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Evaluation of the Enhancing Vehicle-to-Vehicle Crash Compatibility Agreement: Effectiveness of the Primary and Secondary Energy-Absorbing Structures on Pickup Trucks and SUVs

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16. Abstract

The Enhancing Vehicle-to-Vehicle Crash Compatibility Agreement (EVC) was established in 2003 as a voluntary measure to reduce occupant fatalities of passenger cars in crashes with light trucks and vans, including pickup trucks, SUVs, minivans, and full-size vans, generically abbreviated as LTVs. Manufacturers agreed upon voluntary standards for LTVs to reduce the height mismatches between these LTVs and passenger cars. NHTSA statistically compared car-occupant fatality risk in crashes with pickup trucks and SUVs, referred throughout the report as light trucks, built just before and just after self-certification to the agreement based on FARS and Polk data from 2002 to 2010. Overall, there was a statistically significant 8-percent reduction in car-occupant fatalities of passenger cars after light trucks self-certified to the agreement. However, for pickup trucks and SUVs separately, the effectiveness is inconsistent. Pickup trucks experienced a non-significant increase of 5-percent likelihood of occupant fatalities of passenger cars, while SUVs were associated with a significant 17-percent reduction. Furthermore, a supplementary non-parametric analysis does not show fatality reduction for significantly more than 50 percent of the makes and models. Overall, these results provide some evidence that the EVC has reduced fatalities but are not sufficiently strong to permit an unequivocal conclusion that it has been effective in reducing fatality risk to car occupants.

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List of Abbreviations

CY	calendar year
CUV	crossover utility vehicle
FARS	Fatality Analysis Reporting System, a census of the nation's fatalities since 1975
EVC	Enhancing Vehicle-to-Vehicle Crash Compatibility
IIHS	Insurance Institute for Highway Safety
LTV	light trucks and vans, includes pickup trucks, SUVs, minivans, and full-size vans
MY	model year
NVPP	Polk National Vehicle Population Profile
PEAS	primary energy-absorbing structure
SEAS	secondary energy-absorbing structure

Executive Summary

This report analyzes the effects of the Enhancing Vehicle-to-Vehicle Crash Compatibility Agreement, generically abbreviated as EVC, which the vehicle manufacturers established in 2003 as a voluntary measure, as a means to reduce occupant fatalities of passenger cars in crashes with pickup trucks or SUVs. Specifically, the report addresses the fatality reduction due to compatibility improvements at the moment of self-certification, which varies by make and model but, according to the EVC, would be sometime up to September 2009.

Under the compatibility agreement, voluntary standards for LTVs (pickup trucks, SUVs, and vans) were agreed upon to reduce the height mismatches between these LTVs and passenger cars. These measures were specifically aimed to reduce fatalities when the front of the LTV contacts the side or the front of the car.

Based on data from both the Fatality Analysis Reporting System and R.L. Polk & Company, the number of occupant fatalities in passenger cars in crashes with light trucks per million light trucks registration-years was calculated for selected LTV makes and models. This data was collected for each model's last three model years before self-certification to the compatibility agreement and also the first three model years after self-certification.

The evaluation methods in this report compared the overall fatality rates before and after self-certification (main analysis) and the number of makes and models that had lower fatality rates after self-certification to the number of models that had higher rates (supplementary non-parametric analysis). The main analysis is similar to a 2008 evaluation of the compatibility agreement by the Insurance Institute for Highway Safety, but it now includes additional model years (1998-2009) and calendar years (2002-2010).

The principal finding is a statistically significant 8 percent reduction in car-occupant fatalities after light trucks self-certified to the compatibility agreement. But the results are inconsistent for pickup trucks and SUVs. The observed fatality reduction for pickup trucks is negative (-5%) and not statistically significant, while for SUVs it is a positive and statistically significant 17 percent. Furthermore, the non-parametric analysis does not show fatality reduction for significantly more than 50 percent of the makes and models. Overall, these results provide some evidence that the EVC has reduced fatalities but are not sufficiently strong to permit an unequivocal conclusion that it has been effective in reducing fatality risk to car occupants.

1. Introduction

1.1 Enhancing Vehicle-to-Vehicle Crash Compatibility Agreement

In 2003, vehicle manufacturers[1] agreed to voluntary measures aimed at reducing the height mismatches between cars and LTVs, especially when the front of the LTV contacts the front or the side of the car. The measures agreed upon would be achieved with full adherence for all LTVs[2] built after September 2009. Indeed, all LTVs in model year (MY) 2010 self-certified to the agreement. A number of LTVs on the road had already met these criteria even before 2003, e.g., Chevrolet Blazer or Ford F150 in MY 2000.[3]

From this voluntary agreement came forth two options to improve compatibility. Option 1 refers to the primary energy-absorbing structure of the LTVs. Option 1 specifies that at least 50 percent of the LTVs' PEAS should overlap at least 50 percent of the Part 581 bumper zone of the car, which is located 16 to 20 inches from the ground and runs the full width of the car. If the PEAS of the LTV is more than 8 inches tall from bottom to top, then complete overlap of the car bumper zone is required.

Option 2 is concerned with LTVs that do not meet the criteria for option 1. In this option, a secondary energy-absorbing structure (SEAS) is required. The SEAS is connected to the primary structure with a lower edge no higher than the bottom of the car bumper zone. SEAS are sometimes called "blocker beams."

1.2 Previous Analyses of Effectiveness

IIHS has completed two studies on LTV/car compatibility. The first study was published by Baker et al. in 2008.[4] This report analyzed the real-world crash experience of LTVs already meeting the height-matching criteria and compared them with that of LTVs not meeting the criteria. The data comprised MY 2000–2003 LTVs in collisions with passenger cars during CY 2001 to 2004. To identify the MY 2000-2003 LTVs that met the criteria for Option 1 or 2, a survey was provided to automakers. The study calculated the risk reduction by obtaining the ratio of the observed fatalities in crashes with LTVs that met the height-matching criteria to the expected fatalities of LTVs that did not meet the criteria. The estimated benefits of energy-

[1] Participating vehicle manufacturers were: BMW Group, DaimlerChrysler Corporation, Ford Motor Company, General Motors, Honda, Hyundai Motor, Isuzu Motors, Kia Motors, Mazda, Mitsubishi Motors, Nissan, Subaru, Suzuki, Toyota, and Volkswagen Group.

[2] Applicability: All light truck vehicles with GVWRs up to 10,000 pounds, except, low production volume vehicles, vehicles over 8,500 pounds GVWR with functional criteria which preclude them from meeting the performance criteria, and other vehicles that a manufacturer determines cannot meet the performance criteria without severely compromising their practicality or functionality.

[3] *Memorandum: Docket Letter and Report, Enhancing Vehicle-to-Vehicle Crash Compatibility, Commitment for Continued Progress by Leading Automakers.* NHTSA, March 5, 2004, (Docket # NHTSA-2003-14623-13). Washington, DC: National Highway Traffic Safety Administration.

[4] Baker, B. C.,, Nolan, J. M., O'Neill, B., & Genetos, A. P. (2008). Crash compatibility between cars and light trucks: Benefits of lowering front-end energy-absorbing structure in SUVs and pickups. *Accident Analysis and Prevention*, Vol 40, pp 116-125.

absorbing structures were a 19-percent reduction ($p < 0.05$) in fatality risk to belted car drivers in front-to-front crashes with LTVs and a 19-percent reduction ($p < 0.05$) in fatality risk to belted car drivers in front-to-driver-side crashes with LTVs. These results suggested that the voluntary EVC commitment would produce important benefits to car occupants.

The second study by IIHS[5] examined two types of fatality rates for 1- to 4-year-old case vehicles during CY 2000-2001 and during 2008-2009 in the United States. In both study periods, case-vehicle occupant fatalities per million registered case-vehicle years in the passenger vehicles were computed by case-vehicle type and curb-weight category (500 lb increments). Fatalities to occupants of other cars that collided with these case vehicles in two-vehicle crashes were also computed per million registered case-vehicle years by case-vehicle type and weight category. In both study periods, occupant fatality rates generally declined with increasing curb weight for each type of vehicle. And overall, occupant fatality rates declined for all vehicle and weight categories between these time periods, with SUVs experiencing the greatest declines compared with cars and pickup trucks. Fatality rates in other cars in two-vehicle crashes declined over time for all vehicle categories, but more steeply for SUVs and pickup trucks colliding with cars than for cars colliding with cars. This second study acknowledges the difficulty of identifying the specific contribution of the EVC agreement to the long-term reduction in fatality rates, but believes that the large reductions in car-occupant fatality rates when cars collide with LTVs indicate the likely benefits of the EVC agreement.

1.3 Goal of the Evaluation

The goal of this analysis is to estimate the fatality reduction in passenger cars that collide with light trucks due to compatibility improvements in the LTVs that were apparently implemented in the year of self-certification to the EVC. It is important to understand as clearly as possible the changes that will occur as the LTV fleet is redesigned to meet the EVC agreement. The first IIHS study had the same goal but was limited with their amount of data, while the second study did not analytically isolate factors for the long-term decline in fatality rates. The second study provided a broad general perspective of really how the driving environment has changed from CY 2000-2001 to 2008-2009. The overall effect may be due to a combination of compatibility improvements in the LTVs; crashworthiness improvements in the cars; crash avoidance technologies; and changes in vehicle mix, vehicle use, or driving patterns. Furthermore, the compatibility improvements in LTVs are not necessarily limited to those involved in certifying to the voluntary standard, but could include any prior or subsequent modifications.

[5]Nolan, J. M., & Teoh, E. R. (2011). *Is passenger vehicle incompatibility still a problem*? Arlington, VA: Insurance Institute for Highway Safety.

2. Methods

2.1 The Fatality Rates Risk Ratio

The principal methodology for this evaluation is similar to the first IIHS study. It examines the number of car-occupant fatalities in crashes with light trucks that met the height-matching criteria to the number of car-occupant fatalities in crashes with light trucks that did not meet the criteria. Examining these numbers, one can estimate the effectiveness of both Option 1 and Option 2 by computing associated risk ratios.

FARS for CY 2002-2010 was used to obtain information on two-vehicle crashes between MY 1998-2009 light trucks and any passenger car in which a car-occupant fatality occurred. For the initial MY in which a light-truck model was self-certified (for example, the Toyota Tacoma was certified for Option 2 in MY 2005), fatalities in cars that crashed with light trucks of this model and MY starting from the following CY (in this example, 2006) up through 2010 were tallied. This is also done for the next 2 sequential model years (in this example, 2006 and 2007) and also the last 3 model years before the self-certification of that light truck model (2002, 2003, and 2004). But for all 6 MY, the same range of CY is used – in this example, 2006-2010. The first 3 model years following self-certification were classified in the "post" group while the last 3 model years before self-certification were in the "pre" group. Corresponding registration data for the light trucks were obtained from R.L. Polk's National Vehicle Population Profile (NVPP). The data was restricted to calendar years following the initial certification model year because new vehicles initially are registered at varying times throughout the year they are sold (when MY $\geq$ CY), so the NVPP count of registrations as of July 1 may not accurately reflect the actual exposure during that year. So for example, data for the Toyota Tacoma was collected for MY 2002-07 for CY 2006-10. The same range of calendar years (in this example, 2006-2010) is used regardless of the model year to assure that the "pre" and "post" vehicles are observed at the same time, i.e., in the same crash environment.

The fatality rates risk ratios were calculated as shown below in Table 1. The rows identify the time period either before or after EVC self-certification. The center column identifies the number of occupant fatalities in cars that collided with the case vehicles and the right column identifies the number of registration years for the case vehicles.

Table 1: Computation of Risk Ratios

	FATALITIES	REGISTRATIONS
PRE	# of occupant fatalities in passenger cars involved in crashes with selected light trucks before EVC self-certification (A)	# of registrations for the selected light trucks before EVC self-certification (B)
POST	# of occupant fatalities in passenger cars involved in crashes with selected light trucks after EVC self-certification (C)	# of registrations for the selected light trucks after EVC self-certification (D)

From Table 1, the relative risks are calculated as the ratio of the number of fatalities per million number of light trucks registrations for both time periods. The relative risks can then be used to determine the effectiveness of the EVC agreement on light trucks before the light trucks were self-certified. The effectiveness is calculated by first obtaining the risk ratio, which is simply dividing the relative risk of the post group by the relative risk of the pre group. Then the risk ratio is subtracted from one to yield a point estimate of the effectiveness. The statistical significance of the relationships in this table is assessed by calculating the Z score. The null hypothesis of the statistical test is that the risk ratio is 1. But a Z score greater than 1.96 leads to the rejection of the null hypothesis and the conclusion that the risk ratio is significantly different from one. Figure 1 provides the formula for calculating the risk ratio and Z score.

Figure 1: Risk Ratio and Z Score Equations

$$RelativeRisk(PRE) = A/B$$

$$RelativeRisk(POST) = C/D$$

$$RiskRatio = RelativeRisk(Post) / RelativeRisk(PRE) = \frac{C/D}{A/B} = \frac{C \times B}{D \times A}$$

$$PercentEffectiveness = (1 - RiskRatio) \times 100 = \left(1 - \left(\frac{C \times B}{D \times A}\right)\right) \times 100$$

$$Z = \frac{\left(A/B\right) - \left(C/D\right)}{\sqrt{\left(\left(A+C\right)/\left(B+D\right)\right) \times \left(1/B + 1/D\right)}}$$

2.2 Non-Parametric Analysis

An additional test of non-parametric analysis is conducted to provide additional evidence that the results provided from the risk ratio capture the sole effects of the compatibility agreement only. The non-parametric analysis observes the same fatality rates and risk ratio, but computes them separately for each make and model and then simply compares the number of models that had lower fatality rates after self-certification to the number of models that had higher rates. In other words, did significantly more than half the models improve (have lower rates)? Advantages of this method are: (1) It “controls” for make and model; it is not influenced by some models having mostly “pre” cases and others have mostly “post” cases. (2) Overall findings are not overly influenced by one or two high-sales make-models with anomalous results: all models have equal weight. The disadvantage from this analysis, though, is that it is less likely to produce significant results, from the same number of cases, than the principal method; thus, a non-significant finding is not necessarily a negative result, just a caution flag.

The non-parametric method has also been used in past NHTSA evaluations where the principal analysis yielded significant results. “The Effectiveness of Amber Rear Turn Signals for

Reducing Rear Impacts"[6] compared rear turn signal colors of either red or amber. Initially, a risk ratio analysis showed significantly lower aggregate risk of rear impacts with amber turn signals. To confirm the results, Allen used a non-parametric analysis by make and model. In the sample, there were 33 make-models that switched from red to amber or vice-versa, with 24 models having lower crash rates with amber signals and only 9 having lower rates with red signals. The binomial probability test provided that the probability for getting more than 23 "heads" if an honest coin is flipped 33 times is .007. This result signified that it is unlikely to have such a high proportion of models favoring amber, given a null hypothesis that amber and red are equally effective. Similarly, in an ongoing, unpublished analysis of the effect of curtain plus torso air bags versus no air bags on fatality risk in side impacts, 23 of 32 make-models that switched from no air bags to curtain and torso air bags have lower fatality risk with the air bags, while 9 have lower fatality risk with no air bags. With the null hypothesis of curtain plus torso bags and no air bags being equally effective, the probability of obtaining more than 22 out of 32 is .010. Thus, in both cases, the non-parametric analysis corroborated the significance of the overall result and strengthened the conclusion that the safety technologies are effective. A similar binomial test can be applied to the list of makes and models considered in this report, or to any subgroup of that list.

2.3 Selection of Vehicle Models

Because little data is on file for MY 2010 vehicles as of January 2012, the study is limited to light trucks of MY 2009 or earlier. Light trucks self-certified to the EVC as early as MY 2000 or as late as MY 2010 (full adherence to the voluntary agreement by September 2009) light trucks that self-certified to the voluntary agreement beginning in MY 2000 were excluded from the analysis due to the concern that these vehicles may have already met the height matching criteria before MY 2000. Light trucks self-certifying in 2008 or later were excluded because they would not have had three full years of certification by MY 2009. In other words, the report is limited to models that self-certified during MY 2001-2007. Table 2 lists the included models, the model years considered, and which option the vehicle certified to. It should be noted that these ranges of model years apply to the light trucks; the passenger cars that collided with the light trucks, in which occupants were fatally injured, may be of any model year.

[6] Allen, K. (2009). *The Effectiveness of Amber Rear Turn Signals for Reducing Rear Impacts*, (NHTSA Technical Report No. DOT HS 811 115). Washington, DC: National Highway Traffic Safety Administration.

Table 2: List of Tested Vehicles

Make	Model	Years Before EVC Certification	Years After EVC Certification	Certification Option
Cadillac	Escalade 4DR	2004-2006	2007-2009	PEAS
Cadillac	Escalade 4DR AWD	2004-2006	2007-2009	PEAS
Cadillac	Escalade ESV AWD	2004-2006	2007-2009	PEAS
Cadillac	Escalade EXT AWD	2004-2006	2007-2009	PEAS
Chevrolet	Silverado K1500 4x4	2004-2006	2007-2009	SEAS
Chevrolet	Silverado K1500 4x4 X-Cab	2004-2006	2007-2009	SEAS
Chevrolet	Silverado K1500 4x4 Crew Cab	2004-2006	2007-2009	SEAS
Chevrolet	Tahoe 4DR	2004-2006	2007-2009	PEAS
Chevrolet	Tahoe 4DR 4x4	2004-2006	2007-2009	PEAS
Chevrolet	C1500 Suburban	2004-2006	2007-2009	PEAS
Chevrolet	K1500 4x4 Suburban	2004-2006	2007-2009	PEAS
Chrysler	Pacifica	2004-2006	2007-2009	SEAS
Dodge	Ram 1500 4WD	2003-2005	2006-2008	SEAS
Dodge	Ram 1500 4WD Quad Cab	2003-2005	2006-2008	SEAS
Dodge	Ram 2500 4WD	2003-2005	2006-2008	SEAS
Dodge	Ram 2500 4WD Quad Cab	2003-2005	2006-2008	SEAS
Dodge	Ram 3500 4WD	2003-2005	2006-2008	SEAS
Dodge	Ram 3500 4WD Quad Cab	2003-2005	2006-2008	SEAS
Dodge	Ram 3500 4WD DRW	2003-2005	2006-2008	SEAS
Dodge	Ram 3500 4WD DRW Quad Cab	2003-2005	2006-2008	SEAS
Dodge	Durango 4x4	2003-2005	2006-2008	SEAS
Ford	F250	1998-2000	2001-2003	SEAS
Ford	F250 4x4	1998-2000	2001-2003	SEAS
Ford	F250 Supercab	1998-2000	2001-2003	SEAS
Ford	F250 Supercab 4x4	1998-2000	2001-2003	SEAS
Ford	F250 Crew Cab	1998-2000	2001-2003	SEAS
Ford	F250 Crew Cab 4x4	1998-2000	2001-2003	SEAS
Ford	F350	1998-2000	2001-2003	SEAS
Ford	F350 4x4	1998-2000	2001-2003	SEAS
Ford	F350 Supercab	1998-2000	2001-2003	SEAS
Ford	F350 Supercab 4x4	1998-2000	2001-2003	SEAS
Ford	F350 Crew Cab	1998-2000	2001-2003	SEAS
Ford	F350 Crew Cab 4x4	1998-2000	2001-2003	SEAS
Ford	Escape 4DR	2004-2006	2007-2009	SEAS
Ford	Escape 4DR 4x4	2004-2006	2007-2009	SEAS
Ford	Escape Hybrid	2004-2006	2007-2009	SEAS
Ford	Escape Hybrid 4x4	2004-2006	2007-2009	SEAS
Ford	Explorer 4DR	1999-2001	2002-2004	PEAS
Ford	Explorer 4DR 4x4	1999-2001	2002-2004	PEAS
Ford	Explorer 4DR AWD	1999-2001	2002-2004	PEAS
Ford	Expedition 4DR 4x4	2000-2002	2003-2005	PEAS
GMC	Sierra K1500 4x4	2004-2006	2007-2009	SEAS
GMC	Sierra K1500 4x4 X-Cab	2004-2006	2007-2009	SEAS
GMC	Sierra K1500 4x4 Crew Cab	2004-2006	2007-2009	SEAS
GMC	Sierra Denali Crew Cab AWD	2004-2006	2007-2009	SEAS
GMC	Yukon 4DR	2004-2006	2007-2009	PEAS
GMC	Yukon 4DR 4x4	2004-2006	2007-2009	PEAS
GMC	Denali 4DR AWD	2004-2006	2007-2009	PEAS
GMC	Yukon XL	2004-2006	2007-2009	PEAS
GMC	Yukon XL 4x4	2004-2006	2007-2009	PEAS
GMC	Denali XL AWD	2004-2006	2007-2009	PEAS
Jeep	Wrangler	2004-2006	2007-2009	SEAS
Land Rover	Range Rover 4DR 4x4	2000-2002	2003-2005	SEAS
Lincoln	Navigator 4DR 4x4	2000-2002	2003-2005	PEAS
Mercury	Mariner	2004-2006	2007-2009	SEAS
Mercury	Mariner 4x4	2004-2006	2007-2009	SEAS
Mercury	Mariner Hybrid 4x4	2004-2006	2007-2009	SEAS
Mercury	Mountaineer 4DR	1999-2001	2002-2004	PEAS
Mercury	Mountaineer 4DR 4x4	1999-2001	2002-2004	PEAS
Mercury	Mountaineer 4DR AWD	1999-2001	2002-2004	PEAS
Nissan	Pathfinder 4DR	2002-2004	2005-2007	PEAS
Nissan	Pathfinder 4DR 4x4	2002-2004	2005-2007	PEAS
Toyota	Tacoma 4x4	2002-2004	2005-2007	SEAS
Toyota	Tacoma Xtracab	2002-2004	2005-2007	SEAS
Toyota	Tacoma Xtracab 4x4	2002-2004	2005-2007	SEAS
Toyota	Tacoma Double Cab	2002-2004	2005-2007	SEAS
Toyota	Tacoma Double Cab 4x4	2002-2004	2005-2007	SEAS
Toyota	4Runner	2000-2002	2003-2005	SEAS
Toyota	4Runner 4x4	2000-2002	2003-2005	SEAS
Toyota	RAV4 4DR 4x2	2003-2005	2006-2008	SEAS
Toyota	RAV4 4DR 4x4	2003-2005	2006-2008	SEAS

3. Results of Effects of Light Trucks Compatibility in Fatal Crashes

Table 3 computes the fatality rates for these make-models in the first 3 MY after certification (post-) to the corresponding rates for the last 3 MY before certification (pre-). The tables show the aggregate fatality rate for all these make-models, compute the percentage reduction, and test whether it is statistically significant (as evidenced by Z > 1.96 in bold type).

Table 3: Fatality Rates Tables

PICKUP TRUCKS & SUVS

	FATALITIES	REGISTRATIONS	RATE	
PRE	1,411	28,990,710	48.67	
POST	1,231	27,476,344	44.80	
Z	**2.12**		**8.0%**	**EFFECTIVENESS**

PICKUP TRUCKS ONLY

	FATALITIES	REGISTRATIONS	RATE	
PRE	784	12,399,508	63.23	
POST	706	10,647,902	66.30	
Z	-0.92		-4.9%	EFFECTIVENESS

SUVS ONLY

	FATALITIES	REGISTRATIONS	RATE	
PRE	627	16,591,202	37.79	
POST	525	16,828,442	31.20	
Z	**3.25**		**17.5%**	**EFFECTIVENESS**

The overall effect in the entire database is an 8.0 percent fatality reduction (from 48.67 to 44.80), which is statistically significantly at the two-sided .05 level (Z=2.12). Even though the overall effectiveness of 8.0 percent is statistically significant there is a caution flag, namely, the wide difference between the effectiveness for pickup trucks (-4.9%) and SUVs (+17.5%). Intuitively, there is no obvious reason for inconsistency between pickup trucks and SUVs. Perhaps other factors are causing SUVs to have a larger fatality reduction than pickup trucks.

One possible factor could be a vehicle-age effect, due to the certified vehicles in the database being newer than the pre-certified vehicles. The age effect might be different for pickup trucks and SUVs. Table 4 limits the preceding analyses to just ±1 or ±2 MY before and after certification. Reducing the database to just ±1 MY eliminates most of the age effect because the Pre and Post vehicles are nearly the same age.

Table 4: Fatality Rates Tables Limited to ±1 and ±2 MY

PICKUP TRUCKS ONLY LIMITED TO ±1 MY

	FATALITIES	REGISTRATIONS	RATE	
PRE	317	4,820,845	65.76	
POST	315	4,354,040	72.35	
Z	-1.20		-10.0%	EFFECTIVENESS

PICKUP TRUCKS ONLY LIMITED TO ±2 MY

	FATALITIES	REGISTRATIONS	RATE	
PRE	687	10,230,041	67.16	
POST	547	7,950,769	68.80	
Z	-0.42		-2.4%	EFFECTIVENESS

SUVS ONLY LIMITED TO ±1 MY

	FATALITIES	REGISTRATIONS	RATE	
PRE	125	3,442,413	36.31	
POST	269	8,352,955	32.20	
Z	1.11		11.3%	EFFECTIVENESS

SUVS ONLY LIMITED TO ±2 MY

	FATALITIES	REGISTRATIONS	RATE	
PRE	376	10,037,973	37.46	
POST	434	13,562,355	32.00	
Z	**2.24**		**14.6%**	**EFFECTIVENESS**

The effect is consistently negative in pickup trucks, consistently positive in SUVs, regardless of whether it is based on ±1, ±2 or ±3 MY of data.

Table 5 presents the result of the non-parametric analysis. Overall, among 57 light trucks models included in the report, 34 improved (had lower car-occupant fatality rates) after certification and 23 became worse. This is still within the acceptance range for the null hypothesis of a 50/50 split, as evidenced by the P value of 0.09 for the binomial test. The data from the non-parametric comparison shows that only SUVs show fatality reductions for significantly more than 50 percent of the make-models (as evidenced by P <0.05 in bold type). Among only pickup trucks, the proportion of models that improved is not significantly different from a 50-50 split. This shows that even though the analysis of fatality rates for all vehicles resulted in positive effectiveness with statistical significance, that result may be questioned, at least to some degree, because the proportion of the make-models that improved was not significantly higher than 50 percent.

Table 5: Non-Parametric Analysis Tables

PICKUP TRUCKS & SUVS

IMPROVED	34
WORSEN	23
TOTAL	57
P(>33)	0.09

PICKUP TRUCKS ONLY

IMPROVED	9
WORSEN	12
TOTAL	21
P(<10)	0.33

SUVS ONLY

IMPROVED	25
WORSEN	11
TOTAL	36
P(>24)	**0.02**

We also examined the effects of the compatibility improvements when looking at specific types of crashes, especially front-to-front and front-to-side crashes. Front-to-front crashes are those in which both the light truck and the car have damage at the 11-, 12-, or 1 o'clock positions. Front-to-side impacts are those in which the light truck has damage at the 11-, 12-, or 1 o'clock position while the car has damage at the 8- to-10 or 2-to-4 o'clock positions. These are two types of crashes where the front-end design of the LTV, the subject of the EVC, is relevant. Intuitively, higher effectiveness would be expected in the front-to-side impacts because the car occupants are especially at risk if the LTV overrides the sill of the struck car. Table 6 presents the fatality rates and Table 7 presents the non-parametric analysis for front-to-front impacts.

Table 6: Fatality Rates Tables Limited to Front-to-Front Impact

PICKUP TRUCKS & SUVS FRONT-TO-FRONT

	FATALITIES	REGISTRATIONS	RATE	
PRE	484	28,990,710	16.70	
POST	407	27,476,344	14.81	
Z	1.78		11.3%	EFFECTIVENESS

PICKUP TRUCKS ONLY FRONT-TO-FRONT

	FATALITIES	REGISTRATIONS	RATE	
PRE	250	12,399,508	20.16	
POST	210	10,647,902	19.72	
Z	0.24		2.2%	EFFECTIVENESS

SUVS ONLY FRONT-TO-FRONT

	FATALITIES	REGISTRATIONS	RATE	
PRE	234	16,591,202	14.10	
POST	197	16,828,442	11.71	
Z	1.93		17.0%	EFFECTIVENESS

Table 7: Non-Parametric Analysis Tables Limited to Front-to-Front Impact

PICKUP TRUCKS & SUVS FRONT-TO-FRONT

IMPROVED	31
WORSEN	23
TOTAL	54
P(>30)	0.17

PICKUP TRUCKS ONLY FRONT-TO-FRONT

IMPROVED	9
WORSEN	12
TOTAL	21
P(<10)	0.33

SUVS ONLY FRONT-TO-FRONT

IMPROVED	22
WORSEN	11
TOTAL	33
P(>21)	**0.04**

In front-to-front crashes, both pickup truck and SUVs and pickup trucks only show a more positive result than in the all-crashes analysis (Table 3). In the non-parametric analysis, the results are very similar to the results for all crashes with only the SUVs being statistically significant from a 50-50 split.

Table 8 and 9 show the corresponding results for front-to-side impacts. Here, results for every group are at least somewhat more positive (or less negative) than in the all-crashes analysis (Table 3). The observed result for pickup trucks is not positive as for front-to-front crashes, but is not as negative as the result for all crashes. Here, for the first time, the non-parametric analysis also shows significantly better than a 50-50 split for pickup trucks and SUVs combined (36 out of 52 improved).

Table 8: Fatality Rates Tables Limited to Front-to-Side Impact

PICKUP TRUCKS & SUVS FRONT-TO-SIDE

	FATALITIES	REGISTRATIONS	RATE	
PRE	685	28,990,710	23.63	
POST	565	27,476,344	20.56	
Z	**2.45**		**13.0%**	**EFFECTIVENESS**

PICKUP TRUCKS ONLY FRONT-TO-SIDE

	FATALITIES	REGISTRATIONS	RATE	
PRE	404	12,399,508	32.58	
POST	348	10,647,902	32.68	
Z	-0.04		-0.3%	EFFECTIVENESS

SUVS ONLY FRONT-TO-SIDE

	FATALITIES	REGISTRATIONS	RATE	
PRE	281	16,591,202	16.94	
POST	217	16,828,442	12.89	
Z	**3.03**		**23.9%**	**EFFECTIVENESS**

Table 9: Non-Parametric Analysis Tables Limited to Front-to-Side Impact

PICKUP TRUCKS & SUVS FRONT-TO-SIDE

IMPROVED	36
WORSEN	16
TOTAL	52
P(>35)	**<0.01**

PICKUP TRUCKS ONLY FRONT-TO-SIDE

IMPROVED	11
WORSEN	8
TOTAL	19
P(>10)	0.32

SUVS ONLY FRONT-TO-SIDE

IMPROVED	25
WORSEN	8
TOTAL	33
P(>24)	**<0.01**

A possible factor that might explain some of the wide difference between the effectiveness in pickup trucks and SUVs is the difference in the design of their body frames. The pickup trucks in this study have a frame-rail body. The SUVs in this study may either have a frame-rail body or a unibody construction. The frame-rail is fitted on SUVs that are usually of heavier weight and are often shaped in the front like pickup trucks, e.g., Dodge Durango, Ford Explorer, Lincoln Navigator, Chevrolet Trailblazer, and Cadillac Escalade. Unibody construction is typical on the group of SUVs called crossover utility vehicles (CUVs), such as the Toyota RAV4, Honda CR-V, and the Chrysler Pacifica. Table 10 analyzes fatality rates separately for the two types of SUVs.

Table 10: Separate Analyses of Frame-Rail and Unibody SUVs

SUV FRAME-RAIL

	FATALITIES	REGISTRATIONS	RATE	
PRE	569	13,608,592	41.81	
POST	495	14,449,118	34.26	
Z	**3.25**		**18.1%**	**EFFECTIVENESS**

SUV UNIBODY

	FATALITIES	REGISTRATIONS	RATE	
PRE	58	2,982,610	19.45	
POST	30	2,379,324	12.61	
Z	1.94		35.2%	EFFECTIVENESS

The vast majority of the SUVs included in this report are of frame-rail design, as evidenced by the counts of registration years in Table 10. The SUVs with the frame-rail produced a positive effectiveness that tested significant and was even higher than the overall effect for SUVs (Table 3). The far less numerous group of unibody SUV/CUVs also produced a positive effectiveness, but it was not statistically significant. So in other words, the high overall effectiveness in SUVs is not coming primarily from the unibody models, but primarily from the frame-rail models that most closely resemble pickup trucks. The discrepancy in the results between pickup trucks and SUVs remains unexplained.

4. Discussion

In conclusion, the analysis of fatality rates yielded a statistically significant positive effectiveness for PEAS and SEAS in crashes between light trucks and cars as a whole. But the results of this analysis are inconsistent for pickup trucks and SUVs and are also not fully corroborated by the non-parametric analysis. The somewhat more positive results from the tables observing exclusively front-to-side impacts are encouraging because it is the type of crash where higher effectiveness would be expected, but even here, the result for pickup trucks is not positive, let alone significant. The analysis on the body frames of SUV/CUVs still leaves open the question regarding the wide difference between the percent effectiveness of the SUVs and the pickups. Overall, the results fall short of permitting an unequivocal conclusion that the technologies introduced upon LTV certification have reduced fatality risk to car occupants.

Nevertheless, these results can be reconciled with the study recently released by IIHS. That study is strong evidence that fatality risk to car occupants in impacts by late-model light trucks has declined in absolute terms over the past decade, and, in particular, that pickup trucks and SUVs have become less aggressive over time, relative to cars. However, that study did not analytically isolate or quantify specific factors accounting for the decline. It may be due to a combination of compatibility improvements in the light trucks; crashworthiness improvements in the cars; crash avoidance technologies; and changes in vehicle mix, vehicle use, driving patterns, or the overall decline in fatality risk for all vehicles. Furthermore, the compatibility improvements in the light trucks are not limited to those involved in certifying to the voluntary standard, but could include any prior or subsequent modifications. By contrast, our results try to address exclusively the fatality reduction due to compatibility improvements close to the time of self-certification, and it is this limited effect that falls short of being unequivocally significant.

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