope may require an external tripping force (curb, pothole, etc.).
3. *Driver ejection* is more often reported among JEEPS than other makes of utility vehicles or passenger cars. Driver ejection is also more often reported among open- or canvas-top utility vehicles than among rigid-top utility vehicles.
4. *Rollover* occurs in about 30 percent of U.S. fatal crashes involving utility vehicles. In comparison, rollover is reported in only six percent of U.S. fatal car crashes.
5. Until 1977, rollover was coded in the Fatal Accident Reporting System (FARS) data (when it occurred) as the first harmful event, yielding a rollover rate of 29 percent. In contrast, the 1978 FARS coded rollover as both first and subsequent harmful events. This yielded a fatal on-off-road vehicle overturn rate of 45 percent. In this study, the more conservative (first harmful event) definition was used.
6. *Rollover and ejection* of unrestrained occupants are observed to be primary factors in fatal utility vehicle crashes.
7. *Rollover protection* (roll-bars, cages, etc.) particularly in open vehicles is inadequate, as the roll protection frequently collapses or is a source of injury to the occupants.
8. *Occupant ejection* is more common in single-vehicle crashes than multiple-vehicle crashes. Fifteen percent of utility vehicle occupants were

passenger cars.

2. *Ejection* from open and canvas-enclosed vehicles occurred in three-quarters (75%) of the fatal crashes but in only two-fifths (40%) of the rigid-cab vehicles in three study states (Arizona, Michigan, and Colorado) in 1978.

C. *Rate of Injury and Death*

1. Traffic *death rates and rates of disabling injury* are higher in utility vehicles than in passenger cars, whether considering all occupants or just drivers. Considering all occupants, both the death rate and rate of serious injury are about twice as high in utility vehicles. Additionally, both death and injury rates are approximately twice as high in JEEPS as in Blazers.
2. The likelihood of *serious (disabling) injury* is about twice as great in utility vehicles as in passenger cars, for all occupants and for drivers, based on Michigan and Washington data.
3. The Blazer exhibits the lowest serious injury rate when compared with Scout, Bronco, and JEEP.
4. The likelihood of *death* as a consequence of a crash (for all occupants) was found to be twice as high in utility vehicles as in passenger cars, based on Michigan, Texas, and Washington data. At least one person was killed in a utility vehicle in almost three-fourths of all fatal crashes involving a utility vehicle (the remainder killed were occupants of the other vehicles).

D. *Occupant Protection*

1. A steel *cab enclosure* reduces the chance of ejection and subsequent fatal crushing of the ejected occupant by the vehicle. In all vehicles, the use of *restraints* prevents ejection, which is a primary cause of death and injury. *Roll-bars* in open, canvas, and fiberglass-type cabs produce a measure of safety only if the occupant is not ejected. However, rollbars without sufficient upper body restraint do not offer the occupant adequate protection against flailing injury. Roll-bars themselves can produce injuries.
2. Little difference in *seat belt usage* is found between drivers of utility vehicles and passenger cars. In Washington, 17 percent of drivers of utility vehicles wore a seat belt at the time of the crash, compared with 16 percent among the passenger car drivers.

dards (Numbers 201-219), only six apply to utility vehicles in their entirety. They are: 205—Glazing Materials; 207—Seating Systems; 209—Seat Belt Assemblies; 210—Seat Belt Assembly Anchorages; 211—Wheel Nuts, Discs, Hub Caps; 213—Child Seating Systems. In two standards (201—Occupant Protection, Interior Impact; and 212—Windshield Mounting) multi-purpose vehicles are exempted from the safety requirements. In another (208—Occupant Crash Protection) there are differences in requirements between passenger cars and multi-purpose vehicles. Of particular importance, lap and shoulder belt restraint are not required (209—Seat Belt Assemblies).

2. Post-crash *fire* for utility vehicles as a result of collision is rare and was not found to be a safety problem.

Recommendations for Improving Utility Vehicle Safety

A. Federal safety standards that apply to passenger cars should be extended to utility vehicles. In particular, restraint systems should be installed in all utility vehicles, with the design of a particular system geared to the vehicle style (i.e.: full harness in open vehicles).

B. Performance standards (and perhaps design standards) should be promulgated for roll protection equipment—particularly for open vehicles.

C. Manufacturers, dealers, insurance companies, etc., should develop and distribute to prospective purchasers, drivers, educators, insureds, etc., literature describing the performance limitations (handling and stability) of these vehicles for both on-road and off-road use. Adequate consumer information can help alleviate many of the problems.

D. Additional research on the behavior of utility vehicle drivers should be conducted. We need to know to what extent the relatively high rates of utility vehicle fatal and serious-injury accidents are a reflection of how the vehicles are driven. To answer that question satisfactorily, more information is needed.

E. Additional studies need to be undertaken to examine and link the factors of vehicle design, occupant protection, driver, and environmental factors as they relate to the production of crash-induced injuries.

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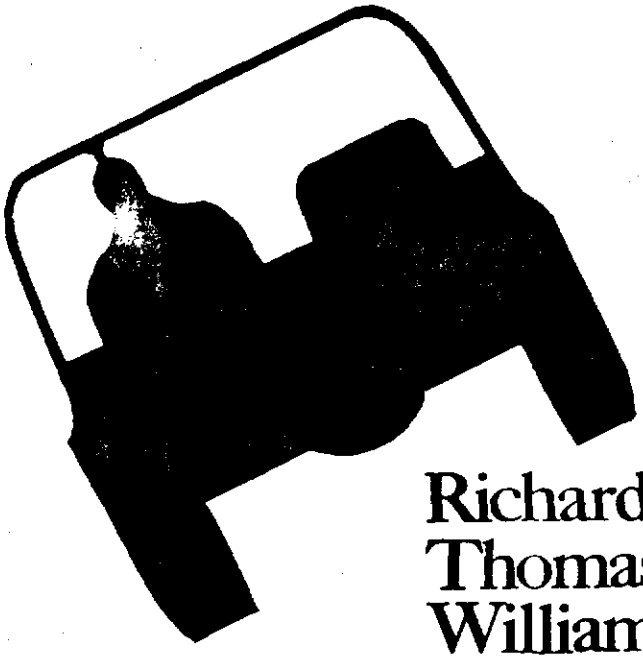

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FINAL TECHNICAL REPORT

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16. Abstract

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Major conclusions are that: utility vehicles experience a rollover rate 5 to 11½ times higher than passenger cars; the JEEP and pre-1978 Bronco overturn at least twice as often as Blazer; rollover and ejection in open cab vehicles appear to be major fatal injury factors; death and injury rates are approximately twice as high in utility vehicles as in passenger cars and are about twice as high in JEEPS as in Blazers.

The study findings raise serious questions concerning the safety and stability of these vehicles, which are exempted from or not covered by several of the Federal Motor Vehicle Safety Standards required for passenger cars.

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EXECUTIVE SUMMARY

Use of utility vehicles designed for on/off-road use, such as the Blazer, Bronco, JEEP, Jimmy, Land Cruiser, and Scout, has increased rapidly over the past few years. The purpose of this study has been to analyze the available on-road collision experience involving this type of vehicle to determine the nature, extent, and seriousness of any problems unique to this category of vehicle, and to provide a basis for further investigation and/or safety recommendation.

The study involved large-scale accident data analysis, evaluation of in-depth reports on individual crashes, and the measurement of physical parameters on some utility vehicles. The data sources included the Fatal Accident Reporting System (FARS) of the U.S. Department of Transportation, Collision Performance and Injury Report (CPIR) file, and clinical case studies of serious traffic collisions from various locations in the U.S. Data obtained included reports on about 14,000 utility vehicle accidents occurring in the states of Michigan, New York, Texas, Washington, Arizona, Colorado, Maryland, North Carolina, and New Mexico during 1976, 1977, and 1978. From the CPIR in-depth collision files 93 utility vehicles (out of a total of 7,799 vehicles with 35,132 injuries) were analyzed. Supplemental data were added where possible to the CPIR data relative to roll-bar, cab type, restraints, and vehicle modifications (such as suspension and tires). The original written records of fatal accident reports from FARS and selected state files were also reviewed. Using these data the accident characteristics of utility vehicles were compared to those of passenger automobiles. To assist in determining the role of handling and stability, since many of these vehicles have a relatively high center of gravity and short wheelbase (as potential contribution to lateral motion instability), direct physical analyses of a Chevrolet Blazer, AMC CJ-5 and CJ-7 JEEP, Ford Bronco, and a modified Ford Bronco were conducted.

Major conclusions of the study are that:

** Utility vehicles experience rollover at a rate that is at least five times higher (and up to 11-1/2 times higher in Michigan) than that experienced by the average passenger car. The JEEP and pre-1978 Bronco overturn at least twice as often as the Blazer;

tire side forces alone in vehicles with a small stability envelope (such as the JEEP) may be sufficient to initiate overturn. Rollover and ejection from open-cab vehicles and lack of upper-torso restraints with roll bar protection appear to be major injury factors.

** Both the death rate and the rate of disabling injury (per accident) are about twice as high in utility vehicles, and both rates are approximately twice as high in JEEPS as in Blazers.

Only 6 of 20 Federal Motor Vehicle Safety Standards that apply to passenger cars also presently apply to utility vehicles without exception. Utility vehicles, for example, are exempted from the lap and shoulder belt requirements (FMVSS 209). The study findings indicate that the stability, crashworthiness, and occupant protection features of utility vehicles need to be improved.

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TABLE 2.1-1

SUMMARY OF 1,102 U. S. ARMY
JEEP CRASHES REPORTED DURING
FY1974-1976

Year	Rollover	Vehicle Ran Off Road	Fire	Fatality	Injury
1976	236	129	0	17	159
1975	211	135	0	8	173
1974	278	113	0	17	175
Totals	725	337	0	42	507

(Department of the Army, 26 October 1976)

M718A1 (0.5 accidents per million miles) are attributed to subsequent design changes (Brune, 1979, p. 16-17).

Not until 1971 did the federal government officially recognize the serious hazards to occupants of military utility vehicles in crashes. At that time an NHTSA "position paper" (Office of Defects Management, 1971) disclosed the M151 FY1967-1970 accident record of 7,460 accidents world-wide involving 138 fatalities. The Army world-wide M-151 fatality rate was 12.18 (per 100,000,000 miles driven) and the accident rate was 0.83 (per 100,000 miles driven). As a result, the NHTSA refused to sanction a Department of the Army plan to sell surplus jeeps to the general public (IIHS, 1972; Anon, 1969; Mohbat, 1969). The National Highway Traffic Safety Administration (NHTSA) was pressed by the Department of the Army and the Defense Supply Agency to allow sale of the M151 (including the older models M151A1, M151AC, and 718, and the more recent models M151A1, M825, and M718A1). An estimated 73,309 vehicles were planned to be disposed of during the next six to ten years (1971-1981 period) at the Army's estimated salvage value of $300 to $1,200 per vehicle at an average return of $750 per vehicle. Approximately $55 million was at stake.

However, it was concluded by the NHTSA Office of Defects Investigation (ODI) that the Department of Defense had already

Although similar data for the earlier M38 series vehicle were not given in the referenced study, based upon a fatality rate (in 100,000,000 miles driven) of 59 for the M38A1 in fiscal 1963 (July 1963 - 30 June 1964), the Army had projected 182 fatalities for the period FY1963 (fiscal year) through FY1967 in the European Theatre. This compares with 113 actual fatalities for the same period involving the M151 (U.S. Army Material Command, 1967).

Eight of 14 (57%) fatal U.S. Army M151 accidents occurring in Europe during fiscal year 1967 involved rollover. Two were collisions with subsequent rollover, and six (43%) involved non-collision single-vehicle rollovers; two of the latter occurred on straight sections of road and four on curves. The two non-single-vehicle collisions with rollover both occurred on straight roads (U.S. Army Material Command, 1967).

The M151 jeep was involved in 7,460 accidents world-wide in the years FY1967 through FY1970, involving 138 fatalities; 2,201 (30%) were rollover accidents (Department of the Army, 27 November 1970). During the three-year period FY1974-FY1976 the U.S. Army reported 1,102 M-151 jeep crashes, involving 42 fatalities and 507 injured occupants. Overall, 66 percent of the total FY1974-FY1976 jeep accidents involved rollovers. It is significant to note that in none of these 1,102 crashes was post-crash fire reported (Table 2.1-1).

The M151 series jeep accounted for 965 (45%) of the 2151 Department of the Army rollover crashes occurring between April 1974 and September 1978 (from U.S. Army computer data printouts cited in Brune, 1979). The basic M151 military jeep has an overturn rate of 16.1 accidents per million miles. This is reflected in the warning printed in the M151 operator's Manual stating: WARNING: Extreme care should be used when driving M151 series vehicles. They have more responsive steering and acceleration than other vehicles. Watch speed, especially on turns. A full right or left turn at speeds over 20 mph can cause any vehicle to go out of control and/or turn over (U.S. Army, 1978). It should be noted that significantly reduced overturn rates in the later M151A1, M151A1C, M718 (1.8 accidents per million miles), and in the M151A2, M825, and

During the 1968 evaluation by the Army of the M561/792 1-1/4 ton utility vehicle Gamma Goat, seat belts were recommended.

Although relatively little injury data concerning the M151A jeep are available to provide insight into the specific safety problems with this vehicle, its problems are considerably better documented than for the earlier MB and M-38 series. The military had frequently reported problems of rollovers with the M151 to the manufacturer, and single accident reports began to appear to support this (Huelke, 1968), including a rollover of an M151 at the Arizona Proving Ground which ironically injured the manufacturer's chief designer (Muller, 1966).

Impact tests of the M-151, conducted by the manufacturer, included inclined-plane sled tests of six M-151 steering wheels (King, 1966), and seven ramp rollover tests from 15-45 mph (Saalbrank, 1965). The original roll-bar withstood low-velocity rollovers up to 15 and 20 mph. A redesigned roll-bar for the production vehicle collapsed in tests at 45 mph, and even when dummy occupants were fitted with lap belt and shoulder harness, they leaned outside the rolling vehicle. In a 31-mph barrier crash, the lap-belted dummy occupant jackknifed into the sharp upper edge of the instrument panel (Schafenek, 1965). An unpublished evaluation of the M-151A1 jeep crash problems and injury mechanisms was conducted by Snyder (1968).

Accident experience for the M151, M151A1, M151A1C, and the M718 Front Line Ambulance, for the six-year period 1962 through 1967 for the U.S. Army in Europe, included 126 deaths (U.S. Army Material Command, 1967). From 1963 through 1967 some 4,870 accidents were recorded involving the M151 for that theater of operations alone (935 accidents in 1963 with 21 fatalities; 951 in 1964 with 30 fatalities; 1,074 in 1965 with 23 fatalities; 923 in 1966 with 14 fatalities; and 987 accidents in 1967 with 15 fatalities). The Army accident rate (per 100,000 miles driven) in the European Theatre during the period for the M151 vehicle was 1.57, varying from 2.01 (1963) to 1.17 (1967), compared to an Army world-wide M151 accident rate of 1.44. The fatality rate was reported as 26.90 per 100,000,000 miles driven for Europe, and 20.94 for the Army world-wide for the M151 vehicles.

military jeep injuries until the 1960's (although statistics clearly indicated that a major problem existed).

A statistical analysis of U.S. Air Force ground vehicle crashes involving jeeps during 1951 and 1952 indicated that crashes with this type vehicle comprised eight to nine percent of all crashes involving USAF military ground vehicles. During 1951, 839 (8%) involved jeep crashes and in 1952, 727 (9%) involved jeep crashes (Mathewson et al., 1954). The Air Force reported that over 1,000 airmen per day were unavailable for duty (killed or recuperating from injuries) because of ground vehicle crashes in 1951 and 1952 (Mathewson et al., 1954). In the U.S. Navy, fatal motor vehicle (including jeeps) crashes were by far the leading cause of Navy deaths (62.4 per 100,000) leading all other causes combined, including Viet Nam casualties--until mid-1966 (U.S. Navy, 1967).

The Ford military M151 series includes seven different models of utility vehicles. The M151, M151l, and M151A2 1/4 ton 4x4 utility trucks are used as general-purpose personnel or cargo carriers. The basic M151 was further modified in the M151A1C and M785 models, equipped with a 106mm recoilless rifle on an M79 rifle mount, and the subsequent M718 and M718A1 vehicles, which were longer, higher, and weighed about 1400 pounds more, and modified as front-line ambulances.

By 1968 the Army had conducted several tests of M151 jeep components at Aberdeen Proving Grounds, including brakes, windshield, a deep-dish steering wheel, and new acceleration pedal (personal communication, 16 September 1968). For the conduct of crash and rollover tests, the Aberdeen Proving Ground issued a Vehicle Collision and Accident Safety Test Procedure 2-2-621, effective 15 May 1968 (U.S. Army Test and Evaluation Command, 1968), and at least two M151 stability test studies were completed (Cooke, 1968; Jurrat, 1969).

During that period there was an Army regulation stating that seat belts will not be used on tactical type vehicles unless equipped with roll-bars. Making rules for use of seat belts was delegated to the local commanding officer. But field usage was slow in developing because field combat requirements differ from those of normal usage.

2.1.2 Military Accident Experience

Injury data involving jeep accidents have in the past come primarily from studies of the military vehicles. In 1947 an article appeared in the American Journal of Surgery concerning an analysis of 58 injuries of the hip joint. A surgeon in the European Theater of Operations treated these over a period of 18 months (1944-1946) in 20 U.S. Army hospitals. Of these 58 injuries, 40 were incurred in jeep crashes (Urist, 1947). It was suggested that all dislocations, and certain types of fractures of the hip joint, were produced by a forceful blow on the flexed knee or on the sole of the foot. Force was believed to be transmitted th ugh the extended knee, whether alone or in combination with violent blows against the lower back and the lateral aspect of the hip. This early study of a special class of injury, considered particularly common with regard to the jeep, may be of current interest, since it was noted that most of these occurred on concrete highways prevalent in Europe, but not found in other operational theaters.

By 1955 there was still "considerable doubt...as to the relative hazard of seat belts in military open-top vehicles, including jeeps, whether it is better or worse to be strapped to the seat in the event of an accident" (Babione, 1955). In order to estimate the possible benefits with respect to mortality that might accrue if seat belts were installed in military vehicles; data were collected from Navy and Marine Corps vehicle fatal accidents from 1952 to 1954. Rollover occurred in 33 out of 38 fatal accidents occurring in connection with jeeps, weapons carriers, heavy trucks, and one DUKW (duck). It was concluded that ten persons who escaped death in rollover accidents by being thrown out "would probably have been killed if they had been kept in by seat belts" (Babione, 1955). However at that time no consideration was apparently given to the potential benefits of use of belts combined with a roll-bar. It was found that the costs of preventive measures compared to savings, both for fatalities and injuries, could not be determined without more detailed reporting of the causes of trauma in crashes. Except for isolated studies and accident records by the military, little attention appears to have been paid to the problems associated with

(1941); the Ford GPW (1942-1945); and the Willys MA (1941) and MB, including 277,896 GPW and 361,349 MB models (Vanderveen, 1969). By V-J day Willys and Ford had reportedly provided a total of 651,068 Jeeps (Conley, 1978).

The British Standard 5-cwt[5] 4x2 car experimentally appeared as the British version of the American "Jeep," in 1943. It had 75-inch wheelbase and 4-cylinder 44 b.h.p. motor, but no front-wheel drive. Since U.S. Lend-Lease supplied Great Britain with sufficient numbers of the Ford and Willys Jeeps, no wartime British utility vehicle was further developed (Vanderveen, 1969). However, in early 1950, the Austin Motor Co. Ltd., of Birmingham, designed and produced the first British Jeep (designated FV1801) for the War Office. The initial production contract was for 15,000 vehicles. It was powered by a Rolls Royce B.40 MK.2A/4 cylinder engine, developing 69 b.h.p. Wheelbase was 84 inches, weight 3,470 lbs., length 91.5 inches. Overall length compliance tests included a c.g. fully loaded ("laden") of 27.6 inches from the ground and 41.5 inches from the front wheels (Blake, 1979).

The M38 series (military counterpart of the CJ-5 and CJ-6) was produced from 1952 until introduction of the M151 in 1966 (Vanderveen, 1966). By the late 1960's the military had switched from the M-38A1 series of Jeep to the Ford M-151 series. The M151A1 military jeep represents the most recent of a long series of utility military vehicles, which although continually undergoing modification, have the same basic configuration. As rigidly specified by military procurement, size and clearance dimensions result in a relatively high center of gravity and resultant stability characteristics. The addition of equipment such as plows, gun mounts, or high loading accentuates instability conditions. The Ford M151 series has been found to have stability problems which will be discussed in the following section.

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[5] cwt = hundred weight

In the armored forces, the Jeep was first known as the Peep, Quad, Pygmy, GP, and Midget. During 1940-41 the 1/2-ton Command Reconnaissance Vehicle (Dodge) was called "Jeep" (Vanderveen, 1974). The name "Jeep" replaced "Peep" in soldier and test driver terminology. When riding with a test driver in February, 1941, Katy Hillyer, a reporter for the Washington Daily News, asked what the vehicle was called, wrote it up as a "Jeep," and the name apparently stuck (Lamm, 1975). Joe Frazer, president of Willys Overland from 1939 until 1944, also was credited with coining the word "Jeep" by slurring the initials G.P. (military designation for General Purpose) (Lamm, 1975). But Sterns (1941) claims the Ford version of the G.P. was the origin of the generic term "jeep." Technical background concerning the origin of the "Jeep" may be found in Sterns (1941), Vanderveen (1969;1974), Lamm (1975), Conley (1978), and Wallace (1978). However it originated, the name "Jeep" has become synonymous with the four-wheel-drive military utility vehicle, even if it is often erroneously applied.

The first 1/4-ton 4x4 was produced by Bantam in 1940 (American Bantam Car Company, 1941), in response to a U.S. Army request for a vehicle that could carry personnel and light cargo and also tow a 37mm AT gun or 1/4-ton two-wheel trailer. Performance requirements included climbing a 65 degree grade, carrying an 800 lb. load, towing a 1/2-ton trailer, and driving along a hillside tipped laterally at an angle of 55 degrees. Seventy Bantams were produced. In late 1941 Willys-Overland produced a pilot model known as "quad." Both the Bantam 40 BRC (Bantam Reconnaissance Car) and Willys (MA) models were subsequently redesigned and 1,500 of each were ordered by the Army for further tests, as well as 1,500 of a Ford GP (General Purpose) pilot model.

The 45-hp Bantam and 40-hp Ford (tractor engine equipped) did not perform as well as the 60-hp Willys MA. Willys exploited the innovations contained in all three prototypes and developed the standardized model MB. To assure a second source Ford was awarded a contract to produce a model completely interchangeable with the MB, resulting in the Ford Model GPW (General Purpose Willys), which went into mass production in December 1941. The military jeep was produced in the following models: American Bantam 40 BRC (1941); the Ford GP

2. BACKGROUND

2.1 Utility Vehicles: Past, Present, Future

2.1.1 Military Development

Historically, today's four-wheel-drive utility vehicles have evolved from the "Jeep" of World War II. Credit for the origin of the "Jeep" has been a controversy discussed in numerous publications. A memorial plaque listing the American Bantam employees responsible marks the Jeep's "birthplace" in Butler, Pennsylvania. One individual who may have been instrumental in its development was Karl K. Probst, temporary Chief Engineer for Bantam. He reportedly drew up the first plans "during a grinding three-day weekend in the deserted, dusty engineering rooms" (Lamm, 1975). Credits for the Jeep's design have been suggested by Vanderveen as: concept and general layout, U.S. Army; general design of vehicle and body work, Bantam; front end, Ford; power unit, Willys. But one could go on and say that the driveline layout was used by Spijker in 1902, the type of driven front axle was pioneered by Otto Zachow (FWD) in 1907, and that mechanically the Jeep was a scaled-down Ford/Marmon Herrington 1/2-ton 4x4 which has been dubbed "granddaddy of the Jeep" (Vanderveen, 1974).

The name "Jeep" was reportedly used as early as 1914-1918 by Army mechanics testing new vehicles (Lamm, 1975). A pioneering attempt at developing a military utility vehicle occurred in the early 1920's when the commanding officer of the 1st Tank Regiment at Fort Meade developed the "Puddle Jumper," the "first Jeep" (Wallace, 1978). Intended for following tanks over rough terrain, it was constructed from a 3/4-ton Ford chassis and motor, and was equipped with bucket seats taken from the salvage dump. About 1931 a War Department inspector saw these unauthorized vehicles; and the Infantry School (Tank Section) was ordered to get rid of them.

In 1936 the comic strip "Popeye" introduced a character called "Eugene the Jeep," a mythical animal who had magical talents, and this has also been suggested as a source for the name "Jeep." In 1937 tractors supplied to the Army by Minneapolis Moline were called "Jeeps."

(5) Evaluate the effectiveness of safety related equipment in utility vehicles, including roll-bars, restraint systems, and interior protection;

(6) Determine the incidence of and injury potential existing in post-crash fires involving utility vehicles.

The focus of this study has been limited to on-road collisions involving utility vehicles only.

(2) Compare the on-road utility vehicle crash experience, injury potential, and operator profiles with the same for other vehicle types;

(3) Describe the injury mechanisms and injury potential for occupants of utility vehicles;

(4) Analyze available injury data (fatal and non-fatal) resulting from utility vehicle accidents;

(5) Describe ejection from utility vehicles during rollover collisions and other crashes;

(6) Compare rollover frequency, injury rates, and severity of injury to utility vehicle occupants and passenger car occupants;

(7) Describe and compare the accident involvement patterns and vehicle occupancy patterns of utility vehicles with those of passenger cars;

(8) Develop a profile of the crash-involved operator of various vehicle types.

Several secondary objectives were included. These were to:

(1) Review nationwide utility vehicle and passenger car registration data and evaluate various geographic and demographic differences;

(2) Physically measure and compare typical utility vehicles for factors that could influence stability and thus likelihood of rollover: e.g., wheelbases, track widths, suspension systems, steering, center of gravity or weight distribution, tire design;

(3) Review product liability allegations involving utility vehicles to identify specific problem areas;

(4) Review existing or proposed Federal Safety Standards and their applicability to utility vehicles;

rollover (as a first event) occurs for about 2 percent of the vehicles involved.[4]

A previous U.S. Army review (1968) found that 36 percent of all European Theater of Operations military jeep crashes involved rollovers without collision, suggesting stability and operating problems. Many of these crashes reportedly resulted in fatal injuries to occupants, even at relatively low highway speeds (30-45 mph). Thus it is important to know whether comparable civilian-owned utility vehicles have similar problems, and, if so, the nature and extent of those problems.

Contrasted to passenger car occupants, utility vehicle occupants may be subjected to increased injury risk for the following reasons: (1) the combination of short wheelbase, narrow track width, and high center of gravity may make them more prone to rollover; (2) lack of substantial side and roof structure may reduce occupant protection; (3) interior structure and instrument panels may have sharp, rigid non-yielding surfaces and projections; (4) in addition, the off-road usage of this type of vehicle may also increase occupants' exposure to crash and rollover involvement.

In view of these considerations, data concerning current utility vehicle collision and occupant injury experience has been collected and analyzed to assess these problems, and recommendations have been developed concerning means of improving occupant safety.

1.2 Scope and Objectives

The purpose of this study was to provide a systematic in-depth investigation into the on-road crash experience, injury mechanisms, and potential hazards to occupants of utility vehicles. Major objectives were to:

(1) Describe the on-road crash experience, including incidence of rollover, for utility vehicles;

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[4]Based on police-reported accident data from Texas, Washington, and Michigan.

1. INTRODUCTION

1.1 Statement of Problem[1]

The versatility of utility vehicles has considerably increased their popularity and use in recent years, as available production and registration figures reveal. For example, between 1975 and 1977, total utility vehicle registrations increased 35 percent, from 831,058 to 1,125,923. In comparison, passenger car registrations increased during the same period less than seven percent.

Often popularly identified as "Jeeps," a utility vehicle as defined in this study is a multi-purpose vehicle usually designed for both on-road and off-road use. Utility vehicles considered in this study included various models of the Willys Jeep[2], AMC JEEP[3], Ford Bronco, International Scout, Toyota Land Cruiser, Chevrolet Blazer, GMC Jimmy, Dodge Ramcharger, Plymouth Trail Duster, and Volkswagen Thing.

Some of the smaller utility vehicles have evolved directly from original military designs. All utility vehicles share certain general characteristics in contrast to conventional vehicles; among these are a relatively short wheelbase, higher center of gravity, stiffer suspension systems, and, often, four-wheel drive.

Despite the increased civilian use of these utility vehicles, their civilian crash experience has not previously been comprehensively evaluated. Yet previous studies of similar military vehicles have found an extremely high incidence of occupant ejection in both collisions and rollover crashes. Among police-reported crashes in the United States,

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[1] This study was conducted under standards established by The University of Michigan Medical Center Committee to Review Grants for Clinical Research and Investigation Involving Human Beings, and conformed to guidelines of the Institutional Guide to Department of Health, Education, and Welfare Policy on Protection of Human Subjects. The research has been supported mainly by a research grant from the Insurance Institute for Highway Safety, Washington, D.C.

[2] Prior to 1963.

[3] The word JEEP is the registered trademark of Jeep Corporation, subsidiary of American Motors Corporation.

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recognized the unsafe handling characteristics of the M151 jeep, and pointed out that it was Department of Defense policy not to sell an item if it is considered unsafe for a non-military user. They noted that the Army had required special training of drivers, including a film to illustrate the hazards of unsafe handling. They also noted the rollover propensity of the rear swing axle assembly despite modifications (M151A2), and the apparent rollover problem, involving a record of 7,460 world-wide M151 jeep accidents (FY67 through FY70) with 138 fatalities. Of those 7,460 accidents, 2,201, or roughly 30 percent, were rollover accidents. The full text of this NHTSA position paper is provided in Appendix A. At present surplus M151 jeeps must be rendered unusable by cutting the frame and suspensions before they can be purchased in the open market. Despite this some have been repaired and are in civilian use.

2.1.3 Utility Vehicles[6] in Domestic Use

Subsequent to World War II sales of military equipment popularized the "Jeep" as a civilian utility vehicle. Post-war civilian models were produced by Willys (to 1963), Kaiser-Willys (after 1963) and Ford. The name "Jeep" became a registered trade mark of Willys-Overland in 1945. In April 1953 the name was changed to Willys Motors Inc., when the company was taken over by the Henry J. Kaiser Industrial interests. In March 1963 it became Kaiser Jeep Corporation, until 1970 when the company became part of the American Motors Corporation (Vanderveen, p. 62, n.d.).

In June 1945 Willys produced the first civilian Jeeps which were actually demilitarized MB's. By August, 1945 the first redesigned "Universal Jeep" model CJ-2A was introduced. The slightly modified model CJ-3A was produced in 1950, followed by the CJ-3B in 1953. In 1952 the 81 inch wheelbase CJ-5 and 101 inch wheelbase CJ-6 was

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[6]This study purposely excluded certain "utility vehicles" of limited production or vehicle design, such as the Willys Jeepster, Chevrolet Suburban, etc., as not being central to the scope of this study. The vehicles depicted in figure 2.1.3-1 are representative of, but not inclusive of, the vehicles included in the study population. Section 2.2 provides a precise definition of the study population.

introduced which featured a new body design (the military counterparts were the M38A1 utility truck and M170 ambulance truck 1/4 ton 4x4). American Motors Corporation bought manufacturing rights to the Jeep from Kaiser Industries in 1970. Following this acquisition, substantial body style changes were made in the CJ-5 and CJ-6 with no corresponding change in model designation. The CJ-7 was introduced in 1976.

Figure 2.1.3-1 shows the utility vehicles in domestic use and illustrates their years of manufacture and/or sales in the domestic market.

Current domestic manufacturers include AMC JEEP, Chevrolet Blazer (introduced in 1968) and GMC Jimmy (introduced in 1969), Ford Bronco (the 92 inch wheelbase model was produced from 1965 - 1968, and now produced in a 104 inch wheelbase), International Scout (introduced in 1961), and Dodge Ramcharger/Plymouth Trail Duster (introduced in 1973).

Foreign competitors include the British Land Rover (1949) and the Japanese Toyota Land Cruiser (1970). The German Volkswagen "Thing," introduced in 1973 and 1974, and markedly different in construction, is also classed as a utility vehicle.

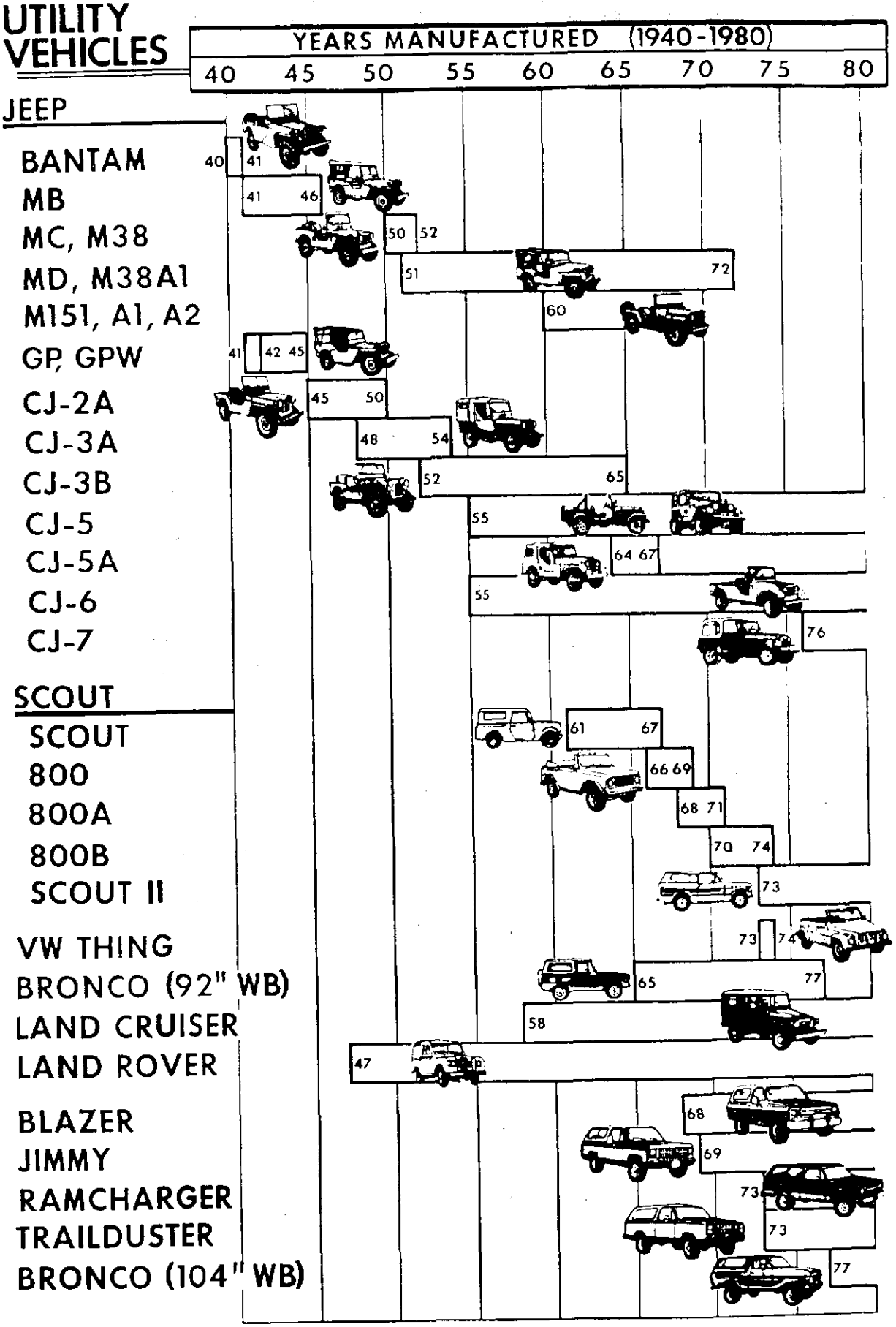
2.1.4 Utility Vehicles in Foreign Use

Although this study is concerned with utility vehicles in use in the United States, there are a large number of four-wheel-drive multipurpose (utility) vehicles in use in other parts of the world.

Leyland Australia's Mini Moke utility vehicle can be converted into a Gran Turismoke through conversion kits marketed through dealers. This kit (about $2,500 Australian) allows the Moke owner to restyle his vehicle with fiberglass panels, suede sheepskin upholstery and carpet, and two roll-bars. The Moke, designed in England, is manufactured in Australia, and exported worldwide (Automotive News, May 22, 1978).

An Italian utility vehicle, the Moretti Midimaxi 127, Features front-wheel drive and uses Fiat 127 running gear (Automotive News March 27, 1978). The Moretti Jungla, with roll-bar, fold-down windshield, and open body, has a rear-wheel drive only. It uses a Fiat 126 two-cylinder engine, and has limited off-road capability. Another Italian utility

Figure 2.1.3-1 Utility Vehicles and Years of Manufacture*



*Certain foreign vehicles may still be in production but are no longer for sale in the U.S.

vehicle, designed by Ferriccio Covini, is four-wheel drive and features a turbo-charged diesel engine and symmetrical steel body (Automotive News, May 22, 1978).

In 1979 the light weight (715Kg) Citroen Mehari front-wheel-drive utility vehicle, produced since May, 1968, was modified to a 4-wheel-drive utility vehicle (Automotive News, June 25, 1979).

A new Russian utility vehicle, the ZAZ 969, is four-wheel-drive, 132 inches long, and powered by a 1,196-CC V-4 engine (Automotive News, May 22, 1978).

Annual market growth of utility four-wheel-drive vehicles in Europe currently ranges from 15 to 25 percent per year. An excellent review of a number of utility vehicles world-wide was provided in Automotive News (November 27, 1978). Other current utility vehicles described include the Austrian Pinzgaver by Steyr-Daimler-Puch, British Leyland Land Rover (since 1948) and Range Rover (since 1970), the Italian Fiat Campagnola, the Russian Lada Niva, the Embo four-wheel-drive wagon with a Fiat engine, the Swedish Volvo Laplander, Rumanian ARO-244, the Portuguese UMM-Uniao Metalo Mecanica Cournil, the Italian Soleado, the French Stemat Veltt, Society Sinpar Renault 4L, and ACL Rodeo 4x4 vehicles.

The Japanese produce a number of utility vehicle models including the Nissan Patrol 4x4, Subaru 4x4, Daihatsu F-20 LV 4x4 Wagon, Suzuki LJ10, Isuzu Unicab, Mitsubishi Jeep-type models (J-3R, J-20C), and Toyota Land Cruiser Hardtop FJ40V.

2.1.5 Future Utility Vehicles

Several new utility vehicles are in production or planned for the future, and suggest the direction of future designs.

Mercedes-Benz initiated production in February, 1979, on a four-wheel-drive utility vehicle known as Explorer. During its development phase it is being marketed as the Mercedes-Benz G-series (G=Gelande, for Terrain). Frame and body is by Steyr-Daimler-Puch of Austria. The 240 GD is powered by a 2.4 liter four-cylinder diesel engine, and has a built-in roll-bar. Several gasoline and diesel engines are offered

along with a number of body types (Automotive News, November 27, 1978; Time, December 18, 1978; Automotive News, January 29, 1979).

AMC's 1980 model Eagle is the only U.S. manufactured four wheel drive (4WD) passenger car. Standard equipment is reported to include a 258-cid L-6 engine, three speed automatic transmission, automatic 4WD system, power steering, power front disc brakes and radial tires. It is available both in Standard and Limited versions of the two-door and four-door automobile and four-door station wagon (Automotive News, August 27, 1979; American Eagle, 1979; Lund, 1979). It appears to be identical to the AMC Concord in design and options, except that the Eagle is a four-wheel drive version. It is anticipated that the AMC Spirit of 1981 will also be available in two- and four-wheel drive models.

In England the Yak Yeoman, designed and developed by Manchester Garages (Motorcraft) Ltd. is going into production for export to developing countries. It has a wheelbase of 109.2 inches and features an automatic differential lock fitted into the rear axle, instead of four-wheel-drive (Automotive News, May 7, 1979).

Besides the present Toyota Land Cruiser, the Japanese may market the Diahatsu Taft Gran, "a four-wheel-drive vehicle that closely resembles the Jeep," in the United States in the early 1980's (Automotive News, March 20, 1978). The Taft Gran has a wheelbase of 79.5 inches. It has a flip-down windshield and integral roll-bar. It is described as smaller than the Jeep. Daihatsu engineers are reported to be reducing weight (2,380 lbs) and increasing power output (from the Toyota Corolla 1,600cc four-cylinder engine to an 1,800cc engine).

An advanced four-wheel-drive vehicle concept by American Motors indicates the directions utility vehicles may take during the next decade. The 100-inch wheelbase Jeepster II design features extensive use of light-weight materials, soft front and rear panels, a built-in roll-bar, flat glass folding windshield, and aluminum or fiberglass detachable doors. Basically envisioned as a two-seat vehicle, the Jeepster II concept would feature two additional removable seats in the rear cargo areas as required. The roof, of two-piece light-weight panels, could be stored behind the front bucket seats. Power would be

from a four-cylinder turbo gasoline or diesel engine, and body size dimensions would be 160 inches long, 65 inches wide, and 60 inches high (Automotive News, January 1, 1979). In 1980 the AMC Spirit will have four-wheel drive, joining the AMC four-wheel drive JEEP and Concord-based Eagle (Dunne, 1979).

Described as an "off-road Fiesta," Ford Motor Company's Tuareg is another concept car whose ideas may be incorporated in production utility vehicles of the 1980's (Skwira, 1979).

By far the most expensive utility vehicle design is the German Sea Ranger, designed by Luigi Colani. An all-terrain vehicle, it is much larger than most--6.? meters (20 feet) in length and 4,000kg (8,800 lbs) in weight. Equipped for long expeditions, it carries four occupants in bucket seats and has a swivel chair mounted on top. To date only one prototype has been built. The price will be about $385,000.00, depending upon equipment (Automotive News, January 15, 1979).

2.2 Study Population

The population of utility vehicles considered in the present study consists of the vehicle makes and models listed in Table 2.2-1.

Utility vehicles are a sub-class of the more general grouping of vehicles called multi-purpose passenger vehicles. A multi-purpose passenger vehicle is designed primarily to carry passengers but is easily converted to other non-passenger carrying uses. Common vehicle types under this classification include truck based station wagons (GM Suburban, for example), jeep-type[7] open vehicles (Toyota Land Cruiser, Willys Jeep, etc.), some vans, pick-up cars, sport-recreational vehicles, etc.

The utility vehicles shown in Table 2.2-1 were selected because they account for approximately 95 percent of the utility vehicles registered in the U.S. in recent years.

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[7] The National Highway Traffic Safety Administration (NHTSA) defines "jeep-type vehicle" as a "four-wheel-drive, general purpose automobile capable of off-highway operation that has a wheelbase not more than 110 inches, and that has a jeep-type configuration" (Code of Federal Regulations, 49. Part 533.4. Revised. October 1, 1977).

TABLE 2.2-1

STUDY POPULATION

Make	Model	Type of Drive (2 or 4 wheel)
Chevrolet	Blazer	2
	Blazer K10	4
Dodge	Ramcharger	2
	Ramcharger	4
Ford	Bronco	4
	Bronco Pick-up	4
	Bronco Wagon	4
	Bronco Roadster	4
GMC	Jimmy	2
	Jimmy K1500,K1550	4
	K1500	4
International	Scout, Scout II	2
	Scout, Scout II	4
AMC	CJ3, CJ3B JEEP	4
	DJ3A JEEP	2
	CJ5, CJ5A JEEP	4
	DJ5 JEEP	2
	CJ6, CJ6A JEEP	4
	DJ6 JEEP	2
	CJ7 JEEP	4
Plymouth	Trail Duster	2
	Trail Duster	4
Toyota	Land Cruiser	4
VW	Thing	2

Excluded from this list were some vehicles such as the Jeep Wagoneer, which appears to be a four-wheel drive version of a truck-based station wagon, or, as in the case of the Land Rover, Jeepster, Kaiser and/or Willys, are no longer for sale or in production in the United States.

A good example of the problem in defining a utility vehicle is presented by the 1980 AMC Eagle. Advertised and Marketed as a "four-wheel drive automobile" in three body styles (two-door and four-door sedans, and a four-door station wagon version) it is classified by its manufacturer as a multi-purpose (utility) vehicle (American Eagle sales brochure, 1979) yet classified as a truck by the government relative to meeting Federal fuel standards (personal communication, 1979; Automotive Industries, p. 52, 1979). Similarly the four-wheel-drive Subaru, while also marketed as a passenger car, is also classified as a multi-purpose vehicle.

2.3 Utility Vehicle Registration

Data obtained from the National Vehicle Population Profile (produced by R. L. Polk & Company from national motor vehicle registration data) show that in 1975 there were 831,058 utility vehicles and 106,712,551 passenger vehicles registered. This gives a percentage of utility vehicles to passenger cars of 0.78 percent. In 1976 these figures were 971,510 utility vehicles and 109,675,855 passenger vehicles, for a percentage of 0.89 percent, and in 1977 1,125,923 utility vehicles and 114,113,000 passenger cars, for a percentage of 0.99 percent.

Utility vehicles are a growing segment of the motor vehicle population, now accounting for almost one percent of all vehicles on the road. From 1976 to 1977 the utility vehicle growth was 15.9 percent, compared to passenger cars' growth of 4.1 percent for the same period. For the two-year period of 1975-1977, utility vehicles had a growth of 35.5 percent compared to passenger cars' rate of 6.9 percent.

Table 2.3-1 shows the number of utility vehicles by make and percent of total for each of the three years, 1975, 1976, and 1977.

Production data for the 1978 model year, as provided in Ward's 1979 Automotive Yearbook, show that the top three 1978 models were: Blazer (78,507); JEEP CJ-5, CJ-6, CJ-7 (76,628); and Bronco (69,120). For the 1978 model year, AMC reported "145,716 JEEPS were sold," and 156,000