Changes in Driver Fatality Rates and Vehicle Incompatibility Concurrent with Changes in the Passenger Vehicle Fleet

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SYNOPSIS

Objective. With more sport utility vehicles (SUVs) on the road, public concern has been expressed about their influence on traffic safety. The present study examined changes in the mix of passenger vehicles between 1988 and 2004 and concurrent changes in driver fatality rates and vehicle incompatibility.

Method. Vehicle registrations and driver deaths per registered vehicle were examined using data from R.L. Polk and Company and the Fatality Analysis Reporting System.

Results. Between 1988 and 2004, SUVs comprised an increasingly larger proportion of registered passenger vehicles (5% of one- to three-year-old vehicles in 1988 vs. 22% in 2004), yet driver deaths per registered vehicle decreased 43% to 47% for all passenger vehicle types. Reductions in driver fatality rates were greater for two-vehicle crashes than for single-vehicle crashes and greater for two-vehicle frontal crashes than for two-vehicle side-impact crashes. Driver death rates declined more on rural roads than on urban roads, and this difference was most pronounced for SUVs. Among cars struck by other vehicles, driver death rates in front-to-front and front-to-side impacts decreased more when the striking vehicle was an SUV than a pickup or car.

Conclusions. Factors likely contributing to the overall reductions in fatality rates include advances in occupant protection, increases in average vehicle weight, increased availability of SUVs with car-based designs, and reductions in alcohol-impaired driving. Reductions of driver death rates in two-vehicle collisions between 1988 and 2004 are encouraging, but SUVs and pickups continue to pose a substantially higher risk to drivers of cars than when the striking vehicle is another car.

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The composition of passenger vehicles in the U.S. fleet has changed with the ever-growing popularity of sport utility vehicles (SUVs). O'Neill and Kyrychenko[1] reported that SUVs accounted for only 1% of new vehicle sales in 1970 vs. 27% in 2003. SUVs and pickups are different from cars in several important respects. They generally are heavier, larger, and higher off the ground; their frame rails tend to be higher; and their front ends are stiffer, although this may be changing somewhat as more SUV designs are based on car designs.

Several studies have examined the differential risks to occupants of different passenger vehicle types. Controlling for vehicle weight, occupants of cars generally have lower fatality rates per registered vehicle than occupants of either pickups or SUVs. O'Neill and Kyrychenko[1] reported that among one- to four-year-old vehicles in 1990–1991 and 2000–2001, occupant death rates were lower for cars than for SUVs or pickups and generally highest for pickups across vehicle weight categories. Between 1990–1991 and 2000–2001, occupant death rates declined substantially for cars, pickups, and SUVs in every weight category, but the decline was greater among SUVS than among cars and pickups. Lund and Chapline[2] found that for 1990–1995 model-year passenger vehicles, occupant deaths per registered vehicle generally were lowest for cars and highest for pickups across vehicle weight categories. Similarly, Kahane[3] found that for 1996–1999 model-year passenger vehicles, pickups and SUVs had, on average, higher occupant fatality rates per mile traveled than cars of comparable weight, when controlling for a variety of factors, including driver age and gender and urban/rural crash location.

The primary reason for the lower occupant fatality rates for cars compared with pickups or SUVs of similar weight is their lower death rate in single-vehicle crashes. Occupant death rates (per million registered vehicles) for 1990–1996 model-year passenger vehicles in single-vehicle crashes were found to be substantially lower for cars than for pickups or SUVs across all weight categories.[4] In two-vehicle crashes, however, cars fare less well. Occupant death rates (per million registered vehicles per year) for 1990–1996 model-year passenger vehicles in two-vehicle crashes were similar for cars and pickups of similar weights, and both had higher fatality rates than SUVs.[4]

With the increase in SUV sales, a growing concern is the risk to drivers of cars in collisions with heavier SUVs and pickups. The issue of vehicle incompatibility is not new. In the 1960s, there was concern that cars with curb weights of less than 1,000 pounds would be too light to protect their occupants in collisions with heavier cars.[5] In 2004, two-vehicle crashes among passenger vehicles accounted for 36% of all motor vehicle occupant crash fatalities, and two-vehicle collisions between cars (including minivans) and SUVs or pickups accounted for 23% of all car occupant deaths (unpublished analysis of 2004 data from the Fatality Analysis Reporting System [FARS]). Pickups and SUVs pose greater potential for harm than cars in collisions with other vehicles due to their greater mass, greater front-end stiffness, and higher crush zones.

Several studies have found that car occupant death rates in two-vehicle crashes were lower when the other vehicle was another car vs. an SUV or pickup when measured per registered vehicle[1,6] or per mile traveled.[3] Examining one- to four-year old vehicles, O'Neill and Kyrychenko[1] reported that between 1990–1991 and 2000–2001, car occupant death rates declined regardless of whether the striking vehicle was a car, pickup, or SUV. Another change between 1990–1991 and 2000–2001 was a smaller difference in car occupant death rates between striking cars and striking SUVs. All three studies confirmed that the risk of death to car occupants from striking pickups or SUVs was much more likely in side impacts than in frontal impacts. Using a different approach, Joksch et al.[7] computed the ratio of driver fatalities in striking vehicles to driver fatalities in the struck vehicles for cars vs. pickups and SUVs between 1991 and 1994. In both car-to-SUV and car-to-pickup collisions, car drivers were substantially more likely to be fatally injured than pickup or SUV drivers. Consistent with other studies,[1,3,6] this difference was larger for side impacts than for frontal impacts.

Research to date provides some indication of the risk of occupant fatality by vehicle type for a variety of crash types and the risk of car driver death in crashes with other vehicles for various model years.[2–4] O'Neill and Kyrychenko[1] compared fatality risk between two points in time: 1990 to 1991 and 2000 to 2001. The goal of the present study was to *(1)* describe changes in driver death rates between 1988 and 2004 concurrent with changes in the mix of passenger vehicles during the same period and *(2)* examine changes between 1988 and 2004 in vehicle incompatibility of cars struck by other cars, pickups, and SUVs, in front-to-front and front-to-side two-vehicle crashes.

METHOD

Data on fatal crashes were extracted from FARS,[8] a census of fatal collisions on public roads in which a death occurs within 30 days of the crash. Driver deaths per million registered vehicles were examined overall and by crash type (e.g., single vehicle, two vehicle).

For each vehicle type (car, pickup, SUV), driver death rates were examined for rural and urban crash locations. Vehicle type classifications were based on vehicle identification numbers (VINs), which are contained in more than 95% of passenger vehicle records in FARS. For each calendar year, analyses were restricted to one- to three-year-old passenger vehicles to minimize the effects of vehicle aging. Passenger vehicles were defined as cars (including minivans), pickups, SUVs, and large cargo/passenger vans, but most analyses focused on cars, pickups, and SUVs. Nationwide registration counts for one- to three-year-old passenger vehicles by vehicle type were obtained from R.L. Polk and Company. Data on vehicle curb weight (approximately equal to the shipping weight, in pounds, of the vehicle, plus 100 pounds) were obtained from the Vehicle Features Database maintained by the Highway Loss Data Institute.

Vehicle incompatibility

Vehicle incompatibility in two-vehicle crashes was examined by calculating driver death rates for all model-year cars in collisions with the fronts of one- to three-year-old cars, pickups, or SUVs. Front-to-front and front-to-side crashes were examined separately. Car driver death rates for each calendar year were calculated as the number of deaths per million registrations of the striking vehicle type.

The decreasing percentage of cars in the vehicle fleet meant that fewer cars were at risk of colliding with other cars, SUVs, or pickups. To account for the decreasing proportion of cars, car driver death rates in each calendar year were divided by the following proportion. This adjustment of fatality rates applied only to the vehicle incompatibility analyses.

$$\frac{\text{All model-year cars}}{\text{All model-year cars + one- to three-year-old pickups + one- to three-year-old SUVs}}$$

RESULTS

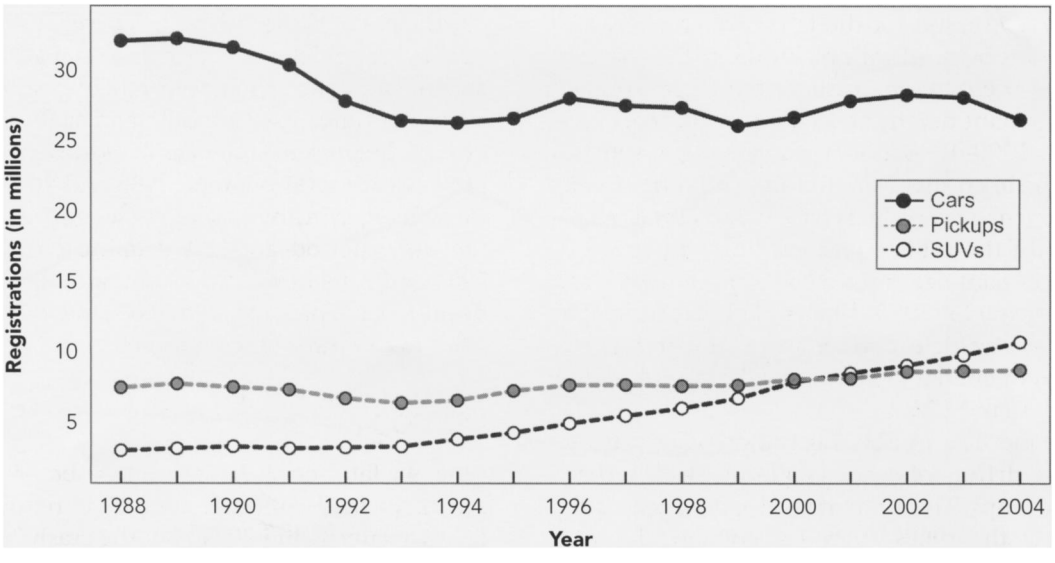
Registered vehicles and vehicle weight

The number of registered one- to three-year-old passenger vehicles in the United States increased 7%, from 43 million in 1988 to 46 million in 2004. Registrations increased 19% for pickups and more than 350% for SUVs but declined 18% for cars (Figure 1). Vehicle curb weights also increased for all vehicle types between 1988 and 2004 (Figure 2), although average SUV weights leveled off after 2000.

Driver fatalities

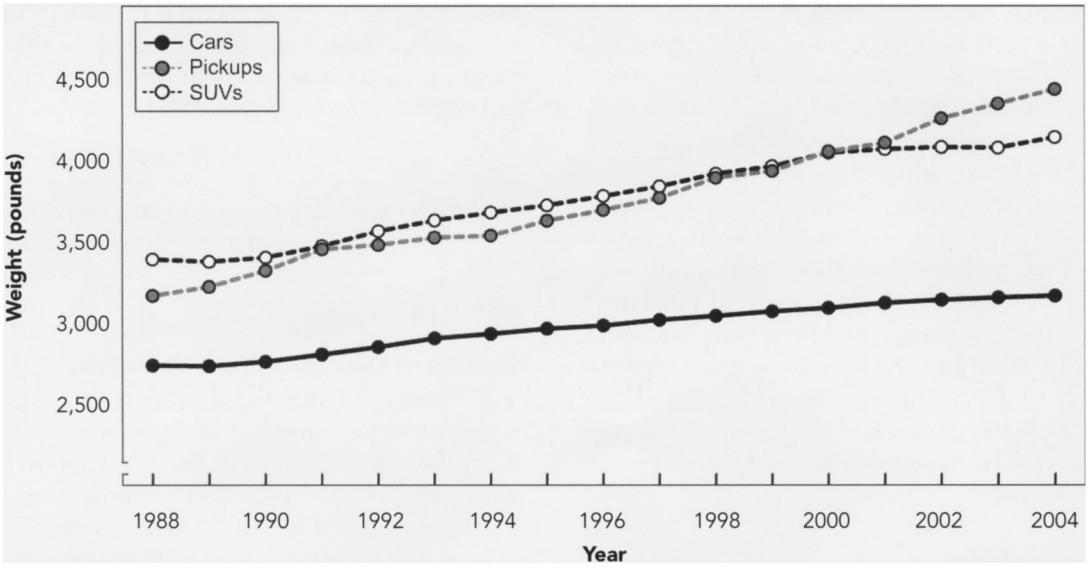
The number of driver deaths in these late-model passenger vehicles declined 40%, from 6,034 in 1988 to 3,607 in 2004. Driver deaths decreased 53% for cars and 33% for pickups but more than doubled for SUVs (137% increase) (Figure 3). So, whereas SUV

Figure 1. Number (in millions) of registered passenger vehicles 1–3 years old, 1988 to 2004



SUV = sport utility vehicle

Figure 2. Mean curb weights (in pounds) of passenger vehicles 1–3 years old, 1988 to 2004

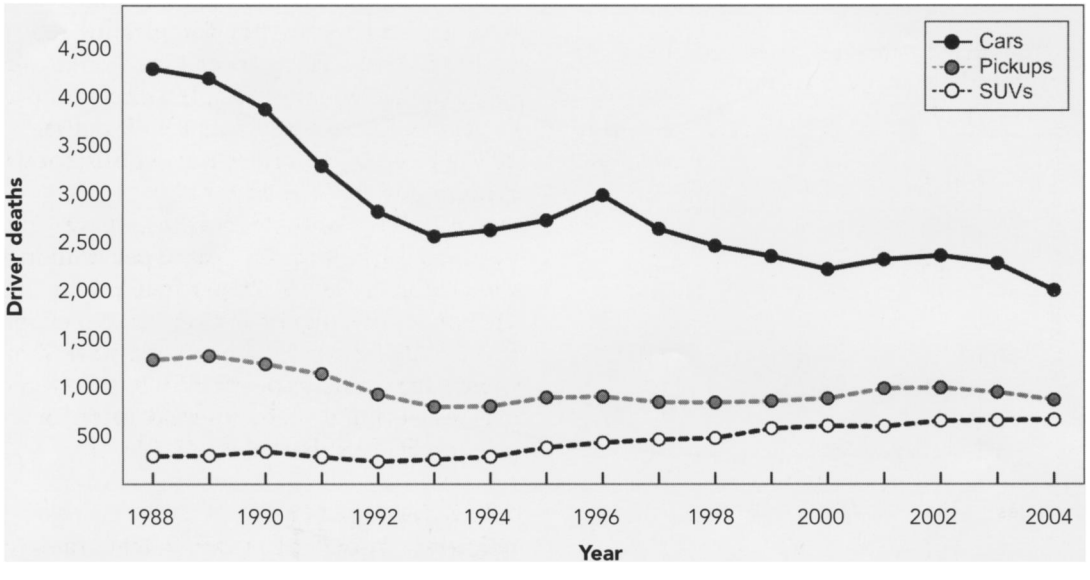


SUV = sport utility vehicle

drivers accounted for only 5% of the deaths in 1988, they constituted 18% in 2004. This increase in SUV representation among driver deaths occurred for both males and females and for all age groups (Table 1), increasing most for females aged 26–54 who had the largest proportion of driver fatalities in SUVs compared with cars and pickups in 2004. For all vehicle types, there was a greater reduction in driver death rates for crashes that occurred on rural roads compared with urban roads, and this difference was most pronounced for SUVs (Table 2).

Driver death rates per million registered one- to

Figure 3. Driver deaths in passenger vehicles 1–3 years old, 1988 to 2004



SUV = sport utility vehicle

Table 1. Percentage of driver deaths in passenger vehicles 1–3 years old by driver age and gender, 1988 and 2004

	Males				Females				
	16–25	*26–54*	*55–69*	*70+*	*16–25*	*26–54*	*55–69*	*70+*	*Total*[a]
1988									
Cars	66	61	67	82	85	85	90	98	72
Pickups	28	29	26	14	12	9	8	1	21
SUVs	5	7	4	2	3	5	1	1	5
Total[a]	100	100	100	100	100	100	100	100	100
2004									
Cars	61	40	42	69	75	59	70	91	56
Pickups	27	37	33	19	8	12	8	2	24
SUVs	12	20	23	11	17	28	22	6	18
Total[a]	100	100	100	100	100	100	100	100	100

[a]Total includes other and/or unknowns.

SUV = sport utility vehicle

three-year-old passenger vehicles, by gender and location, are shown in Table 3. Among males, driver death rates decreased more for crashes occurring on rural roads than urban roads. This decrease was primarily due to a greater reduction in rural rather than urban single-vehicle crashes among males. Overall, among females for all crashes, there was a greater reduction in driver fatality rates on urban rather than rural roads. However, there was an increase in female single-vehicle fatalities among pickup and SUV drivers on urban roads.

Driver death rates per registered passenger vehicle by crash type are shown in Table 4. For all crash types, the downward trends between 1988 and 2004 for each passenger vehicle type were generally consistent, so figures conveyed no additional information and were therefore omitted.

Table 2. Driver deaths in urban and rural crashes per million registered passenger vehicles 1–3 years old, 1988 and 2004

	1988	*2004*	*Percent change*
Cars			
Urban	53	32	−40
Rural	81	44	−46
Pickups			
Urban	41	26	−36
Rural	146	79	−46
SUVs			
Urban	37	24	−33
Rural	85	39	−54
All passenger vehicles			
Urban	49	29	−41
Rural	90	49	−46

SUV = sport utility vehicle

For all crashes combined, driver death rates for one- to three-year-old passenger vehicles decreased 44%, from 140 deaths per million registered vehicles in 1988 to 78 per million in 2004 (Table 4). Driver death rates were consistently higher for pickups than for cars and SUVs, but the changes over time were similar for the three vehicle types.

For all single-vehicle crashes, driver death rates for one- to three-year-old passenger vehicles decreased 38%, from 63 deaths per million registered vehicles in 1988 to 39 per million in 2004 (Table 4). Again, rates were consistently higher for pickups than for SUVs and cars, and changes over time were similar for the three vehicle types. For single-vehicle rollover crashes, driver death rates decreased 33% between 1988 and 2004 (Table 4), and rates were consistently higher for pickups and SUVs than for cars.

For all two-vehicle crashes, driver death rates declined 50%, from 65 deaths per million registered vehicles in 1988 to 32 per million in 2004 (Table 4). Rates were higher for cars and pickups than for SUVs, but the changes over time were similar for all vehicle types. Driver death rates for two-vehicle frontal crashes declined 55%, whereas rates for two-vehicle side impacts declined 40% (Table 4).

Vehicle incompatibility

In front-to-front crashes, driver death rates for cars (all model years) struck by one- to three-year-old SUVs or pickups (per million registered SUVs or pickups and

Table 3. Driver deaths per million registered passenger vehicles 1–3 years old, by gender, location, crash type, and vehicle type, 1988 and 2004

	Male drivers					
	Urban			Rural		
	1988	2004	Percent change	1988	2004	Percent change
All crashes						
Cars	33	20	−39	50	24	−52
Pickups	36	23	−36	126	69	−45
SUVs	29	16	−45	64	23	−64
All passenger vehicles	34	20	−41	63	32	−49
Single-vehicle crashes						
Cars	13	9	−31	24	12	−50
Pickups	19	12	−37	79	44	−44
SUVs	18	9	−50	45	15	−67
All passenger vehicles	15	10	−33	34	18	−47
Two-vehicle crashes						
Cars	16	9	−44	22	11	−50
Pickups	29	17	−41	60	28	−53
SUVs	23	7	−70	36	9	−75
All passenger vehicles	15	8	−47	25	12	−52
	Female drivers					
	Urban			Rural		
	1988	2004	Percent change	1988	2004	Percent change
All crashes						
Cars	19	11	−42	31	19	−39
Pickups	4	3	−25	19	10	−47
SUVs	8	8	0	21	17	−19
All passenger vehicles	16	9	−44	28	17	−39
Single-vehicle crashes						
Cars	5	3	−40	10	7	−30
Pickups	1	9	800	12	7	−42
SUVs	1	4	300	12	11	−8
All passenger vehicles	4	3	−25	11	8	−27
Two-vehicle crashes						
Cars	12	7	−42	18	10	−44
Pickups	16	<1	−100	18	9	−50
SUVs	7	4	−43	10	5	−50
All passenger vehicles	10	5	−50	15	8	−47

SUV = sport utility vehicle

adjusted for changes in the number of cars on the road) were at least 1.5 times as high as rates for cars struck by other cars in both 1988 and 2004 (Figure 4). Between 1988 and 2004, driver death rates for struck cars decreased across all striking vehicle types, but the decrease was smallest when the striking vehicle was a pickup. The fatality rate for drivers of cars in front-to-front crashes with pickups decreased 27% between 1988 and 2004. This statistic compares with a 44% decrease in the fatality rate for car drivers in front-to-front collisions with other cars and a 56% decrease in the fatality rate for car drivers in front-to-front collisions with SUVs.

In front-to-side crashes in 1988 and 2004, driver death rates for side-struck cars (all model years) were about 2.5 times higher when the striking vehicles were SUVs rather than cars. Rates in side-struck cars were at least three times higher when striking vehicles were pickups rather than cars. Driver death rates decreased more when the striking vehicle was an SUV than a car

Table 4. Driver deaths per million registered passenger vehicles 1–3 years old, by crash type, 1988 and 2004

	1988	2004	Percent change
All crashes			
Cars	134	76	−43
Pickups	186	106	−43
SUVs	121	64	−47
All passenger vehicles	140	78	−44
Single-vehicle crashes			
Cars	53	31	−41
Pickups	111	66	−40
SUVs	76	39	−49
All passenger vehicles	63	39	−38
Single-vehicle rollover crashes			
Cars	26	15	−44
Pickups	70	44	−37
SUVs	55	29	−47
All passenger vehicles	34	23	−33
Two-vehicle crashes			
Cars	68	36	−47
Pickups	64	34	−47
SUVs	39	20	−49
All passenger vehicles	65	32	−50
Two-vehicle front-impact crashes			
Cars	38	17	−54
Pickups	42	20	−51
SUVs	25	11	−55
All passenger vehicles	37	17	−55
Two-vehicle side-impact crashes			
Cars	26	17	−32
Pickups	18	11	−41
SUVs	9	7	−22
All passenger vehicles	23	14	−40

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or pickup (Figure 5). The fatality rate for drivers of side-struck cars in collisions with SUVs decreased 44% between 1988 and 2004. This statistic compares with a 28% decrease in the driver fatality rate for side-struck cars in collisions with other cars and an 11% decrease in the driver fatality rate for side-struck cars in collisions with pickups.

DISCUSSION

In part due to public concern about the rising number of SUVs and the subsequent effect on traffic safety, a number of studies in recent years have highlighted the incompatibility of pickups and SUVs in crashes with cars. The present study describes changes in driver fatality rates and vehicle incompatibility concurrent with changes in the mix of vehicles in the fleet. Vehicle registrations were used as the denominator for calculating driver fatality rates. A limitation of registrations is that they do not take into account potential differences in travel exposure by vehicle type. However, registrations provide a reasonable measure of the population at risk of dying in a crash involving particular vehicle types, which was the focus of the study.

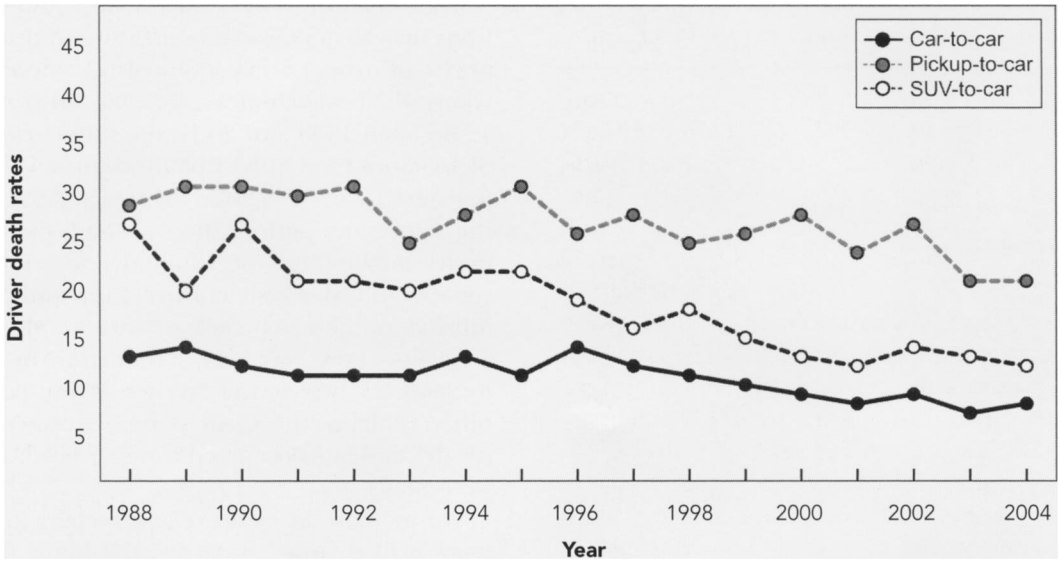
Between 1988 and 2004, the number of registered SUVs more than quadrupled, whereas the number of registered cars decreased by nearly 20%. Yet during the same time period, there was a 50% reduction in driver fatality rates per million registered passenger vehicles in two-vehicle crashes. Even among cars—the most vulnerable vehicle type in collisions with other vehicles—there was a 47% reduction in driver fatality rates for two-vehicle crashes. When colliding with other vehicles, the greatest percentage reduction in car driver deaths occurred when the colliding vehicles were SUVs.

An increase in mean vehicle weight for all vehicle types is likely one reason for the lower fatality rates. In general, heavier vehicles provide greater occupant protection than lighter vehicles in both single-vehicle and two-vehicle crashes.[3]

There was a greater reduction in driver fatality rates for two-vehicle frontal crashes than for two-vehicle side-impact crashes (55% vs. 40%). These data may reflect improvements in frontal crash protection (e.g., standard front airbags, structural improvements) that preceded advances in side-impact protection (e.g., side airbags for the head and torso).[9] Ferguson et al.[10] found that front airbags reduced deaths in frontal crashes by 26% among belted drivers and by 32% among nonbelted drivers. Vehicle structural improvements also have helped. In a study of the relationship between frontal offset crash test ratings (based in large part on structural performance) and real-world fatality rates in two-vehicle crashes of similar vehicles, Farmer[11] found that the odds of a driver fatality were 34% lower for vehicles rated good than for those rated poor. The increased use of seat belts, which offer more protection in frontal crashes than in many side crashes, may have been another factor. Nationwide, observed belt use increased from 58% in 1994 to 80% in 2004.[12] Reductions in alcohol-impaired driving also likely played a role in reducing both single- and two-vehicle driver fatality rates.

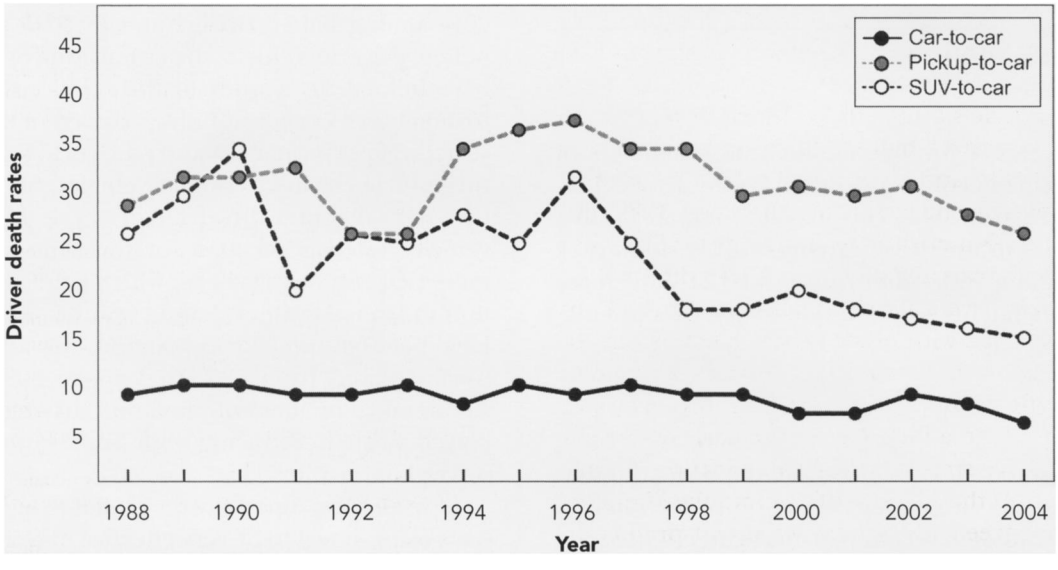
Side airbags, especially those that protect the head, have been shown to be very effective in reducing driver deaths in nearside side-impact crashes.[13] By 2004, 27% of all passenger vehicle models offered head-protecting side airbags as standard equipment, and another 21% offered side airbags as optional equipment.[14]

Figure 4. Adjusted[a] driver deaths in cars (all model years) by type of striking vehicle in front-to-front crashes per million registered striking vehicles, 1–3 years old, 1988 to 2004



[a]Driver death rates were adjusted for the decreasing percentage of cars in the passenger vehicle fleet.
SUV = sport utility vehicle

Figure 5. Adjusted[a] driver deaths in side-struck cars (all model years) by type of striking vehicle in front-to-side crashes per million registered striking vehicles, 1–3 years old, 1988 to 2004



[a]Driver death rates were adjusted for the decreasing percentage of cars in the passenger vehicle fleet.
SUV = sport utility vehicle

Car driver death rates in two-vehicle front or side crashes typically were higher when the striking vehicle was a pickup compared with an SUV, and this difference grew between 1988 and 2004. One factor may be vehicle weight. Mean vehicle weight increased more for pickups than for SUVs between 1988 and 2004. Another possibility is that pickups are involved in more severe crashes than SUVs. Pickups are more likely than other vehicle types to be driven on rural roads, which typically have higher travel speeds and higher traffic fatalities per mile compared with urban roads.[15] Conversely, SUVs are driven less frequently on rural roads than they once were. SUV drivers experienced a greater decline than pickup drivers in death rates for crashes occurring on rural roads (54% vs. 46%). Unpublished insurance data from the Highway Loss Data Institute corroborate this trend. The percentage of late-model SUVs (one to two years old) insured in rural counties decreased from 69% in 1988 to 59% in 2004. In contrast, the percentage of late-model pickups insured in rural counties changed little during the same period (77% in 1988, 76% in 2004). Coupled with the increase in female SUV drivers, the reduced proportion of SUVs on rural roads may account in part for their decreasing aggressivity relative to pickups. Crashes involving females and crashes occurring on urban roads tend to be less severe than those involving males[16] and those occurring on rural roads.[15]

Another change that may have contributed to the greater decline in incompatibility of SUVs compared with pickups is a change in the type of vehicles that comprise the SUV population. Increasingly, these vehicles (e.g., crossover SUVs) are based on car designs—some are lighter and lower to the ground than older SUVs. Static stability factor (SSF) is a ratio of half of a vehicle's track width divided by the height of its center of gravity; higher SSF values reflect lower centers of gravity and thus lower vehicle structures (given comparable track widths). Between 1992 and 2003, average SSF increased substantially for SUVs but changed little for cars and pickups.[17] Given the elevated fatality rates for drivers of cars in collisions with pickups or SUVs compared with other cars, vehicle incompatibility remains an important issue. Ways are needed to mitigate its effects. Improving occupant protection in side impacts will go a long way, particularly in crashes in which cars are struck by SUVs or pickups. To this end, members of the Alliance of Automobile Manufacturers[18] have agreed to improve occupant protection in front-to-side crashes. These efforts are focusing initially on improving head protection in side impacts. Manufacturers have committed to designing 50% of their cars, pickups, and SUVs to meet an agreed-upon head injury criterion by 2007 and 100% by 2009.

During the past two decades, there have been large changes in the vehicle fleet and, accordingly, focus has been on the implications of these changes, especially in terms of vehicle incompatibility. Undoubtedly, some changes in driver death rates are due to changes in driver characteristics and behaviors (e.g., increased seat belt use, reduced alcohol-impaired driving), but these were not the focus of the present study. This study examined one particular aspect, namely changes in driver fatality rates per registered vehicle between 1988 and 2004 and concurrent changes in the mix of vehicles in the fleet. Future research should seek to determine how many more (or fewer) deaths occurred as a result of changes in the passenger vehicle fleet.

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