

**Potential Benefits from Enhancing Crash
Compatibility between Cars and Light
Trucks in Front-to-Front Crashes**

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Introduction

Real-world crash data plus results from crash tests show that in front-to-front crashes between cars and light trucks of similar weights, differences in the heights and stiffnesses of the front-end structures result in increased risks for car occupants.

If the principal energy-absorbing structures of two vehicles in a head-on crash do not engage, underride and override will occur. In crashes at lower closing speeds, override and underride actually can result in less severe crashes, as measured by occupant compartment decelerations, compared with crashes in which the energy-absorbing structures interact. This is because underride and override produce more crushing and, therefore, more “crush distance.” However, in crashes at higher closing speeds, because there is more crush override and underride increase the likelihood of intrusion into the occupant compartments. When the principal energy-absorbing structures engage there is a lower likelihood of intrusion into the occupant compartments; however, if the front end of one vehicle is much stiffer than the occupant compartment of the other, then this also can increase the likelihood of intrusion in high-speed crashes. For optimum performance in head-on crashes, vehicles’ front-end energy-absorbing structural and stiffnesses characteristics should match, and the occupant compartments should be stiffer than the vehicles’ front ends.

Tests conducted by the Insurance Institute for Highway Safety, National Highway Traffic Safety Administration, and Transport Research Laboratory in the United Kingdom have demonstrated that, compared with head-on crashes between vehicles with energy-absorbing structures that engage during collisions, crashes between vehicles with mismatched energy-absorbing structures result in override and underride and more occupant compartment intrusion. For the vehicles that are overridden — which would be the cars in crashes between light trucks and cars — the intrusion will occur higher up in the compartment (e.g., at the dashboard level). For the vehicles that are underridden, the intrusion is more likely to occur in the footwell region (Meyerson et al., 2001; Summers et al., 2003; Wykes et al., 1998).

The proposed enhancements for front-to-front crash compatibility between cars and light trucks are intended to increase the likelihood that the energy-absorbing structures of cars and light trucks will engage, thereby reducing the intrusion caused by override and underride in head-on crashes at higher closing speeds. The benefits of reduced intrusion, especially the intrusion that occurs higher up in cars, will principally occur in crashes at higher closing speeds, in which intrusion can cause deaths and serious injuries. The matching of energy-absorbing structures is a necessary first step toward enhancing compatibility in front-to-front crashes. When front-end structures are matched, then matching of stiffnesses should produce further reductions in intrusion.

Benefits Estimates

One way to assess the adverse consequences for car occupants in serious head-on crashes between cars and light trucks — sports utility vehicles (SUVs) and pickups — is to compare occupant deaths in cars of all model years in head-on crashes with recent model light trucks per million of them registered and in head-on crashes with recent model cars per million of them registered. Differences in these occupant death rates reflect the differential risks to car occupants in head-on crashes posed by recent model light trucks and cars. To isolate the effects of differences in mass among cars, SUVs, and pickups, the results are grouped by the weights of the recent models. Table 1 shows these occupant death rates for 1997-99 model year SUVs, pickups, and cars per million registered during calendar years 2000-01.

Table 1
Occupant Deaths in Cars (All Model Years) in Front-to-Front Crashes with 1997-99 Model SUVs, Pickups, and Cars per Million Registered in Calendar Years 2000-01

Weight	Cars			Pickups			SUVs		
	Deaths	Exposure	Rate	Deaths	Exposure	Rate	Deaths	Exposure	Rate
<2500	95	9,580,525	10						
2500-	156	134,47,592	12	23	961,864	24	7	531,950	13
3000-	209	18,480,081	11	80	3,015,267	27	40	2,474,318	16
3500-	121	9,447,408	13	64	2,222,160	29	59	4,309,377	14
4000-	26	2,544,680	10	129	4,108,588	31	70	3,637,869	19
4500-				97	2,514,804	39	24	1,219,445	20
5000+				60	2,094,337	29	53	2,293,498	23

Within each weight group, the car occupant death rates in head-on crashes with recent model pickups are substantially higher than the rates in crashes with recent model SUVs. This suggests that in head-on crashes between pickups and cars additional effects beyond front-end structures are contributing to the increased risks for the car occupants. It is likely, for example, that pickups are more often loaded with cargo, so their effective weights in crashes are heavier than the unloaded weights used for the weight groups in Table 1. In addition, the results in Table 1 reflect not only what happens when head-on crashes occur but also the likelihood of involvement in such crashes. This is because the denominator is registered vehicles, not vehicles involved in crashes. Because pickups are more likely than SUVs to be operated on rural two-lane roads where head-on crashes are prevalent, it is probable that some of the increased risk for car occupants indicated in Table 1 is due to the increased exposure of pickups on such roads. For these reasons, estimates of benefits will be computed from comparisons of the results for recent model SUVs and recent model cars, which are more likely to have comparable exposure.

Ideally the front-ends of light trucks should be designed so their front-end energy-absorbing structures are at the same heights as comparable structures in cars and their front-end stiffnesses also should be matched. Then in head-on crashes the rates of occupant deaths in other cars would be the same regardless of whether the crash partner vehicles are recent model cars or SUVs, as long as their weights were similar. This assumes the exposures of recent model cars and SUVs to the risk of head-on crashes

are comparable. Thus differences in the car occupant death rates in front-to-front crashes with recent model SUVs and cars of similar weights can be used to estimate a range of potential benefits that could be expected if light truck front-end stiffness and structural alignment characteristics matched those of cars.

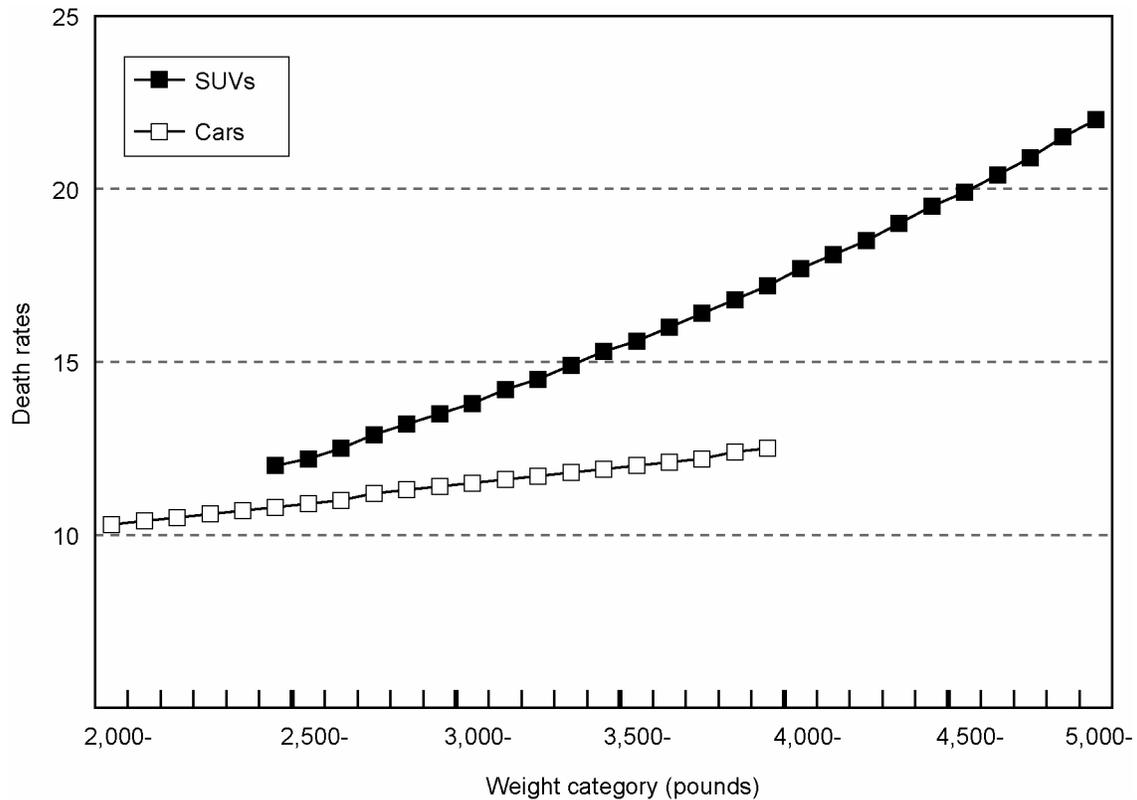
To obtain these estimates, car occupant death rates similar to those shown in Table 1, but using 100-pound weight categories instead of 500-pound weight groupings, were used to compute poisson regression equations with weight. The fitted regression equations were:

$$\text{cars: } R = \exp(2.15 + 0.0000936 \times W)$$

$$\text{SUVs: } R = \exp(1.87 + 0.0002437 \times W),$$

where W is weight in pounds and R is the fatality rate per million. Figure 1 shows these estimated relationships. These regression equations then were used to obtain hypothetical car occupant death rates in head-on crashes with cars and SUVs weighing 3,000-3,099 pounds and 4,000-4,099 pounds.

Figure 1
Estimated Relationships between Occupant Deaths in Cars (All Model Years) in Front-to-Front Crashes with 1997-99 Model SUVs and Cars per Million Registered in Calendar Years 2000-01



Differences between these computed rates for SUVs and cars provide an estimate of the range of potential benefits in terms of reduced car occupant fatalities that could be expected if the front ends of cars and light trucks were matched for geometry and stiffness. Thus, for the lighter vehicles (3,000-3,099 pounds) the estimated benefit is 16 percent; for the heavier vehicles (4,000-4,099 pounds) it is 28 percent.

The higher potential benefit for the heavier SUVs is because the fitted regression equation for SUVs has a steeper slope than in the equation for cars. This could be because the override and underide that, by definition, is very likely in head-on crashes between these vehicles and other cars will more likely lead to intrusion in the cars' occupant compartments when the light truck is heavier, whereas in head-on crashes between cars the better engagement of the energy-absorbing structures will make intrusion less likely even in crashes with weight mismatches.

Conclusions

The analyses presented here suggest that the potential benefits from enhancing the compatibility between cars and light trucks in serious front-to-front crashes can be substantial, especially for enhancements applied to heavier SUVs and pickups. The fatality risks for car occupants in front-to-front crashes with light trucks could be reduced by about 16 percent for lighter (3,000-3,099 pounds) SUVs and pickups. For heavier trucks (4,000-4,099 pounds) the fatality risks for car occupants could be reduced as much as 28 percent.

References

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