

The Evolution of Side Crash Compatibility Between Cars, Light Trucks and Vans

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ABSTRACT

Several research studies have concluded that light trucks and vans (LTVs) are incompatible with cars in traffic collisions. These studies have noted that crash incompatibility is most severe in side crashes. These early research efforts however were conducted before complete introduction of crash injury countermeasures such as dynamic side impact protection. Based upon U.S. traffic accident statistics, this paper investigates the side crash compatibility of late model cars, light trucks and vans equipped with countermeasures designed specifically to provide side crash protection. The paper explores both LTV-to-car crash compatibility and crash incompatibility in car-to-car collisions.

INTRODUCTION

The compatibility of a vehicle is a combination of its crashworthiness and its aggressivity when involved in crashes with other members of the vehicle fleet. While crashworthiness focuses on the capability of a vehicle to protect its occupants in a collision, aggressivity is measured in terms of the casualties to occupants of the other vehicle involved in the collision. Crashworthiness is sometimes referred to as self-protection while reduction in aggressivity is sometimes referred to as partner-protection. [Zobel, 1998]

Several research studies have concluded that light trucks and vans (LTVs) are incompatible with cars in traffic collisions [Gabler and Hollowell, 1998, IIHS, 1998, Joksch, 1998]. These studies have noted that crash incompatibility is particularly severe in side crashes. These early research efforts however were conducted before the complete introduction of crash injury countermeasures such as airbags and dynamic side impact protection mandated by FMVSS 214 beginning in 1994 and fully implemented in 1997. The purpose of this paper is to re-evaluate the side crash compatibility of late model cars, light trucks and vans equipped with countermeasures designed specifically to provide side crash protection.

In the year 2000, over 9000 occupants of passenger vehicles in the U.S. were fatally injured when side struck in traffic collisions. As shown in Figure 1, over 7200 of these fatalities were car occupants while 2300 of the fatally injured were the occupants of light trucks and vans (LTVs).

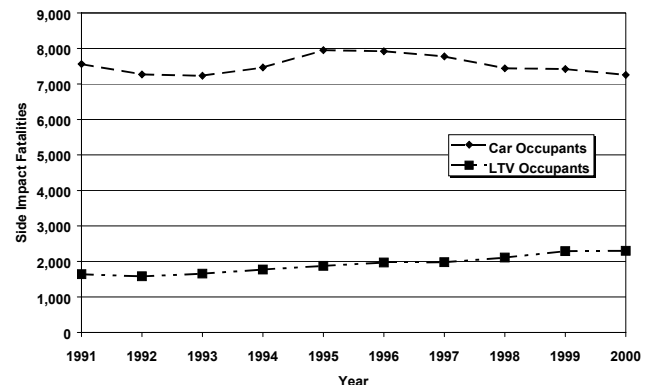


Figure 1. U.S. Side Impact Fatalities 1991-2000

Figure 2 examines fatalities resulting from side impact in two-vehicle collisions from 1991-2001. Despite only comprising about one-third of the passenger fleet, striking LTVs accounted for the majority of side impact fatalities. In the year 2001, 4442 side struck occupants of either cars or LTVs died in collisions with other cars and LTVs. Over 62 percent of these fatalities occurred when the striking vehicle was an LTV. In the U.S., the LTV population is a growing segment of the registered passenger vehicle fleet. This demographic trend is reflected in Figure 2 as a declining number of fatalities in car-to-car crashes and a growing number of LTV-to-car and LTV-to-LTV fatalities.

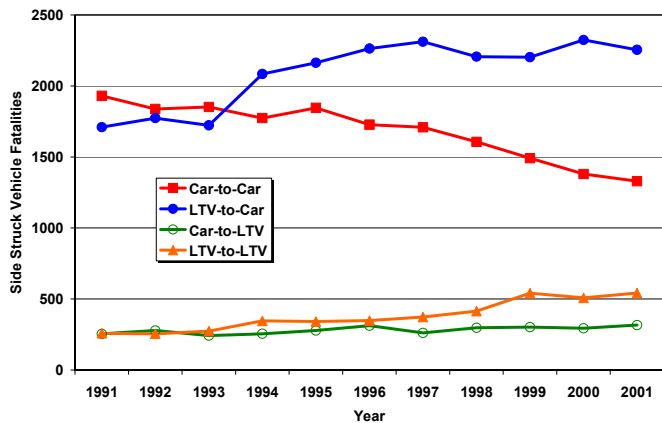


Figure 2. U.S. Side Impact Fatalities in Two Vehicle collisions - 1991-2001

There are two strategies to improve side crash compatibility: (1) improve the crashworthiness of the struck car can be improved (self-protection) and (2) reduce the aggressivity of the striking vehicle can be reduced (partner protection). Since the first studies of car-LTV compatibility were completed in 1996 and 1998, both of these strategies have been pursued to varying degrees.

- Improved Side Crashworthiness.** During the early 1990s, significant improvements were made to side impact crashworthiness as a result of a major upgrade to Federal Motor Vehicle Safety Standard (FMVSS) 214. In 1990 the National Highway Traffic Safety Administration (NHTSA) modified FMVSS 214 to require dynamic side impact protection for passenger cars in the United States. Phase-in of FMVSS 214 began for model year 1994 cars with complete implementation for all cars beginning in model year 1997. All light trucks under 6000 pounds Gross Vehicle Weight were required to comply with the regulation starting in model year 1999.

To meet this requirement, automakers introduced vehicles with a number of innovative side impact countermeasures including improvements to side structure integrity, door padding, and, most recently, side door airbags and inflatable head restraints. A study by Vander Lugt et al (1999) has shown that FMVSS 214 has led to enhanced side impact protection for passenger car occupants.

- Side Impact Protection and Frontal Airbags.** Also, during this period, frontal airbags became mandatory for both cars and LTVs. Frontal airbags are, of course, designed primarily to provide occupant protection in frontal impacts. However, frontal airbags may also reduce occupant protection in those side crashes where there is a significant longitudinal component of acceleration, e.g. angled side impacts.

Reduced Aggressivity. In the late 1990s, several automakers began to voluntarily introduce LTV models with improved crash compatibility. Improvements in partner protection included lowered frame rails and underframe structural bars. These structural changes were designed to better engage the side and frontal structures of cars, and lead to a more uniform sharing of crash energy in a collision.

OBJECTIVE

The goal of this paper is to determine the evolution of side crash compatibility of cars and LTVs in the current U.S. fleet. This paper will compare and contrast the self-protection provided by these enhancements both before and after full implementation of the dynamic side impact protection standard. The paper will also evaluate vehicle aggressivity over the same period to determine the status of improved partner-protection strategies in the fleet.

APPROACH

Our approach will be to compare the side crash compatibility of cars designed before and after the dynamic side impact protection enhancement required by FMVSS No. 214. To perform this comparison, our study divides the span of model years into three groups: 1980-89 (pre-214), 1990-96 (transition period), and 1997-2001 (full FMVSS 214 certification). Vehicles manufactured before 1980 were excluded from this grouping. To reflect the phase-in of FMVSS 214 from 1994-96 and the likelihood that many manufacturers began early enhancement of side impact protection in anticipation of FMVSS 214 implementation, this study assumes that a mix of pre-214 and post-214 compliant cars were introduced into the fleet during a seven-year transition period from 1990-96.

The analysis was based upon the 1997-2001 Fatality Analysis Reporting System (FARS) and the 1997-2001 NASS General Estimates System (GES). Occupant fatality counts were obtained from FARS. FARS is a comprehensive census of all traffic related fatalities in the U.S. GES was analyzed to determine the number of occupants who were involved - both fatally and non-fatally - in side impacts. GES is a comprehensive database containing information on approximately 60,000 randomly sampled police reported accidents each year. Cases from GES are assigned weights that can be used to estimate the number of similar accidents that may have taken place that year that were not sampled. Because GES is a sample of police reported accidents, it is important to note that these estimates could be subject to sampling errors [NHTSA, 1999]

For the purposes of this study, only side impacts involving two vehicles were analyzed. Only cases in which both vehicles were either a car or an LTV were included. To avoid the issue of occupancy rate differences between different types of vehicles, only

driver fatalities are considered as presumably all vehicles have a single driver. For GES, side impacts were defined to be either IMPACT =2 or 3 (left or right side impact point) and the striking vehicle IMPACT = 01, 11, or 12. For FARS, left side impacts were defined to be cases in which the first harmful event was equal to be 8, 9, or 10 o'clock. Right side impacts in FARS were defined to be those cases in which the first harmful event was equal to be 2, 3, or 4 o'clock. Striking vehicle impact point in FARS was required to be 11, 12, or 1 o'clock. First harmful event was used in FARS to be consistent with the GES IMPACT field which indicates the zone of impact corresponding to the first harmful event.

RESULTS

THE EVOLUTION OF FATALITY RATIOS

The ratio of striking-to-struck driver fatalities resulting from left side impacts is presented in Figure 3 as a function of the model year of the struck car. For crashes in which the struck car is of model year 1980-89 and the striking vehicle was a car from the current fleet, 12 drivers died in the struck car for every driver killed in the striking car. On the other hand, if the struck car was of model year 1997-2001 and certified to FMVSS 214, there were 7 drivers died in the struck car for every driver killed in the striking car. This indicates a significant improvement in side crash compatibility.

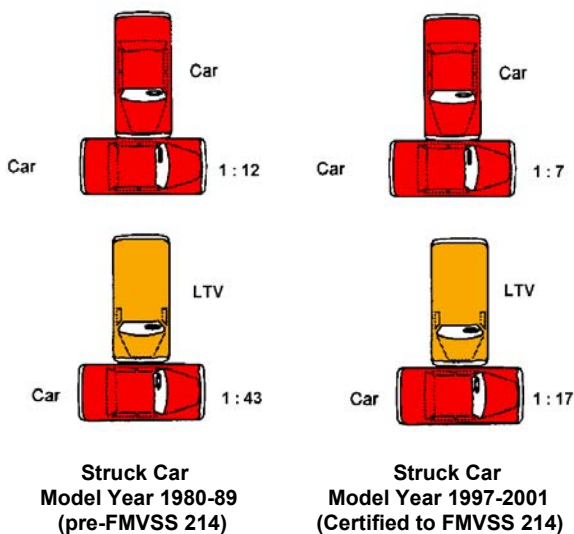


Figure 3. Fatality Ratios as a function of struck car model year (FARS 1997-2001)

For every driver who dies in a striking LTV, 43 side-struck car drivers are fatally injured when the struck car is of model year 1980-89. By contrast, if the struck car is of model year 1997-2001, for every fatally injured driver of a striking LTV, only 17 side-struck car drivers

are killed. As noted in other studies, the drivers of passenger cars disproportionately shoulder the fatality toll in car-LTV frontal crashes. However, it can be seen that as with car-to-car side crashes, there has been a significant improvement in side crash compatibility in collisions between LTVs and cars.

Because fatality ratios are computed by dividing struck car fatalities by striking car fatalities, they are a composite of the striking car crashworthiness, the striking car aggressivity, and the struck car crashworthiness. Although frequently quoted in compatibility papers, fatality ratios are not the ideal measurement of either struck car crashworthiness or striking car aggressivity. For example, a high fatality ratio can be the result of either an aggressive striking vehicle or the result of a striking vehicle with superior crashworthiness (if there are no deaths in the striking vehicle, the fatality ratio is infinite). This paper has provided fatality ratios for comparison with the research results of other studies.

A much better measure of compatibility is the probability of fatality. The probability of fatality as presented below is defined as the number of struck driver deaths divided by the number of police-reported left side impacts. This metric directly measures either side impact crashworthiness or side impact aggressivity as discussed below.

EVOLUTION OF SIDE IMPACT CRASHWORTHINESS

The first goal of this study was to determine how the side impact crashworthiness of cars has evolved from model year 1980 to the present when struck by LTVs. Struck vehicles were broken down by model year into 1980-89 (pre-FMVSS 214), 1990-96 (transition period), and 1997-2001 (full FMVSS 214 certification) groups. The crash performance of vehicles from each period was determined through analysis of all side impacts occurring using the current fleet. Only cases in which the striking vehicle was either a car or LTV were included. To maintain a sufficiently large sample for analysis, no restriction was placed upon striking vehicle model year. This approach provides an assessment of the crashworthiness of vehicles in each model year category when subjected to side impacts with the current fleet. Assuming that all vehicles are exposed to the same mix of striking vehicles, this approach allows the comparison of side impact crashworthiness for each of the three model year categories.

As shown in Figure 4, the side impact crashworthiness of cars of model year 1997-2001 was significantly improved over the crashworthiness of cars of model years 1980-89. This observation was noted both for all LTV striking body types and when the striking vehicle was a passenger car. In all cases, the probability of driver fatality in left side impacts dropped by approximately half for cars certified to the FMVSS 214 standard. It should be noted that, as airbags were introduced to the car fleet during this time period, some

of this improvement is in all likelihood due to this countermeasure as well.

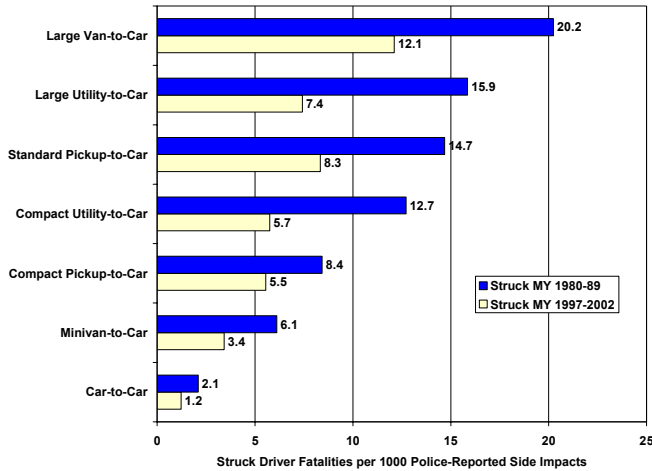


Figure 4. Side Impact Crashworthiness vs. Model Year (GES/FARS 1997-2001)

EVOLUTION OF SIDE IMPACT AGGRESSIVITY

The second goal of this study was to determine how the aggressivity of LTVs has evolved from model year 1980 to the present. Striking vehicles were broken down by model year into 1980-89 (pre-214), 1990-96 (transition period), and 1997-2001 (full FMVSS 214 certification) groups. The aggressivity of vehicles from each model year group was determined by examining side impacts in which these vehicles side struck a passenger vehicle of the current fleet. Only cases in which both the striking and struck vehicle were either a car or an LTV were included. To maintain a sufficiently large sample for analysis, no restriction was placed upon struck vehicle model year. This approach provides an assessment of the aggressivity of vehicles in each model year category in side impacts with the current fleet. Assuming that all striking vehicles collide with the same mix of struck vehicles, this approach allows the comparison of side impact aggressivity for each of the three model year categories.

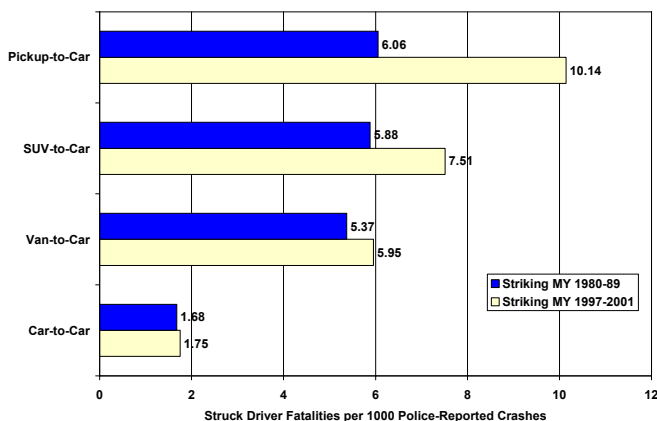


Figure 5. Side Impact Aggressivity vs. Model Year (GES/FARS 1997-2001)

As shown in the Figure 5, the aggressivity of LTVs when side impacting a car actually increased when LTVs of the 1980-89 vintage are compared with the more recent 1997-2001 models. This figure indicates that a driver of a car was significantly more likely to be fatally injured when struck by a 1997-2001 LTV model than when struck by a 1980-89 model LTV. This observation may be due to the increase in weight of late model LTVs over LTVs of ten years ago, and the growth in the SUV market which our earlier work (Gabler and Hollowell, 2000) noted to be particularly incompatible with cars in side crashes.

It has been suggested that efforts to improve side crash compatibility should focus on improving side crash compatibility. This analysis has shown that although side impact injury countermeasures have been significantly improved between the 1980's and the late 1990's, vehicle aggressivity increased during this same time period – nullifying, to some degree, the benefits of improved crashworthiness.

LIMITATIONS

This paper has presented an analysis which shows that the number of driver fatalities per police-reported left side impact dropped by approximately half for cars certified to the FMVSS 214 standard. This finding however should not be viewed as an evaluation of FMVSS 214 effectiveness. During the 1997-2001 time period, airbags were standard equipment in all passenger cars. During the 1980-89 time period however, airbags were not standard equipment in cars. The improvement in side crashworthiness reported in this paper is in all likelihood due to the combination of frontal airbags and dynamic side impact protection. Our approach is limited to showing only the combined effectiveness of these countermeasures – and does not provide a measure of each countermeasure separately.

Our approach has tracked the evolution of side crash compatibility by comparing self-protection and partner-protection for a sequence of three distinct model year time intervals. Implicit in our approach has been the assumption that each of the three groups was subjected to the same traffic crash environment over the time period of interest. All three groups were assumed to have experienced the same delta-V, impact angle, and collision partner distribution. Likewise, the distribution of driver age, and hence injury tolerance, was assumed to be the same for all three groups. An improved approach would be to explicitly compute these distributions where possible and correct for any deviations from the assumption of a shared traffic crash environment.

CONCLUSION

This paper has investigated side crash compatibility for passenger cars designed to provide enhanced side crash safety. For this study, enhanced side crash safety

was indicated by compliance with FMVSS No. 214. Our analysis was based upon the coupled analysis of 1997-2001 FARS and 1997-2001 NASS/GEISS accident databases. Our findings include:

- Side impact crashworthiness in cars of model year 1997-2001 was found to be significantly better than the side impact crashworthiness of cars of model years 1980-89. This improvement in crashworthiness was noted when these vehicles were struck by cars and every class of LTV. For this comparison, both sets of cars were subjected to the side impacts from the same group of vehicles, i.e. the striking vehicle mix of the current fleet.
- The side impact aggressivity of LTVs of model year 1997-2001 was noted to be significantly worse than the side impact aggressivity of LTVs of model years 1980-89. The side impact aggressivity of striking cars was noted to be approximately constant over this same time period.

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