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Mazda collision avoidance features: initial results

Three collision avoidance features offered by Mazda appear to be reducing some insurance losses, but the reductions are not completely in line with expectations. The Adaptive Front Lighting System is associated with a large reduction in claims for damage to other vehicles even though most crashes at night are single-vehicle. Blind Spot Monitoring appears to reduce the frequency of all types of injury claims and claims for damage to other vehicles, which was more expected. For backup cameras, the only significant effect on claim frequency was a paradoxical increase in collision claims. There was also a decrease in high-severity claims for bodily injury, suggesting a reduction in collisions with nonoccupants.

Introduction

Collision avoidance technologies are becoming popular in U.S. motor vehicles, and more and more automakers are touting the potential safety benefits. However, the actual benefits in terms of crash reductions still are being measured. This Highway Loss Data Institute bulletin examines the early insurance claims experience for Mazda vehicles equipped with three features:

Adaptive Front Lighting System is Mazda's term for headlamps that respond to driver steering. The system uses sensors to measure vehicle speed and steering angle while small electric motors turn the headlights accordingly to facilitate vision around a curve at night. It is functional after the headlights have been turned on, at vehicle speeds above 2 mph. The adaptive lighting can be deactivated by the driver. At the next ignition cycle, it will be in the previous on/off setting.

Blind Spot Monitoring is Mazda's term for a side view assist system that alerts drivers to vehicles that are adjacent to them. The system uses radar sensors mounted inside the rear bumper to scan a range behind the vehicle. If a vehicle has been detected in the blind spot, a warning light on the appropriate side mirror is illuminated, and an additional auditory warning is given if a turn signal is activated. The system is functional at speeds over 20 mph and can be deactivated by the driver, but will reactivate at the next ignition cycle. Additionally, the driver can eliminate the audio warning but leave the visual alert.

A back-up camera is mounted in the rear deck lid above the license plate and shows the area behind the vehicle on the navigation screen. The images are overlaid with guidelines for assistance only on the 2010 CX-9. The camera is active when the transmission is in reverse.

Method

Vehicles

Adaptive Front Lighting, Blind Spot Monitoring and back-up cameras are offered as optional equipment on various Mazda models. The presence or absence of these features is not discernible from the information encoded in the vehicle identification numbers (VINs), but rather, this must be determined from build information maintained by the manufacturer. Mazda supplied HLDI with the VINs for any vehicles that were equipped with at least one of the collision avoidance features listed above. Vehicles of the same model year and series not identified by Mazda were assumed not to have these features, and thus served as the control vehicles in the analysis. Electronic stability control was standard on most vehicles but optional on one trim level of the Mazda 3, so this trim level was excluded from the analysis. No additional features are available on these vehicles. Two high-performance vehicles, the Mazda Speed3 and Speed6, also were excluded. Table 1 lists the vehicle series and model years included in the analysis. In addition, exposure for each vehicle, measured in insured vehicle years is listed. The exposure of each feature in a given series is shown as a percentage of total exposure.

Table 1 : Feature exposure by vehicle series

Make	Series	Model year range	Adaptive Front Lighting System	Blind Spot Monitoring	Back-up camera	Total exposure
Mazda	3 4dr	2010	39%			29,492
Mazda	3 station wagon	2010	28%			34,145
Mazda	6 4dr	2009-10		45%		96,199
Mazda	CX-7 4dr	2010		5%	38%	30,505
Mazda	CX-7 4dr 2WD/4WD	2007-09			20%	264,845
Mazda	CX-7 4dr 4WD	2010		38%	65%	5,571
Mazda	CX-9 4dr	2007-10		33%	38%	91,322
Mazda	CX-9 4dr 4WD	2008-10		55%	25%	69,515

Insurance data

Automobile insurance covers damages to vehicles and property as well as injuries to people involved in crashes. Different insurance coverages pay for vehicle damage versus injuries, and different coverages may apply depending on who is at fault. The current study is based on property damage liability, collision, bodily injury liability, personal injury protection and medical payment coverages. Exposure is measured in insured vehicle years. An insured vehicle year is one vehicle insured for one year, two for six months, etc.

Because different crash avoidance features may affect different types of insurance coverage, it is important to understand how coverages vary among the states and how this affects inclusion in the analyses. Collision coverage insures against vehicle damage to an at-fault driver's vehicle sustained in a crash with an object or other vehicle; this coverage is common to all 50 states. Property damage liability (PDL) coverage insures against vehicle damage that at-fault drivers cause to other people's vehicle and property in crashes; this coverage exists in all states except Michigan, where vehicle damage is covered on a no-fault basis (each insured vehicle pays for its own damage in a crash, regardless of who's at fault). Coverage of injuries is more complex. Bodily injury (BI) liability coverage insures against medical, hospital, and other expenses for injuries that at-fault drivers inflict on occupants of other vehicles or others on the road; although motorists in most states may have BI coverage, this information is analyzed only in states where the at-fault driver has first obligation to pay for injuries (33 states with traditional tort insurance systems). Medical payment coverage (MedPay), also sold in the 33 states with traditional tort insurance systems, covers injuries to insured drivers and the passengers in their vehicles, but not injuries to people in other vehicles involved in the crash. Seventeen other states employ no-fault injury systems (personal injury protection coverage, or PIP) that pay up to a specified amount for injuries to occupants of involved-insured vehicles, regardless of who's at fault in a collision. The District of Columbia has a hybrid insurance system for injuries and is excluded from the injury analysis.

Statistical methods

Regression analysis was used to quantify the effect of each vehicle feature while controlling for the other two features and several covariates. The covariates included calendar year, model year, garaging state, vehicle density (number of registered vehicles per square mile), rated driver age group, rated driver gender, rated driver marital status, deductible range (collision coverage only), and risk. For each safety feature supplied by the manufacturer a binary variable was included. Based on the model year and series a single variable called SERIESMY was created for inclusion in the regression model. Statistically, including such a variable in the regression model is equivalent to including the interaction of series and model year. Effectively, this variable restricted the estimation of the effect of each feature within vehicle series and model year, preventing the confounding of the collision avoidance feature effects with other vehicle design changes that could occur from model year to model year.

Claim frequency was modeled using a Poisson distribution, whereas claim severity (average loss payment per claim) was modeled using a Gamma distribution. Both models used a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models. Estimates for frequency, severity, and overall losses are presented for collision and property damage liability. For PIP, BI and MedPay three frequency estimates are presented. The first frequency is the frequency for all claims, including those that already have been paid and those for which money has been set aside for possible payment in the future, known as claims with reserves. The other two frequencies include only paid claims separated into low and high severity ranges. Note that the percentage of all injury claims that were paid by the date of analysis varies by coverage: 79.2 percent for PIP, 68.1 percent for BI, and 61.7 percent for MedPay. The low severity range was <$1,000 for PIP and MedPay, <$5,000 for BI; high severity covered all loss payments greater than that.

A separate regression was performed for each insurance loss measure for a total of 15 regressions (5 coverages x 3 loss measures each). For space reasons, only the estimates for the individual crash avoidance features are shown on the following pages. To illustrate the analyses, however, the Appendix contains full model results for collision claim frequencies. To further simplify the presentation here, the exponent of the parameter estimate was calculated, 1 was subtracted, and the resultant multiplied by 100. The resulting number corresponds to the effect of the feature on that loss measure. For example, the estimate of the effect of adaptive lighting on PDL claim frequency was -0.10692; thus, vehicles with adaptive lighting had 10.1 percent fewer PDL claims than expected ((exp(-0.10692)-1)*100=-10.1).

Results

Results for Mazda's Adaptive Front Lighting System are summarized in Table 2. The lower and upper bounds represent the 95 percent confidence limits for the estimates. For vehicle damage losses, frequency of claims are generally down as well as overall losses. The reduction in frequency of collision claims, 6.4 percent, was statistically significant. In addition, frequency, severity and overall loss reductions for property damage liability were significant.

For injury losses, overall frequency of claims (paid plus reserved) decrease for all coverages, with the decreases for medical payments and personal injury protection being significant (indicated in blue in the table). Among paid claims, reductions are seen for all coverage types at both low and high severity.

Table 2 : Change in insurance losses for Adaptive Front Lighting System

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-12%	**-6.4%**	-0.6%	-$132	$126	$403	-$33	-$9	$17
Property damage liability	-18.3%	**-10.1%**	-1.2%	-$574	**-$381**	-$170	-$33	**-$23**	-$12

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-35.3%	-12.5%	18.2%	-45.2%	-12.8%	38.7%	-54.1%	-11.1%	72.4%
Medical payments	-48.8%	**-28.9%**	-1.4%	-98.9%	**-92%**	-40.8%	-42.6%	-8%	47.5%
Personal injury protection	-43.7%	**-28.8%**	-9.9%	-48.5%	-20.6%	22.3%	-55.8%	**-37.4%**	-11.4%

Results for Mazda's Blind Spot Monitoring are summarized in **Table 3**. Again, the lower and upper bounds represent the 95 percent confidence limits for the estimates. For vehicle damage losses, frequency of claims are down for property damage liability but remain unchanged for collision coverage. Losses per insured vehicle year (overall losses) are down slightly. The frequency reduction for property damage liability was significant.

Under injury coverages, the frequency of paid plus reserved claims decreases for all coverages, and all of the decreases are significant. Among paid claims, reductions are seen for all coverage types at both low and high severity with the reductions at high severity being significant.

Table 3 : Change in insurance losses for Blind Spot Monitoring

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-3.0%	0.0%	3.2%	-$148	-$17	$118	-$14	-$1	$12
Property damage liability	-11.3%	**-7.5%**	-3.4%	-$47	$61	$174	-$11	-$5	$0

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-32.8%	**-20.9%**	-7.0%	-41.4%	-23.5%	0.0%	-46.5%	**-27.1%**	-0.5%
Medical payments	-35.6%	**-23.9%**	-10.0%	-36.3%	-4.2%	44.0%	-39.7%	**-22.6%**	-0.6%
Personal injury protection	-23.3%	**-14.5%**	-4.8%	-24.9%	-6.4%	16.6%	-27.0%	**-15.7%**	-2.6%

Results for Mazda's back-up camera are summarized in **Table 4**. The lower and upper bounds represent the 95 percent confidence limits for the estimates. For vehicle damage losses, frequency claims are down for property damage liability and up for collision coverage. The increases in frequency, severity and overall losses for collision coverage are significant.

For injury losses, overall frequency of claims (both paid and reserved) is lower for both BI and PIP, but not for Med-Pay, and none of the differences is statistically significant. Among paid claims, those of higher severity tend to show reductions in frequency, but only the reduction for BI is statistically significant.

Table 4 : Change in insurance losses for back up camera

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	0.5%	**3.1%**	5.8%	$12	**$125**	$241	$7	**$18**	$30
Property damage liability	-5.8%	-2.3%	1.3%	-$56	$34	$126	-$6	-$1	$4

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-14.6%	-3.1%	9.8%	-17.4%	1.3%	24.1%	-38.3%	**-22.2%**	-1.8%
Medical payments	-12.1%	0.6%	15.1%	-13.0%	24.3%	77.4%	-24.2%	-7.6%	12.6%
Personal injury protection	-10.1%	-2.1%	6.7%	-17.9%	-1.2%	18.8%	-9.2%	1.6%	13.6%

Discussion

The results for these three Mazda collision avoidance features — Adaptive Front Lighting System, Blind Spot Monitoring System, and backup cameras — are mixed. Analyses of steering responsive headlamps indicate a strong benefit in claims reductions but the pattern is not consistent with expectations. For example, the prevalence of single-vehicle crashes at night suggests that adaptive lighting would have a greater effect on collision coverage than PDL. However, to the extent that adaptive lighting is effective, it appears to reduce PDL claims more than collision claims. Making the pattern even more perplexing is the fact that the reduction in all PDL crashes (10.1 percent) is slightly larger than the 7 percent of police-reported crashes that occur between 9 p.m. and 6 a.m. and involve more than one vehicle. This raises questions about the exact source of the estimated benefits: does adaptive lighting work because the lamps are steerable or is there something else about cars with adaptive lighting that have not been adequately accounted for in the current analyses? One noteworthy difference is that the adaptive lighting lamps are high intensity discharge (HID) while the vehicles without the feature have halogen lights. A difference in the nature of the illumination provided by these two different light sources may help explain the advantage of Mazda's adaptive lighting. A small study conducted by the Insurance Institute for Highway Safety with Consumers Union compared the standard (halogen) lights with the HID adaptive lighting lamps on the Mazda 3. In that comparison, the low beams of HID lights threw light farther down the test area than the base halogen low beams — 400 vs. 350 ft. The adaptive lighting beam pattern was also wider and perceived as brighter by the testers. However, the base high beams illuminated farther down the test area than the adaptive lighting high beam — 600 vs. 500 feet. These differences were not consistent among other pairs of cars included in the tests.

The results for Blind Spot Monitoring are patterned more as expected. Incursion into occupied adjacent lanes would be expected to result in two-vehicle crashes that lead to PDL claims against the encroaching driver. The estimated reduction in PDL claims is statistically significant and much larger than that estimated for collision claims. That is consistent with the fact that any reduction in collision claims from such crashes would be diluted by the many single vehicle crashes that result in collision claims and are unaffected by blind spot information. Given that blind spot monitoring is intended to assist with lane changes which typically occur on multi-lane roads, many of which are higher speed roads, it is expected that the system would help to prevent higher speed crashes and the injuries involved. All of the injury coverages have statistically significant reductions in claim frequency, with larger reductions occurring for the more severe claims.

Back-up cameras would be expected to reduce impacts with other vehicles, objects, and some nonoccupants when operating the vehicle in reverse. This would be expected to yield reductions in collision and PDL losses and, perhaps, in BI losses. Contrary to expectation, collision claims increased significantly for the vehicles with backup cameras; although PDL claims did decrease, the change was small and not statistically significant. There was a reduction in BI claims as well, which was statistically significant for paid claims of high severity. This suggests that the cameras may be reducing some nonoccupant crashes. At a 22 percent reduction, this result was unexpected as BI-only claims (nonoccupants) make up a very small proportion of all BI claims.

This early analysis indicates that Mazda's adaptive headlights and side view blind spot assistance are reducing some insurance losses, although there remains some uncertainty about how the adaptive lamps are achieving the effect. Conclusions about the backup cameras must wait for additional data, both from additional experience with Mazdas and also from other vehicle makes equipped with similar technology.

Limitations

There are limitations to the data used in this analysis. At the time of a crash, the status of a feature is not known. The features in this study can be deactivated by the driver and there is no way to know how many, if any of the drivers in these vehicles had manually turned off the system prior to the crash. If a significant number of drivers do turn these features off, any reported reductions may actually be underestimates of the true effectiveness of these systems.

Additionally, the data supplied to HLDI does not include detailed crash information. Information including point of impact is not available. The technologies in this report target certain crash types. For example, the backup camera is designed to prevent collisions when a vehicle is backing up. Transmission status is not known – therefore, all collisions, regardless of the ability of a feature to mitigate or prevent the crash, are included in the analysis.

All of these features are optional and are associated with increased costs. In particular, the adaptive headlights could add as much as 13 percent to the price of Mazda 3 cars without them. The type of person who is willing to pay such a large additional cost for an otherwise inexpensive car may be different from the person who is not. While the analysis controls for several driver characteristics, there may be other uncontrolled attributes associated with people who select these features.

Appendix : Illustrative regression results — collision frequency

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Intercept		1	-8.6154		0.1047	-8.8205	-8.4102	6774.08	<0.0001
Calendar year	2006	1	0.0255	2.6%	0.0648	-0.1015	0.1524	0.15	0.6939
	2007	1	0.1223	13.0%	0.0225	0.0782	0.1663	29.54	<0.0001
	2008	1	0.0535	5.5%	0.0165	0.0212	0.0859	10.51	0.0012
	2009	1	0.0105	1.1%	0.0133	-0.0156	0.0366	0.62	0.4304
	2011	1	-0.0265	-2.6%	0.0124	-0.0509	-0.0022	4.57	0.0325
	2010	0	0	0	0	0	0		
Vehicle model year and series	2010 3 4dr	1	0.0289	2.9%	0.0394	-0.0483	0.1060	0.54	0.4633
	2010 3 station wagon	1	-0.1006	-9.6%	0.0386	-0.1763	-0.0249	6.79	0.0092
	2009 6 4dr	1	-0.0954	-9.1%	0.0349	-0.1638	-0.0271	7.50	0.0062
	2010 6 4dr	1	-0.0902	-8.6%	0.0370	-0.1628	-0.0177	5.94	0.0148
	2010 CX-7 4dr	1	-0.0413	-4.0%	0.0373	-0.1145	0.0319	1.22	0.2687
	2007 CX-7 4dr 2WD/4WD	1	-0.0364	-3.6%	0.0332	-0.1014	0.0286	1.21	0.2722
	2008 CX-7 4dr 2WD/4WD	1	-0.0217	-2.1%	0.0341	-0.0887	0.0452	0.41	0.5241
	2009 CX-7 4dr 2WD/4WD	1	0.0281	2.8%	0.0395	-0.0494	0.1056	0.51	0.4768
	2010 CX-7 4dr 4WD	1	0.0530	5.4%	0.0541	-0.0530	0.1590	0.96	0.3268
	2007 CX-9 4dr	1	-0.1070	-10.1%	0.0401	-0.1855	-0.0285	7.13	0.0076
	2008 CX-9 4dr	1	-0.1201	-11.3%	0.0368	-0.1922	-0.0480	10.67	0.0011
	2009 CX-9 4dr	1	-0.1570	-14.5%	0.0515	-0.2579	-0.0562	9.31	0.0023
	2010 CX-9 4dr	1	-0.0868	-8.3%	0.0459	-0.1769	0.0032	3.57	0.0587
	2008 CX-9 4dr	1	-0.0329	-3.2%	0.0356	-0.1026	0.0368	0.86	0.3546
	2009 CX-9 4dr	1	-0.0522	-5.1%	0.0456	-0.1416	0.0372	1.31	0.2520
	2010 CX-9 4dr	0	0	0	0	0	0		
Rated driver age group	14-20	1	0.3093	36.2%	0.0303	0.2500	0.3686	104.42	<0.0001
	21-24	1	0.2465	28.0%	0.0218	0.2038	0.2892	128.22	<0.0001
	25-39	1	0.0703	7.3%	0.0107	0.0493	0.0912	43.18	<0.0001

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Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	65+	1	0.0816	8.5%	0.0213	0.0399	0.1233	14.71	0.0001
	Unknown	1	0.0960	10.1%	0.0268	0.0434	0.1486	12.80	0.0003
	40-64	0	0	0	0	0	0		
Rated driver gender	Male	1	-0.0613	-5.9%	0.0115	-0.0838	-0.0387	28.40	<0.0001
	Unknown	1	-0.2003	-18.2%	0.0301	-0.2593	-0.1412	44.20	<0.0001
	Female	0	0	0	0	0	0		
Rated driver marital status	Single	1	0.2177	24.3%	0.0126	0.1929	0.2425	296.28	<0.0001
	Unknown	1	0.2337	26.3%	0.0297	0.1755	0.2920	61.80	<0.0001
	Married	0	0	0	0	0	0		
Risk	Nonstandard	1	0.1248	13.3%	0.0143	0.0969	0.1527	76.61	<0.0001
	Standard	0	0	0	0	0	0		
State	Alabama	1	-0.2114	-19.1%	0.1079	-0.4229	0.0002	3.83	0.0502
	Arizona	1	-0.3411	-28.9%	0.1053	-0.5474	-0.1347	10.49	0.0012
	Arkansas	1	-0.2209	-19.8%	0.1181	-0.4523	0.0105	3.50	0.0614
	California	1	-0.1205	-11.4%	0.0998	-0.3162	0.0751	1.46	0.2272
	Colorado	1	-0.2294	-20.5%	0.1043	-0.4339	-0.0250	4.84	0.0278
	Connecticut	1	-0.2283	-20.4%	0.1055	-0.4350	-0.0216	4.69	0.0304
	Delaware	1	-0.2260	-20.2%	0.1175	-0.4563	0.0042	3.70	0.0543
	District of Columbia	1	0.3115	36.5%	0.1304	0.0559	0.5671	5.71	0.0169
	Florida	1	-0.4675	-37.3%	0.0997	-0.6630	-0.2721	21.98	<0.0001
	Georgia	1	-0.3785	-31.5%	0.1036	-0.5815	-0.1755	13.35	0.0003
	Idaho	1	-0.4568	-36.7%	0.1509	-0.7527	-0.1610	9.16	0.0025
	Illinois	1	-0.1932	-17.6%	0.1010	-0.3911	0.0047	3.66	0.0557
	Indiana	1	-0.2002	-18.1%	0.1075	-0.4108	0.0105	3.47	0.0626
	Iowa	1	-0.2055	-18.6%	0.1193	-0.4392	0.0283	2.97	0.0849
	Kansas	1	-0.2895	-25.1%	0.1108	-0.5067	-0.0722	6.82	0.0090
	Kentucky	1	-0.3424	-29.0%	0.1092	-0.5563	-0.1284	9.83	0.0017
	Louisiana	1	-0.1002	-9.5%	0.1035	-0.3031	0.1028	0.94	0.3333
	Maine	1	-0.0156	-1.5%	0.1467	-0.3032	0.2720	0.01	0.9154
	Maryland	1	-0.1822	-16.7%	0.1024	-0.3829	0.0185	3.17	0.0752
	Massachusetts	1	-0.0440	-4.3%	0.1055	-0.2508	0.1628	0.17	0.6768
	Michigan	1	0.1219	13.0%	0.1025	-0.0790	0.3228	1.41	0.2342
	Minnesota	1	-0.2407	-21.4%	0.1043	-0.4452	-0.0362	5.32	0.0211
	Mississippi	1	-0.0858	-8.2%	0.1236	-0.3280	0.1565	0.48	0.4878
	Missouri	1	-0.3286	-28.0%	0.1058	-0.5359	-0.1214	9.66	0.0019
	Montana	1	-0.3406	-28.9%	0.1979	-0.7285	0.0473	2.96	0.0852
	Nebraska	1	-0.3528	-29.7%	0.1155	-0.5792	-0.1264	9.33	0.0023
	Nevada	1	-0.3839	-31.9%	0.1150	-0.6094	-0.1584	11.14	0.0008
	New Hampshire	1	-0.1484	-13.8%	0.1232	-0.3898	0.0930	1.45	0.2282
	New Jersey	1	-0.2244	-20.1%	0.1007	-0.4217	-0.0270	4.97	0.0259
	New Mexico	1	-0.4422	-35.7%	0.1276	-0.6922	-0.1922	12.02	0.0005
	New York	1	-0.0571	-5.6%	0.0997	-0.2526	0.1384	0.33	0.5672
	North Carolina	1	-0.4705	-37.5%	0.1033	-0.6729	-0.2681	20.77	<0.0001

Appendix : Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	North Dakota	1	0.1475	15.9%	0.1617	-0.1694	0.4645	0.83	0.3616
	Ohio	1	-0.3775	-31.4%	0.1016	-0.5767	-0.1784	13.80	0.0002
	Oklahoma	1	-0.3960	-32.7%	0.1124	-0.6164	-0.1757	12.41	0.0004
	Oregon	1	-0.3606	-30.3%	0.1093	-0.5749	-0.1463	10.88	0.0010
	Pennsylvania	1	-0.0930	-8.9%	0.1002	-0.2895	0.1035	0.86	0.3536
	Rhode Island	1	-0.1051	-10.0%	0.1182	-0.3368	0.1267	0.79	0.3743
	South Carolina	1	-0.3586	-30.1%	0.1114	-0.5770	-0.1402	10.36	0.0013
	South Dakota	1	-0.0088	-0.9%	0.1606	-0.3236	0.3060	0.00	0.9562
	Tennessee	1	-0.2749	-24.0%	0.1057	-0.4821	-0.0678	6.77	0.0093
	Texas	1	-0.2990	-25.8%	0.0995	-0.4940	-0.1041	9.04	0.0026
	Utah	1	-0.4414	-35.7%	0.1119	-0.6607	-0.2221	15.57	<0.0001
	Vermont	1	-0.0636	-6.2%	0.1759	-0.4083	0.2811	0.13	0.7176
	Virginia	1	-0.1739	-16.0%	0.1014	-0.3727	0.0249	2.94	0.0865
	Washington	1	-0.2808	-24.5%	0.1035	-0.4836	-0.0780	7.36	0.0067
	West Virginia	1	-0.36090	-30.3%	0.1365	-0.6285	-0.0933	6.99	0.0082
	Wisconsin	1	-0.26700	-23.4%	0.1081	-0.4789	-0.0551	6.10	0.0135
	Wyoming	1	-0.06490	-6.3%	0.1899	-0.4372	0.3073	0.12	0.7324
	Hawaii	1	-0.0194	-1.9%	0.1127	-0.2403	0.2015	0.03	0.8632
	Alaska	0	0	0	0	0	0		
Deductible range	0-250	1	0.5311	70.1%	0.0184	0.4950	0.5672	831.81	<0.0001
	251-500	1	0.3167	37.3%	0.0161	0.2851	0.3484	385.00	<0.0001
	1001+	1	-0.2287	-20.4%	0.0997	-0.4242	-0.0332	5.26	0.0218
	501-1000	0	0	0	0	0	0		
Registered vehicle density	0-99	1	-0.1846	-16.9%	0.0170	-0.2180	-0.1513	117.85	<0.0001
	100-499	1	-0.1388	-13%	0.0113	-0.1608	-0.1167	152.08	<0.0001
	500+	0	0	0	0	0	0		
Active Front Lighting System		1	-0.0665	-6.4%	0.0311	-0.1274	-0.0055	4.57	0.0326
Blind Spot Monitoring		1	0.0004	0%	0.0158	-0.0306	0.0313	0	0.9822
Back-up camera		1	0.0305	3.1%	0.0133	0.0045	0.0565	5.29	0.0215

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The Highway Loss Data Institute is a nonprofit public service organization that gathers, processes, and publishes insurance data on the human and economic losses associated with owning and operating motor vehicles.

HIGHWAY LOSS DATA INSTITUTE

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Acura collision avoidance features: initial results

This analysis examines three Acura collision avoidance features — Collision Mitigation Braking System, Active Front Lighting System, and Blind Spot Information. Vehicles with Collision Mitigation Braking show significant reductions in property damage liability claims, as would be expected from a forward collision warning system. Results for the other two features are not significant, nor are they patterned as expected. Additional data is needed before conclusions can be drawn.

Introduction

Collision avoidance technologies are becoming popular in U.S. motor vehicles, and more and more automakers are touting the potential safety benefits. However, the actual benefits in terms of crash reductions still are being measured. This Highway Loss Data Institute bulletin examines the early insurance claims experience for Acura vehicles fitted with three features:

Collision Mitigation Braking System is Acura's term for a forward collision warning system that includes some autonomous emergency braking. The system is an enhancement of Acura's Adaptive Cruise Control system, which uses a radar sensor behind the front grille to maintain a particular speed and distance interval from traffic ahead, both of which are set by the driver. With collision mitigation, the system will also provide visual and auditory warnings when speed and distance indicates risk of a crash with the leading traffic and, if the driver does not respond by reducing speed, the system will tug at the seat belt to get the driver's attention and begin braking to mitigate — but probably not prevent — the crash. Collision mitigation becomes functional at speeds over 10 mph and deactivates when speed drops below 10 mph. The system operates whether or not Adaptive Cruise Control is activated. Collision mitigation can be deactivated by the driver but will reactivate at the next ignition cycle. Adaptive Cruise Control is always present on vehicles with Collision Mitigation Braking, and therefore the analysis cannot separate out the individual effects of these features. Adaptive Cruise Control is available at speeds over 25 mph and must be activated by the driver during each ignition cycle. Adaptive Cruise Control cannot bring the vehicle to a complete stop. Once activated, it continues until the driver deactivates it or until vehicle speed falls below 25 mph.

Active Front Lighting System is Acura's term for headlamps that respond to driver steering input. It uses sensors to measure vehicle speed, steering angle and vehicle yaw while small electric motors turn the headlights accordingly, up to 20 degrees, to facilitate vision around a curve at night. At a stop, the right headlight turns right when you turn the steering wheel to the right. However, the left headlight does not turn left when you turn the steering wheel to the left to prevent the light from pointing at oncoming traffic. Once the headlights are turned on by the driver, Active Front Lighting goes on after the vehicle has been driven a short distance. The system can be deactivated by the driver but will reactivate the next time the headlights are turned on.

Blind Spot Information is Acura's term for a side view assist system that alerts drivers to vehicles that are adjacent to them. There are two radar sensors, one in each corner of the rear bumper to scan a range behind and to the side of the vehicle, areas commonly known as driver blind spots. If a vehicle is detected in a blind spot, a warning light on the appropriate A-pillar is illuminated. If the driver activates a turn signal in the direction a vehicle has been detected, the warning light will flash. The system is functional at speeds over 6 mph and can be deactivated by the driver. At the next ignition cycle Blind Spot Information will be in the previous on/off setting.

Method

Vehicles

Collision Mitigation Braking (with Adaptive Cruise Control), Active Front Lighting, and Blind Spot Information are offered as optional equipment on various Acura models. The presence or absence of some of these features is not always discernible from the information encoded in the vehicle identification numbers (VINs), but rather, this must be determined from build information maintained by the manufacturer. Acura supplied HLDI with the VINs for any vehicles that were equipped with at least one of the collision avoidance features listed above. Vehicles of the same model year and series identified by Acura as not having these features served as the control vehicles in the analysis. It should be noted that some of these vehicles may have been equipped also with Rear Parking Sensors or Rear View Camera (MDX and RL), but no VIN-level information was supplied about rear sensors or cameras. Therefore, it must assumed that these features — which can affect some insurance losses — were equally distributed among the controls and the study vehicles. Certain features are always bundled together on a vehicle and cannot be standalone features. The MDX and ZDX vehicles that have collision mitigation also have Blind Spot Information. **Table 1** lists the vehicle series and model years included in the analysis and the exposure for each vehicle, measured in insured vehicle years. The exposure of each feature in a given series is shown as a percentage of total exposure.

Table 1 : Feature exposure by vehicle series

Make	Series	Model year range	Active Front Lighting System	Collision Mitigation Braking System (includes Adaptive Cruise Control)	Blind Spot Information	Total exposure
Acura	MDX 4dr 4WD	2010-11		12%	12%	42,123
Acura	RL 4dr 4WD	2005-11	97%	4%		174,044
Acura	ZDX 4dr 4WD	2010-11		28%	28%	2,034

Insurance data

Automobile insurance covers damages to vehicles and property as well as injuries to people involved in crashes. Different insurance coverages pay for vehicle damage versus injuries, and different coverages may apply depending on who is at fault. The current study is based on property damage liability, collision, bodily injury liability, personal injury protection and medical payment coverages. Exposure is measured in insured vehicle years. An insured vehicle year is one vehicle insured for one year, two for six months, etc.

Because different crash avoidance features may affect different types of insurance coverage, it can be important to understand how coverages vary among the states and how this affects inclusion in the analyses. Collision coverage insures against vehicle damage to an at-fault driver's vehicle sustained in a crash with an object or other vehicle; this coverage is common to all 50 states. Property damage liability (PDL) coverage insures against vehicle damage that at-fault drivers cause to other people's vehicle and property in crashes; this coverage exists in all states except Michigan, where vehicle damage is covered on a no-fault basis (each insured vehicle pays for its own damage in a crash, regardless of who's at fault). Coverage of injuries is more complex. Bodily injury (BI) liability coverage insures against medical, hospital, and other expenses for injuries that at-fault drivers inflict on occupants of other vehicles or others on the road; although motorists in most states may have BI coverage, this information is analyzed only in states where the at-fault driver has first obligation to pay for injuries (33 states with traditional tort insurance systems). Medical payment coverage (MedPay), also sold in the 33 states with traditional tort insurance systems, covers injuries to insured drivers and the passengers in their vehicles, but not injuries to people in other vehicles involved in the crash. Seventeen other states employ no-fault injury systems (personal injury protection coverage, or PIP) that pay up to a specified amount for injuries to occupants of involved-insured vehicles, regardless of who's at fault in a collision. The District of Columbia has a hybrid insurance system for injuries and is excluded from the injury analysis.

Statistical methods

Regression analysis was used to quantify the effect of vehicle feature while controlling for other covariates. The covariates included calendar year, model year, garaging state, vehicle density (number of registered vehicles per square mile), rated driver age group, rated driver gender, rated driver marital status, deductible range (collision coverage only), and risk. For each safety feature supplied by the manufacturer a binary variable was included. Based on the model year and series a single variable called SERIESMY was created for inclusion in the regression model. Statistically, including such a variable in the regression model is equivalent to including the interaction of series and model year. Effectively, this variable restricted the estimation of the effect of each feature within vehicle series and model year, preventing the confounding of the collision avoidance feature effects with other vehicle design changes that could occur from model year to model year.

Claim frequency was modeled using a Poisson distribution, whereas claim severity (average loss payment per claim) was modeled using a Gamma distribution. Both models used a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models. Estimates for frequency, severity, and overall losses are presented for collision and property damage liability. For PIP, BI and MedPay three frequency estimates are presented. The first frequency is the frequency for all claims, including those that already have been paid and those for which money has been set aside for possible payment in the future, known as claims with reserves. The other two frequencies include only paid claims separated into low and high severity ranges. Note that the percentage of all injury claims that were paid by the date of analysis varies by coverage: 78.9 percent for PIP, 67.8 percent for BI, and 61.6 percent for MedPay. The low severity range was <$1,000 for PIP and MedPay, <$5,000 for BI; high severity covered all loss payments greater than that.

A separate regression was performed for each insurance loss measure for a total of 15 regressions (5 coverages x 3 loss measures each). For space reasons, only the estimates for the individual crash avoidance features are shown on the following pages. To illustrate the analyses, however, the Appendix contains full model results for collision claim frequencies. To further simplify the presentation here, the exponent of the parameter estimate was calculated, 1 was subtracted, and the resultant multiplied by 100. The resulting number corresponds to the effect of the feature on that loss measure. For example, the estimate of the effect of Collision Mitigation Braking System on PDL claim frequency was -0.15293; thus, vehicles with the feature had 14.2 percent fewer PDL claims than expected ((exp(-0.15293)-1)*100=-14.2).

Results

Results for Acura's Collision Mitigation Braking System are summarized in **Table 2**. The lower and upper bounds represent the 95 percent confidence limits for the estimates. For vehicle damage losses, frequency of claims are generally down while the average cost of the remaining claims is slightly higher and overall losses are slightly lower. Only the reduction in frequency of property damage liability claims, 14.2 percent, is statistically significant (indicated in blue in the table).

For injury losses, overall frequency of claims (paid plus reserved) decrease for all coverages, but none of the decreases is significant, and the confidence bounds are quite wide. Among paid claims, those of higher severity tend to show larger reductions in frequency, but still the reductions are not statistically significant, and the confidence bounds are even larger due to the reduced sample size.

Table 2 : Change in insurance losses for Collision Mitigation Braking System (includes Adaptive Cruise Control)									
Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower Bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-11.2%	-3.1%	5.7%	-$452	$31	$567	-$52	-$9	$41
Property damage liability	-25.9%	**-14.2%**	-0.6%	-$323	$69	$523	-$24	-$10	$7
Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower Bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-46.5%	-15.0%	35.0%	-45.5%	9.8%	121.1%	-78.8%	-41.3%	62.5%
Medical payments	-40.8%	-3%	58.8%	-12.9%	119.5%	453.4%	-67.7%	-25%	74%
Personal injury protection	-40.1%	-16.5%	16.4%	-74.3%	-36%	59.4%	-42.7%	-13.1%	31.8%

Results for Acura's Active Front Lighting System are summarized in **Table 3**. Again, the lower and upper bounds represent the 95 percent confidence limits for the estimates. Reductions in loss claims are estimated for both first- and third-party vehicle damage coverages, resulting in somewhat lower losses per insured vehicle year (overall losses). However, none of the estimated effects for active lighting on collision or PDL losses is statistically significant.

Under injury coverages, the frequency of claims is lower for both MedPay and PIP, but not for BI, and none of the differences is statistically significant. Among paid claims, there appears to be a reduction in high severity injury claims under all coverages, though still not statistically significant and the confidence bounds are quite large. No pattern is observed for low severity claims and the confidence bounds are even larger.

Table 3 : Change in insurance losses for Active Front Lighting System									
Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower Bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-11.9%	-2%	9%	-$466	$12	$556	-$40	-$4	$38
Property damage liability	-20.3%	-6.3%	10.3%	-$418	-$9	$473	-$20	-$5	$14
Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower Bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-38.2%	8.7%	91%	-51.9%	39.4%	304.1%	-68%	-23.6%	82.7%
Medical payments	-59.7%	-28.2%	27.8%	-92.1%	-25.9%	597.1%	-65.5%	-24.9%	63.3%
Personal injury protection	-38.6%	-7.9%	38.1%	-43.9%	88.7%	535.2%	-50.1%	-16.7%	39.3%

Results for Acura's Blind Spot Information system are summarized in **Table 4**. The lower and upper bounds represent the 95 percent confidence limits for the estimates. Both vehicle damage loss frequencies are lower with the blind spot information feature, with larger reductions for PDL than collision; however, neither reduction is statistically significant and, in the case of collision, the small reduction in frequency is more than offset by an increase in average cost of the remaining claims. The $19 reduction in loss payments per insured vehicle year for PDL coverage is encouraging but still not statistically significant.

Under injury coverages, the pattern is unclear, and the confidence bounds for all estimated effects are quite large. The central finding is that the data are insufficient.

Table 4 : Change in insurance losses for Blind Spot Information									
Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower Bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-18.5%	-5.4%	9.7%	-$523	$315	$1,315	-$70	$3	$94
Property damage liability	-34%	-16.2%	6.3%	-$739	-$187	$512	-$38	-$19	$8

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower Bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-47%	24.1%	190.6%	-37.9%	116%	651.6%	-43.5%	197.3%	1463.9%
Medical payments	-60%	-5%	125.7%	-89.6%	-37.8%	272.4%	-60.7%	41.8%	411.3%
Personal injury protection	-21.5%	43.1%	161%	-81.8%	-0.2%	446.5%	-26.8%	58.5%	243.3%

Discussion

The results for these three Acura collision avoidance features — Collision Mitigation Braking System (with Adaptive Cruise Control), Blind Spot Information, and Active Front Lighting System — are encouraging. Collision mitigation, in particular, shows reductions in claim frequencies across all coverages. Additionally, the pattern of findings for vehicle damage coverages is consistent with the expected benefits; that is, the reduction in claims is greater for PDL coverage than for collision coverage. Collision Mitigation Braking is operative in following traffic and intended to reduce the occurrence and/or severity of front-to-rear collisions, and those types of crashes are more common among PDL claims than among collision claims, which include many single vehicle crashes. Adaptive Cruise Control, which is always bundled with Collision Mitigation Braking, if used, could reduce the likelihood that drivers get into situations that lead to a crash.

Analyses of Active Front Lighting indicate a benefit in claims reductions, but the effects are not significant, and the pattern is not consistent with expectations. For example, the prevalence of single-vehicle crashes at night suggests that active lighting would have a greater effect on collision coverage than PDL. However, to the extent that this feature is effective, it appears to reduce PDL claims more than collision claims. Making the pattern even more perplexing is the fact just 7 percent of police-reported crashes occur between 9 p.m. and 6 a.m. and involve more than one vehicle. Given the reduction in PDL claim frequency (6.3 percent), this would mean that over 70 percent of night time PDL claims were prevented. This raises questions about the exact source of the estimated benefits: Does active lighting work because the lamps are steerable or is there something else about cars with active lighting that has not been adequately accounted for in the current analyses?

Although not statistically significant, results for Blind Spot Information are patterned as expected. Incursion into occupied adjacent lanes would be expected to result in two-vehicle crashes that lead to PDL claims against the encroaching driver. Again, although neither estimate is statistically significant, the estimated reduction in PDL claims is much larger than that estimated for collision claims. This is consistent with the fact that the reduction in collision claims from such crashes would be diluted by the many single-vehicle crashes that result in collision claims and are unaffected by blind spot information.

Taken alone, these data leave much uncertainty about the real-world effectiveness of Acura's collision-avoidance features. The benefits seen for Collision Mitigation Braking are consistent with those identified for Volvo City Safety (HLDI, 2011) — another system intended to prevent front-to-rear crashes — and indicate that the warning system probably is having some benefit. It's still too early to tell if the autonomous emergency braking feature is having additional benefit, as this is not expected to reduce the frequency of crashes but only the resulting severity. In that regard, the increase in average cost of the remaining vehicle damage claims is not encouraging, but the confidence bounds are quite wide. Conclusions about the other features examined — even tentative conclusions — must wait for additional data, both from additional experience with Acuras and also from other vehicle makes fitted with similar technology.

Limitations

There are limitations to the data used in this analysis. At the time of a crash, the status of a feature is not known. The features in this study can be deactivated by the driver and there is no way to know how many of the drivers in these vehicles turned off a system prior to the crash. If a significant number of drivers do turn these features off, any reported reductions may actually be underestimates of the true effectiveness of these systems.

Additionally, the data supplied to HLDI does not include detailed crash information. Information on point of impact and the vehicle's transmission status is not available. The technologies in this report target certain crash types. For example, Blind Spot Information is designed to prevent sideswipe type collisions. All collisions, regardless of the ability of a feature to mitigate or prevent the crash, are included in the analysis.

All of these features are optional and are associated with increased costs. The type of person who selects this additional cost may be different from the person declining. While the analysis controls for several driver characteristics, there may be other uncontrolled attributes associated with people who select these features that are different among people who do not.

References

Highway Loss Data Institute. 2011. Volvo City Safety loss experience — initial results. Loss bulletin Vol. 28, No. 6. Arlington, VA.

Appendix : Illustrative regression results — collision frequency

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Intercept		1	-8.3515		0.3931	-9.1220	-7.5811	451.37	<0.0001
Calendar year	2004	1	-0.4270	-34.8%	0.2364	-0.8904	0.0364	3.26	0.0709
	2005	1	0.0435	4.4%	0.0445	-0.0438	0.1308	0.95	0.3286
	2006	1	-0.0116	-1.2%	0.0335	-0.0773	0.0541	0.12	0.7286
	2007	1	0.0917	9.6%	0.0292	0.0345	0.1490	9.87	0.0017
	2008	1	0.0395	4%	0.0282	-0.0158	0.0947	1.96	0.1614
	2009	1	0.0348	3.5%	0.0272	-0.0186	0.0882	1.63	0.2015
	2011	1	0.0094	0.9%	0.0259	-0.0413	0.0601	0.13	0.7172
	2010	0	0		0	0	0		
Vehicle model year and series	2010 MDX 4dr 4WD	1	-0.6334	-46.9%	0.3175	-1.2556	-0.0112	3.98	0.0460
	2011 MDX 4dr 4WD	1	-0.7472	-52.6%	0.3187	-1.3720	-0.1225	5.50	0.0191
	2005 RL 4dr 4WD	1	-0.3810	-31.7%	0.3220	-1.0121	0.2501	1.40	0.2367
	2006 RL 4dr 4WD	1	-0.3603	-30.3%	0.3222	-0.9917	0.2712	1.25	0.2635
	2007 RL 4dr 4WD	1	-0.4246	-34.6%	0.3211	-1.0540	0.2048	1.75	0.1861
	2008 RL 4dr 4WD	1	-0.3579	-30.1%	0.3222	-0.9893	0.2735	1.23	0.2666
	2009 RL 4dr 4WD	1	-0.4388	-35.5%	0.3262	-1.0781	0.2006	1.81	0.1786
	2010 RL 4dr 4WD	1	-0.2985	-25.8%	0.3300	-0.9452	0.3483	0.82	0.3657
	2011 RL 4dr 4WD	1	-0.2076	-18.7%	0.4119	-1.0148	0.5997	0.25	0.6143
	2010 ZDX 4dr 4WD	1	-0.1332	-12.5%	0.3249	-0.7700	0.5036	0.17	0.6818
	2011 ZDX 4dr 4WD	0	0		0	0	0		

Appendix : Illustrative regression results — collision frequency

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Rated driver age group	14-20	1	-0.0135	-1.3%	0.0792	-0.1687	0.1417	0.03	0.8649
	21-24	1	0.3072	36.0%	0.0646	0.1806	0.4338	22.61	<0.0001
	25-39	1	0.1906	21.0%	0.0220	0.1474	0.2337	74.93	<0.0001
	65+	1	0.0982	10.3%	0.0230	0.0531	0.1433	18.23	<0.0001
	Unknown	1	-0.0480	-4.7%	0.0398	-0.1260	0.0301	1.45	0.2284
	40-64	0	0		0	0	0		
Rated driver gender	Male	1	-0.0071	-0.7%	0.0202	-0.0466	0.0324	0.12	0.7256
	Unknown	1	-0.1748	-16.0%	0.0439	-0.2608	-0.0887	15.85	<0.0001
	Female	0	0		0	0	0		
Rated driver marital status	Single	1	0.2463	27.9%	0.0240	0.1992	0.2934	105.19	<0.0001
	Unknown	1	0.2633	30.1%	0.0427	0.1796	0.3469	38.04	<0.0001
	Married	0	0		0	0	0		
Risk	Nonstandard	1	0.2267	25.4%	0.0282	0.1714	0.2820	64.50	<0.0001
	Standard	0	0		0	0	0		
State	Alabama	1	-0.1181	-11.1%	0.2429	-0.5942	0.3580	0.24	0.6269
	Arizona	1	-0.3956	-32.7%	0.2415	-0.8690	0.0778	2.68	0.1015
	Arkansas	1	-0.4271	-34.8%	0.2697	-0.9556	0.1014	2.51	0.1132
	California	1	-0.1291	-12.1%	0.2311	-0.5821	0.3239	0.31	0.5764
	Colorado	1	-0.1853	-16.9%	0.2370	-0.6497	0.2792	0.61	0.4343
	Connecticut	1	-0.2477	-21.9%	0.2359	-0.7101	0.2147	1.10	0.2937
	Delaware	1	-0.1446	-13.5%	0.2574	-0.6490	0.3599	0.32	0.5744
	District of Columbia	1	0.3615	43.5%	0.2510	-0.1305	0.8535	2.07	0.1498
	Florida	1	-0.4921	-38.9%	0.2319	-0.9466	-0.0376	4.50	0.0338
	Georgia	1	-0.3481	-29.4%	0.2347	-0.8081	0.1120	2.20	0.1381
	Hawaii	1	-0.1277	-12.0%	0.2640	-0.6452	0.3898	0.23	0.6286
	Idaho	1	-0.4292	-34.9%	0.3206	-1.0575	0.1992	1.79	0.1807
	Illinois	1	-0.2105	-19.0%	0.2326	-0.6664	0.2454	0.82	0.3656
	Indiana	1	-0.3830	-31.8%	0.2518	-0.8765	0.1104	2.31	0.1281
	Iowa	1	-0.3286	-28.0%	0.3103	-0.9368	0.2796	1.12	0.2896
	Kansas	1	-0.4180	-34.2%	0.2469	-0.9019	0.0659	2.87	0.0904
	Kentucky	1	-0.5863	-44.4%	0.2740	-1.1234	-0.0493	4.58	0.0324
	Louisiana	1	0.0222	2.2%	0.2447	-0.4573	0.5018	0.01	0.9276
	Maine	1	-0.3658	-30.6%	0.4049	-1.1593	0.4278	0.82	0.3663
	Maryland	1	-0.1215	-11.4%	0.2325	-0.5773	0.3342	0.27	0.6013
	Massachusetts	1	0.0366	3.7%	0.2371	-0.4281	0.5012	0.02	0.8774
	Michigan	1	0.2192	24.5%	0.2428	-0.2568	0.6952	0.81	0.3667
	Minnesota	1	-0.2572	-22.7%	0.2414	-0.7303	0.2158	1.14	0.2866
	Mississippi	1	-0.2945	-25.5%	0.2678	-0.8194	0.2305	1.21	0.2715
	Missouri	1	-0.3255	-27.8%	0.2415	-0.7987	0.1478	1.82	0.1777
	Montana	1	0.0376	3.8%	0.3470	-0.6426	0.7177	0.01	0.9138
	Nebraska	1	-0.3995	-32.9%	0.2884	-0.9646	0.1657	1.92	0.1659

Appendix : Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	Nevada	1	-0.3395	-28.8%	0.2551	-0.8394	0.1604	1.77	0.1831
	New Hampshire	1	-0.0394	-3.9%	0.2560	-0.5412	0.4625	0.02	0.8778
	New Jersey	1	-0.1780	-16.3%	0.2326	-0.6339	0.2779	0.59	0.4441
	New Mexico	1	-0.2699	-23.7%	0.2723	-0.8035	0.2638	0.98	0.3216
	New York	1	-0.0509	-5.0%	0.2315	-0.5047	0.4028	0.05	0.8259
	North Carolina	1	-0.5858	-44.3%	0.2369	-1.0501	-0.1215	6.12	0.0134
	North Dakota	1	-0.1745	-16.0%	0.5511	-1.2548	0.9057	0.10	0.7515
	Ohio	1	-0.3258	-27.8%	0.2361	-0.7885	0.1370	1.90	0.1677
	Oklahoma	1	-0.1432	-13.3%	0.2515	-0.6361	0.3498	0.32	0.5692
	Oregon	1	-0.2525	-22.3%	0.2423	-0.7274	0.2225	1.09	0.2975
	Pennsylvania	1	-0.0947	-9.0%	0.2320	-0.5494	0.3600	0.17	0.6831
	Rhode Island	1	-0.0351	-3.4%	0.2573	-0.5395	0.4693	0.02	0.8916
	South Carolina	1	-0.4679	-37.4%	0.2486	-0.9552	0.0194	3.54	0.0598
	South Dakota	1	-0.4356	-35.3%	0.5031	-1.4217	0.5504	0.75	0.3866
	Tennessee	1	-0.3693	-30.9%	0.2402	-0.8400	0.1015	2.36	0.1242
	Texas	1	-0.3717	-31.0%	0.2327	-0.8278	0.0844	2.55	0.1102
	Utah	1	-0.7246	-51.5%	0.2614	-1.2369	-0.2122	7.68	0.0056
	Vermont	1	-0.3147	-27.0%	0.3689	-1.0377	0.4084	0.73	0.3937
	Virginia	1	-0.2223	-19.9%	0.2328	-0.6785	0.2339	0.91	0.3396
	Washington	1	-0.3025	-26.1%	0.2356	-0.7642	0.1593	1.65	0.1992
	West Virginia	1	-0.9880	-62.8%	0.3601	-1.6937	-0.2823	7.53	0.0061
	Wisconsin	1	-0.2542	-22.4%	0.2462	-0.7367	0.2283	1.07	0.3019
	Wyoming	1	-1.3263	-73.5%	0.7440	-2.7844	0.1318	3.18	0.0746
	Alaska	0	0		0	0	0		
Deductible range	0-250	1	0.6052	83.2%	0.0276	0.5511	0.6593	481.07	<0.0001
	251-500	1	0.3616	43.6%	0.0241	0.3144	0.4088	225.51	<0.0001
	1001+	1	-0.3644	-30.5%	0.1461	-0.6507	-0.0780	6.22	0.0126
	501-1000	0	0		0	0	0		
Registered vehicle density	0-99	1	-0.2368	-21.1%	0.0374	-0.3102	-0.1634	39.99	<0.0001
	100-499	1	-0.1157	-10.9%	0.0202	-0.1554	-0.0760	32.67	<0.0001
	500+	0	0		0	0	0		
Active Front Lighting System		1	-0.0203	-2.0%	0.0544	-0.1268	0.0863	0.14	0.7093
Collision Mitigation Braking System		1	-0.0318	-3.1%	0.0446	-0.1191	0.0556	0.51	0.4759
Blind Spot Information		1	-0.0559	-5.4%	0.0757	-0.2043	0.0926	0.54	0.4608

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Buick collision avoidance features: initial results

Several collision avoidance systems are options on the Buick Lucerne. Lane Departure Warning and Side Blind Zone Alert are offered together. Ultrasonic Rear Parking Assist is available separately. This analysis of insurance claims shows that the parking assist feature is working to reduce losses. The frequency of both collision and property damage liability claims is lower for vehicles that have it than for those that don't. No insurance loss benefit was found for Buick's side assist systems of Lane Departure Warning and Side Blind Zone Alert.

Introduction

Collision avoidance technologies are becoming popular in U.S. motor vehicles, and more and more automakers are touting the potential safety benefits. However, the actual benefits in terms of crash reductions still are being measured. This Highway Loss Data Institute bulletin examines the early insurance claims experience for Buick vehicles fitted with three features:

Lane Departure Warning utilizes a forward-facing camera mounted near the interior rearview mirror to identify traffic lane markings. Audio and visual warnings will indicate if the vehicle path deviates from the intended lane. The system is functional at speeds over 35 mph but does not warn if the turn signal is on or the movement is determined to be sufficiently sudden as to be evasive. The system may be deactivated by the driver, and at the next ignition cycle it will be in the previous on/off setting. All vehicles equipped with this feature are also equipped with Side Blind Zone Alert.

Side Blind Zone Alert is Buick's term for a side view assist system that alerts drivers to vehicles that are adjacent to them. Side Blind Zone Alert utilizes radar sensors mounted behind each rear quarter panel to scan a range behind and to the side of the vehicle, areas commonly known as driver blind spots. If a vehicle is detected in a blind spot, a warning light on the appropriate side mirror is illuminated. If the driver activates a turn signal in the direction a vehicle has been detected, the warning light will flash. The feature may be deactivated by the driver and will be in the previous on/off setting at the next ignition cycle.

Ultrasonic Rear Parking Assist uses ultrasonic sensors to detect objects within 8 feet of the rear bumper and at least 10 inches off the ground. A single warning tone sounds when an object is first detected and sounds continually when the object is within 1 foot of the vehicle. While backing, a display mounted on the rear shelf changes color from amber to red indicating the vehicle's closing distance. The visual display communicates four distance zones utilizing two amber and one red indicator lights. As the vehicle gets closer to an object additional lights are illuminated and all the lights flash within a 1 foot distance. The system is functional at speeds less than 5 mph while the transmission is in reverse. The system may be deactivated by the driver but will reactivate on the next ignition cycle.

In addition to the features listed above the vehicles in this study could also be equipped with electronic stability control (ESC). There were three distinct feature groupings: vehicles with no collision avoidance features, vehicles with ultrasonic rear park assist and electronic stability control and vehicles with Lane Departure Warning, Side Blind Zone Alert, Ultrasonic Rear Park Assist and electronic stability control. ESC is always bundled with another collision avoidance feature and therefore it is not possible to know with absolute certainty whether or not any changes in insurance losses are related ESC or the other collision avoidance features.

Method

Vehicles

Ultrasonic Rear Parking Assist and the combination of Lane Departure Warning and Side Blind Zone Alert are offered as optional equipment on Buick Lucernes. The presence or absence of these features is not discernible from the information encoded in the vehicle identification numbers (VINs), but rather, this must be determined from build information maintained by the manufacturer. Buick supplied HLDI with the VINs for any Lucerne that was equipped with at least one of the collision avoidance features listed above. Vehicles of the same model year not identified by Buick were assumed not to have these features and thus served as the control vehicles in the analysis. **Table 1** lists the vehicle series and model years included in the analysis. In addition, exposure for each vehicle, measured in insured vehicle years is listed. The exposure of each feature in a given series is shown as a percentage of total exposure.

Table 1 : Feature exposure by vehicle series

Make	Series	Model year range	Lane Departure Warning and SZBA	Ultrasonic Rear Parking Assist	Total exposure
Buick	Lucerne 4dr	2008-09	17%	62%	171,777

Insurance data

Automobile insurance covers damages to vehicles and property as well as injuries to people involved in crashes. Different insurance coverages pay for vehicle damage versus injuries, and different coverages may apply depending on who is at fault. The current study is based on property damage liability, collision, bodily injury liability, personal injury protection and medical payment coverages. Exposure is measured in insured vehicle years. An insured vehicle year is one vehicle insured for one year, two for six months, etc.

Because different crash avoidance features may affect different types of insurance coverage, it is important to understand how coverages vary among the states and how this affects inclusion in the analyses. Collision coverage insures against vehicle damage to an at-fault driver's vehicle sustained in a crash with an object or other vehicle; this coverage is common to all 50 states. Property damage liability (PDL) coverage insures against vehicle damage that at-fault drivers cause to other people's vehicle and property in crashes; this coverage exists in all states except Michigan, where vehicle damage is covered on a no-fault basis (each insured vehicle pays for its own damage in a crash, regardless of who's at fault). Coverage of injuries is more complex. Bodily injury (BI) liability coverage insures against medical, hospital, and other expenses for injuries that at-fault drivers inflict on occupants of other vehicles or others on the road; although motorists in most states may have BI coverage, this information is analyzed only in states where the at-fault driver has first obligation to pay for injuries (33 states with traditional tort insurance systems). Medical payment coverage (MedPay), also sold in the 33 states with traditional tort insurance systems, covers injuries to insured drivers and the passengers in their vehicles, but not injuries to people in other vehicles involved in the crash. Seventeen other states employ no-fault injury systems (personal injury protection coverage, or PIP) that pay up to a specified amount for injuries to occupants of involved-insured vehicles, regardless of who's at fault in a collision. The District of Columbia has a hybrid insurance system for injuries and is excluded from the injury analysis.

Statistical methods

Regression analysis was used to quantify the effect of each vehicle feature while controlling for other covariates. The covariates included calendar year, model year, garaging state, vehicle density (number of registered vehicles per square mile), rated driver age group, rated driver gender, rated driver marital status, deductible range (collision coverage only), and risk. For each safety feature supplied by the manufacturer a binary variable was included. Based on the model year and series a single variable called SERIESMY was created for inclusion in the regression model. Statistically, including such a variable in the regression model is equivalent to including the interaction of series and model year. Effectively, this variable restricted the estimation of the effect of each feature within vehicle series and model year, preventing the confounding of the collision avoidance feature effects with other vehicle design changes that could occur from model year to model year.

Claim frequency was modeled using a Poisson distribution, whereas claim severity (average loss payment per claim) was modeled using a Gamma distribution. Both models used a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models. Estimates for frequency, severity, and overall losses are presented for collision and property damage liability. For PIP, BI, and MedPay, three frequency estimates are presented. The first frequency is the frequency for all claims, including those that already have been paid and those for which money has been set aside for possible payment in the future, known as claims with reserves. The other two frequencies include only paid claims separated into low and high severity ranges. Note that the percentage of all injury claims that were paid by the date of analysis varies by coverage: 79.4 percent for PIP, 72.4 percent for BI, and 72.8 percent for MedPay. The low severity range was <$1,000 for PIP and MedPay, <$5,000 for BI; high severity covered all loss payments greater than that.

A separate regression was performed for each insurance loss measure for a total of 15 regressions (5 coverages x 3 loss measures each). For space reasons, only the estimates for the individual crash avoidance features are shown on the following pages. To further illustrate the analyses, however, the Appendix contains full model results for collision claim frequencies. To simplify the presentation here, the exponent of the parameter estimate was calculated, 1 was subtracted, and the resultant multiplied by 100. The resulting number corresponds to the effect of the feature on that loss measure. For example, the estimate of the effect of Ultrasonic Rear Parking Assist on PDL claim frequency was -0.18199; thus, vehicles with that feature had 16.6 percent fewer PDL claims than expected ((exp(-0.18199)-1)*100=-16.6).

Results

Results for Buick's Lane Departure Warning System and Side Blind Zone Alert, are summarized in **Table 2**. The lower and upper bounds represent the 95 percent confidence limits for the estimates. For vehicle damage losses, frequency of claims and overall losses are generally up. The increases are not statistically significant.

For injury losses, overall frequency of claims is lower for BI but not for MedPay or PIP, and none of the differences is statistically significant. Among paid claims, there appears to be an increase in low severity injury claims under all coverages, though still not statistically significant. No pattern is observed for high severity claims.

Table 2 : Change in insurance losses for Lane Departure Warning and Side Blind Zone Alert

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper Bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-1.1%	4.2%	9.7%	-$212	-$34	$154	-$10	$6	$24
Property damage liability	-1.3%	7.2%	16.4%	-$138	$46	$247	-$2	$6	$15

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper Bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-24.2%	-1.5%	27.9%	-33.7%	1.3%	54.9%	-38.3%	-3.4%	51.1%
Medical payments	-15%	12.5%	48.9%	-25.1%	39.4%	159.4%	-32.9%	0.1%	49.2%
Personal injury protection	-11.6%	11.6%	40.8%	-20%	25.8%	97.7%	-34.8%	-9%	26.9%

Results for Buick's Ultrasonic Rear Parking Assist are summarized in **Table 3**. Again, the lower and upper bounds represent the 95 percent confidence limits for the estimates. Significant reductions (indicated in blue) in loss claims are estimated for both first- and third-party vehicle damage coverages, resulting in somewhat lower losses per insured vehicle year (overall losses). The change in overall losses for PDL is statistically significant.

Under injury coverages, the frequency of paid plus reserved claims is higher for PIP, lower for MedPay and remains essentially unchanged for BI. None of the differences are statistically significant. Among paid only claims, there is no pattern for both low and high severity claims. Only the frequency reduction for MedPay at high severity is statistically significant (30 percent).

Table 3 : Change in insurance losses for Ultrasonic Rear Parking Assist

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper Bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-8.7%	**-5%**	-1.1%	-$93	$49	$198	-$20	-$7	$6
Property damage liability	-21.6%	**-16.6%**	-11.4%	-$96	$43	$190	-$16	**-$11**	-$6

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper Bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-17.9%	-0.8%	19.9%	-30.4%	-5.4%	28.5%	-27.5%	0.3%	38.8%
Medical payments	-28.9%	-12.3%	8.1%	-31%	19.7%	107.4%	-46.9%	**-30%**	-7.8%
Personal injury protection	-13.8%	4.7%	27%	-3%	50.1%	132.4%	-26.8%	-6.1%	20.5%

Discussion

This analysis confirms that Buick's Ultrasonic Rear Parking Assist system is reducing insurance costs. The frequency of both collision and PDL coverage claims dropped for vehicles with the system, with a corresponding reduction in overall losses even though the average cost of the remaining crashes rose slightly. This increased severity may reflect the elimination of lower severity crashes, typical of parking situations, meaning that the average cost of the remaining crashes is higher. The greater benefit for PDL claims than collision may indicate the sensors are more effective at eliminating two-vehicle crashes than single-vehicle crashes with trees or poles. It also might reflect the fact that people are less likely to file a collision claim for damage that is less than the deductible. Given that the feature is always bundled with ESC we cannot be entirely certain that the reduction in losses is coming from the parking system. However, previous HLDI studies have not shown ESC to reduce PDL losses in cars. The size of the PDL frequency reduction for the parking system suggests the benefits are coming from the parking system.

Rear parking assist also was associated with fewer MedPay claims, especially those of higher severity. HLDI is currently unaware of any mechanism by which rear park assist would cause such a reduction. Until this effect is replicated with other manufacturers, it seems prudent to treat this effect as tentative, despite its statistical significance.

This analysis did not find an insurance loss benefit for Buick's side assist systems of Lane Departure Warning and Side Blind Zone Alert. Losses under both vehicle damage coverages were somewhat elevated with these systems, as were losses for both first-party medical coverages, MedPay and PIP, although none of the changes was statistically significant. BI liability was essentially unchanged. As both of these systems could reasonably be expected to prevent some crashes, it is not clear how their combination would have the opposite effect. It seems prudent to treat this effect as tentative until more data is available.

Limitations

There are limitations to the data used in this analysis. At the time of a crash, the status of a feature is not known. The features in this study can be deactivated by the driver and there is no way to know how many, if any of the drivers in these vehicles had manually turned off the system prior to the crash. If a significant number of drivers do turn these features off, any reported reductions may actually be underestimates of the true effectiveness of these systems.

Additionally, the data supplied to HLDI does not include detailed crash information. Information including point of impact is not available. The technologies in this report target certain crash types. For example, rear parking assist is designed to prevent collisions when a vehicle is backing up. Transmission status is not known – therefore, all collisions, regardless of the ability of a feature to mitigate or prevent the crash, are included in the analysis.

All of these features are optional and are associated with increased costs. The type of person who selects these options may be different from people who decline. While the analysis controls for several driver characteristics, there may be other uncontrolled attributes associated with people who select these features.

Appendix : Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Intercept		1	-9.2426		0.5032	-10.2289	-8.2563	337.33	<0.0001
Calendar year	2007	1	-0.2473	-21.9%	0.1036	-0.4503	-0.0443	5.70	0.0170
	2008	1	-0.0011	-0.1%	0.0300	-0.0599	0.0576	0.00	0.9697
	2009	1	0.0223	2.3%	0.0228	-0.0225	0.0671	0.95	0.3293
	2011	1	-0.0807	-7.8%	0.0260	-0.1318	-0.0297	9.62	0.0019
	2010	0	0	0	0	0	0		
Vehicle model year and series	2008 Lucerne 4dr	1	-0.0478	-4.7%	0.0223	-0.0915	-0.0041	4.60	0.0319
	2009 Lucerne 4dr	0	0	0	0	0	0		
Rated driver age group	14-20	1	0.0861	9.0%	0.2023	-0.3103	0.4826	0.18	0.6702
	21-24	1	0.3780	45.9%	0.1553	0.0736	0.6823	5.93	0.0149
	25-39	1	0.3312	39.3%	0.0751	0.1840	0.4783	19.46	<0.0001
	65+	1	0.1491	16.1%	0.0232	0.1037	0.1946	41.36	<0.0001
	Unknown	1	0.0773	8.0%	0.0473	-0.0154	0.1700	2.67	0.1024
	40-64	0	0	0	0	0	0		
Rated driver gender	Male	1	0.0379	3.9%	0.0247	-0.0106	0.0864	2.34	0.1261
	Unknown	1	0.0438	4.5%	0.0574	-0.0686	0.1562	0.58	0.4453
	Female	0	0	0	0	0	0		
Rated driver marital status	Single	1	0.2633	30.1%	0.0283	0.2079	0.3188	86.70	<0.0001
	Unknown	1	0.1369	14.7%	0.0575	0.0243	0.2496	5.67	0.0172
	Married	0	0	0	0	0	0		
Risk	Nonstandard	1	0.1864	20.5%	0.0577	0.0732	0.2996	10.42	0.0012
	Standard	0	0	0	0	0	0		
State	Alabama	1	0.1090	11.5%	0.5047	-0.8802	1.0983	0.05	0.8290
	Arizona	1	0.1031	10.9%	0.5058	-0.8883	1.0945	0.04	0.8384
	Arkansas	1	0.1510	16.3%	0.5089	-0.8464	1.1484	0.09	0.7667
	California	1	0.0817	8.5%	0.5040	-0.9062	1.0697	0.03	0.8712
	Colorado	1	0.1078	11.4%	0.5076	-0.8872	1.1027	0.05	0.8318
	Connecticut	1	-0.0860	-8.2%	0.5099	-1.0854	0.9134	0.03	0.8661
	Delaware	1	0.2081	23.1%	0.5130	-0.7975	1.2136	0.16	0.6851
	District of Columbia	1	0.2309	26.0%	0.5780	-0.9019	1.3637	0.16	0.6896
	Florida	1	-0.1058	-10.0%	0.5019	-1.0896	0.8779	0.04	0.8330
	Georgia	1	-0.1348	-12.6%	0.5056	-1.1258	0.8561	0.07	0.7897
	Hawaii	1	-0.1689	-15.5%	0.7075	-1.5556	1.2177	0.06	0.8113
	Idaho	1	-0.1468	-13.7%	0.5271	-1.1799	0.8864	0.08	0.7807
	Illinois	1	0.0654	6.8%	0.5014	-0.9173	1.0482	0.02	0.8961
	Indiana	1	0.0751	7.8%	0.5029	-0.9105	1.0607	0.02	0.8813
	Iowa	1	0.0070	0.7%	0.5048	-0.9823	0.9963	0.00	0.9889
	Kansas	1	0.0757	7.9%	0.5051	-0.9143	1.0657	0.02	0.8809
	Kentucky	1	0.0229	2.3%	0.5063	-0.9695	1.0154	0.00	0.9639
	Louisiana	1	0.2525	28.7%	0.5057	-0.7385	1.2436	0.25	0.6175
	Maine	1	0.1557	16.8%	0.5265	-0.8763	1.1876	0.09	0.7675
	Maryland	1	0.1386	14.9%	0.5042	-0.8497	1.1269	0.08	0.7835
	Massachusetts	1	0.1578	17.1%	0.5072	-0.8363	1.1520	0.10	0.7557
	Michigan	1	0.4229	52.6%	0.5016	-0.5603	1.4061	0.71	0.3992
	Minnesota	1	0.0635	6.6%	0.5024	-0.9213	1.0483	0.02	0.8995

Appendix : Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	Mississippi	1	0.2782	32.1%	0.5069	-0.7153	1.2716	0.30	0.5831
	Missouri	1	0.0175	1.8%	0.5031	-0.9686	1.0035	0.00	0.9723
	Montana	1	0.0870	9.1%	0.5202	-0.9325	1.1065	0.03	0.8672
	Nebraska	1	0.0339	3.4%	0.5071	-0.9601	1.0279	0.00	0.9467
	Nevada	1	0.1872	20.6%	0.5235	-0.8387	1.2132	0.13	0.7206
	New Hampshire	1	0.4565	57.9%	0.5198	-0.5624	1.4753	0.77	0.3799
	New Jersey	1	0.0042	0.4%	0.5049	-0.9853	0.9937	0.00	0.9933
	New Mexico	1	-0.0224	-2.2%	0.5209	-1.0434	0.9986	0.00	0.9657
	New York	1	0.1234	13.1%	0.5016	-0.8597	1.1066	0.06	0.8056
	North Carolina	1	-0.1875	-17.1%	0.5037	-1.1748	0.7998	0.14	0.7098
	North Dakota	1	0.2022	22.4%	0.5168	-0.8108	1.2152	0.15	0.6956
	Ohio	1	-0.0994	-9.5%	0.5020	-1.0834	0.8846	0.04	0.8431
	Oklahoma	1	-0.0134	-1.3%	0.5065	-1.0062	0.9794	0.00	0.9788
	Oregon	1	-0.1825	-16.7%	0.5186	-1.1990	0.8341	0.12	0.7250
	Pennsylvania	1	0.1383	14.8%	0.5015	-0.8446	1.1212	0.08	0.7827
	Rhode Island	1	0.0591	6.1%	0.5406	-1.0004	1.1186	0.01	0.9130
	South Carolina	1	-0.1056	-10.0%	0.5063	-1.0979	0.8867	0.04	0.8348
	South Dakota	1	0.1122	11.9%	0.5120	-0.8913	1.1157	0.05	0.8266
	Tennessee	1	0.1632	17.7%	0.5036	-0.8238	1.1503	0.11	0.7458
	Texas	1	0.0456	4.7%	0.5016	-0.9375	1.0287	0.01	0.9276
	Utah	1	0.0765	8.0%	0.5109	-0.9249	1.0779	0.02	0.8810
	Vermont	1	0.0965	10.1%	0.5479	-0.9773	1.1703	0.03	0.8602
	Virginia	1	0.1115	11.8%	0.5037	-0.8756	1.0987	0.05	0.8247
	Washington	1	-0.0310	-3.1%	0.5108	-1.0322	0.9702	0.00	0.9516
	West Virginia	1	-0.0923	-8.8%	0.5110	-1.0939	0.9093	0.03	0.8566
	Wisconsin	1	0.0836	8.7%	0.5027	-0.9017	1.0690	0.03	0.8679
	Wyoming	1	-0.1527	-14.2%	0.5272	-1.1860	0.8807	0.08	0.7721
	Alaska	0	0	0	0	0	0		
Deductible range	0-250	1	0.7745	117.0%	0.0443	0.6877	0.8614	305.39	<0.0001
	251-500	1	0.3913	47.9%	0.0446	0.3039	0.4788	76.95	<0.0001
	1001+	1	-1.0688	-65.7%	0.4483	-1.9475	-0.1900	5.68	0.0171
	501-1000	0	0	0	0	0	0		
Registered vehicle density	0-99	1	-0.2554	-22.5%	0.0265	-0.3073	-0.2036	93.18	<0.0001
	100-499	1	-0.1422	-13.3%	0.0233	-0.1879	-0.0965	37.21	<0.0001
	500+	0	0	0	0	0	0		
Lane Departure Warning and Side Blind Zone Alert		1	0.0410	4.2%	0.0265	-0.0109	0.0929	2.40	0.1216
Ultrasonic Rear Parking Assist		1	-0.0511	-5.0%	0.0203	-0.0909	-0.0112	6.31	0.0120

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Volvo collision avoidance features: initial results

This initial analysis of the effect on insurance claims of 4 crash avoidance features, 2 of which are combinations of multiple features, suggests that they are helping drivers avoid some crashes reported to insurers. However, except in the case of Volvo's steering-responsive headlights, the estimated benefits are not statistically significant. Volvo's Active Bending Lights reduce PDL claim frequency as well as BI claim frequency, but there was not a corresponding reduction in collision claim frequency.

Introduction

Collision avoidance technologies are becoming popular in U.S. motor vehicles, and more and more automakers are touting the potential safety benefits. However, the actual benefits in terms of crash reductions still are being measured. This Highway Loss Data Institute (HLDI) bulletin examines the early insurance claims experience for Volvo vehicles equipped with five features:

Active Bending Lights is Volvo's term for headlamps that respond to driver steering. The system uses sensors to measure vehicle speed, steering angle and vehicle yaw, and small electric motors turn the headlights accordingly, up to 15 degrees, to facilitate vision around a curve at night. It is activated automatically when the engine is started and can be deactivated by the driver. At the next ignition cycle, it will be in the previous on/off setting. A sensor disengages the adaptive function during daylight.

Forward Collision Warning uses radar sensors mounted in the front bumper to detect the risk of a collision. Driver warnings are both auditory and visual (red lights in a heads-up windshield display). If the driver brakes, the warnings are canceled. The forward collision warning system is active only between speeds of 20 and 120 mph. Vehicles with Forward Collision Warning also have Adaptive Cruise Control and Distance Alert.

> **Adaptive Cruise Control** is a system that uses radar sensors mounted in the front bumper to monitor traffic ahead and maintain the driver's selected following distance. As traffic conditions dictate, the system employs braking force to maintain the set following distance. Adaptive cruise control is available at speeds over 19 mph and can bring the car to a stop in traffic. Forward Collision Warning remains active even when adaptive cruise control is turned off.
>
> **Distance Alert** provides information about the time interval to the vehicle ahead. Red warning lights located in the windshield glow if the vehicle is closer to the vehicle ahead than the set time interval. Distance Alert is active at speeds above 20 mph and can be deactivated.

Forward Collision Warning with Auto Brake is Volvo's term for a forward collision warning system that includes some autonomous emergency braking. With Auto Brake, the system will also provide visual and auditory warnings when speed and distance indicate risk of a crash with the leading traffic and, if the driver's reaction does not eliminate that risk, the system will begin emergency braking to mitigate – but probably not prevent – the crash. Auto Brake becomes functional at speeds over 3 mph and deactivates when speed drops below 3 mph. Auto Brake operates whether or not Adaptive Cruise Control is activated. The auditory warnings can be deactivated by the driver. If deactivated, the warnings stay deactivated at the next ignition cycle. Vehicles with Forward Collision Warning with Auto Brake also have Adaptive Cruise Control, Distance Alert, Lane Departure Warning and Driver Alert.

Adaptive Cruise Control functions the same as the Adaptive Cruise Control system described under Forward Collision Warning.

Distance Alert has the identical functionality as described under Forward Collision Warning.

Lane Departure Warning utilizes a forward-facing camera mounted near the interior rearview mirror to identify traffic lane markings. An audio warning will indicate if the vehicle path deviates from the lane and the turn signal is not on. The system is functional at speeds above 40 mph. The system may be deactivated by the driver while the vehicle is in motion, and at the next ignition cycle it will be in the previous on/off setting. The system can also be set to switch on each time the engine is started regardless of the previous setting. Lane Departure Warning is always present on vehicles with Forward Collision Warning with Auto Brake and therefore the analysis cannot separate out the individual effects of these features.

Driver Alert is designed to aid a driver who becomes fatigued by monitoring a combination of vehicle, road, and driving parameters and assess whether the vehicle is being driven in an uncontrolled manner. An evaluation of the Driver Alert System is not included in this bulletin.

Blind Spot Information System is Volvo's term for a side view assist system that alerts drivers to vehicles that are adjacent to them. The system utilizes cameras mounted in each external side mirror to scan a range behind and to the side of the vehicle, areas commonly known as driver blind spots. If a vehicle is detected in a blind spot, a warning light on the appropriate A-pillar is illuminated. The system is functional at speeds over 6 mph and can be deactivated by the driver but will reactivate at the next ignition cycle.

Method

Vehicles

The features in this study are offered as optional equipment on various Volvo models. The presence or absence of these features is not discernible from the information encoded in the vehicle identification numbers (VINs), but rather, this must be determined from build information maintained by the manufacturer. Volvo supplied HLDI with the VINs for any vehicles that were equipped with at least one of the collision avoidance features listed above. Vehicles of the same model year and series not identified by Volvo were assumed not to have these features, and thus served as the control vehicles in the analysis. It should be noted that some of these vehicles may have been equipped also with Park Assist or Rear View Camera, but are not features included in this analysis due to apparent inconsistencies with the data provided to HLDI by Volvo. **Table 1** lists the vehicle series and model years included in the analysis. In addition, exposure for each vehicle, measured in insured vehicle years is listed. The exposure of each feature in a given series is shown as a percentage of total exposure.

Table 1 : Feature exposure by vehicle series							
Make	Series	Model year range	Active bending lights	Forward collision warning[1]	Forward collision warning with auto brake[2]	Blind spot information system	Total exposure
Volvo	C30 2dr	2008-10				4%	22,283
Volvo	C70 convertible	2008-10				10%	25,282
Volvo	S40 4dr	2007-10	1%			2%	93,323
Volvo	S40 4dr 4WD	2008-10	18%			19%	2,961
Volvo	S60 4dr	2007-09	6%				70,577
Volvo	S60 4dr 4WD	2007-09	14%				22,503
Volvo	S80 4dr	2007-10	12%	3%	<1%	19%	52,937
Volvo	S80 4dr 4WD	2007-10	34%	15%	4%	52%	21,836
Volvo	V50 station wagon	2008-10	4%			9%	6,265
Volvo	V50 station wagon 4WD	2008-10	23%			25%	1,690
Volvo	V70 station wagon	2008-10	5%		4%	25%	10,658
Volvo	V70 station wagon 4WD	2007-10	10%	2%	2%	22%	82,027
Volvo	XC60 4dr	2010	4%		4%	25%	5,051
Volvo	XC60 4dr 4WD	2010	18%		15%	48%	15,148
Volvo	XC90 4dr	2007-10	5%			16%	62,986
Volvo	XC90 4dr 4WD	2007-10	21%			21%	136,137

[1]Includes Adaptive Cruise Control and Distance Alert
[2]Includes Adaptive Cruise Control, Distance Alert, Lane Departure Warning and Driver Alert

Insurance data

Automobile insurance covers damages to vehicles and property as well as injuries to people involved in crashes. Different insurance coverages pay for vehicle damage versus injuries, and different coverages may apply depending on who is at fault. The current study is based on property damage liability, collision, bodily injury liability, personal injury protection and medical payment coverages. Exposure is measured in insured vehicle years. An insured vehicle year is one vehicle insured for one year, two for six months, etc.

Because different crash avoidance features may affect different types of insurance coverage, it is important to understand how coverages vary among the states and how this affects inclusion in the analysis. Collision coverage insures against vehicle damage to an at-fault driver's vehicle sustained in a crash with an object or other vehicle; this coverage is common to all 50 states. Property damage liability (PDL) coverage insures against vehicle damage that at-fault drivers cause to other people's vehicle and property in crashes; this coverage exists in all states except Michigan, where vehicle damage is covered on a no-fault basis (each insured vehicle pays for its own damage in a crash, regardless of who's at fault). Coverage of injuries is more complex. Bodily injury (BI) liability coverage insures against medical, hospital, and other expenses for injuries that at-fault drivers inflict on occupants of other vehicles or others on the road; although motorists in most states may have BI coverage, this information is analyzed only in states where the at-fault driver has first obligation to pay for injuries (33 states with traditional tort insurance systems). Medical payment coverage (MedPay), also sold in the 33 states with traditional tort insurance systems, covers injuries to insured drivers and the passengers in their vehicles, but not injuries to people in other vehicles involved in the crash. Seventeen other states employ no-fault injury systems (personal injury protection coverage, or PIP) that pay up to a specified amount for injuries to occupants of involved-insured vehicles, regardless of who's at fault in a collision. The District of Columbia has a hybrid insurance system for injuries and is excluded from the injury analysis.

Statistical methods

Regression analysis was used to quantify the effect of each vehicle feature while controlling for the other features and several covariates. The covariates included calendar year, model year, garaging state, vehicle density (number of registered vehicles per square mile), rated driver age group, rated driver gender, rated driver marital status, deductible range (collision coverage only), and risk. For each safety feature supplied by the manufacturer a binary variable was included. Based on the model year and series a single variable called SERIESMY was created for inclusion in the regression model. Statistically, including such a variable in the regression model is equivalent to including the interaction of series and model year. Effectively, this variable restricted the estimation of the effect of each feature within vehicle series and model year, preventing the confounding of the collision avoidance feature effects with other vehicle design changes that could occur from model year to model year.

Claim frequency was modeled using a Poisson distribution, whereas claim severity (average loss payment per claim) was modeled using a Gamma distribution. Both models used a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models. Estimates for frequency, severity, and overall losses are presented for collision and property damage liability. For PIP, BI and MedPay three frequency estimates are presented. The first frequency is the frequency for all claims, including those that already have been paid and those for which money has been set aside for possible payment in the future, known as claims with reserves. The other two frequencies include only paid claims separated into low and high severity ranges. Note that the percentage of all injury claims that were paid by the date of analysis varies by coverage: 77.4 percent for PIP, 69.1 percent for BI, and 62.6 percent for MedPay. The low severity range was <$1,000 for PIP and MedPay, <$5,000 for BI; high severity covered all loss payments greater than that.

A separate regression was performed for each insurance loss measure for a total of 15 regressions (5 coverages x 3 loss measures each). For space reasons, only the estimates for the individual crash avoidance features are shown on the following pages. To illustrate the analysis, however, the **Appendix** contains full model results for collision claim frequencies. To further simplify the presentation here, the exponent of the parameter estimate was calculated, 1 was subtracted, and the resultant multiplied by 100. The resulting number corresponds to the effect of the feature on that loss measure. For example, the estimate of Active Bending Light's effect on PDL claim frequency was -0.09478; thus, vehicles with Active Bending Lights had 9.0 percent fewer PDL claims than expected (exp(-0.09478)-1*100=-9.0).

Results

Results for Volvo's Active Bending Lights are summarized in **Table 2**. The lower and upper bounds represent the 95 percent confidence limits for the estimates. For vehicle damage losses, frequency of claims are generally down. Active Bending Lights reduce PDL frequency by a statistically significant 9.0 percent (indicated in blue in the table). Combined with a non-significant estimate of reduced severity resulted in a statistically significant $9 reduction in overall losses. Collision claim frequency for vehicles with Active Bending Lights was not much different from those without, although a non-significant increase in severity was estimated.

For injury losses, Active Bending Lights reduced overall BI frequency by a statistically significant 16.8 percent and other injury claim frequencies by smaller and not significant amounts. Estimates for paid claims were generally down but confidence intervals were fairly wide.

Table 2 : Change in insurance losses for Active Bending Lights									
Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-4.2%	-0.7%	2.9%	-$28	$149	$333	-$7	$8	$24
Property damage liability	-13.4%	**-9.0%**	-4.4%	-$152	-$29	$101	-$14	**-$9**	-$3
Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-30.1%	**-16.8%**	-0.9%	-38.7%	-18.2%	9.2%	-43.5%	-22.7%	5.5%
Medical payments	-22.2%	-6.3%	12.8%	-52.3%	-22.9%	24.8%	-41.7%	-22.4%	3.3%
Personal injury protection	-18.3%	-6.6%	6.8%	-37.0%	-16.4%	11.0%	-12.9%	3.9%	23.9%

Results for Volvo's Forward Collision Warning are summarized in **Table 3**. Again, the lower and upper bounds represent the 95 percent confidence limits for the estimates. For vehicle damage losses, frequency of claims are down while severity and overall losses are up. The changes are not statistically significant.

Under injury coverages, the frequency of paid plus reserved claims is higher for PIP, and lower for MedPay and BI. None of the differences are statistically significant. The confidence intervals for estimated frequency effect among paid claims are too wide to detect a pattern.

Table 3 : Change in insurance losses for Forward Collision Warning									
Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-16.5%	-6.6%	4.5%	-$125	$445	$1,093	-$36	$9	$62
Property damage liability	-21.9%	-7.1%	10.6%	-$201	$266	$821	-$18	$2	$27
Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-50.3%	-9.2%	66.1%	-81.0%	-36.4%	113.4%	-50.5%	18.1%	182.1%
Medical payments	-62.5%	-27.5%	39.9%	-94.2%	-52.9%	284.2%	-82.4%	-48.7%	50.0%
Personal injury protection	-28.0%	14.0%	80.5%	-58.8%	8.2%	184.0%	-34.8%	20.1%	121.2%

Results for Volvo's Forward Collision Warning with Auto Brake and Lane Departure Warning are summarized in **Table 4**. The lower and upper bounds represent the 95 percent confidence limits for the estimates. Non-significant reductions in claims, severity and overall losses are estimated for both first- and third-party vehicle damage coverages.

For injury losses, overall frequency of claims (reserved plus paid) is higher for MedPay and PIP, but not for BI. For high-severity paid only claims, a similar pattern appears, with increases for MedPay and PIP and a decrease for BI. None of the estimates are significant. The confidence intervals for estimated frequency effect among paid claims are too wide to detect a pattern.

Table 4 : Change in insurance losses for Forward Collision Warning with Auto Brake (includes Lane Departure Warning)

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-13.8%	-2.9%	9.3%	-$700	-$179	$417	-$62	-$19	$32
Property damage liability	-25.1%	-10.0%	8.2%	-$501	-$83	$415	-$29	-$11	$11

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-68.5%	-31.9%	47.2%	-75.0%	-18.2%	167.5%	-72.0%	-7.1%	208.2%
Medical payments	-41.5%	13.3%	119.5%				-8.2%	98.8%	330.4%
Personal injury protection	-23.5%	21.3%	92.3%				-3.6%	65.9%	185.7%

Results for Volvo's Blind Spot Information System are summarized in **Table 5**. Again, the lower and upper bounds represent the 95 percent confidence limits for the estimates. For vehicle damage losses, frequency of claims are down for property damage liability and up for collision coverage. Reductions in severity and overall losses are estimated for both first- and third-party vehicle damage coverages, and the collision severity reduction is significant.

For injury losses, overall frequency of claims (reserved plus paid) is lower for both BI and MedPay, but not for PIP. Among paid claims, there appears to be a decrease in low severity injury claims under all coverages, though not statistically significant while high severity claims appear to increase.

Table 5 : Change in insurance losses for Blind Spot Information System

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-1.9%	1.3%	4.6%	-$311	**-$159**	-$2	-$20	-$7	$7
Property damage liability	-6.6%	-2.4%	2.0%	-$140	-$27	$90	-$8	-$3	$2

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-21.0%	-6.2%	11.4%	-30.1%	-6.9%	24.0%	-21.1%	7.2%	45.6%
Medical payments	-26.5%	-11.4%	6.9%	-58.4%	-32.3%	10.2%	-17.5%	7.7%	40.6%
Personal injury protection	-7.2%	3.9%	16.4%	-24.5%	-4.9%	19.8%	-9.4%	6.0%	24.0%

Discussion

Active Bending Lights

It was expected that Volvo's steering responsive headlamps would reduce crashes, but it was also expected that the crashes affected would be largely single-vehicle, run-off-road crashes. However, collision claims were least affected by Volvo's Active Bending Lights. Instead, PDL claims saw significant reductions in frequency and consistent with the PDL frequency reduction, BI claim frequency was also reduced significantly. Although these results indicate a significant benefit for insurance claims of steerable headlamps, further research is needed to explore the kinds of crashes that are being affected.

Collision claim frequency was little affected by the presence of active bending lights, however, the average collision claim severity was estimated to increase, albeit not significantly. As with several crash avoidance technologies, this may be a result of the systems depending on expensive components. Steerable headlights depend on high-intensity discharge technology with higher replacement costs ($1,220 compared to $450 for base halogen lamps) when they are damaged.

Forward Collision Warning

Forward Collision Warning and Forward Collision Warning with full-Autobrake are forward collision warning systems that differ in two principal ways: In addition to warnings, Forward Collision Warning with full-Autobrake will apply brakes autonomously in certain emergency situations, and it is active at lower speeds in following traffic (more than 3 mph vs. more than 19 mph for basic Forward Collision Warning). Moreover, the system with autobrake is always bundled with Volvo's lane departure warning system. Both systems are expected to have larger benefits for PDL coverage than collision coverage because a larger proportion of PDL crashes are two-vehicle front-to-rear-end crashes that occur in following traffic where the systems would be active (compared with collision coverage, under which some number of crashes are single-vehicle). In addition, the system with full-autobrake should have larger effects than the one without because of the autonomous braking feature and because it is operative at lower speeds. Both systems reduced PDL claim frequency to a greater extent than collision claim frequency, although none of the estimates was significant. Additionally, the system with full-autobrake was associated with greater reductions in PDL claim frequency than the one without. Consistent with this reduction in PDL frequency, BI frequency is also estimated to be lower with these two forward collision warning systems, although lack of data results in neither estimate being significant. Adaptive Cruise Control, which is always bundled with Forward Collision Warning, if used, could reduce the likelihood that drivers get into situations that lead to a crash.

Curiously, the estimated effect of Forward Collision Warning with full-autobrake on collision frequency is less than the effect for the system without the auto-brake feature. This is contrary to expectations and different from the patterns observed for Mercedes-Benz Distronic and Distronic Plus (Vol. 29, No. 7) – forward collision warning systems that differ from each other in ways similar to the differences between the Volvo systems. One possible explanation is that the full-autobrake benefits are diminished by the presence of lane departure warning, although the mechanism by which this might occur is unclear. Nevertheless, while statistically inconclusive HLDI's analysis for Mercedes-Benz Lane Keeping Assist was associated with estimated increases in claim frequencies for all coverage types except BI. It is too early to know the true effects of lane departure systems, but the initial evidence from insurance losses is not encouraging.

Blind Spot Information System

Volvo's Blind Spot Information System would be expected to prevent or reduce two-vehicle crashes associated with incursion into occupied adjacent lanes. As such, it likely would lead to a reduction in PDL claim frequencies. This analysis finds only a 2 percent reduction, which is not statistically significant. Non significant reductions in BI and Medpay claim frequencies are consistent with the reduction in PDL. Results for collision coverage are somewhat confusing. On the one hand a non-significant increase in frequency is estimated, but a significant reduction in severity suggests that the system may be reducing the severity of collisions that do occur. Further research is needed to explore the kinds of crashes that are being affected.

Limitations

There are limitations to the data used in this analysis. At the time of a crash, the status of a feature is not known. The features in this study can be deactivated by the driver and there is no way to know how many of the drivers in these vehicles turned off a system prior to the crash. If a significant number of drivers do turn these features off, any reported reductions may actually be underestimates of the true effectiveness of these systems.

Additionally, the data supplied to HLDI does not include detailed crash information. Information on point of impact, or information on vehicle operation at the time of the event is not available. The technologies in this report target certain crash types. For example, the Blind Spot Information system is designed to prevent sideswipe type collisions. However, all collisions, regardless of the ability of a feature to mitigate or prevent the crash, are included in the analysis.

All of these features are optional and are associated with increased costs. The type of person who selects these options may be different from the person who declines. While the analysis controls for several driver characteristics, there may be other uncontrolled attributes associated with people who select these features.

Reference

Highway Loss Data Institute. 2012. Mercedes-Benz collision avoidance features — initial results. Loss bulletin Vol. 29, No. 7. Arlington, VA.

Appendix : Illustrative regression results — collision frequency

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Intercept		1	-9.1612		0.1415	-9.4385	-8.8838	4190.69	<0.0001
Calendar year	2006	1	-0.2623	-23.1%	0.0817	-0.4225	-0.1021	10.30	0.0013
	2007	1	0.0240	2.4%	0.0216	-0.0183	0.0662	1.24	0.2664
	2008	1	0.0061	0.6%	0.0156	-0.0244	0.0365	0.15	0.6971
	2009	1	-0.0112	-1.1%	0.0135	-0.0377	0.0153	0.69	0.4063
	2011	1	-0.0346	-3.4%	0.0143	-0.0625	-0.0066	5.87	0.0154
	2010	0	0	0	0	0	0		
Vehicle model year and series	2008 C30 2dr	1	0.2733	31.4%	0.0578	0.1600	0.3865	22.36	<0.0001
	2009 C30 2dr	1	0.2022	22.4%	0.0670	0.0708	0.3336	9.10	0.0026
	2010 C30 2dr	1	0.2631	30.1%	0.1054	0.0565	0.4697	6.23	0.0126
	2008 C70 convertible	1	0.2098	23.3%	0.0571	0.0980	0.3217	13.52	0.0002
	2009 C70 convertible	1	0.2647	30.3%	0.0694	0.1288	0.4007	14.56	0.0001
	2010 C70 convertible	1	0.2168	24.2%	0.0962	0.0282	0.4055	5.08	0.0243
	2007 S40 4dr	1	0.2577	29.4%	0.0519	0.1559	0.3594	24.63	<0.0001
	2008 S40 4dr	1	0.3301	39.1%	0.0548	0.2227	0.4375	36.29	<0.0001
	2009 S40 4dr	1	0.3371	40.1%	0.0602	0.2191	0.4551	31.33	<0.0001
	2010 S40 4dr	1	0.3626	43.7%	0.0701	0.2251	0.5000	26.72	<0.0001
	2008 S40 4dr 4WD	1	0.3506	42.0%	0.0957	0.1630	0.5383	13.41	0.0002
	2009 S40 4dr 4WD	1	0.1967	21.7%	0.1423	-0.0823	0.4757	1.91	0.1671
	2010 S40 4dr 4WD	1	0.4032	49.7%	0.1510	0.1073	0.6991	7.13	0.0076

Appendix : Illustrative regression results — collision frequency								
Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
2007 S60 4dr	1	0.1321	14.1%	0.0529	0.0283	0.2358	6.22	0.0126
2008 S60 4dr	1	0.1542	16.7%	0.0562	0.0441	0.2643	7.53	0.0061
2009 S60 4dr	1	0.0185	1.9%	0.0750	-0.1286	0.1656	0.06	0.8051
2007 S60 4dr 4WD	1	0.2164	24.2%	0.0577	0.1033	0.3295	14.05	0.0002
2008 S60 4dr 4WD	1	0.0756	7.9%	0.0722	-0.0659	0.2171	1.10	0.2949
2009 S60 4dr 4WD	1	0.1299	13.9%	0.1037	-0.0734	0.3332	1.57	0.2104
2007 S80 4dr	1	0.1887	20.8%	0.0552	0.0806	0.2968	11.71	0.0006
2008 S80 4dr	1	0.2118	23.6%	0.0572	0.0997	0.3239	13.72	0.0002
2009 S80 4dr	1	0.1714	18.7%	0.0654	0.0432	0.2995	6.87	0.0088
2010 S80 4dr	1	0.1562	16.9%	0.0727	0.0138	0.2986	4.62	0.0315
2007 S80 4dr 4WD	1	0.2095	23.3%	0.0714	0.0696	0.3495	8.61	0.0033
2008 S80 4dr 4WD	1	0.2069	23.0%	0.0625	0.0844	0.3294	10.95	0.0009
2009 S80 4dr 4WD	1	0.1573	17.0%	0.0799	0.0007	0.3139	3.88	0.0489
2010 S80 4dr 4WD	1	0.2751	31.7%	0.0903	0.0981	0.4521	9.28	0.0023
2008 V50 station wagon	1	0.1987	22.0%	0.0807	0.0406	0.3568	6.07	0.0137
2009 V50 station wagon	1	0.2024	22.4%	0.0937	0.0187	0.3862	4.66	0.0308
2010 V50 station wagon	1	0.2405	27.2%	0.1371	-0.0283	0.5092	3.08	0.0795
2008 V50 station wagon 4WD	1	0.2400	27.1%	0.1255	-0.0061	0.4860	3.65	0.0559
2009 V50 station wagon 4WD	1	0.2325	26.2%	0.1920	-0.1439	0.6088	1.47	0.2261
2010 V50 station wagon 4WD	1	-0.1193	-11.2%	0.2628	-0.6344	0.3957	0.21	0.6498
2008 V70 station wagon	1	0.1268	13.5%	0.0664	-0.0034	0.2570	3.65	0.0562
2009 V70 station wagon	1	0.0317	3.2%	0.1203	-0.2041	0.2676	0.07	0.7921
2010 V70 station wagon	1	0.2373	26.8%	0.1097	0.0224	0.4522	4.68	0.0305
2007 V70 station wagon 4WD	1	-0.2184	-19.6%	0.0546	-0.3255	-0.1113	15.98	<0.0001
2008 V70 station wagon 4WD	1	-0.1100	-10.4%	0.0553	-0.2185	-0.0015	3.95	0.0469
2009 V70 station wagon 4WD	1	-0.0421	-4.1%	0.0697	-0.1786	0.0944	0.37	0.5457
2010 V70 station wagon 4WD	1	-0.1277	-12.0%	0.0769	-0.2785	0.0231	2.76	0.0969
2010 XC60 4dr	1	-0.1343	-12.6%	0.0804	-0.2918	0.0233	2.79	0.0949
2010 XC60 4dr 4WD	1	0.0170	1.7%	0.0595	-0.0997	0.1337	0.08	0.7751
2007 XC90 4dr	1	-0.0394	-3.9%	0.0562	-0.1496	0.0707	0.49	0.4830
2008 XC90 4dr	1	-0.0188	-1.9%	0.0567	-0.1298	0.0923	0.11	0.7403
2009 XC90 4dr	1	0.2140	23.9%	0.0805	0.0562	0.3719	7.06	0.0079
2010 XC90 4dr	1	0.0251	2.5%	0.0829	-0.1374	0.1876	0.09	0.7624
2007 XC90 4dr 4WD	1	0.0046	0.5%	0.0518	-0.0969	0.1062	0.01	0.9289

Appendix : Illustrative regression results — collision frequency

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	2008 XC90 4dr 4WD	1	0.0264	2.7%	0.0520	-0.0756	0.1284	0.26	0.6123
	2009 XC90 4dr 4WD	1	0.0883	9.2%	0.0654	-0.0398	0.2163	1.82	0.1769
	2010 XC90 4dr 4WD	0	0	0	0	0	0		
Rated driver age group	14-20	1	0.3053	35.7%	0.0327	0.2413	0.3693	87.32	<0.0001
	21-24	1	0.2405	27.2%	0.0301	0.1814	0.2995	63.78	<0.0001
	25-39	1	0.0713	7.4%	0.0124	0.0470	0.0956	33.10	<0.0001
	65+	1	0.1173	12.4%	0.0170	0.0840	0.1506	47.63	<0.0001
	Unknown	1	0.0825	8.6%	0.0251	0.0333	0.1317	10.80	0.0010
	40-64	0	0	0	0	0	0		
Rated driver gender	Male	1	-0.0315	-3.1%	0.0124	-0.0558	-0.0072	6.47	0.0110
	Unknown	1	-0.2144	-19.3%	0.0304	-0.2740	-0.1548	49.72	<0.0001
	Female	0	0	0	0	0	0		
Rated driver marital status	Single	1	0.2338	26.3%	0.0141	0.2061	0.2615	274.33	<0.0001
	Unknown	1	0.2702	31.0%	0.0299	0.2117	0.3288	81.81	<0.0001
	Married	0	0	0	0	0	0		
Risk	Nonstandard	1	0.1861	20.5%	0.0162	0.1543	0.2179	131.58	<0.0001
	Standard	0	0.0000	0	0	0	0		
State	Alabama	1	0.0508	5.2%	0.1403	-0.2243	0.3258	0.13	0.7175
	Arizona	1	0.0239	2.4%	0.1393	-0.2491	0.2969	0.03	0.8637
	Arkansas	1	0.1326	14.2%	0.1686	-0.1979	0.4631	0.62	0.4318
	California	1	0.1934	21.3%	0.1327	-0.0666	0.4534	2.13	0.1448
	Colorado	1	0.0957	10.0%	0.1360	-0.1708	0.3622	0.50	0.4815
	Connecticut	1	0.0048	0.5%	0.1349	-0.2595	0.2692	0.00	0.9713
	Delaware	1	-0.0642	-6.2%	0.1566	-0.3711	0.2427	0.17	0.6817
	District of Columbia	1	0.2470	28.0%	0.1448	-0.0369	0.5309	2.91	0.0881
	Florida	1	-0.0893	-8.5%	0.1330	-0.3500	0.1714	0.45	0.5019
	Georgia	1	-0.1196	-11.3%	0.1352	-0.3846	0.1453	0.78	0.3761
	Hawaii	1	0.0374	3.8%	0.1550	-0.2664	0.3412	0.06	0.8092
	Idaho	1	-0.2146	-19.3%	0.1874	-0.5819	0.1528	1.31	0.2523
	Illinois	1	0.0660	6.8%	0.1340	-0.1966	0.3286	0.24	0.6222
	Indiana	1	-0.0685	-6.6%	0.1488	-0.3601	0.2231	0.21	0.6452
	Iowa	1	-0.0416	-4.1%	0.1644	-0.3638	0.2806	0.06	0.8002
	Kansas	1	-0.0368	-3.6%	0.1491	-0.3290	0.2555	0.06	0.8051
	Kentucky	1	-0.2033	-18.4%	0.1486	-0.4946	0.0880	1.87	0.1714
	Louisiana	1	0.1228	13.1%	0.1388	-0.1493	0.3948	0.78	0.3766
	Maine	1	0.0907	9.5%	0.1539	-0.2110	0.3924	0.35	0.5558
	Maryland	1	0.0486	5.0%	0.1347	-0.2154	0.3126	0.13	0.7182
	Massachusetts	1	0.0778	8.1%	0.1359	-0.1887	0.3442	0.33	0.5673
	Michigan	1	0.4431	55.8%	0.1358	0.1769	0.7093	10.64	0.0011
	Minnesota	1	-0.0246	-2.4%	0.1397	-0.2984	0.2492	0.03	0.8604
	Mississippi	1	0.1773	19.4%	0.1584	-0.1331	0.4877	1.25	0.2629
	Missouri	1	-0.0068	-0.7%	0.1403	-0.2818	0.2682	0.00	0.9611
	Montana	1	-0.1166	-11.0%	0.2337	-0.5746	0.3414	0.25	0.6178
	Nebraska	1	-0.0617	-6.0%	0.1631	-0.3813	0.2579	0.14	0.7052
	Nevada	1	0.0933	9.8%	0.1497	-0.2000	0.3866	0.39	0.5331

Appendix : Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	New Hampshire	1	0.1018	10.7%	0.1416	-0.1756	0.3793	0.52	0.4719
	New Jersey	1	-0.0410	-4.0%	0.1336	-0.3028	0.2208	0.09	0.7589
	New Mexico	1	0.0429	4.4%	0.1589	-0.2686	0.3545	0.07	0.7871
	New York	1	0.1138	12.1%	0.1327	-0.1463	0.3739	0.73	0.3913
	North Carolina	1	-0.3476	-29.4%	0.1363	-0.6148	-0.0805	6.50	0.0108
	North Dakota	1	-0.1585	-14.7%	0.4665	-1.0728	0.7558	0.12	0.7341
	Ohio	1	-0.1420	-13.2%	0.1373	-0.4110	0.1270	1.07	0.3009
	Oklahoma	1	0.0791	8.2%	0.1460	-0.2071	0.3653	0.29	0.5880
	Oregon	1	-0.0333	-3.3%	0.1422	-0.3120	0.2455	0.05	0.8151
	Pennsylvania	1	0.0846	8.8%	0.1331	-0.1763	0.3455	0.40	0.5250
	Rhode Island	1	0.1046	11.0%	0.1430	-0.1756	0.3848	0.54	0.4643
	South Carolina	1	-0.1643	-15.2%	0.1420	-0.4426	0.1139	1.34	0.2471
	South Dakota	1	0.0078	0.8%	0.3586	-0.6950	0.7105	0.00	0.9827
	Tennessee	1	-0.0660	-6.4%	0.1389	-0.3383	0.2064	0.23	0.6350
	Texas	1	0.0577	5.9%	0.1330	-0.2030	0.3184	0.19	0.6645
	Utah	1	-0.0199	-2.0%	0.1556	-0.3247	0.2850	0.02	0.8984
	Vermont	1	0.1624	17.6%	0.1570	-0.1453	0.4701	1.07	0.3010
	Virginia	1	0.0046	0.5%	0.1340	-0.2581	0.2673	0.00	0.9728
	Washington	1	-0.0367	-3.6%	0.1361	-0.3033	0.2300	0.07	0.7876
	West Virginia	1	-0.0747	-7.2%	0.1649	-0.3979	0.2484	0.21	0.6503
	Wisconsin	1	-0.0385	-3.8%	0.1486	-0.3298	0.2528	0.07	0.7956
	Wyoming	1	0.0783	8.1%	0.2553	-0.4220	0.5787	0.09	0.7590
	Alaska	0	0	0	0	0	0		
Deductible range	0-250	1	0.5519	73.7%	0.0183	0.5161	0.5877	913.69	<0.0001
	1001+	1	-0.3083	-26.5%	0.0961	-0.4966	-0.1201	10.30	0.0013
	251-500	1	0.3232	38.2%	0.0156	0.2926	0.3539	426.97	<0.0001
	501-1000	0	0	0	0	0	0		
Registered vehicle density	0-99	1	-0.2367	-21.1%	0.0213	-0.2786	-0.1949	122.95	<0.0001
	100-499	1	-0.1641	-15.1%	0.0125	-0.1885	-0.1396	173.19	<0.0001
	500+	0	0	0	0	0	0		
Blind Spot Information System		1	0.0126	1.3%	0.0164	-0.0196	0.0448	0.59	0.4439
Forward Collision Warning		1	-0.0683	-6.6%	0.0574	-0.1808	0.0441	1.42	0.2336
Forward Collision Warning with Auto Brake (includes LDW)		1	-0.0298	-2.9%	0.0605	-0.1484	0.0887	0.24	0.6219
Active Bending Lights		1	-0.0071	-0.7%	0.0183	-0.0429	0.0287	0.15	0.6979

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The Highway Loss Data Institute is a nonprofit public service organization that gathers, processes, and publishes insurance data on the human and economic losses associated with owning and operating motor vehicles.

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Mercedes-Benz collision avoidance features: initial results

Mercedes-Benz offers a wide range of collision avoidance features. Results for its forward collision warning systems, Distronic and Distronic Plus, are particularly promising. These systems reduce claims under property damage liability (PDL) coverage and, to a lesser extent, collision coverage. The effects are more pronounced for Distronic Plus, which includes adaptive brake assistance and autonomous braking. Headlamp improvements also appeared beneficial. However, the biggest effect for Active Curve Illumination was seen in PDL claims and not, as had been expected, collision claims. Both collision and PDL claim frequency decreased significantly for vehicles with Night View Assist or Night View Assist Plus. Other features did not show significant reductions in claims.

Introduction

Collision avoidance technologies are becoming popular in U.S. motor vehicles, and more and more automakers are touting the potential safety benefits. However, the actual benefits in terms of crash reductions still are being measured. This Highway Loss Data Institute (HLDI) bulletin examines the early insurance claims experience for Mercedes-Benz vehicles fitted with 15 features:

Forward collision warning

Distronic is an adaptive cruise control system that uses a radar sensor mounted on the front bumper to monitor traffic ahead and maintain the driver's selected following distance. As traffic conditions dictate, the system employs up to 20 percent of the vehicle's braking force to maintain the set following distance. The system also provides forward collision warning functionality. Collision warning is active even when adaptive cruise control is turned off. If the system detects the risk of a collision, warnings are both auditory and visual (a dashboard icon). If the driver brakes, the warnings are canceled. Adaptive cruise control is available at speeds of 20 mph or higher and can bring the car to a stop in traffic. The forward collision warning system is active at speeds of 20 mph or higher.

Distronic Plus, like its predecessor Distronic, provides adaptive cruise control and forward collision warning. It is functional at speeds of 20 mph and over if no lead vehicle is detected and at speeds of 0-120 mph when a lead vehicle is detected. Distronic Plus gets additional functionality from two other systems that are available only as part of Distronic Plus: Pre-Safe® Brake and Brake Assist Plus.

Pre-Safe® Brake alerts inattentive drivers when braking is required. If the driver does not respond to the auditory and visual alerts, the system can trigger partial braking as a warning and eventually trigger full braking to mitigate an inevitable rear-end collision. Additionally all Pre-Safe® measures are activated at the final stage. The functional speed range of Pre-Safe® Brake is above 20 mph when following a moving vehicle and 20-45 mph if approaching a stationary vehicle. The system is enabled and deactivated via instrument panel controls. It will intervene unless the driver makes a recognized evasive maneuver (e.g., acceleration, release brake pedal, evasive steering).

Brake Assist Plus supports a driver who is braking to avoid a rear-end collision. If the driver does not brake strongly enough, the system applies the calculated brake pressure needed, up to full braking, without warning to avoid a collision. The functional speed range of Brake Assist Plus is above 20 mph when following a moving vehicle and 20-45 mph if approaching a stationary vehicle. Once activated, the system will stay active until the situation is resolved, even below the 20 mph threshold. Brake Assist Plus is enabled via instrument cluster controls and deactivated via either instrument panel controls or based upon driver intervention (i.e., acceleration, release brake pedal, evasive steering).

Headlamp improvements

Active Curve Illumination improves visibility through curves during nighttime driving by swiveling the headlamps as the driver steers to increase usable illumination. Once the headlights are turned on, Active Curve Illumination is active and functional at all speeds.

High Intensity Discharge (HID) Headlights create light with an arc of electrified gas, typically xenon, rather than a glowing filament. HIDs produce more light than standard tungsten-halogen bulbs.

Active Cornering Lights (ACLS) improve visibility during low speed turning maneuvers. When the driver activates a turn signal or turns the steering wheel, the appropriate fog lamp illuminates the side area in front of the vehicle to a range of approximately 30 meters. The cornering lights are deactivated when the indicator is turned off or when the steering wheel returns to the straight ahead position. Cornering lights are operational at speeds up to 25 mph.

Adaptive High Beam Assist increases visibility by enabling greater use of high and low beams. It automatically dims the headlights when other illuminated traffic is recognized by a camera mounted behind the windshield. After switching from high beam to low beam, the system uses the camera's continuous input to automatically vary the range of low beams, based on the distance both to oncoming vehicles and to those ahead of the vehicle. Therefore, the range of the low beam can be significantly improved and less driver action is required. Adaptive High Beam Assist must be turned on by the driver and can be activated/deactivated via the instrument cluster controls. At the next ignition cycle, the system will be in the previous on/off setting. The system is functional at speeds above 30 mph.

Night Vision Enhancement

Night View Assist is a vision aid system that uses infrared headlamps to illuminate upcoming obstacles (pedestrians, cyclists, animals etc) whose images are projected onto a multifunction display in the instrument cluster to give the driver advance notice beyond typical low beam headlamp range. The system must be turned on by the driver and can be activated/deactivated with a button beside the light switch. The system is functional at speeds above 6 mph.

Night View Assist Plus is a vision aid system that uses infrared headlamps to illuminate upcoming obstacles (pedestrians, cyclists, animals etc) whose images are projected onto a multifunction display in the instrument cluster to give the driver advance notice beyond typical low beam headlamp range. An advanced algorithm enables additional highlighting of pedestrians. The system must be turned on by the driver and can be activated/deactivated with a button beside the light switch. The system is functional at speeds above 6 mph.

Side systems

Blind Spot Assist uses radar sensors integrated in the rear bumper to monitor the area up to 10 feet behind and directly next to the vehicle. The system provides a warning display in the exterior mirrors to alert the driver to the presence of vehicles in the monitored area. If a vehicle is present in the monitored area, a red warning lamp is illuminated in the corresponding exterior rearview mirror. If the driver signals to change into that lane, the warning lamp flashes, accompanied by a warning tone. Blind Spot Assist must be turned on by the driver and can be activated/deactivated via the instrument cluster controls. At the next ignition cycle, the system will be in the previous on/off setting. The system is functional at speeds above 20 mph.

Lane Keeping Assist monitors the area in front of the vehicle by means of a camera at the top of the windshield. The system detects lane markings on the road and provides a 1.5-second steering wheel vibration as a warning when the front wheel passes over a lane marking. Lane Keeping Assist is activated/deactivated via the instrument cluster controls and is functional at speeds above 40 mph.

Low-speed maneuvering systems

Parktronic is an electronic parking aid which uses ultrasonic sensors in the front and rear bumpers to provide visual and audible indications of the distance between the vehicle and an object. The system helps drivers avoid obstacles outside the typical field of vision. Parktronic is functional at or below 11 mph and is activated automatically when both the parking brake is released and the transmission position is D, R or N. The system can be activated manually via a center console switch. Results for another, nearly identical system known as Park Assist are included with the Parktronic results.

Parking Guidance, using ultrasonic sensors in the front bumper, detects appropriately-sized parking spaces, measures them, and then displays steering instructions in the instrument cluster to guide the vehicle into the space. The system is automatically activated at or below 22 mph and can be deactivated/reactivated via a center console switch.

The **backup camera** is an optical parking aid that uses a rear-facing camera mounted at the rear of the vehicle to show the area behind the vehicle on a central display screen. The image may include static distance/guidance lines to aid in parking maneuvers. The display is activated when reverse gear is engaged.

Method

Vehicles

These features are offered as optional equipment on various Mercedes-Benz models. The number of features, and the number of models on which the features were available has increased over the years. The presence or absence of these features is not discernible from the information encoded in the vehicle identification numbers (VINs), but rather, this must be determined from build information maintained by the manufacturer. Mercedes-Benz supplied HLDI with the VINs for any vehicles that were equipped with at least one of the collision avoidance features listed above. Vehicles of the same model year and series not identified by Mercedes-Benz were assumed not to have these features and thus served as the control vehicles in the analysis.

In addition to the listed features, Mercedes-Benz also provided information on feature availability for Attention Assist (driver drowsiness detection) and Pre-Safe® (which tightens seat belts, closes windows, and makes other adjustments ahead of a collision, but does not include autonomous braking). However, for every series and model year combination these features are either standard equipment or not available. They are never optional equipment; consequently, the analysis technique used in this study cannot separate the effect of the feature from the vehicle series.

Some of the analyzed features are always bundled together on a vehicle and are not available individually. The bundled features vary between vehicle series and by model year. For example, the 2010 E-Class vehicles that have Blind Spot Assist also have Lane Keeping Assist. The functionality of several of the features varied by vehicle series and/or by model year. For example, vehicles with rear cameras can have one of three display types. Some displays have no guidelines, some have static guidelines while others have dynamic guidelines. Additional analysis was conducted to determine if the feature differences were associated with measurable differences in loss results. For every feature, the variant with the most exposure had an estimate that was similar to the combined estimate. **Table 1** lists the vehicle series and model years included in the analysis. In addition, exposure for each vehicle, measured in insured vehicle years is listed. For each vehicle, the percentage of the exposure that can be attributed to each feature is listed. The Maybach 57 and Maybach 62 are included in the analysis because Maybach and Mercedes-Benz are both owned by Daimler AG, and the two makes have similar crash avoidance features. However, the Maybach vehicles do not contribute significant exposure.

Table 1 : Feature exposure by vehicle series															
Make	Series	Model year range	Distronic	Distronic Plus	High Intensity Discharge Headlights	Active Curve Illumination	Active Cornering Lights	Adaptive High Beam Assist	Night View Assist/Plus	Blind Spot Assist	Lane Keeping Assist	Parktronic	Parking Guidance	Backup camera	Total exposure (insured vehicle years)
Maybach	57 4dr	2004-10	100%		32%	32%	32%							24%	1,396
Maybach	62 4dr	2004-10	100%		40%	40%	40%							32%	377
Mercedes-Benz	C class 2dr	2003-05			3%		1%								96,166
Mercedes-Benz	C class 4dr	2003-10			11%		5%							<1%	1,065,426
Mercedes-Benz	C class 4dr 4WD	2003-10			7%		6%							<1%	369,242
Mercedes-Benz	C class station wagon	2003-05			4%		1%								19,489
Mercedes-Benz	C class station wagon 4WD	2003-05			7%		1%								23,493
Mercedes-Benz	CL class 2dr	2000-10	9%	5%	13%	13%	13%		12%	2%		46%	2%	12%	100,834
Mercedes-Benz	CL class 2dr 4WD	2009-10		20%	100%	100%	100%		95%	20%		100%	20%	95%	1,515
Mercedes-Benz	CLK class 2dr	2003-09	1%		34%	7%	9%					4%			196,186
Mercedes-Benz	CLK class convertible	2004-09	<1%		33%	12%	18%					5%			203,180
Mercedes-Benz	CLS class 4dr	2006-10	2%		57%	57%	28%					33%			127,286
Mercedes-Benz	E class 2dr	2010		7%	43%	43%	43%	43%				7%	7%	96%	10,331
Mercedes-Benz	E class 4dr	2000-10	<1%	<1%	15%	8%	3%	1%	<1%	<1%	<1%	4%	<1%	2%	1,523,146
Mercedes-Benz	E class 4dr 4WD	2000-02, 2004-10	<1%	1%	13%	11%	6%	2%	<1%	1%	1%	5%	1%	5%	404,621
Mercedes-Benz	E class station wagon	2000-09	<1%		6%	4%	<1%					1%			58,974
Mercedes-Benz	E class station wagon 4WD	2000-09	1%		16%	10%	3%					1%			92,929
Mercedes-Benz	G class 4dr 4WD	2003-10										70%		10%	29,319
Mercedes-Benz	GL class 4dr 4WD	2007-10	1%		40%	40%	37%					91%		69%	174,304
Mercedes-Benz	GLK class 4dr	2010			3%	3%	3%					3%		25%	11,585
Mercedes-Benz	GLK class 4dr 4WD	2010			9%	9%	9%					7%		44%	30,135
Mercedes-Benz	M class 4dr	2009-10	<1%		3%	3%	3%					7%		91%	9,734
Mercedes-Benz	M class 4dr 4WD	2002-10	<1%		13%	7%	7%					6%		18%	956,934
Mercedes-Benz	M class hybrid 4dr 4WD	2010			33%	33%	33%					34%		99%	672
Mercedes-Benz	R class 4dr	2008	<1%		3%	3%	3%					96%		39%	5,578
Mercedes-Benz	R class 4dr 4WD	2006-10	1%		10%	10%	10%					49%		21%	124,906
Mercedes-Benz	S class 4dr	2000-10	3%	2%	27%	15%	15%	1%	4%	1%	<1%	24%	1%	6%	861,865

Make	Series	Model year range	Distronic	Distronic Plus	High Intensity Discharge Headlights	Active Curve Illumination	Active Cornering Lights	Adaptive High Beam Assist	Night View Assist/Plus	Blind Spot Assist	Lane Keeping Assist	Parktronic	Parking Guidance	Backup camera	Total exposure (insured vehicle years)
Mercedes-Benz	S class 4dr 4WD	2003-10	2%	3%	74%	37%	37%	3%	13%	2%	<1%	43%	4%	19%	136,225
Mercedes-Benz	S class hybrid 4dr	2010		18%	100%	97%	96%	97%	18%	18%	18%	83%	83%	83%	968
Mercedes-Benz	SL class convertible	2003-09	7%		67%	4%	18%					26%			285,781
Mercedes-Benz	SLK class convertible	2005-10			22%		11%					<1%			144,386

Table 1 : Feature exposure by vehicle series

Insurance data

Automobile insurance covers damages to vehicles and property as well as injuries to people involved in crashes. Different insurance coverages pay for vehicle damage versus injuries, and different coverages may apply depending on who is at fault. The current study is based on property damage liability, collision, bodily injury liability, personal injury protection and medical payment coverages. Exposure is measured in insured vehicle years. An insured vehicle year is one vehicle insured for one year, two for six months, etc.

Because different crash avoidance features may affect different types of insurance coverage, it can be important to understand how coverages vary among the states and how this affects inclusion in the analyses. Collision coverage insures against vehicle damage to an at-fault driver's vehicle sustained in a crash with an object or other vehicle; this coverage is common to all 50 states. Property damage liability (PDL) coverage insures against vehicle damage that at-fault drivers cause to other people's vehicle and property in crashes; this coverage exists in all states except Michigan, where vehicle damage is covered on a no-fault basis (each insured vehicle pays for its own damage in a crash, regardless of who's at fault). Coverage of injuries is more complex. Bodily injury (BI) liability coverage insures against medical, hospital, and other expenses for injuries that at-fault drivers inflict on occupants of other vehicles or others on the road; although motorists in most states may have BI coverage, this information is analyzed only in states where the at-fault driver has first obligation to pay for injuries (33 states with traditional tort insurance systems). Medical payment coverage (MedPay), also sold in the 33 states with traditional tort insurance systems, covers injuries to insured drivers and the passengers in their vehicles, but not injuries to people in other vehicles involved in the crash. Seventeen other states employ no-fault injury systems (personal injury protection coverage, or PIP) that pay up to a specified amount for injuries to occupants of involved-insured vehicles, regardless of who's at fault in a collision. The District of Columbia has a hybrid insurance system for injuries and is excluded from the injury results.

Statistical methods

Regression analysis was used to quantify the effect of each vehicle feature while controlling for the other features and covariates. The covariates included calendar year, model year, garaging state, vehicle density (number of registered vehicles per square mile), rated driver age, rated driver gender, rated driver marital status, deductible range (collision coverage only), and risk. For each safety feature supplied by the manufacturer a binary variable was included. Based on the model year and series a single variable called SERIESMY was created for inclusion in the regression model. Statistically, including such a variable in the regression model is equivalent to including the interaction of series and model year. Effectively, this variable restricted the estimation of the effect of each feature within series and model year, preventing the confounding of the collision avoidance feature effects with other vehicle design changes that could occur from model year to model year.

Claim frequency was modeled using a Poisson distribution, whereas claim severity (average loss payment per claim) was modeled using a Gamma distribution. Both models used a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models. Estimates for frequency, severity, and overall losses are presented for collision and property damage liability. For PIP, BI, and MedPay three frequency estimates are presented. The first frequency is the frequency for all claims, including those that already have been paid and those for which money has been set aside for possible payment in the future, known as claims with reserves. The other two frequencies include only paid claims separated into low and high severity ranges. Note that the percentage of all injury claims that were paid by the date of analysis varies by coverage: 79.6 percent for PIP, 68.4 percent for BI, and 67.5 percent for MedPay. The low severity range was <$1,000 for PIP and MedPay, <$5,000 for BI; high severity covered all loss payments greater than that.

A separate regression was performed for each insurance loss measure for a total of 15 regressions (5 coverages x 3 loss measures each). For space reasons, only the estimates for the individual crash avoidance features are shown on the following pages. To illustrate the analyses, however, the **Appendix** contains full model results for collision claim frequencies. To further simplify the presentation here, the exponent of the parameter estimate was calculated, 1 was subtracted, and the resultant multiplied by 100. The resulting number corresponds to the effect of the feature on that loss measure. For example, the estimate of Distronic's effect on PDL claim frequency was -0.07373; thus, vehicles with Distronic had 7.1 percent fewer PDL claims than expected (exp(-0.07373)-1*100=-7.1).

Results

Table 2 lists all of the PDL claim frequency, severity and overall loss results by feature. Two-thirds of the features show a frequency benefit. Severities and overall losses show mixed results with overall losses for most features showing a benefit. Significant results are indicated in blue in this and subsequent tables.

Table 2 : Property damage liability losses by feature

Feature	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Distronic	-12.0%	**-7.1%**	-1.9%	-$100	$58	$225	-$10	-$4	$2
Distronic Plus	-23.3%	**-14.3%**	-4.2%	-$191	$126	$479	-$19	-$8	$4
High Intensity Discharge Headlights	-7.2%	**-5.5%**	-3.7%	$15	**$70**	$126	-$5	**-$3**	$0
Active Curve Illumination	-7.7%	**-4.7%**	-1.6%	-$52	$41	$136	-$6	-$3	$1
Active Cornering Lights	-1.4%	1.7%	4.9%	-$148	-$60	$30	-$4	$0	$3
Adaptive High Beam Assist	-16.7%	-5.9%	6.2%	-$555	-$252	$91	-$22	-$11	$2
Night View Assist/Plus	-14.3%	**-8.1%**	-1.3%	-$313	-$125	$77	-$16	**-$10**	-$2
Blind Spot Assist	-20.5%	0.4%	26.9%	-$746	-$158	$590	-$26	-$4	$27
Lane Keeping Assist	-14.6%	10.9%	43.9%	-$548	$150	$1,057	-$16	$13	$55
Parktronic	-3.7%	-1.8%	0.2%	$60	**$119**	$180	$0	$2	$4
Parking Guidance	-9.1%	5.0%	21.2%	-$297	$128	$623	-$9	$8	$28
Backup camera	-3.9%	-0.5%	3.1%	-$13	$91	$199	-$2	$2	$6

Results for Mercedes-Benz's Distronic, an adaptive cruise control and forward collision warning system, are summarized in **Table 3**. Here and in subsequent tables, the lower and upper bounds represent the 95 percent confidence limits for the estimates. For vehicle damage losses, frequency of claims are generally down while the average cost of the remaining claims is higher. The reduction in frequency of property damage liability claims, 7.1 percent was statistically significant as was the increase in severity and overall losses for collision.

For injury losses, overall frequency of claims (paid plus reserved) decrease for all coverages, with the decrease for medical payments being significant. Among paid claims, MedPay had a significant reduction at the higher severity.

Table 3 : Change in insurance losses for Distronic

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-6.1%	-3.1%	0.0%	$586	**$813**	$1,049	$24	**$45**	$67
Property damage liability	-12.0%	**-7.1%**	-1.9%	-$100	$58	$225	-$10	-$4	$2

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-15.6%	-4.0%	9.1%	-15.2%	5.7%	31.7%	-25.5%	-7.3%	15.3%
Medical payments	-34.8%	**-23.1%**	-9.3%	-60.9%	-35.0%	7.9%	-37.0%	**-21.3%**	-1.6%
Personal injury protection	-13.3%	-1.7%	11.4%	-35.2%	-11.2%	21.7%	-12.0%	3.0%	20.5%

Results for Mercedes-Benz's Distronic Plus, an adaptive cruise control and forward collision warning system with collision mitigation braking functionality, are summarized in **Table 4**. Reductions in loss claims are estimated for both first- and third-party vehicle damage coverages, resulting in somewhat lower losses per insured vehicle year (overall losses). Only the frequency reductions for collision and PDL were significant.

Under injury coverages, the frequency of paid and reserved claims is lower for all coverage types but none of the differences is statistically significant. Among paid claims, reductions are seen for all coverage types at both low and high severity.

Table 4 : Change in insurance losses for Distronic Plus

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-12.8%	**-7.1%**	-1.0%	-$258	$145	$578	-$54	-$18	$20
Property damage liability	-23.3%	**-14.3%**	-4.2%	-$191	$126	$479	-$19	-$8	$4

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-36.7%	-16.0%	11.4%	-49.3%	-14.6%	44.1%	-44.8%	-11.1%	43.4%
Medical payments	-43.2%	-21.1%	9.6%	-74.7%	-24.9%	123.4%	-50.5%	-21.6%	24.2%
Personal injury protection	-34.9%	-15.1%	10.7%	-73.9%	-42.8%	25.3%	-42.0%	-17.3%	17.9%

Results for Mercedes-Benz's High Intensity Discharge Headlights are summarized in **Table 5**. For vehicle damage losses, the frequency of claims is down for property damage liability and little-changed for collision coverage. Claim severity is significantly higher for both coverages, resulting in significantly higher overall collision losses and a small significant decrease in PDL overall losses.

Under injury coverages, the frequency of paid plus reserved claims decreases for all coverages, and the decreases for MedPay and PIP are significant. Among paid claims, reductions are seen for all coverage types at both low and high severity with some of the reductions being significant.

Table 5 : Change in insurance losses for High Intensity Discharge Headlights

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-0.3%	0.8%	1.9%	$478	**$553**	$629	$36	**$44**	$51
Property damage liability	-7.2%	**-5.5%**	-3.7%	$15	**$70**	$126	-$5	**-$3**	$0

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-9.0%	-4.5%	0.3%	-14.9%	-7.4%	0.8%	-11.3%	-3.8%	4.4%
Medical payments	-14.4%	**-9.7%**	-4.8%	-15.8%	-2.9%	11.9%	-18.3%	**-12.1%**	-5.5%
Personal injury protection	-10.2%	**-6.4%**	-2.6%	-19.1%	**-11.0%**	-2.0%	-10.7%	**-5.9%**	-0.9%

Results for Mercedes-Benz's Active Curve Illumination are summarized in **Table 6**. For vehicle damage losses, frequency of claims are down for PDL and little-changed for collision. The severity of claims increased for both coverages, resulting in a small increase in overall losses under collision and a small decrease in PDL overall losses, while the average cost of the remaining claims is higher. The change in frequency under PDL coverage is significant while the increase in severity for collision coverage is also significant.

Under injury coverages, the frequency of paid plus reserved claims decreases for all coverage types, and the decreases for bodily injury and MedPay are significant. Among paid claims, reductions are seen for all coverage types at both low and high severity although most of the reductions were not statistically significant.

Table 6 : Change in insurance losses for Active Curve Illumination

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-2.7%	-0.8%	1.1%	$50	**$172**	$296	-$2	$9	$21
Property damage liability	-7.7%	**-4.7%**	-1.6%	-$52	$41	$136	-$6	-$3	$1

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-17.3%	**-9.9%**	-1.7%	-22.7%	-9.9%	5.0%	-18.0%	-5.1%	9.8%
Medical payments	-21.7%	**-14.0%**	-5.5%	-46.2%	**-29.1%**	-6.5%	-25.5%	**-15.3%**	-3.6%
Personal injury protection	-8.6%	-1.9%	5.3%	-16.0%	-0.9%	16.9%	-9.5%	-0.7%	8.9%

Results for Mercedes-Benz's Active Cornering Light System are summarized in **Table 7**. For vehicle damage losses, frequency claims are down for collision and up for property damage liability. The decrease in frequency, severity and overall losses for collision are significant.

For injury losses, overall frequency of claims (reserved plus paid) is higher for both BI and MedPay, but not for PIP, and the decrease for PIP is statistically significant. Among paid claims, the pattern is unclear.

Table 7 : Change in insurance losses for Active Cornering Lights

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-4.5%	**-2.7%**	-0.9%	-$308	**-$198**	-$85	-$35	**-$24**	-$14
Property damage liability	-1.4%	1.7%	4.9%	-$148	-$60	$30	-$4	$0	$3

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-5.1%	3.2%	12.2%	-11.5%	2.8%	19.5%	-7.4%	6.6%	22.8%
Medical payments	-2.9%	6.2%	16.2%	-20.2%	3.5%	34.2%	-0.1%	13.1%	28.0%
Personal injury protection	-13.5%	**-7.4%**	-0.8%	-16.2%	-1.5%	15.8%	-19.6%	**-12.1%**	-3.8%

Results for Mercedes-Benz's Adaptive High Beam Assist System are summarized in **Table 8**. Non-significant reductions in loss claims, severity and overall losses are estimated for both first- and third-party vehicle damage coverages.

For injury losses, overall frequency of claims (reserved plus paid) is higher for both BI and PIP, but not for MedPay. Among paid claims, a similar pattern appears with increases for BI and PIP, and a decrease for MedPay. None of the estimates are significant.

Table 8 : Change in insurance losses for Adaptive High Beam Assist

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-7.2%	-0.7%	6.3%	-$544	-$136	$305	-$51	-$13	$30
Property damage liability	-16.7%	-5.9%	6.2%	-$555	-$252	$91	-$22	-$11	$2

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-13.3%	32.6%	102.9%	-34.5%	73.1%	357.2%	-51.6%	8.8%	144.6%
Medical payments	-43.5%	-17.0%	21.9%	-73.6%	-23.2%	123.6%	-45.5%	-6.5%	60.4%
Personal injury protection	-14.0%	12.9%	48.2%	-29.5%	27.3%	130.1%	-20.4%	14.7%	65.4%

Combined results for Mercedes-Benz's Night View Assist and Night View Assist Plus, vision aid systems are summarized in **Table 9**. Again, the lower and upper bounds represent the 95 percent confidence limits for the estimates. Significant reductions in loss claims are estimated for both 1st and 3rd party vehicle damage coverages.

For injury losses, overall frequency of claims (reserved plus paid) decrease for all coverages, but none of the decreases is significant. The pattern is unclear for paid claims.

Table 9 : Change in insurance losses for Night View Assist/Plus

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-8.1%	**-4.1%**	-0.1%	$160	**$441**	$736	-$11	$14	$41
Property damage liability	-14.3%	**-8.1%**	-1.3%	-$313	-$125	$77	-$16	**-$10**	-$2

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-20.0%	-2.5%	18.9%	-35.4%	-7.3%	33.0%	-31.9%	-4.5%	34.1%
Medical payments	-23.2%	-4.1%	19.9%	-44.0%	11.9%	123.6%	-23.5%	4.4%	42.6%
Personal injury protection	-23.3%	-9.7%	6.3%	-45.1%	-18.7%	20.6%	-21.9%	-2.8%	21.1%

Results for Mercedes-Benz's Blind Spot Assist are summarized in **Table 10**. For vehicle damage losses, frequency claims are down for collision and up for property damage liability coverage, neither is significant. Severity and overall losses are down non-significantly for both coverages.

For injury losses, overall frequency of claims (reserved plus paid) decrease for all coverages, but none of the decreases are significant. The pattern is unclear for low- and high-severity paid claims.

Table 10 : Change in insurance losses for Blind Spot Assist

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-12.4%	-0.1%	13.8%	-$1,161	-$433	$415	-$99	-$32	$50
Property damage liability	-20.5%	0.4%	26.9%	-$746	-$158	$590	-$26	-$4	$27

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-50.8%	-3.6%	88.8%	-81.6%	-30.8%	160.3%	-67.8%	37.3%	485.9%
Medical payments	-65.0%	-26.5%	54.4%	-96.5%	-56.5%	436.5%	-79.5%	-40.3%	73.7%
Personal injury protection	-49.7%	-7.2%	71.2%	-54.0%	108.5%	845.4%	-61.7%	-10.0%	111.5%

Results for Mercedes-Benz's Lane Keeping Assist are summarized in **Table 11**. For vehicle damage losses, frequency of claims, severity and overall losses are generally up. The increases in severity and overall losses for collision coverage are significant.

Under injury coverages, the pattern is unclear, and the confidence bounds for all estimated effects are quite large. The central finding here is that data are insufficient.

Table 11 : Change in insurance losses for Lane Keeping Assist

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-8.5%	5.6%	22.0%	$3	**$1,010**	$2,199	$1	**$99**	$222
Property damage liability	-14.6%	10.9%	43.9%	-$548	$150	$1,057	-$16	$13	$55

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-56.7%	-2.8%	118.3%	-46.4%	138.8%	964.6%	-85.5%	-19.5%	346.7%
Medical payments	-8.0%	106.5%	363.8%	-21.9%	844.4%	11,321.2%	-52.5%	67.0%	486.6%
Personal injury protection	-43.7%	10.6%	117.4%	-85.2%	-25.6%	274.7%	-43.0%	41.7%	252.3%

Results for Mercedes-Benz's Parktronic are summarized in **Table 12**. The lower and upper bounds represent the 95 percent confidence limits for the estimates. For vehicle damage losses, frequency claims are down for property damage liability and up for collision coverage, but neither result is significant. Claim severity is significantly higher for both coverages, resulting in significantly higher overall collision losses and a small, statistically insignificant increase in PDL overall losses.

Under injury coverages, the frequency of paid and reserved claims is significantly lower for both MedPay and PIP, but not for BI. Among paid claims, reductions are seen for all coverage types at both low and high severity with the reductions at high seveity for MedPay and PIP being significant.

Table 12 : Change in insurance losses for Parktronic

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-0.5%	0.8%	2.0%	$185	**$264**	$343	$15	**$22**	$30
Property damage liability	-3.7%	-1.8%	0.2%	$60	**$119**	$180	$0	$2	$4

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-4.7%	0.5%	5.9%	-9.5%	-0.6%	9.1%	-11.2%	-2.8%	6.2%
Medical payments	-12.1%	**-6.7%**	-0.9%	-19.9%	-5.0%	12.6%	-17.6%	**-10.5%**	-2.7%
Personal injury protection	-11.6%	**-7.3%**	-2.8%	-15.0%	-5.0%	6.1%	-13.6%	**-8.1%**	-2.3%

Results for Mercedes-Benz's Parking Guidance system are summarized in **Table 13**. Non-significant increases in loss claims, severity and overall losses are estimated for both first- and third-party vehicle damage coverages.

Under injury coverages, the pattern is unclear and some of the confidence bounds are quite large.

Table 13 : Change in insurance losses for Parking Guidance

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-1.8%	6.3%	15.2%	-$326	$198	$775	-$11	$40	$99
Property damage liability	-9.1%	5.0%	21.2%	-$297	$128	$623	-$9	$8	$28

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-37.4%	1.6%	65.2%	-43.9%	57.4%	341.5%	-84.2%	-51.8%	46.8%
Medical payments	-28.1%	10.7%	70.3%	-64.2%	15.5%	272.9%	-40.3%	11.8%	109.3%
Personal injury protection	-30.8%	-1.6%	39.9%	-77.4%	-46.3%	27.4%	-35.8%	2.7%	64.4%

Results for Mercedes-Benz's backup camera are summarized in **Table 14**. For physical damage losses, frequency claims are down slightly for property damage liability and up slightly for collision coverage, neither is significant.

For injury losses, overall frequency of claims (reserved plus paid) is higher for both BI and MedPay, but not for PIP. Among paid claims, the pattern is unclear.

Table 14 : Change in insurance losses for backup camera

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-1.9%	0.5%	2.9%	-$156	-$6	$149	-$13	$1	$16
Property damage liability	-3.9%	-0.5%	3.1%	-$13	$91	$199	-$2	$2	$6

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-0.8%	10.8%	23.7%	-12.5%	6.4%	29.3%	-5.2%	14.7%	38.8%
Medical payments	-10.7%	1.3%	14.9%	-24.7%	8.1%	55.1%	-17.4%	-1.2%	18.1%
Personal injury protection	-11.9%	-4.0%	4.7%	-24.3%	-7.8%	12.4%	-11.9%	-1.3%	10.7%

Discussion

Forward collision warning

Distronic and Distronic Plus are forward collision warning systems that differ in two principal ways: In addition to warnings, Distronic Plus will apply brakes autonomously in certain situations, and it is active at lower speeds in following traffic (0-120 mph vs. 20-120 mph for Distronic). Both systems are expected to have larger benefits for PDL coverage than collision coverage because a larger proportion of PDL crashes are two-vehicle front-to-rear-end crashes that occur in following traffic where the systems would be active (compared with collision coverage, under which some number of crashes are single-vehicle). In addition, Distronic Plus should have larger effects than Distronic because of the autonomous braking feature and because it is operative at lower speeds. Although there is overlap among the relevant confidence intervals, results are directionally consistent with these expectations. Both Distronic Plus and Distronic reduced PDL claim frequency significantly and to a greater extent than collision claim frequency. Additionally, Distronic Plus was associated with greater reductions in PDL claim frequency than Distronic.

To further explore the differences between Distronic and Distronic Plus, PDL claims were categorized as low cost (<$1500), medium cost ($1500-$6999), or high cost ($7000+). Results (see **Table 15**) indicate that Distronic and Distronic Plus had similar effects on medium severity claims, while Distronic Plus had much stronger effects on low severity claims (perhaps because of the lower activation speed in following traffic) and in high severity claims (perhaps because of the adaptive braking assistance and/or the autonomous braking features), although the high severity estimates have wide confidence bounds. Mercedes-Benz's own studies have shown that the addition of autonomous braking to vehicles reduces or mitigates crashes (Breuer and Feldmann, 2011).

Both Distronic and Distronic Plus also appear to reduce the frequency of injury claims, although only the reduction under medical payments coverage for Distronic is statistically significant. Ultimately, one would expect a reduction in bodily injury liability claims corresponding to the reduction in PDL claims, but that effect is not yet statistically reliable.

Table 15 : Property damage liability claim frequencies by claim severity range, Distronic and Distronic Plus

	Lower bound	Frequency <$1,500	Upper bound	Lower bound	Frequency $1,500 - $6,999	Upper bound	Lower bound	Frequency $7,000+	Upper bound
Distronic	-12.9%	-5.6%	2.3%	-16.8%	**-9.6%**	-1.8%	-17.9%	-3.3%	13.8%
Distronic Plus	-31.7%	**-18.7%**	-3.3%	-24.8%	-11.5%	4.2%	-34.0%	-9.4%	24.3%

In sum, Mercedes-Benz's forward collision warning systems appear to be reducing front-to-rear crashes with observable benefits for PDL coverage but not yet for BI liability coverage. Encouragingly, the increase in collision coverage costs observed for Distronic — associated with a greater average severity of claim — appears to have dissipated for Distronic Plus.

Headlamp improvements

Mercedes-Benz has introduced several new headlamp systems in recent years. From a collision avoidance perspective, their Active Curve Illumination system is similar to adaptive headlamp systems introduced by other automakers. In these systems, headlamps respond to steering inputs to help drivers illuminate curves. It was expected that these lamps would reduce crashes, but it was also expected that the crashes affected would be largely single-vehicle, run-off-road crashes. However, collision claims were least affected by Mercedes-Benz's Active Curve Illumination. Instead, PDL claims, along with some injury coverages, saw significant reductions in frequency. Although these results confirm a significant benefit for insurance claims of adaptive headlamps, further research is needed to explore the kinds of crashes that are being affected.

In addition to Active Curve Illumination, benefits also were observed for Mercedes-Benz's HID lamps. HID lamps resulted in significant reductions in claim frequency for PDL, MedPay and PIP compared with halogen lamps. One important caveat, however, is that the severity of collision coverage claims rose more than $500, resulting in increased loss costs of $44 per insured vehicle year.

Mercedes-Benz's active cornering light system also seemed beneficial. Although effects were small, this low speed corner illumination system reduced collision overall losses by $24 per insured vehicle year and PIP coverage claims by more than 7 percent.

Night vision enhancement

Both collision and PDL claim frequency decreased significantly for vehicles with Night View Assist or Night View Assist Plus. However, the average collision claim severity increased sharply for these vehicles. An additional analysis (see **Table 16**) of collision claim frequency categorized into four severity ranges indicated that the increase in average claim cost was likely due to a much larger frequency reduction among low-cost claims than more expensive ones, rather than a higher cost to repair vehicles with the night vision system. None of the injury coverages were affected significantly, although all showed declines in claim frequency.

Table 16 : Collision claim frequencies by claim severity range, Night View Assist/Plus

	Lower bound	Frequency < $2,000	Upper bound	Lower bound	Frequency $2,000 to $4,999	Upper bound	Lower bound	Frequency $5,000 to $11,999	Upper bound	Lower bound	Frequency $12,000+	Upper bound
Night View Assit/Plus	-13.6%	**-7.4%**	-0.7%	-10.5%	-2.9%	5.4%	-11.1%	-2.6%	6.7%	-10.9%	-1.5%	8.9%

Side systems

Blind Spot Assist: Collision and PDL coverages essentially showed no effect. Injury coverages all indicated reduced claim frequency, but reductions were not statistically significant and the confidence intervals were quite large.

Lane Keeping Assist: Again, lack of data meant that confidence intervals for all coverages were large, and no effects were statistically significant. However, it is noteworthy that only a single coverage, BI liability, showed a reduction in claim frequency. All other estimates suggested an increase in claim frequency with Lane Keeping Assist.

Low-speed maneuvering

Parktronic: This system is intended to reduce low-speed collisions occurring in parking maneuvers, which would be expected to lead to benefits for collision and PDL coverages. Despite high exposure rates and correspondingly small confidence intervals for estimated effects, there was no evidence of these expected benefits. Not only did collision and PDL claim frequency not decline, but the severity of those claims actually increased for vehicles with Parktronic, such that overall losses were higher. While the increase in collision costs might be explained by the expense of replacing damaged sensors that support this system, the increase in average PDL cost suggests higher-severity crashes. Equally unexpected was that Parktronic was associated with fewer MedPay and PIP claims. These findings will require further research to understand.

An additional analysis (see **Table 17**) of collision claim frequency categorized into four severity ranges indicated that the minimal increase in claim frequency is the result of a significant decrease for low-cost claims and significant increases for higher-cost claims. This reduction in low-cost claims may indicate that Parktronic is performing as expected in reducing low speed collisions. The increasing frequencies at higher severities may indicate that there is something else happening with these vehicles that needs to be explored with further research. Similar results are seen for property damage liability claim frequency by severity range (see **Table 18**). A significant decline is seen for low cost claims and non-significant increases at the higher ranges.

Table 17 : Collision claim frequencies by claim severity range, Parktronic

	Lower bound	Frequency < $2,000	Upper bound	Lower bound	Frequency $2,000 to $4,999	Upper bound	Lower bound	Frequency $5,000 to $11,999	Upper bound	Lower bound	Frequency $12,000+	Upper bound
Parktronic	-6.1%	**-4.2%**	-2.2%	0.2%	**2.6%**	5.1%	0.8%	**3.6%**	6.5%	3.1%	**6.4%**	9.8%

Table 18 : Property damage liability claim frequencies by claim severity range, Parktronic

	Lower bound	Frequency <$1,500	Upper bound	Lower bound	Frequency $1,500 - $6,999	Upper bound	Lower bound	Frequency $7,000+	Upper bound
Parktronic	-7.4%	**-4.6%**	-1.8%	-2.6%	0.3%	3.4%	-4.1%	2.2%	8.9%

Parking Guidance: This system is intended to help drivers identify and enter parallel parking spaces. Parking Guidance had no significant effect on claims experience. Although confidence intervals were large, it should be noted that most effect estimates suggested an increase in claims.

Backup camera: It has been thought that rearview cameras could reduce not only minor property damage from parking incidents, but also injuries from crashes involving cars backing into children. In this case, the Mercedes-Benz system showed no effect on any insurance coverage. However, this is a relatively weak analysis for injury effects involving pedestrians. Additional analyses, looking at bodily injury liability claims in the absence of collision or PDL claims, are under way.

Limitations

There are limitations to the data used in this analysis. At the time of a crash, the status of a feature is not known. Many of the features in this study can be deactivated by the driver and there is no way to know how many, if any, of the drivers in these vehicles had manually turned off the system prior to the crash. If a significant number of drivers do turn these features off, any reported reductions may actually be underestimates of the true effectiveness of these systems.

Additionally, the data supplied to HLDI do not include detailed crash information. Information including point of impact is not available. The technologies in this report target certain crash types. For example, the backup camera is designed to prevent collisions when a vehicle is backing up. Transmission status is not known. Therefore, all collisions regardless of the ability of a feature to mitigate or prevent the crash are included in the analysis.

All of these features are optional and are associated with increased costs. The type of person who selects these options may be different from the person who declines. While the analysis controls for several driver characteristics, there may be other uncontrolled attributes associated with people who select these features.

Reference

Breuer, J. and Feldmann, M. 2011. Safety potential of advanced driver assistance systems. Proceedings of the 20th Aachen Colloquium — Automobile and Engine Technology, 771-79. Aachen, Germany.

Appendix : Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Intercept		1	-8.5886		0.1060	-8.7963	-8.3808	6565.82	<0.0001
Calendar year	1999	1	-0.0245	-2.4%	0.0688	-0.1593	0.1103	0.13	0.7213
	2000	1	0.1690	18.4%	0.0207	0.1285	0.2095	66.88	<0.0001
	2001	1	0.1586	17.2%	0.0141	0.1310	0.1862	126.58	<0.0001
	2002	1	0.0350	3.6%	0.0112	0.0130	0.0570	9.74	0.0018
	2003	1	-0.0785	-7.5%	0.0093	-0.0968	-0.0602	70.88	<0.0001
	2004	1	-0.1047	-9.9%	0.0077	-0.1198	-0.0895	183.44	<0.0001
	2005	1	-0.0961	-9.2%	0.0066	-0.1090	-0.0831	211.64	<0.0001
	2006	1	-0.0942	-9.0%	0.0059	-0.1059	-0.0826	251.32	<0.0001
	2007	1	0.0007	0.1%	0.0053	-0.0098	0.0111	0.02	0.9017
	2008	1	0.0010	0.1%	0.0051	-0.0089	0.0109	0.04	0.8407
	2009	1	-0.0078	-0.8%	0.0049	-0.0174	0.0018	2.55	0.1102
	2011	1	-0.0359	-3.5%	0.0056	-0.0468	-0.0250	41.59	<0.0001
	2010	0	0	0	0	0	0		
Vehicle model year and series	2003 C class 2dr	1	-0.1732	-15.9%	0.1001	-0.3695	0.0230	2.99	0.0835
	2004 C class 2dr	1	-0.1781	-16.3%	0.1019	-0.3779	0.0217	3.05	0.0806
	2005 C class 2dr	1	-0.2557	-22.6%	0.1080	-0.4673	-0.0440	5.61	0.0179
	2003 C class 4dr	1	-0.1904	-17.3%	0.0994	-0.3853	0.0044	3.67	0.0554
	2004 C class 4dr	1	-0.1374	-12.8%	0.0995	-0.3324	0.0576	1.91	0.1673
	2005 C class 4dr	1	-0.0483	-4.7%	0.0993	-0.2430	0.1464	0.24	0.6271
	2006 C class 4dr	1	-0.0480	-4.7%	0.0995	-0.2430	0.1469	0.23	0.6291
	2007 C class 4dr	1	-0.0467	-4.6%	0.0996	-0.2419	0.1485	0.22	0.6393
	2008 C class 4dr	1	-0.0222	-2.2%	0.0995	-0.2173	0.1728	0.05	0.8233
	2009 C class 4dr	1	0.0001	0.0%	0.1001	-0.1960	0.1962	0.00	0.9993
	2010 C class 4dr	1	-0.0218	-2.2%	0.1016	-0.2208	0.1773	0.05	0.8301
	2003 C class 4dr 4WD	1	-0.1579	-14.6%	0.1004	-0.3547	0.0388	2.48	0.1157
	2004 C class 4dr 4WD	1	-0.1549	-14.3%	0.1004	-0.3517	0.0419	2.38	0.1230
	2005 C class 4dr 4WD	1	-0.1388	-13.0%	0.1001	-0.3349	0.0574	1.92	0.1655
	2006 C class 4dr 4WD	1	-0.1655	-15.3%	0.1005	-0.3624	0.0315	2.71	0.0996
	2007 C class 4dr 4WD	1	-0.1468	-13.7%	0.1005	-0.3438	0.0501	2.13	0.1440
	2008 C class 4dr 4WD	1	-0.0427	-4.2%	0.1001	-0.2389	0.1535	0.18	0.6699
	2009 C class 4dr 4WD	1	0.0034	0.3%	0.1007	-0.1939	0.2007	0.00	0.9733
	2010 C class 4dr 4WD	1	-0.0106	-1.1%	0.1015	-0.2096	0.1884	0.01	0.9166
	2003 C class station wagon	1	-0.2678	-23.5%	0.1071	-0.4778	-0.0579	6.25	0.0124
	2004 C class station wagon	1	-0.1472	-13.7%	0.1098	-0.3623	0.0679	1.80	0.1799
	2005 C class station wagon	1	-0.2400	-21.3%	0.1204	-0.4759	-0.0041	3.98	0.0462
	2003 C class station wagon 4WD	1	-0.3310	-28.2%	0.1068	-0.5404	-0.1216	9.60	0.0019
	2004 C class station wagon 4WD	1	-0.1207	-11.4%	0.1083	-0.3329	0.0915	1.24	0.2650
	2005 C class station wagon 4WD	1	-0.2071	-18.7%	0.1106	-0.4239	0.0096	3.51	0.0611
	2000 CL class 2dr	1	-0.2675	-23.5%	0.1107	-0.4845	-0.0504	5.83	0.0157
	2001 CL class 2dr	1	-0.2191	-19.7%	0.1037	-0.4223	-0.0160	4.47	0.0345
	2002 CL class 2dr	1	-0.2194	-19.7%	0.1019	-0.4192	-0.0196	4.63	0.0314
	2003 CL class 2dr	1	-0.2367	-21.1%	0.1039	-0.4403	-0.0330	5.19	0.0227

Appendix : Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	2004 CL class 2dr	1	-0.2469	-21.9%	0.1070	-0.4566	-0.0372	5.32	0.0210
	2005 CL class 2dr	1	-0.2552	-22.5%	0.1104	-0.4715	-0.0389	5.35	0.0207
	2006 CL class 2dr	1	-0.2752	-24.1%	0.1225	-0.5153	-0.0351	5.05	0.0247
	2007 CL class 2dr	1	-0.0752	-7.2%	0.1149	-0.3003	0.1500	0.43	0.5129
	2008 CL class 2dr	1	0.0551	5.7%	0.1090	-0.1585	0.2687	0.26	0.6134
	2009 CL class 2dr	1	0.1648	17.9%	0.1673	-0.1631	0.4928	0.97	0.3246
	2010 CL class 2dr	1	-0.0482	-4.7%	0.3329	-0.7007	0.6043	0.02	0.8849
	2009 CL class 2dr 4WD	1	0.2946	34.3%	0.1439	0.0127	0.5766	4.19	0.0405
	2010 CL class 2dr 4WD	1	0.0942	9.9%	0.1777	-0.2541	0.4424	0.28	0.5961
	2003 CLK class 2dr	1	-0.0595	-5.8%	0.1005	-0.2564	0.1374	0.35	0.5535
	2004 CLK class 2dr	1	-0.0560	-5.4%	0.1001	-0.2522	0.1403	0.31	0.5760
	2005 CLK class 2dr	1	-0.0221	-2.2%	0.1010	-0.2200	0.1758	0.05	0.8268
	2006 CLK class 2dr	1	-0.0363	-3.6%	0.1013	-0.2350	0.1623	0.13	0.7200
	2007 CLK class 2dr	1	-0.0112	-1.1%	0.1026	-0.2124	0.1899	0.01	0.9129
	2008 CLK class 2dr	1	-0.1314	-12.3%	0.1043	-0.3359	0.0731	1.59	0.2078
	2009 CLK class 2dr	1	-0.0655	-6.3%	0.1092	-0.2795	0.1485	0.36	0.5487
	2004 CLK class convertible	1	-0.2387	-21.2%	0.1011	-0.4369	-0.0406	5.58	0.0182
	2005 CLK class convertible	1	-0.2089	-18.9%	0.1002	-0.4053	-0.0124	4.34	0.0372
	2006 CLK class convertible	1	-0.2577	-22.7%	0.1012	-0.4560	-0.0594	6.49	0.0109
	2007 CLK class convertible	1	-0.2499	-22.1%	0.1021	-0.4499	-0.0498	5.99	0.0144
	2008 CLK class convertible	1	-0.1873	-17.1%	0.1026	-0.3884	0.0139	3.33	0.0680
	2009 CLK class convertible	1	-0.0782	-7.5%	0.1063	-0.2866	0.1303	0.54	0.4623
	2006 CLS class 4dr	1	0.0260	2.6%	0.0999	-0.1698	0.2218	0.07	0.7945
	2007 CLS class 4dr	1	0.0073	0.7%	0.1016	-0.1917	0.2064	0.01	0.9426
	2008 CLS class 4dr	1	-0.0510	-5.0%	0.1033	-0.2535	0.1515	0.24	0.6213
	2009 CLS class 4dr	1	0.0171	1.7%	0.1088	-0.1962	0.2305	0.02	0.8749
	2010 CLS class 4dr	1	0.0175	1.8%	0.1491	-0.2747	0.3096	0.01	0.9068
	2010 E class 2dr	1	-0.0442	-4.3%	0.1067	-0.2532	0.1649	0.17	0.6789
	2000 E class 4dr	1	-0.1959	-17.8%	0.0995	-0.3910	-0.0008	3.87	0.0491
	2001 E class 4dr	1	-0.1199	-11.3%	0.0994	-0.3147	0.0749	1.46	0.2276
	2002 E class 4dr	1	-0.0897	-8.6%	0.0997	-0.2850	0.1057	0.81	0.3682
	2003 E class 4dr	1	-0.1666	-15.3%	0.0993	-0.3612	0.0280	2.81	0.0934
	2004 E class 4dr	1	-0.1646	-15.2%	0.0996	-0.3598	0.0305	2.73	0.0982
	2005 E class 4dr	1	-0.2088	-18.8%	0.0997	-0.4042	-0.0133	4.38	0.0363
	2006 E class 4dr	1	-0.1868	-17.0%	0.0995	-0.3819	0.0083	3.52	0.0606
	2007 E class 4dr	1	-0.0915	-8.7%	0.0997	-0.2870	0.1039	0.84	0.3587
	2008 E class 4dr	1	-0.1292	-12.1%	0.1001	-0.3255	0.0671	1.66	0.1971
	2009 E class 4dr	1	-0.0823	-7.9%	0.1017	-0.2816	0.1170	0.65	0.4184
	2010 E class 4dr	1	-0.0690	-6.7%	0.1026	-0.2700	0.1320	0.45	0.5008
	2000 E class 4dr 4WD	1	-0.1559	-14.4%	0.1009	-0.3536	0.0418	2.39	0.1222
	2001 E class 4dr 4WD	1	-0.1350	-12.6%	0.1006	-0.3321	0.0621	1.80	0.1796
	2002 E class 4dr 4WD	1	-0.0601	-5.8%	0.1006	-0.2572	0.1371	0.36	0.5504
	2004 E class 4dr 4WD	1	-0.1062	-10.1%	0.1007	-0.3035	0.0911	1.11	0.2916
	2005 E class 4dr 4WD	1	-0.1231	-11.6%	0.1006	-0.3203	0.0741	1.50	0.2212

Appendix : Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	2006 E class 4dr 4WD	1	-0.1067	-10.1%	0.1001	-0.3028	0.0894	1.14	0.2864
	2007 E class 4dr 4WD	1	-0.0688	-6.6%	0.1007	-0.2662	0.1286	0.47	0.4946
	2008 E class 4dr 4WD	1	-0.0675	-6.5%	0.1003	-0.2641	0.1292	0.45	0.5012
	2009 E class 4dr 4WD	1	0.0163	1.6%	0.1029	-0.1853	0.2179	0.03	0.8741
	2010 E class 4dr 4WD	1	-0.0057	-0.6%	0.1028	-0.2073	0.1958	0.00	0.9555
	2000 E class station wagon	1	-0.1539	-14.3%	0.1041	-0.3579	0.0502	2.19	0.1393
	2001 E class station wagon	1	-0.2003	-18.2%	0.1043	-0.4047	0.0041	3.69	0.0548
	2002 E class station wagon	1	-0.0901	-8.6%	0.1061	-0.2981	0.1178	0.72	0.3957
	2003 E class station wagon	1	-0.2203	-19.8%	0.1274	-0.4700	0.0294	2.99	0.0837
	2004 E class station wagon	1	-0.2036	-18.4%	0.1062	-0.4119	0.0046	3.67	0.0552
	2005 E class station wagon	1	-0.2604	-22.9%	0.1293	-0.5138	-0.0070	4.06	0.0440
	2006 E class station wagon	1	-0.2526	-22.3%	0.1194	-0.4865	-0.0187	4.48	0.0343
	2007 E class station wagon	1	-0.5124	-40.1%	0.3672	-1.2322	0.2073	1.95	0.1629
	2008 E class station wagon	1	-2.0276	-86.8%	1.0049	-3.9972	-0.0580	4.07	0.0436
	2009 E class station wagon	1	-0.2848	-24.8%	0.7140	-1.6843	1.1147	0.16	0.6900
	2000 E class station wagon 4WD	1	-0.1552	-14.4%	0.1041	-0.3593	0.0489	2.22	0.1360
	2001 E class station wagon 4WD	1	-0.1550	-14.4%	0.1030	-0.3569	0.0469	2.26	0.1324
	2002 E class station wagon 4WD	1	-0.0794	-7.6%	0.1035	-0.2824	0.1235	0.59	0.4429
	2003 E class station wagon 4WD	1	-0.1156	-10.9%	0.1150	-0.3409	0.1098	1.01	0.3147
	2004 E class station wagon 4WD	1	-0.1355	-12.7%	0.1030	-0.3373	0.0664	1.73	0.1884
	2005 E class station wagon 4WD	1	-0.1009	-9.6%	0.1065	-0.3095	0.1077	0.90	0.3432
	2006 E class station wagon 4WD	1	-0.0994	-9.5%	0.1093	-0.3135	0.1148	0.83	0.3632
	2007 E class station wagon 4WD	1	-0.1806	-16.5%	0.1161	-0.4082	0.0469	2.42	0.1197
	2008 E class station wagon 4WD	1	-0.1521	-14.1%	0.1194	-0.3860	0.0818	1.62	0.2026
	2009 E class station wagon 4WD	1	-0.1669	-15.4%	0.1397	-0.4408	0.1070	1.43	0.2322
	2003 G class 4dr 4WD	1	-0.2011	-18.2%	0.1054	-0.4077	0.0055	3.64	0.0564
	2004 G class 4dr 4WD	1	-0.1877	-17.1%	0.1111	-0.4054	0.0300	2.86	0.0910
	2005 G class 4dr 4WD	1	-0.1882	-17.2%	0.1105	-0.4048	0.0285	2.90	0.0887
	2006 G class 4dr 4WD	1	-0.4460	-36.0%	0.1902	-0.8187	-0.0732	5.50	0.0190
	2007 G class 4dr 4WD	1	-0.1291	-12.1%	0.1356	-0.3949	0.1368	0.91	0.3413
	2008 G class 4dr 4WD	1	-0.1801	-16.5%	0.1348	-0.4443	0.0842	1.78	0.1817
	2009 G class 4dr 4WD	1	-0.0605	-5.9%	0.1659	-0.3856	0.2647	0.13	0.7155
	2010 G class 4dr 4WD	1	-0.5050	-39.6%	0.2400	-0.9754	-0.0347	4.43	0.0353
	2007 GL class 4dr 4WD	1	-0.1979	-18.0%	0.1002	-0.3943	-0.0016	3.90	0.0482
	2008 GL class 4dr 4WD	1	-0.1816	-16.6%	0.1012	-0.3801	0.0168	3.22	0.0728
	2009 GL class 4dr 4WD	1	-0.1971	-17.9%	0.1038	-0.4006	0.0064	3.60	0.0577
	2010 GL class 4dr 4WD	1	-0.0706	-6.8%	0.1042	-0.2749	0.1336	0.46	0.4981

Appendix : Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	2010 GLK class 4dr	1	-0.0953	-9.1%	0.1050	-0.3010	0.1105	0.82	0.3641
	2010 GLK class 4dr 4WD	1	-0.1101	-10.4%	0.1014	-0.3088	0.0885	1.18	0.2772
	2009 M class 4dr	1	-0.2298	-20.5%	0.1224	-0.4696	0.0100	3.53	0.0604
	2010 M class 4dr	1	-0.2483	-22.0%	0.1112	-0.4663	-0.0303	4.99	0.0256
	2002 M class 4dr 4WD	1	-0.1033	-9.8%	0.0994	-0.2980	0.0915	1.08	0.2988
	2003 M class 4dr 4WD	1	-0.0779	-7.5%	0.0994	-0.2728	0.1170	0.61	0.4335
	2004 M class 4dr 4WD	1	-0.1090	-10.3%	0.0998	-0.3046	0.0867	1.19	0.2751
	2005 M class 4dr 4WD	1	-0.1195	-11.3%	0.0998	-0.3151	0.0762	1.43	0.2313
	2006 M class 4dr 4WD	1	-0.2421	-21.5%	0.0995	-0.4372	-0.0470	5.92	0.0150
	2007 M class 4dr 4WD	1	-0.3078	-26.5%	0.1002	-0.5043	-0.1113	9.43	0.0021
	2008 M class 4dr 4WD	1	-0.2805	-24.5%	0.1007	-0.4780	-0.0831	7.76	0.0053
	2009 M class 4dr 4WD	1	-0.2240	-20.1%	0.1017	-0.4232	-0.0247	4.85	0.0276
	2010 M class 4dr 4WD	1	-0.2168	-19.5%	0.1037	-0.4200	-0.0135	4.37	0.0366
	2010 M class hybrid 4dr 4WD	1	-0.0471	-4.6%	0.1698	-0.3798	0.2857	0.08	0.7816
	2004 Maybach 57 4dr	1	-0.7385	-52.2%	0.2357	-1.2004	-0.2765	9.82	0.0017
	2005 Maybach 57 4dr	1	-0.2121	-19.1%	0.2625	-0.7266	0.3025	0.65	0.4193
	2006 Maybach 57 4dr	1	-0.3006	-26.0%	0.5862	-1.4495	0.8483	0.26	0.6081
	2007 Maybach 57 4dr	1	-0.6473	-47.7%	0.5102	-1.6472	0.3526	1.61	0.2045
	2008 Maybach 57 4dr	1	-0.2328	-20.8%	0.4586	-1.1315	0.6660	0.26	0.6117
	2009 Maybach 57 4dr	1	-6.4240	-99.8%	16.1945	-38.1646	25.3166	0.16	0.6916
	2010 Maybach 57 4dr	1	-5.6552	-99.7%	60.9864	-125.1860	113.8760	0.01	0.9261
	2004 Maybach 62 4dr	1	-0.2180	-19.6%	0.3911	-0.9846	0.5485	0.31	0.5772
	2005 Maybach 62 4dr	1	-0.1585	-14.7%	0.3911	-0.9250	0.6080	0.16	0.6853
	2006 Maybach 62 4dr	1	0.4152	51.5%	0.5862	-0.7338	1.5642	0.50	0.4788
	2007 Maybach 62 4dr	1	-0.5281	-41.0%	1.0051	-2.4981	1.4419	0.28	0.5993
	2008 Maybach 62 4dr	1	-1.2628	-71.7%	1.0051	-3.2329	0.7072	1.58	0.2090
	2009 Maybach 62 4dr	1	0.9019	146.4%	0.5862	-0.2470	2.0508	2.37	0.1239
	2010 Maybach 62 4dr	1	-6.8639	-99.9%	172.6545	-345.2610	331.5328	0.00	0.9683
	2008 R class 4dr	1	-0.0535	-5.2%	0.1106	-0.2703	0.1633	0.23	0.6287
	2006 R class 4dr 4WD	1	0.0830	8.7%	0.0999	-0.1129	0.2788	0.69	0.4062
	2007 R class 4dr 4WD	1	0.0888	9.3%	0.1007	-0.1086	0.2862	0.78	0.3780
	2008 R class 4dr 4WD	1	0.0962	10.1%	0.1023	-0.1043	0.2967	0.88	0.3471
	2009 R class 4dr 4WD	1	0.0295	3.0%	0.1112	-0.1884	0.2474	0.07	0.7906
	2010 R class 4dr 4WD	1	0.1927	21.3%	0.1245	-0.0514	0.4367	2.39	0.1218
	2010 S class hybrid 4dr	1	0.3038	35.5%	0.1441	0.0213	0.5863	4.44	0.0350
	2000 S class 4dr	1	-0.1939	-17.6%	0.0995	-0.3890	0.0011	3.80	0.0513
	2001 S class 4dr	1	-0.1358	-12.7%	0.0995	-0.3308	0.0592	1.86	0.1724
	2002 S class 4dr	1	-0.0868	-8.3%	0.0995	-0.2819	0.1082	0.76	0.3829
	2003 S class 4dr	1	-0.1558	-14.4%	0.1000	-0.3518	0.0403	2.42	0.1194
	2004 S class 4dr	1	-0.2177	-19.6%	0.1007	-0.4150	-0.0203	4.67	0.0306
	2005 S class 4dr	1	-0.1189	-11.2%	0.1016	-0.3181	0.0802	1.37	0.2419
	2006 S class 4dr	1	-0.1769	-16.2%	0.1010	-0.3748	0.0209	3.07	0.0797
	2007 S class 4dr	1	-0.0750	-7.2%	0.1003	-0.2715	0.1216	0.56	0.4546
	2008 S class 4dr	1	-0.0279	-2.8%	0.1025	-0.2287	0.1729	0.07	0.7853
	2009 S class 4dr	1	-0.0184	-1.8%	0.1099	-0.2338	0.1969	0.03	0.8667
	2010 S class 4dr	1	-0.0029	-0.3%	0.1184	-0.2349	0.2291	0.00	0.9805

Appendix : Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	2003 S class 4dr 4WD	1	-0.1215	-11.4%	0.1014	-0.3202	0.0773	1.43	0.2311
	2004 S class 4dr 4WD	1	-0.1100	-10.4%	0.1019	-0.3098	0.0898	1.16	0.2805
	2005 S class 4dr 4WD	1	-0.0855	-8.2%	0.1031	-0.2877	0.1167	0.69	0.4072
	2006 S class 4dr 4WD	1	-0.1222	-11.5%	0.1035	-0.3251	0.0807	1.39	0.2377
	2007 S class 4dr 4WD	1	-0.0185	-1.8%	0.1026	-0.2196	0.1825	0.03	0.8565
	2008 S class 4dr 4WD	1	-0.0190	-1.9%	0.1031	-0.2210	0.1831	0.03	0.8539
	2009 S class 4dr 4WD	1	-0.0966	-9.2%	0.1102	-0.3125	0.1193	0.77	0.3804
	2010 S class 4dr 4WD	1	0.0138	1.4%	0.1190	-0.2195	0.2471	0.01	0.9077
	2003 SL class convertible	1	-0.4320	-35.1%	0.1001	-0.6282	-0.2359	18.64	<0.0001
	2004 SL class convertible	1	-0.4588	-36.8%	0.1010	-0.6567	-0.2608	20.63	<0.0001
	2005 SL class convertible	1	-0.4052	-33.3%	0.1011	-0.6035	-0.2070	16.06	<0.0001
	2006 SL class convertible	1	-0.4096	-33.6%	0.1033	-0.6121	-0.2072	15.73	<0.0001
	2007 SL class convertible	1	-0.4114	-33.7%	0.1030	-0.6133	-0.2095	15.95	<0.0001
	2008 SL class convertible	1	-0.3728	-31.1%	0.1100	-0.5884	-0.1573	11.49	0.0007
	2009 SL class convertible	1	-0.2895	-25.1%	0.1069	-0.4991	-0.0800	7.33	0.0068
	2005 SLK class convertible	1	-0.1992	-18.1%	0.1007	-0.3966	-0.0019	3.91	0.0479
	2006 SLK class convertible	1	-0.1994	-18.1%	0.1005	-0.3963	-0.0025	3.94	0.0472
	2007 SLK class convertible	1	-0.3028	-26.1%	0.1025	-0.5036	-0.1019	8.73	0.0031
	2008 SLK class convertible	1	-0.1735	-15.9%	0.1056	-0.3805	0.0334	2.70	0.1003
	2009 SLK class convertible	1	-0.1441	-13.4%	0.1082	-0.3562	0.0681	1.77	0.1832
	2010 SLK class convertible	0	0	0	0	0	0		
Rated driver age group	14-20	1	0.2769	31.9%	0.0122	0.2530	0.3008	514.69	<0.0001
	21-24	1	0.3350	39.8%	0.0098	0.3158	0.3543	1165.57	<0.0001
	25-39	1	0.1724	18.8%	0.0037	0.1652	0.1796	2195.02	<0.0001
	65+	1	0.0279	2.8%	0.0044	0.0194	0.0365	41.01	<0.0001
	Unknown	1	0.0479	4.9%	0.0060	0.0362	0.0597	63.77	<0.0001
	40-64	0	0	0	0	0	0		
Rated driver gender	Male	1	-0.0074	-0.7%	0.0035	-0.0143	-0.0005	4.41	0.0358
	Unknown	1	-0.2950	-25.5%	0.0064	-0.3074	-0.2825	2148.50	<0.0001
	Female	0	0	0	0	0	0		
Rated driver marital status	Single	1	0.2016	22.3%	0.0039	0.1939	0.2093	2633.09	<0.0001
	Unknown	1	0.3188	37.5%	0.0063	0.3064	0.3313	2527.50	<0.0001
	Married	0	0	0	0	0	0		
Risk	Nonstandard	1	0.2708	31.1%	0.0043	0.2623	0.2793	3885.77	<0.0001
	Standard	0	0	0	0	0	0		
State	Alabama	1	-0.1443	-13.4%	0.0401	-0.2230	-0.0657	12.95	0.0003
	Arizona	1	-0.1961	-17.8%	0.0390	-0.2726	-0.1197	25.31	<0.0001
	Arkansas	1	-0.1000	-9.5%	0.0465	-0.1911	-0.0090	4.64	0.0313
	California	1	-0.0091	-0.9%	0.0375	-0.0826	0.0644	0.06	0.8075
	Colorado	1	-0.1116	-10.6%	0.0398	-0.1896	-0.0336	7.86	0.0051

Appendix : Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	Connecticut	1	-0.1679	-15.5%	0.0390	-0.2443	-0.0916	18.59	<0.0001
	Delaware	1	-0.1435	-13.4%	0.0442	-0.2302	-0.0569	10.55	0.0012
	District of Columbia	1	0.2158	24.1%	0.0412	0.1350	0.2965	27.41	<0.0001
	Florida	1	-0.2475	-21.9%	0.0376	-0.3212	-0.1738	43.31	<0.0001
	Georgia	1	-0.2408	-21.4%	0.0382	-0.3157	-0.1658	39.65	<0.0001
	Hawaii	1	-0.1010	-9.6%	0.0421	-0.1834	-0.0185	5.76	0.0164
	Idaho	1	-0.4664	-37.3%	0.0605	-0.5849	-0.3479	59.53	<0.0001
	Illinois	1	-0.0718	-6.9%	0.0379	-0.1462	0.0025	3.59	0.0582
	Indiana	1	-0.1829	-16.7%	0.0417	-0.2647	-0.1012	19.24	<0.0001
	Iowa	1	-0.2438	-21.6%	0.0547	-0.3510	-0.1366	19.86	<0.0001
	Kansas	1	-0.2702	-23.7%	0.0452	-0.3589	-0.1815	35.67	<0.0001
	Kentucky	1	-0.3680	-30.8%	0.0432	-0.4527	-0.2832	72.43	<0.0001
	Louisiana	1	0.0233	2.4%	0.0395	-0.0541	0.1006	0.35	0.5557
	Maine	1	-0.1720	-15.8%	0.0592	-0.2881	-0.0559	8.44	0.0037
	Maryland	1	-0.0722	-7.0%	0.0380	-0.1466	0.0023	3.61	0.0575
	Massachusetts	1	0.0861	9.0%	0.0387	0.0103	0.1619	4.96	0.0259
	Michigan	1	0.2983	34.8%	0.0391	0.2216	0.3750	58.12	<0.0001
	Minnesota	1	-0.2108	-19.0%	0.0415	-0.2921	-0.1295	25.82	<0.0001
	Mississippi	1	-0.1123	-10.6%	0.0434	-0.1973	-0.0272	6.69	0.0097
	Missouri	1	-0.2387	-21.2%	0.0409	-0.3189	-0.1585	34.02	<0.0001
	Montana	1	-0.2846	-24.8%	0.0838	-0.4489	-0.1203	11.53	0.0007
	Nebraska	1	-0.3207	-27.4%	0.0563	-0.4310	-0.2104	32.47	<0.0001
	Nevada	1	-0.0199	-2.0%	0.0396	-0.0974	0.0576	0.25	0.6151
	New Hampshire	1	0.0353	3.6%	0.0452	-0.0533	0.1238	0.61	0.4350
	New Jersey	1	-0.2126	-19.2%	0.0379	-0.2870	-0.1382	31.40	<0.0001
	New Mexico	1	-0.2045	-18.5%	0.0500	-0.3025	-0.1066	16.75	<0.0001
	New York	1	-0.0342	-3.4%	0.0376	-0.1079	0.0396	0.83	0.3635
	North Carolina	1	-0.4755	-37.8%	0.0390	-0.5518	-0.3991	148.91	<0.0001
	North Dakota	1	-0.0444	-4.3%	0.1073	-0.2547	0.1659	0.17	0.6790
	Ohio	1	-0.2985	-25.8%	0.0394	-0.3756	-0.2213	57.49	<0.0001
	Oklahoma	1	-0.2840	-24.7%	0.0426	-0.3676	-0.2005	44.36	<0.0001
	Oregon	1	-0.2471	-21.9%	0.0411	-0.3276	-0.1665	36.12	<0.0001
	Pennsylvania	1	-0.0377	-3.7%	0.0380	-0.1122	0.0368	0.98	0.3211
	Rhode Island	1	0.0035	0.4%	0.0443	-0.0833	0.0902	0.01	0.9378
	South Carolina	1	-0.3387	-28.7%	0.0402	-0.4176	-0.2598	70.82	<0.0001
	South Dakota	1	-0.3615	-30.3%	0.0876	-0.5332	-0.1897	17.01	<0.0001
	Tennessee	1	-0.2957	-25.6%	0.0399	-0.3739	-0.2176	54.97	<0.0001
	Texas	1	-0.2105	-19.0%	0.0378	-0.2845	-0.1366	31.10	<0.0001
	Utah	1	-0.3018	-26.1%	0.0462	-0.3924	-0.2112	42.64	<0.0001
	Vermont	1	-0.0823	-7.9%	0.0698	-0.2192	0.0545	1.39	0.2384
	Virginia	1	-0.1375	-12.8%	0.0380	-0.2121	-0.0630	13.07	0.0003
	Washington	1	-0.1986	-18.0%	0.0390	-0.2751	-0.1221	25.88	<0.0001
	West Virginia	1	-0.3357	-28.5%	0.0500	-0.4337	-0.2377	45.09	<0.0001
	Wisconsin	1	-0.1763	-16.2%	0.0433	-0.2613	-0.0914	16.57	<0.0001
	Wyoming	1	-0.1304	-12.2%	0.0991	-0.3246	0.0637	1.73	0.1879
	Alaska	0	0	0	0	0	0		

Appendix : Illustrative regression results — collision frequency

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Deductible range	0-250	1	0.4434	55.8%	0.0047	0.4343	0.4526	9024.26	<0.0001
	1001+	1	-0.3756	-31.3%	0.0184	-0.4117	-0.3394	414.63	<0.0001
	251-500	1	0.2793	32.2%	0.0039	0.2717	0.2869	5208.15	<0.0001
	501-1000	0	0	0	0	0	0		
Registered vehicle density	0-99	1	-0.2190	-19.7%	0.0061	-0.2309	-0.2071	1300.26	<0.0001
	100-499	1	-0.1569	-14.5%	0.0036	-0.1640	-0.1498	1858.26	<0.0001
	500+	0	0	0	0	0	0		
Distronic		1	-0.0311	-3.1%	0.0161	-0.0626	0.0005	3.73	0.0535
Distronic Plus		1	-0.0732	-7.1%	0.0324	-0.1366	-0.0097	5.11	0.0238
Parktronic		1	0.0075	0.8%	0.0063	-0.0048	0.0198	1.43	0.2310
Parking Guidance		1	0.0613	6.3%	0.0407	-0.0185	0.1412	2.27	0.1321
Backup camera		1	0.0046	0.5%	0.0121	-0.0192	0.0284	0.14	0.7068
Active Curve Illumination		1	-0.0085	-0.8%	0.0098	-0.0277	0.0107	0.76	0.3843
Adaptive High Beam Assist		1	-0.0070	-0.7%	0.0347	-0.0749	0.0610	0.04	0.8404
Blind Spot Assist		1	-0.0015	-0.1%	0.0667	-0.1321	0.1292	0.00	0.9826
Lane Keeping Assist		1	0.0549	5.6%	0.0736	-0.0893	0.1991	0.56	0.4554
Night View Assist/ Plus		1	-0.0423	-4.1%	0.0212	-0.0840	-0.0007	3.97	0.0463
Active Cornering Lights		1	-0.0276	-2.7%	0.0094	-0.0461	-0.0091	8.52	0.0035
High Intensity Discharge Headlights		1	0.0079	0.8%	0.0058	-0.0035	0.0192	1.85	0.1735

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Advanced Safety Technologies and Other Guideposts on the Road to Vision Zero

www.iihs.org

FISITA “Advanced Safety Technologies” Executive Track
Maastricht, Netherlands ● June 5, 2014

Adrian K. Lund, Ph.D.
President, IIHS and HLDI

The Insurance Institute for Highway Safety,

founded in 1959, is an independent, nonprofit, scientific, and educational organization dedicated to reducing the losses — deaths, injuries, and property damage — from crashes on the nation's highways.

The Highway Loss Data Institute,

founded in 1972, shares and supports this mission through scientific studies of insurance data representing the human and economic losses resulting from the ownership and operation of different types of vehicles and by publishing insurance loss results by vehicle make and model.

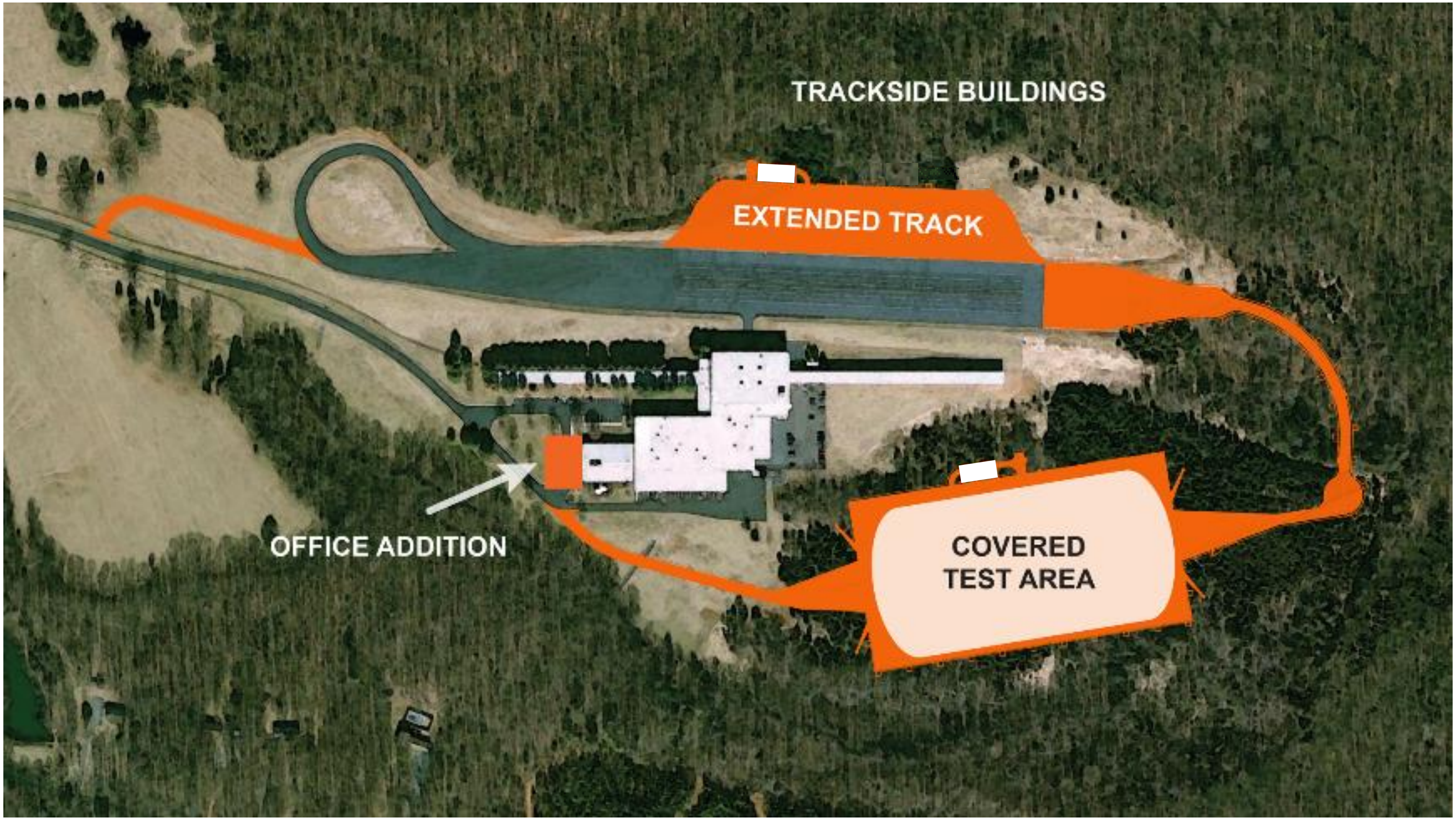
Both organizations are wholly supported by auto insurers.

Where are we?

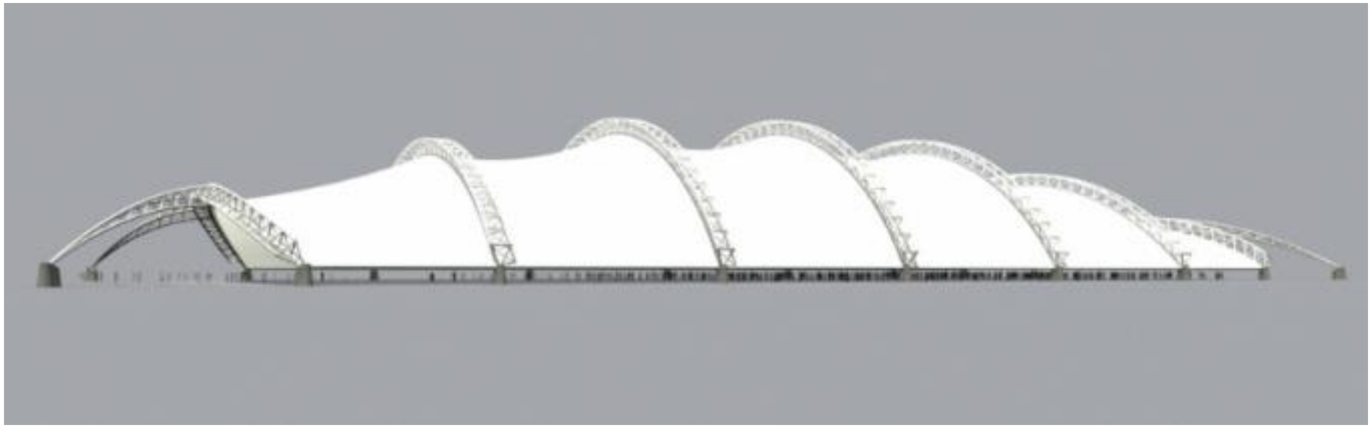
Location of IIHS/HLDI and Vehicle Research Center

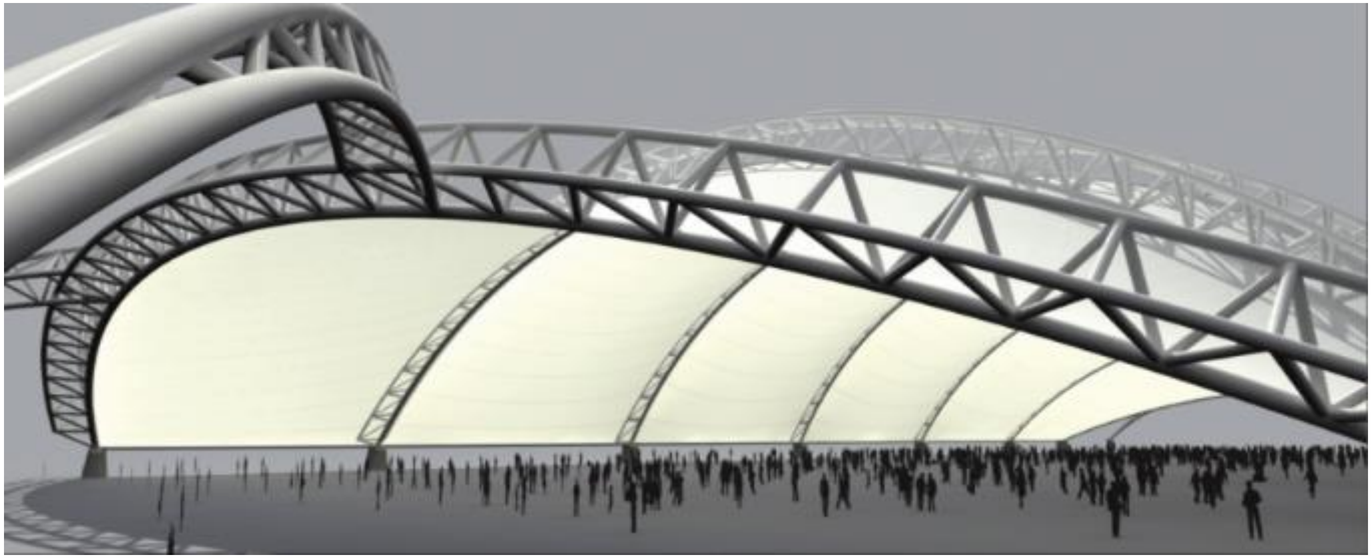
Vehicle Research Center expansion

Estimated $30 million cost



Covered test track (est. July 2014)





Vision Zero

- Adopted by the Swedish parliament in 1997,

> "Vision Zero is a philosophy of road safety that eventually no one will be killed or seriously injured within the road transport system."

Claes Tingvall and Narelle Haworth, 1999

Haddon matrix shows many roads to Vision Zero

Recognizing opportunities to make a difference

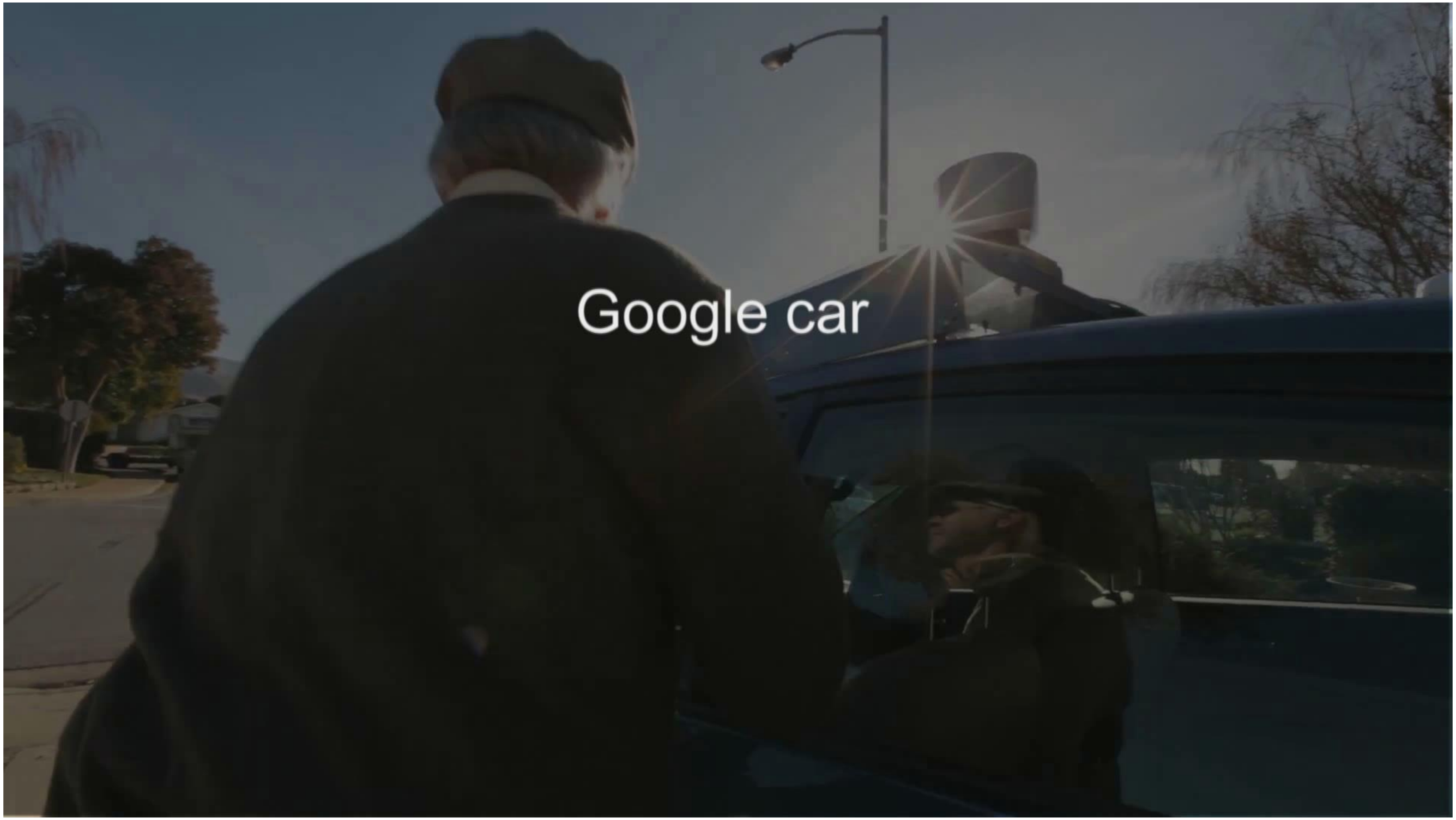
	crash phase		
changes in…	before	during	after
people	•licensing laws •graduated licensing •impaired driving laws •red light cameras •speed camera	•belt use •helmets •speed cameras	•alcohol
vehicles	•lane departure warning •daytime running lights •electronic stability control	•airbags •vehicle structure •bumpers	•crash notification systems •fuel system integrity
environment	•roundabouts •trouble spot treatment •rumble strips	•roundabouts •breakaway poles	•emergency medical services

Advanced safety technology:
What is it?

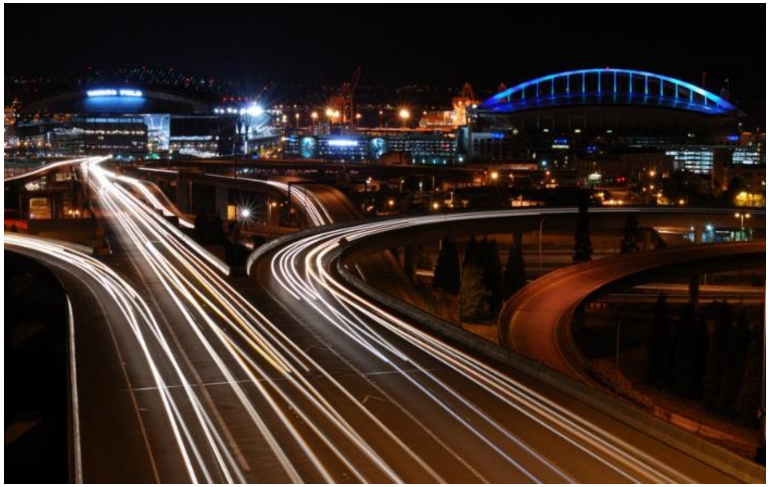
For most, it means smart vehicles that help drivers avoid crashes or take action themselves to avoid or mitigate crashes.

The long-term vision

Autonomous vehicles that don't (hardly ever) crash



V2X communication



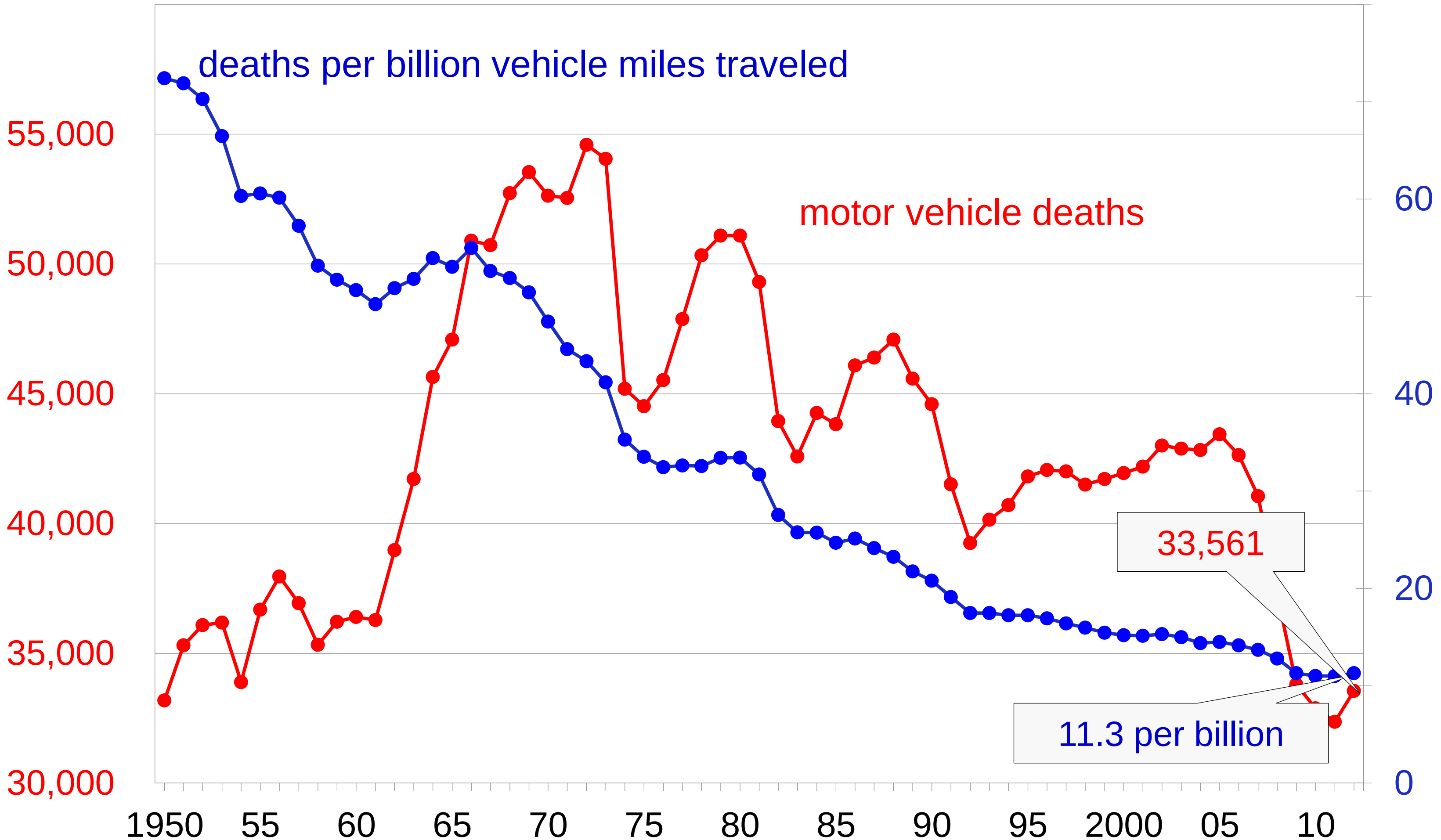
- V2X is a parallel development to autonomous technology
  - V2X provides additional information to onboard systems
  - V2X will not automate or assist any system or driver function
- Because V2X has its own implementation issues, it will not likely speed up the path to autonomy
  - Augmenting or replacing sensors used in current driver assistance systems
  - New capability to “see” around corners and far ahead
  - Potential enabler of autonomous vehicle operation

Where are we now?

Focus on the US experience but the lessons learned apply globally.

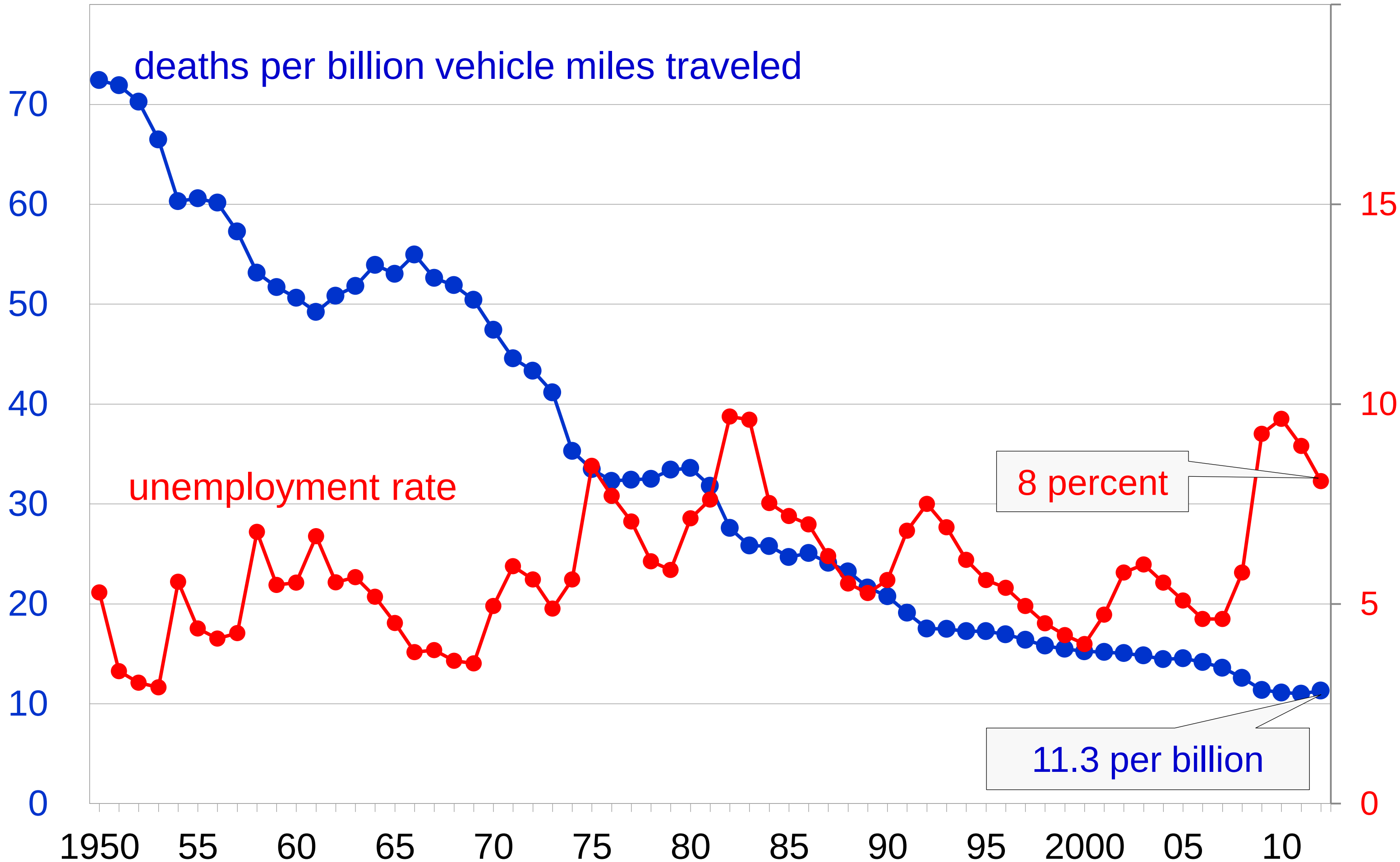
US motor vehicle crash deaths and deaths per billion vehicle miles traveled

1950-2012



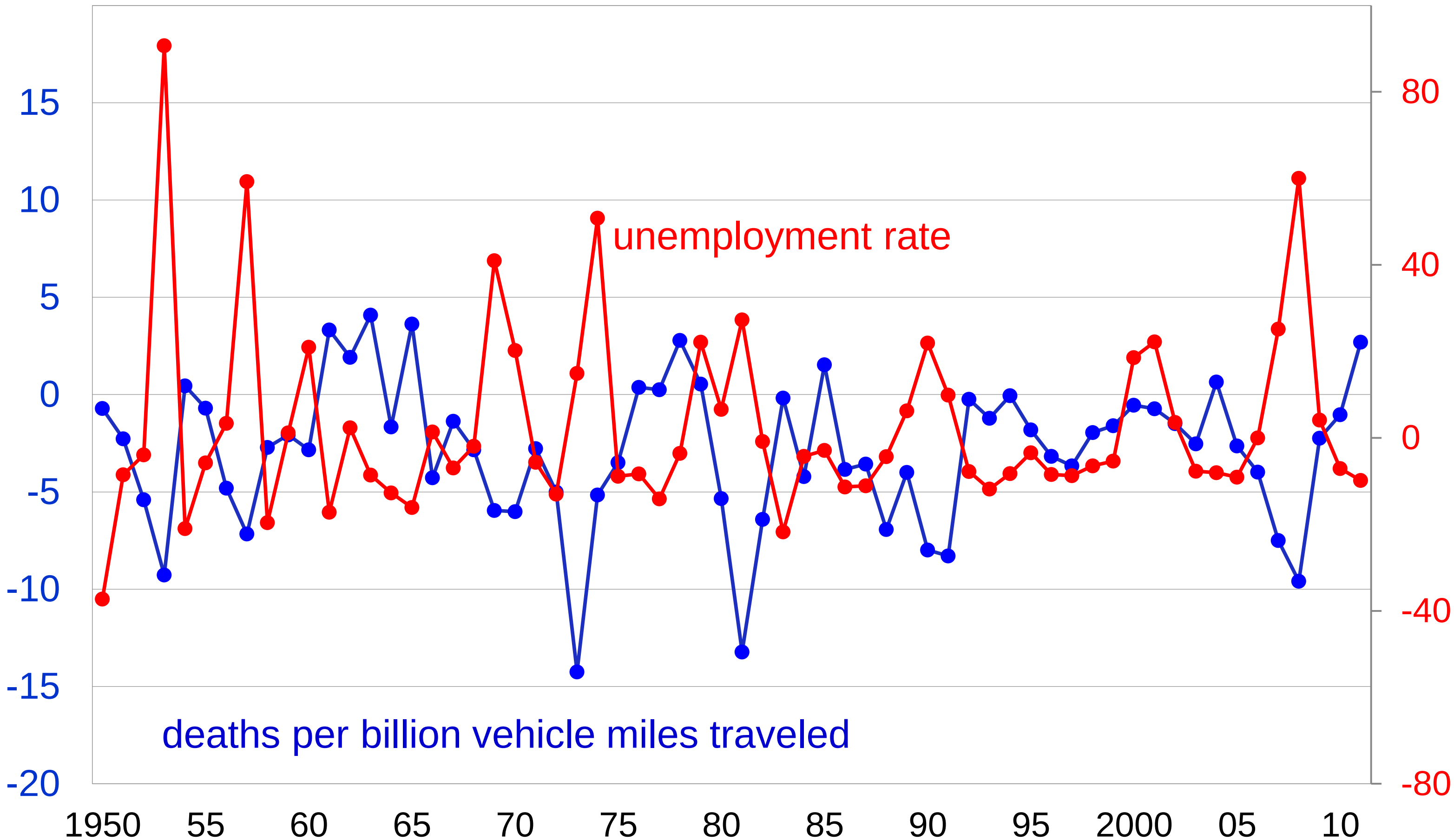
US motor vehicle crash deaths per billion vehicle miles traveled and unemployment rate

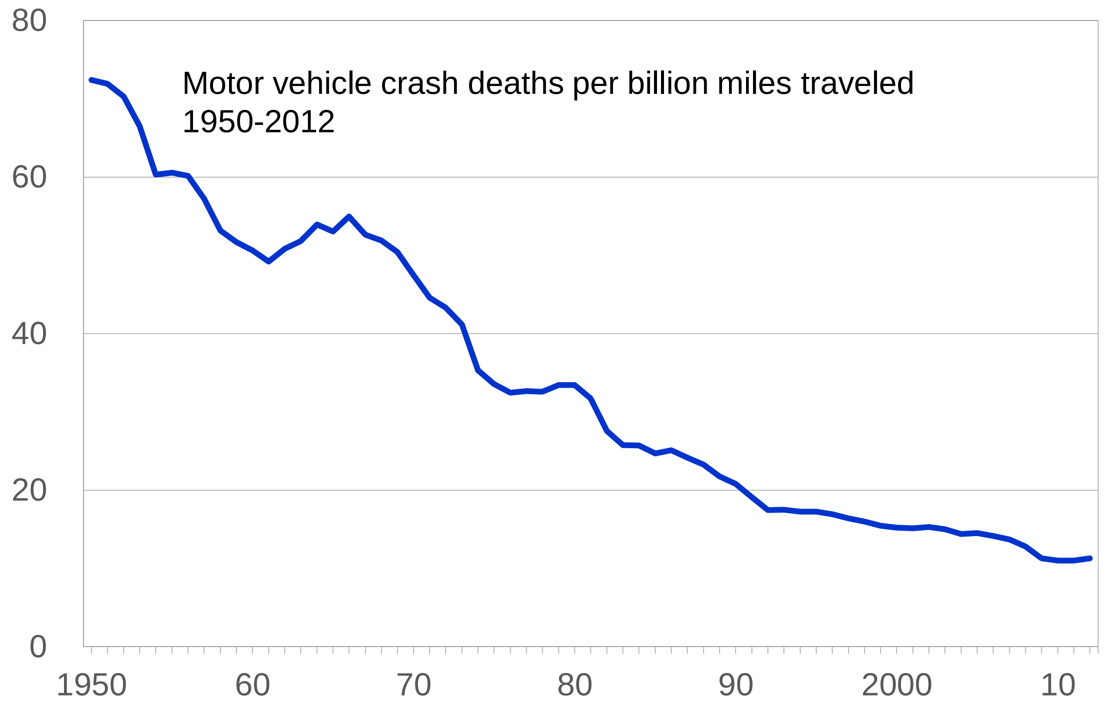
1950-2012



Year-to-year percent changes in US motor vehicle crash deaths per billion vehicle miles traveled and unemployment rate

1951-2012

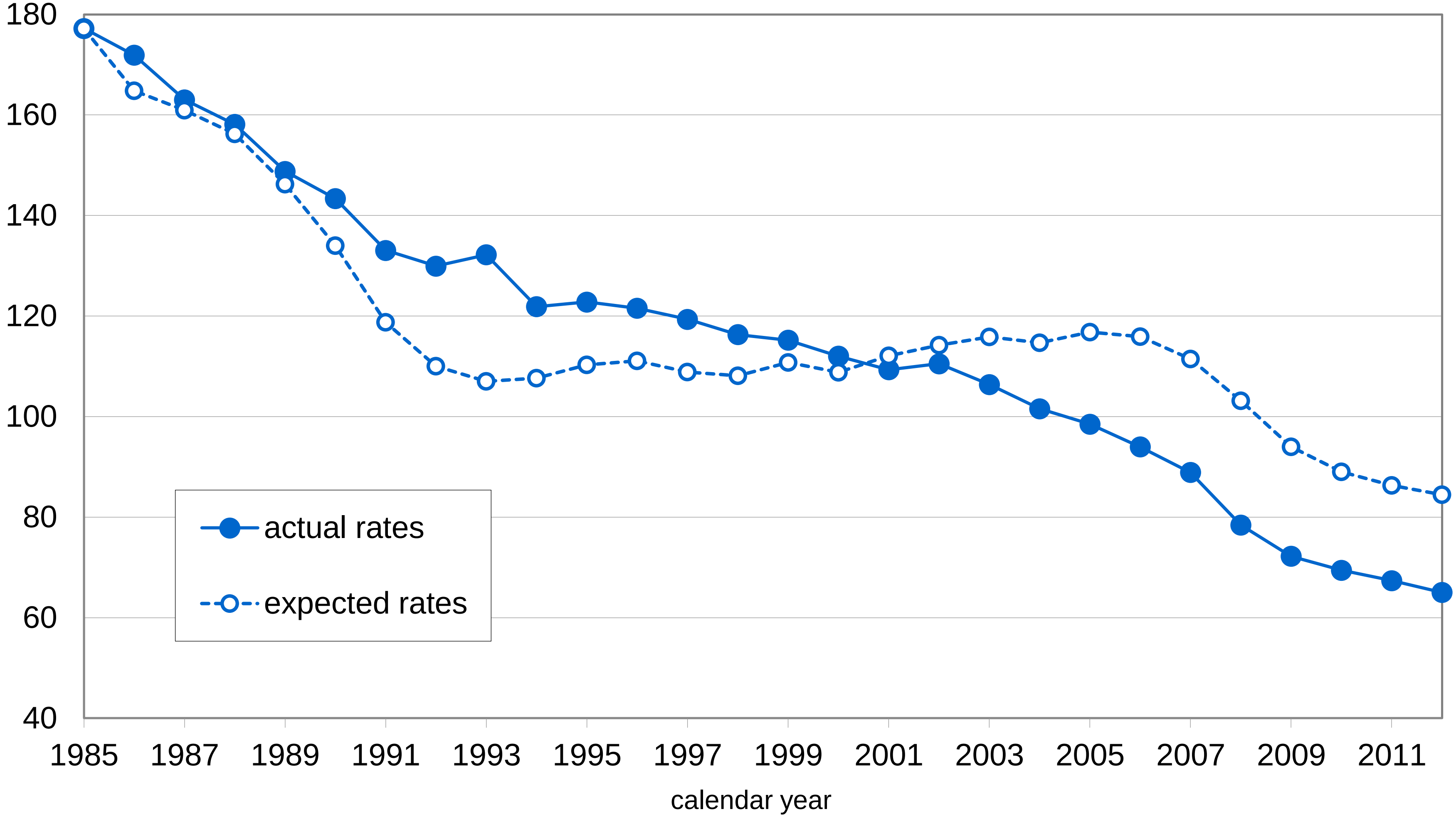




Vehicle improvements have been key to reductions in motor vehicle crash fatality risk

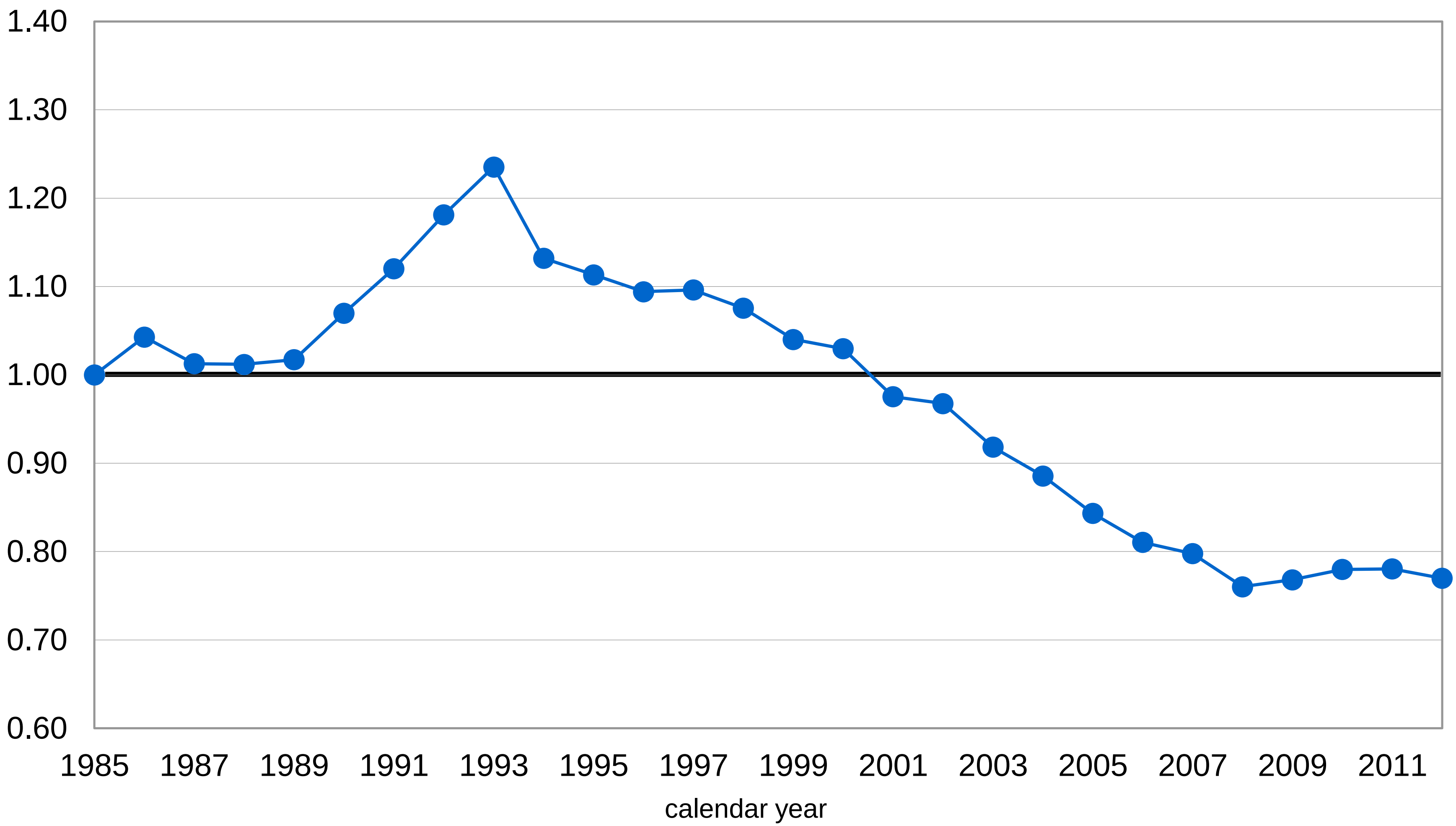
Vehicle and non-vehicle factors and highway safety

Fatal crash rates per million vehicles, actual vs. expected for 1985 fleet



Vehicle and non-vehicle factors and highway safety

Fatal crash rates per vehicle as percentage of expected for 1985 fleet



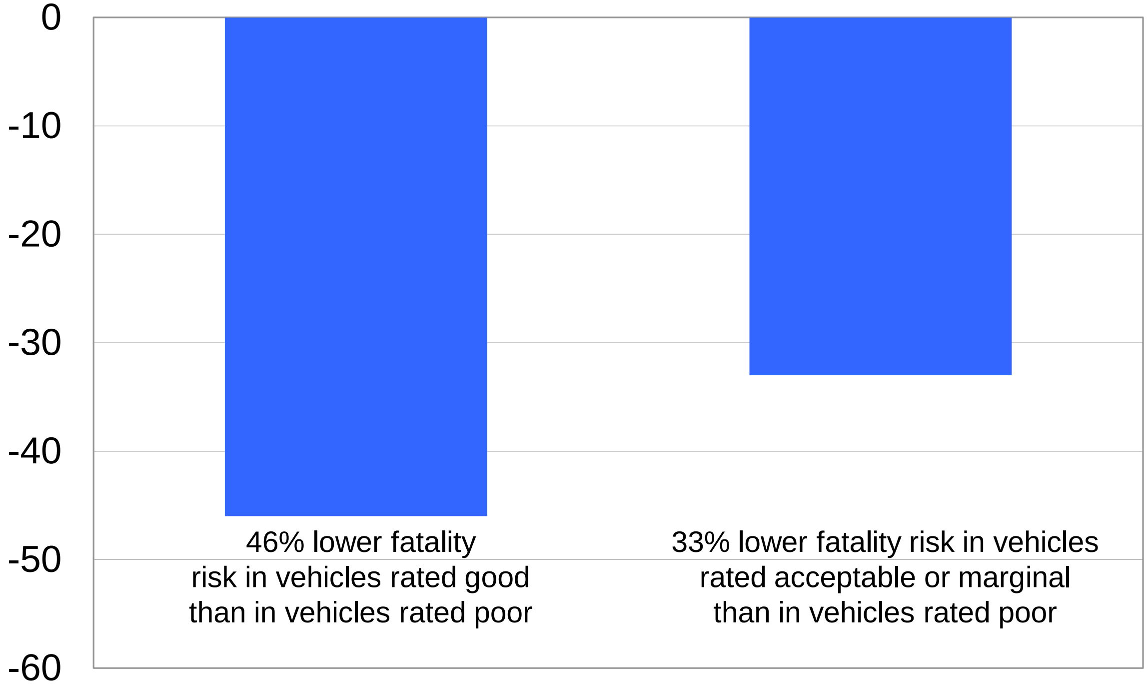
Big gains in occupant protection have been achieved through improvements in vehicle structure –

Four of the five factors in IIHS crash ratings involve vehicle structure

Fatality risk in real-world crashes

Percent driver fatality risk reduction in head-on crashes, by IIHS crash test rating

The risk of death is much lower in vehicles rated good based on IIHS tests, compared with vehicles rated poor.

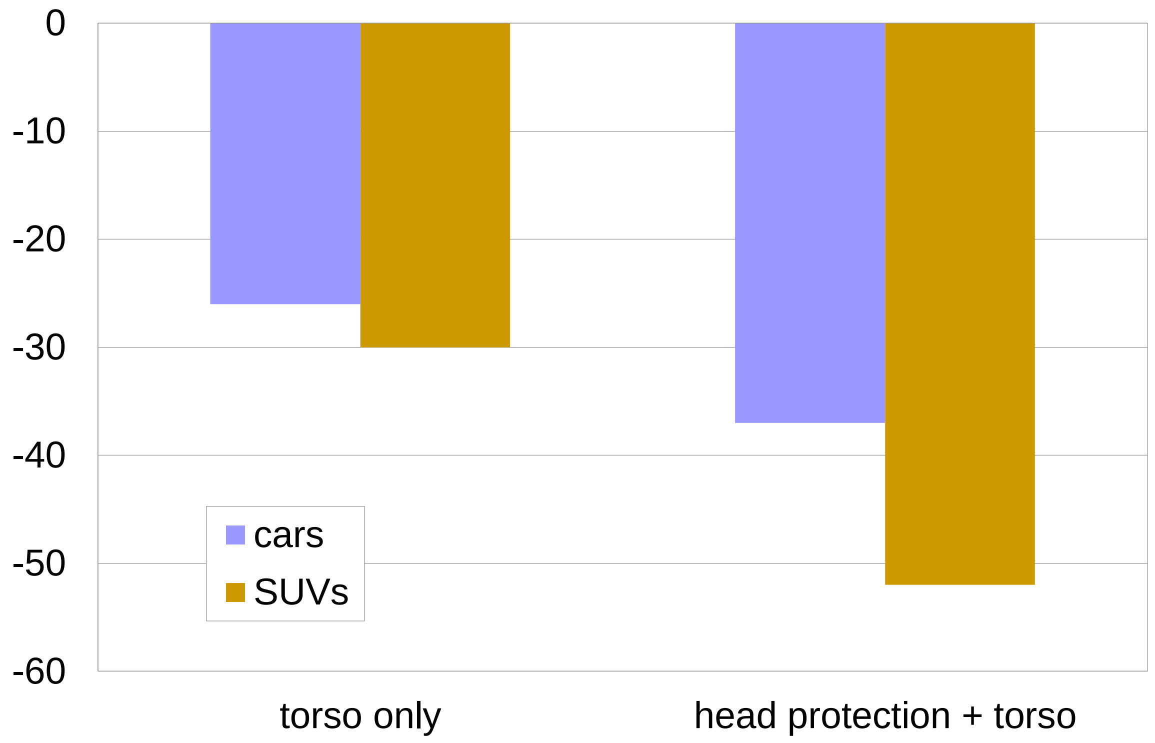



Frontal crash tests:
1997 Pontiac Trans Sport
2005 Chevrolet Uplander

Fatality risk in side impacts

Estimated percent reductions in driver fatality risks in vehicles with side airbags, 2000-04

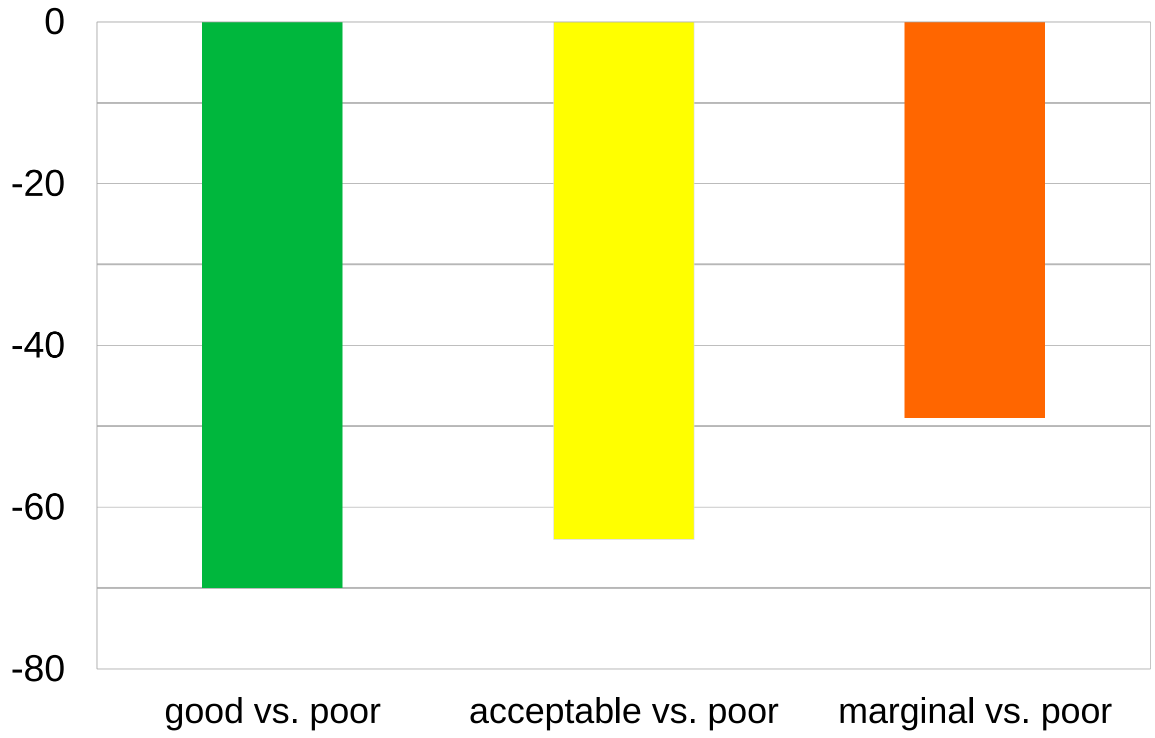
IIHS research shows side airbags save lives. In real-world side impacts, driver fatality risk is 37% lower in cars and 52% lower in SUVs with side airbags with head protection, compared with similar vehicles without this protection.



Percent change in driver death risk in left side impacts

Adjusted for age, gender, vehicle type and curb weight, 2000-09

Good performance in the IIHS side crash test results in strong reductions in driver's risk of death in side impact crashes. These benefits go beyond the addition of side airbags.

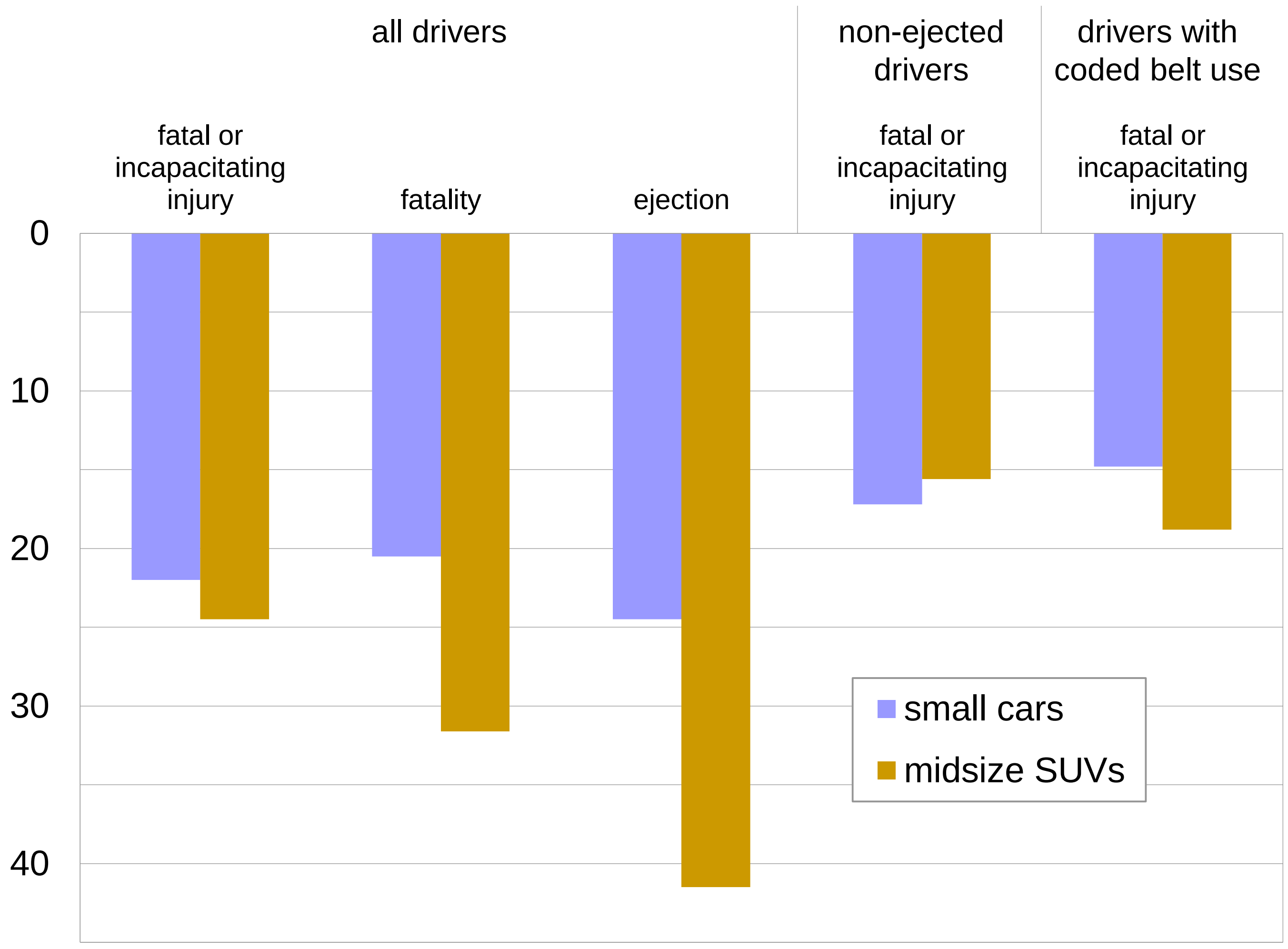


Rating recalculated without data from passenger dummy.

Restricted to vehicles with standard head and torso side airbags.

Estimated effects of increasing SWR by one unit

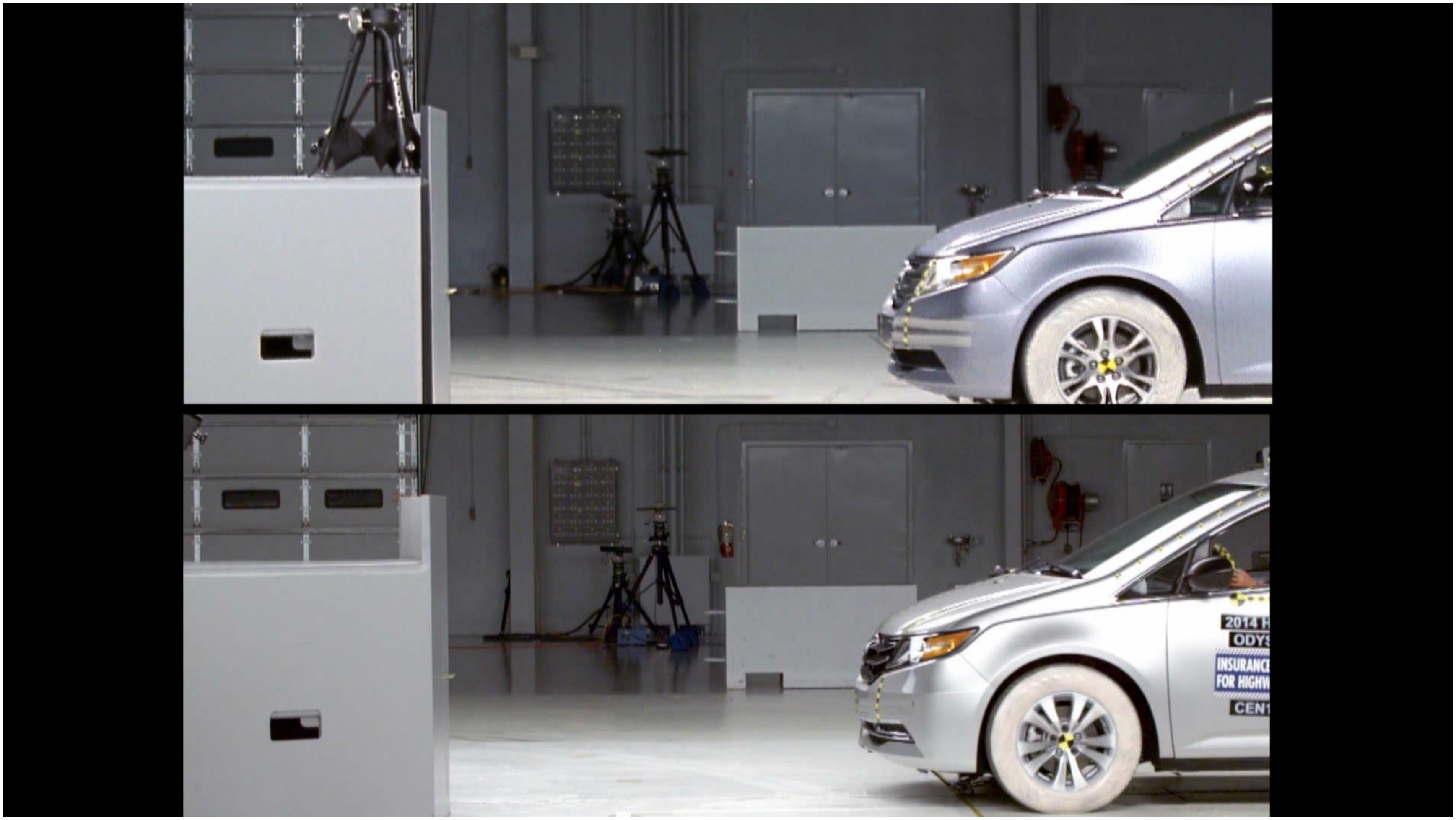
Percent change in risk



Small overlap front crash is latest structural test

2012 Honda Odyssey (shown at top & left) rated Poor

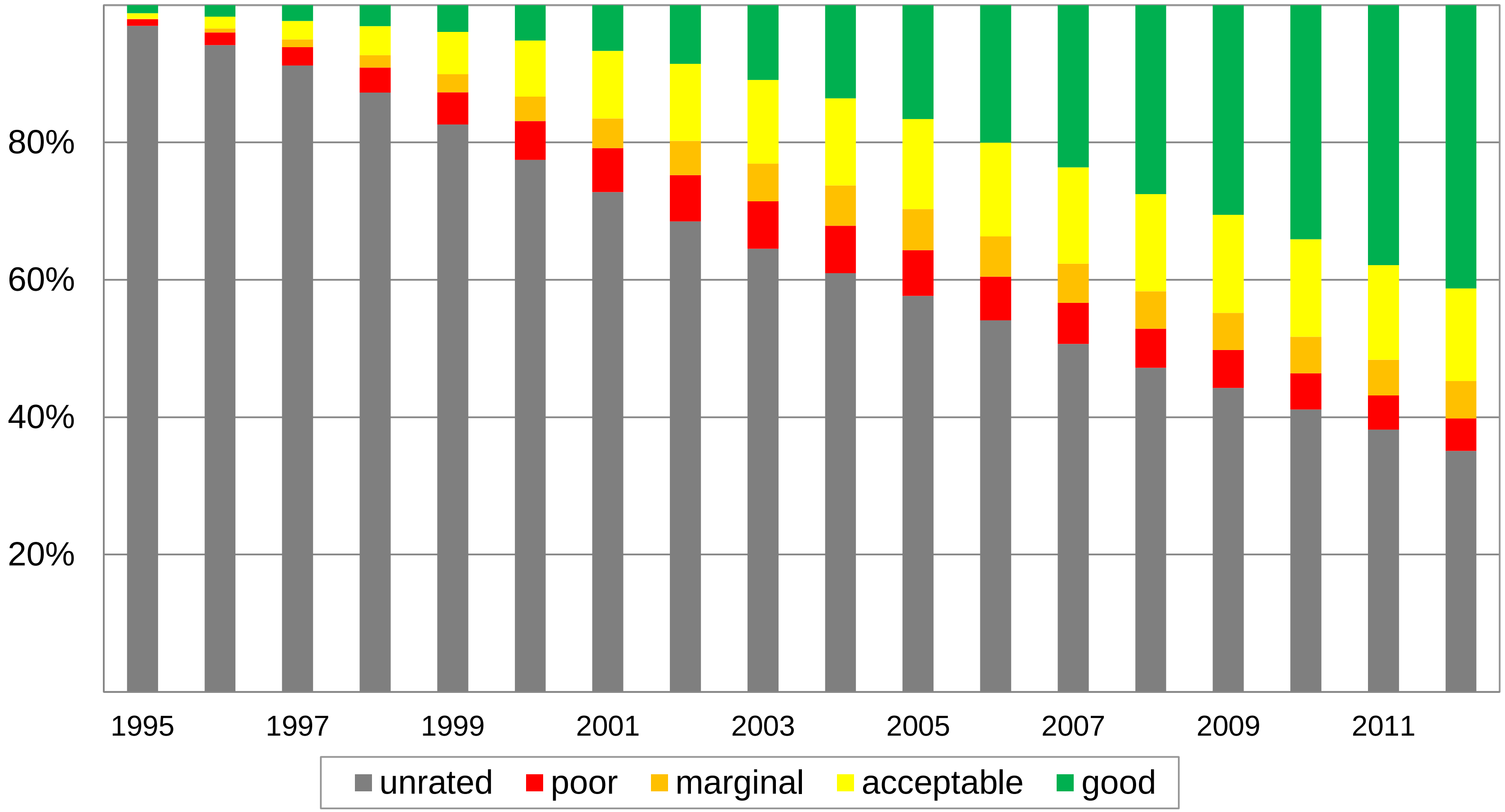
2014 Honda Odyssey (shown at bottom & right) rated Good



Fatal and serious injury rates will continue to decline as many recent improvements in vehicle structures are still working their way through the vehicle fleet

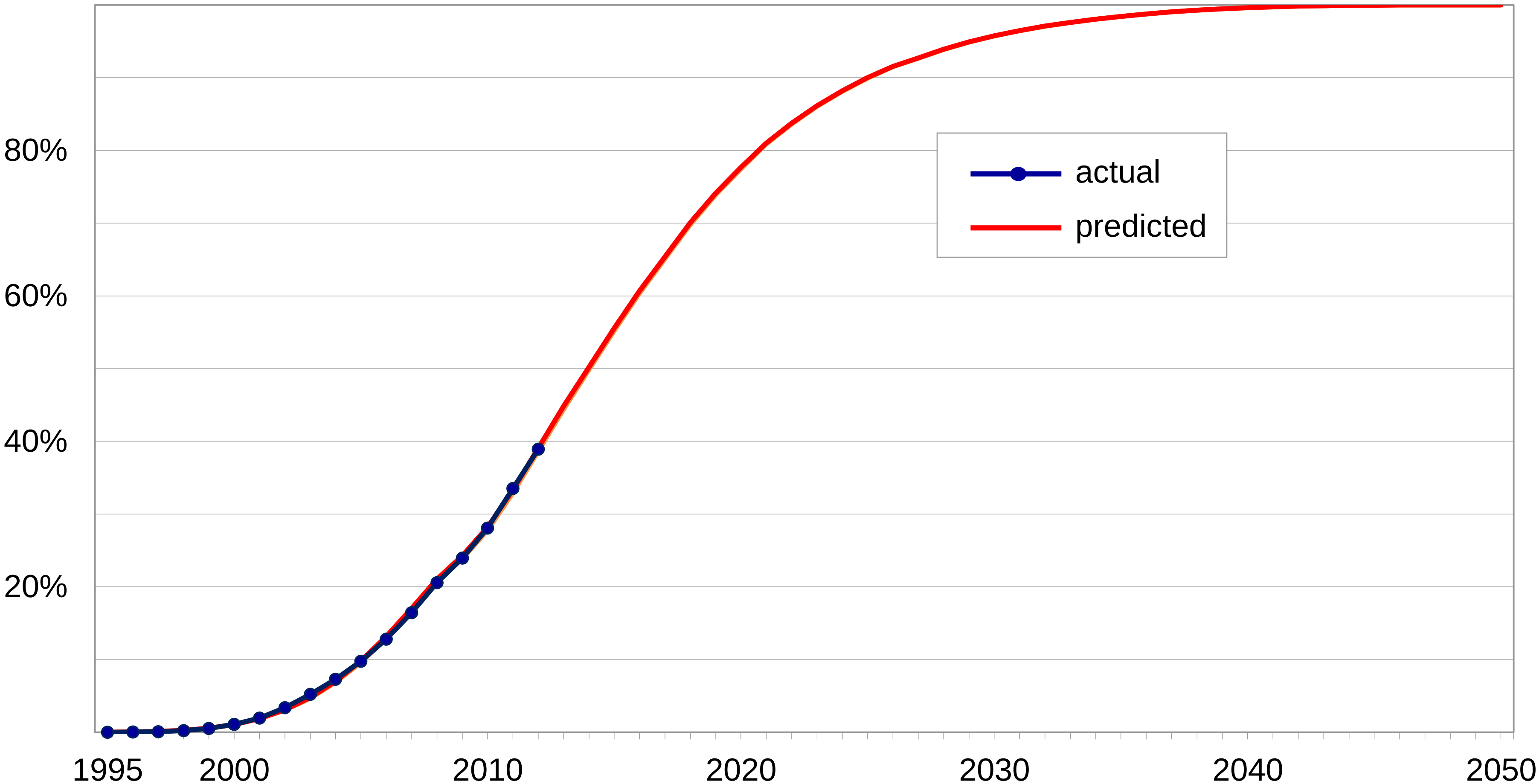
Moderate overlap frontal offset crash test ratings by calendar year in the U.S.

All registered passenger vehicles



Electronic stability control in passenger vehicles registered in the U.S.

By calendar ear



Where are we going?

Crashworthiness is a mature area with uncertain areas for progress

Are there future structural improvements needed?

Some areas but low-hanging fruit has been picked

- NHTSA oblique front crash test – will it challenge structures significantly more than collinear small overlap front test?
- Euro NCAP full overlap 50 km/h – compatibility?
- Higher speed impacts
  - 25 percent of frontal crash deaths involve moderate overlap crashes ≥ 64 km/h
  - IIHS side impact test was set at speed below 50th percentile delta V
  - Higher speeds can have unintended effects (e.g., overly aggressive airbags)
- Dynamic rollover test could alter roof designs, but the specification of the test is complex and we should see what problem remains with the stronger roofs now appearing in the US
- Vulnerable road users
  - Modifying structures to be less injurious
  - Synergy with crash avoidance systems

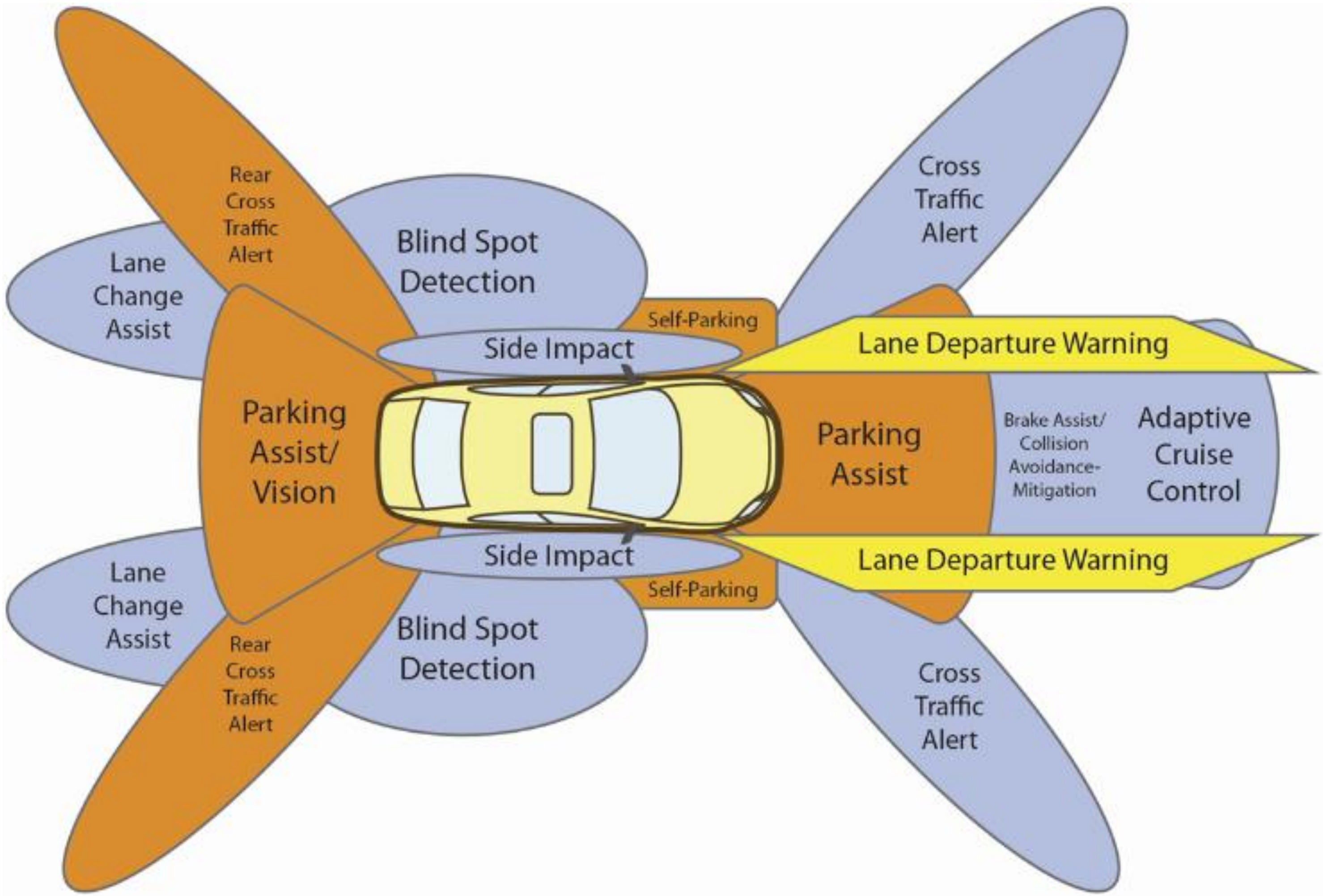
Future occupant protection improvements more likely to focus on restraint system design

- Pre-crash preparation
  - Belt/seat adjustment already in cars
  - Extend to deployable cushions (inside and outside of vehicles?)
- NHTSA oblique side pole test and anti-ejection drives curtain designs
- New front and side impact dummies may tune restraint systems
- Occupants other than the driver
  - Far side occupants in side crashes (center airbag, inflatable belts?)
  - Rear seat occupants (inflatable belts, side airbags)
  - Child occupants (vehicle or child restraints?)

Crash prevention is just developing with much promise and many unknowns

Driver assistance features

Radar, LIDAR, ultrasonic, infrared, cameras, GPS



Near term – trying to understand crash avoidance features already on vehicles

- Forward collision warning and automatic emergency braking (front crashes)
- Blind spot warning
- Unintentional lane departure warning and prevention (active assist)
- Rear view assist (cameras, ultrasonics, radar)
- Automatic parking
- Adaptive headlamps
  - Steering responsive
  - Automatic high beams
- Cross traffic alert – front and rear
- Night view assist
- Super cruise control – adaptive cruise with lane keeping control
- Pedestrian detection and avoidance

What do we need to understand about these systems?

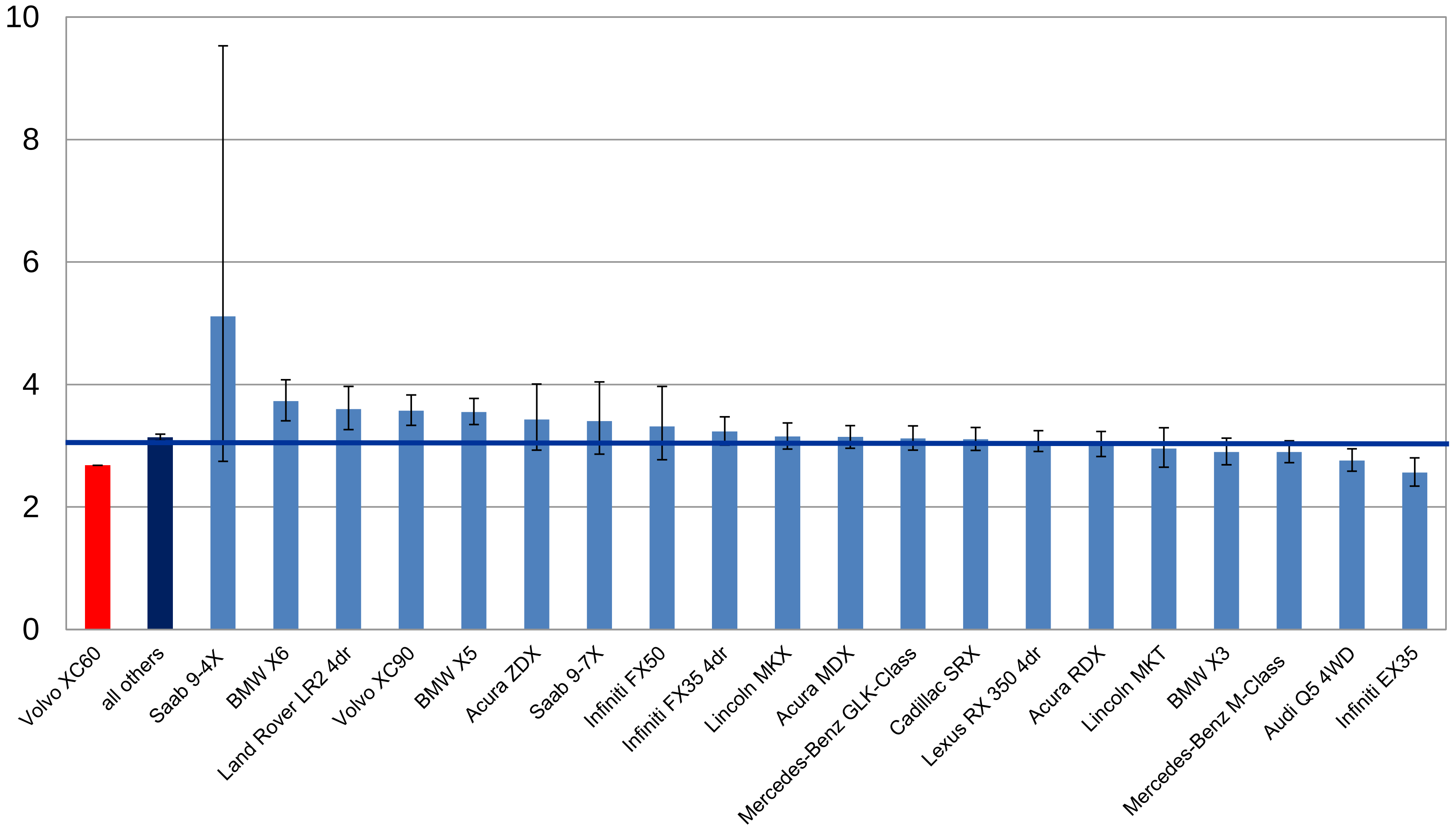
- Vision is of vehicles that control themselves without driver input
- Reality is that, in the near term, the driver is integral to the success of the systems
  - Acceptance
  - Reaction
  - Fit of systems to drivers’ overlearned driving behavior
- On-road effects of systems vs. test track performance
  - Test tracks evaluate physical performance of systems
  - On the road, drivers decide when and how to use systems

Some systems are working as expected:

Forward collision warning, with and without automatic braking

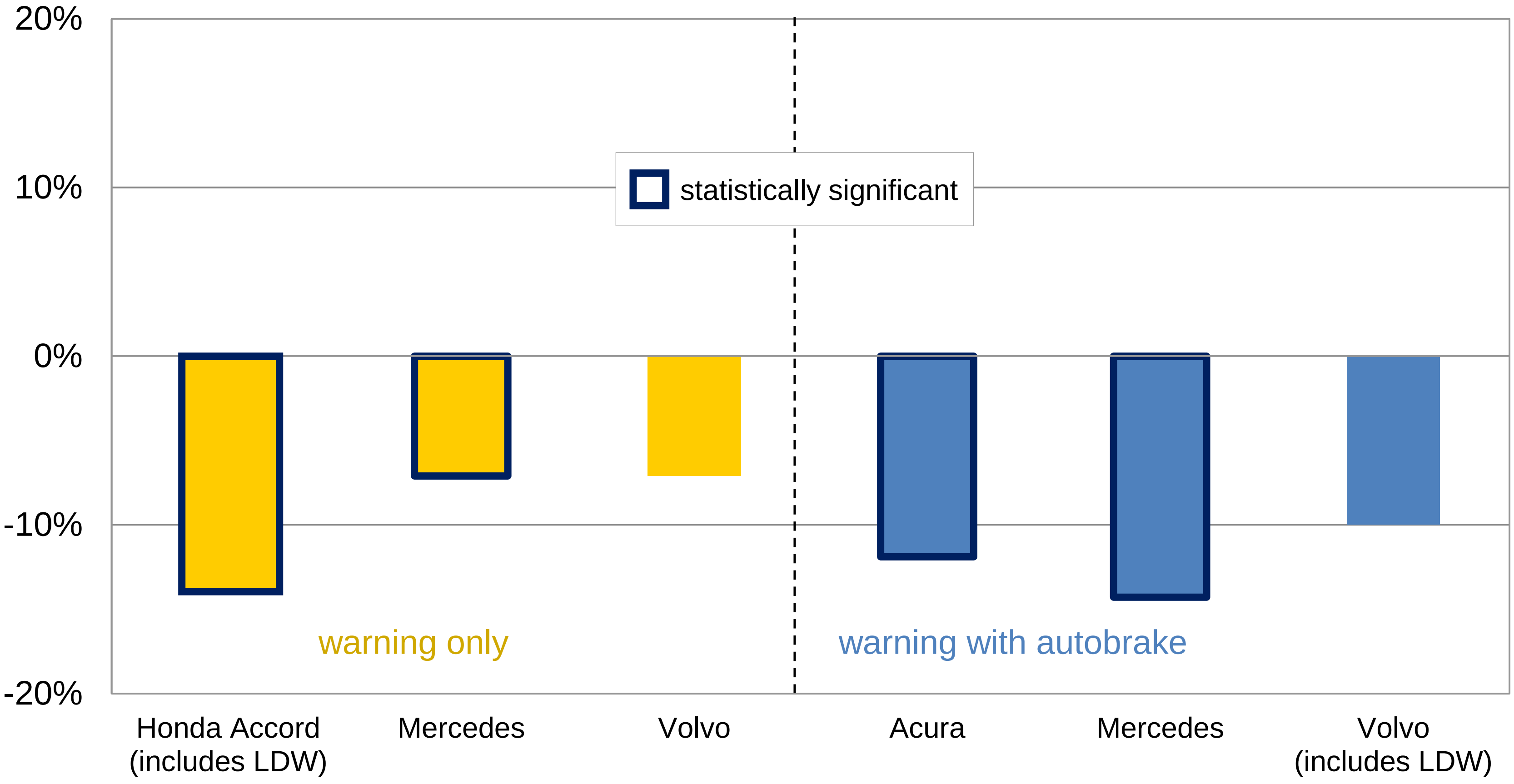
Low speed autobrake is reducing property damage liability claims in Volvos with City Safety

Claims per 100 vehicle years, 2009-12 XC60s vs. comparable SUVs



Higher speed forward collision warning systems

Changes in property damage liability claim frequency w/wo autobrake



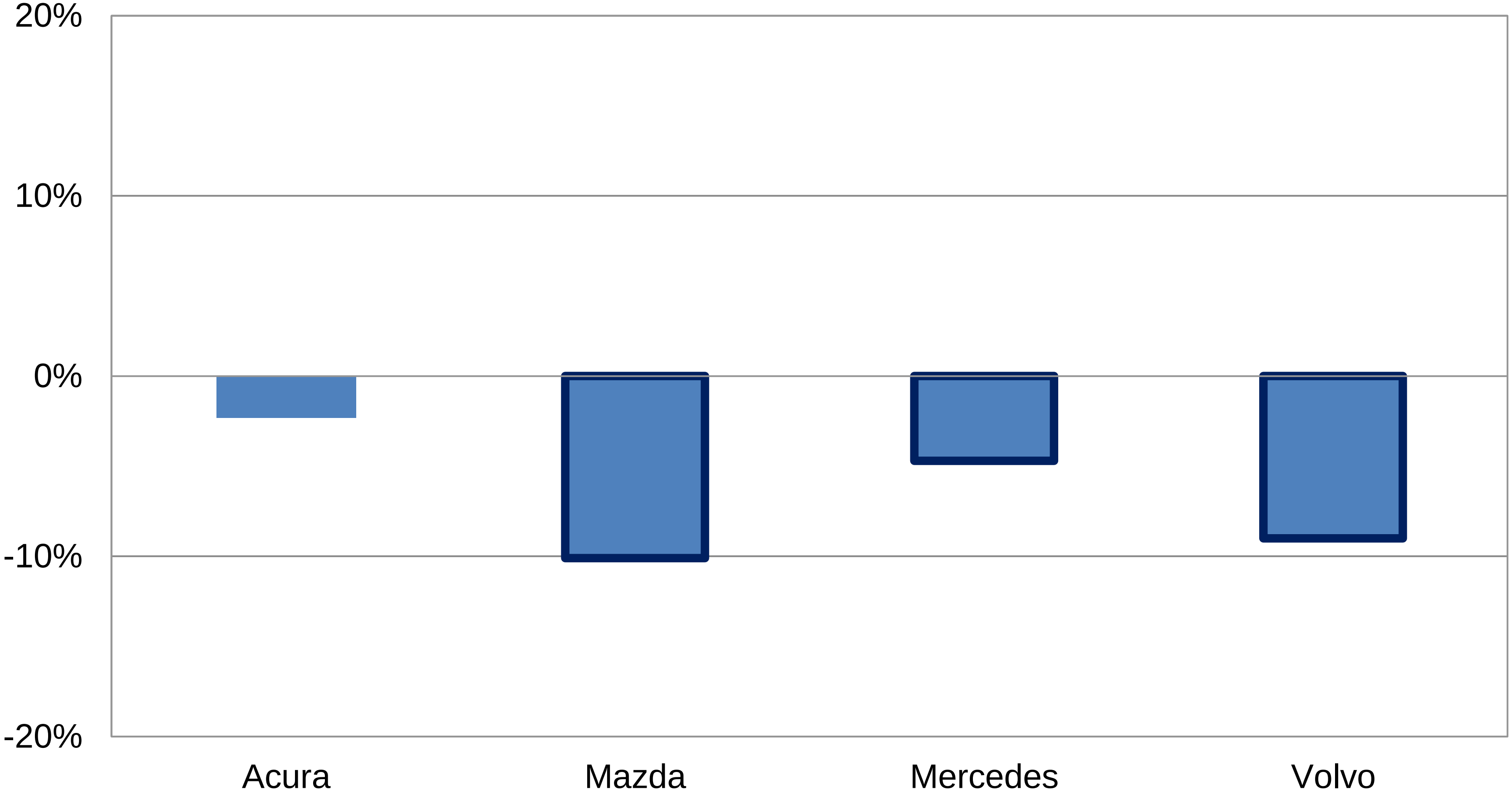
Some systems are working but in unexpected ways:

Adaptive headlights (steering responsive lamps) are not reducing insurance collision claims, where we would expect to see evidence of single vehicle run-off-road crashes (exception of Mazda 3)

Rather, they are reducing property damage liability claims, which are typically two-vehicle crashes

Adaptive headlights

Percent change in property damage liability claims per insured vehicle year

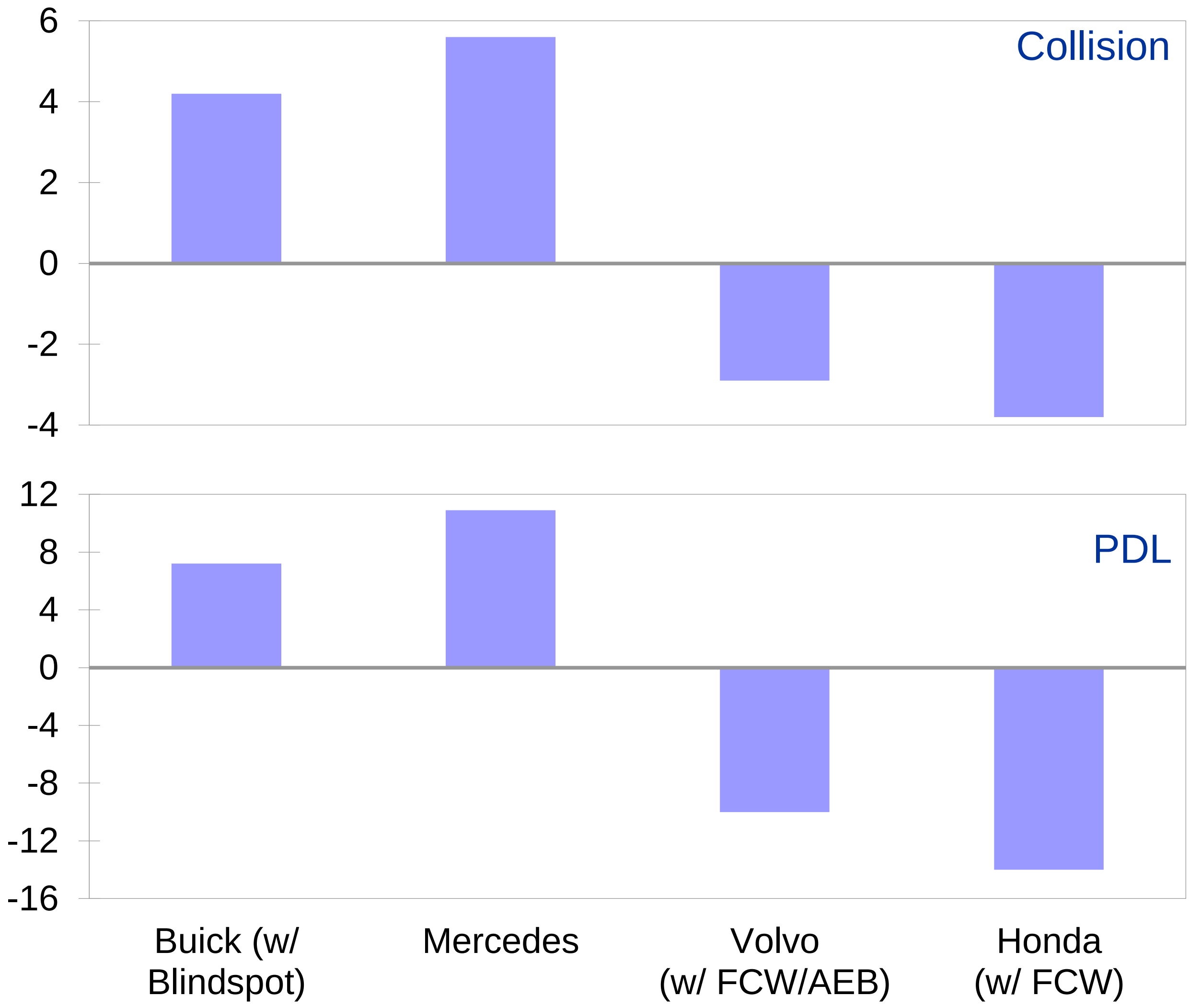


Some crash avoidance systems are showing mixed evidence

Lane departure warning (LDW, without active lane keep assistance) may be increasing crashes claimed with insurers

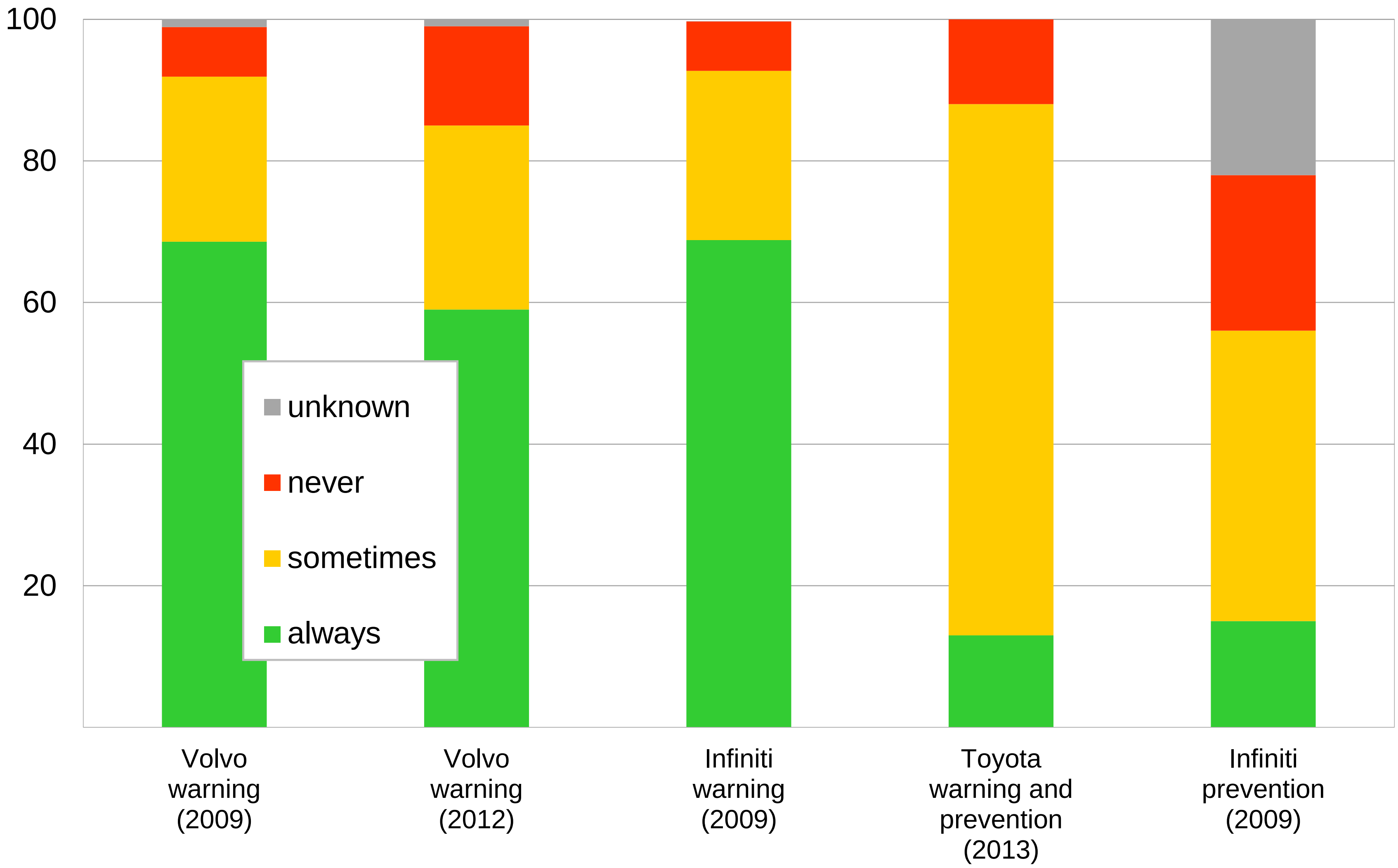
LDW is not reducing crash incidence

Percent change in vehicle damage claims per insured vehicle year



Percent of owners who drive with systems on

Lane departure warning/prevention

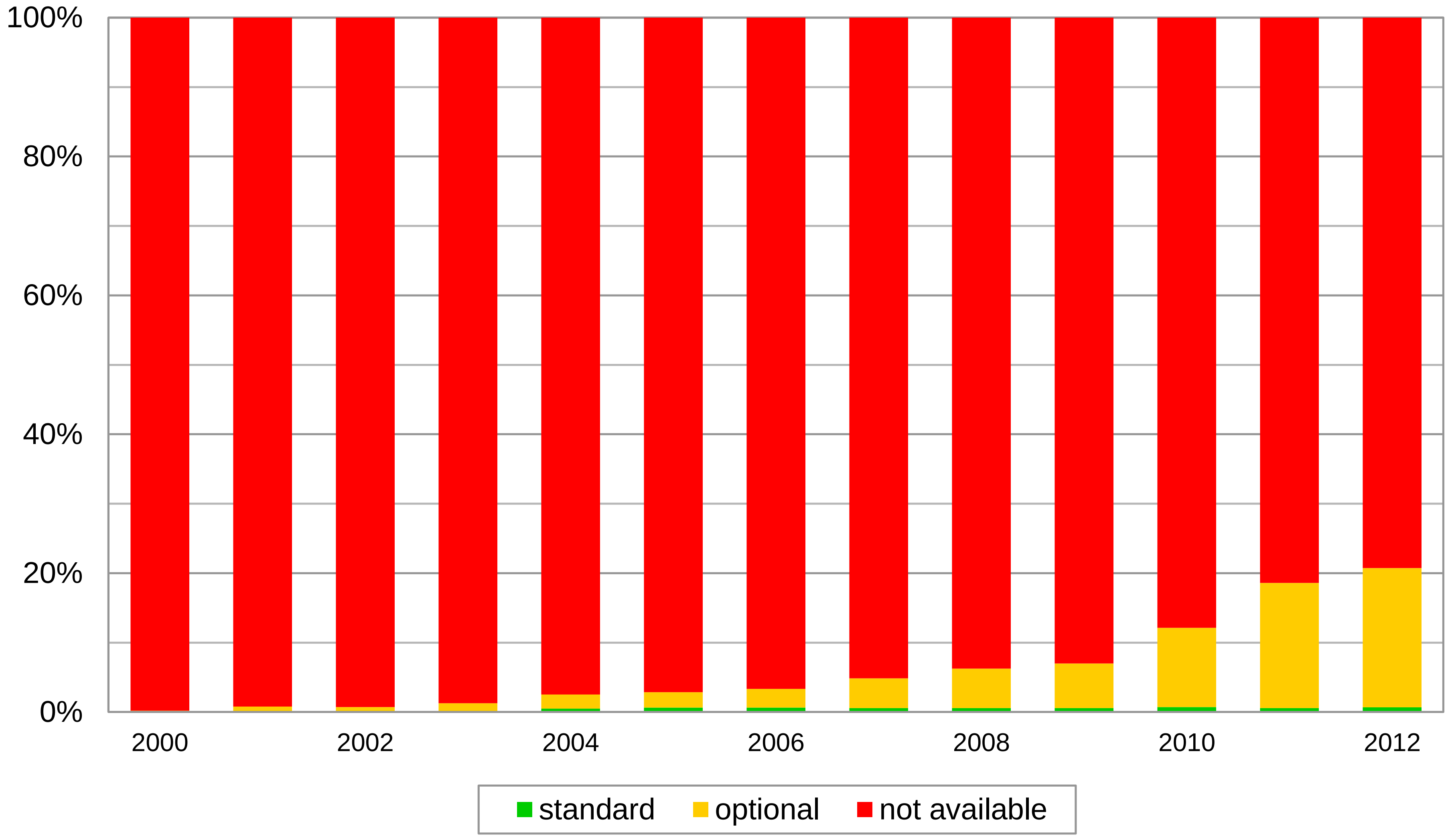


When will we get there?

If crash avoidance technologies develop serially into autonomous driving, then the road is long

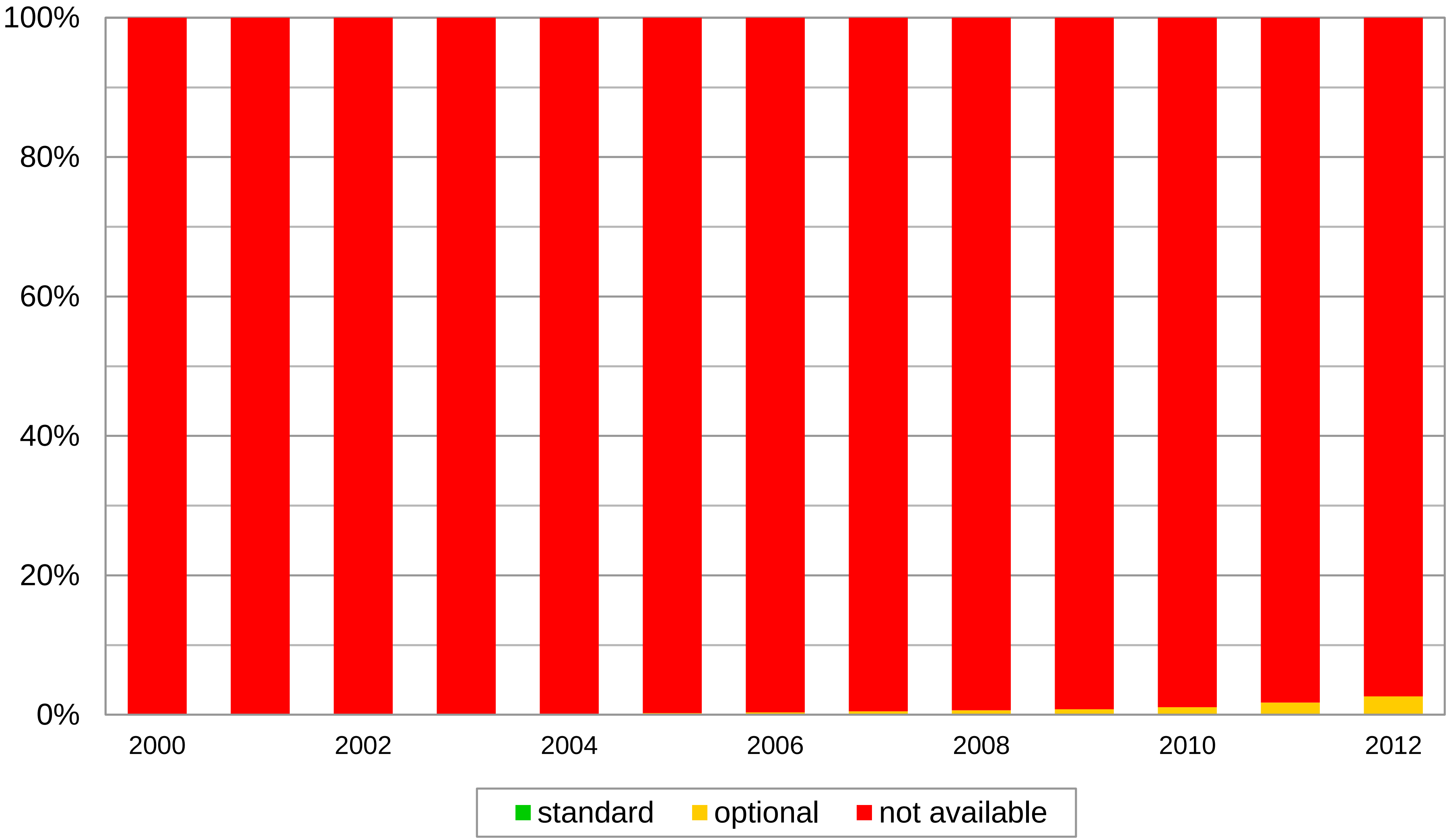
New vehicle series with forward collision warning

By model year

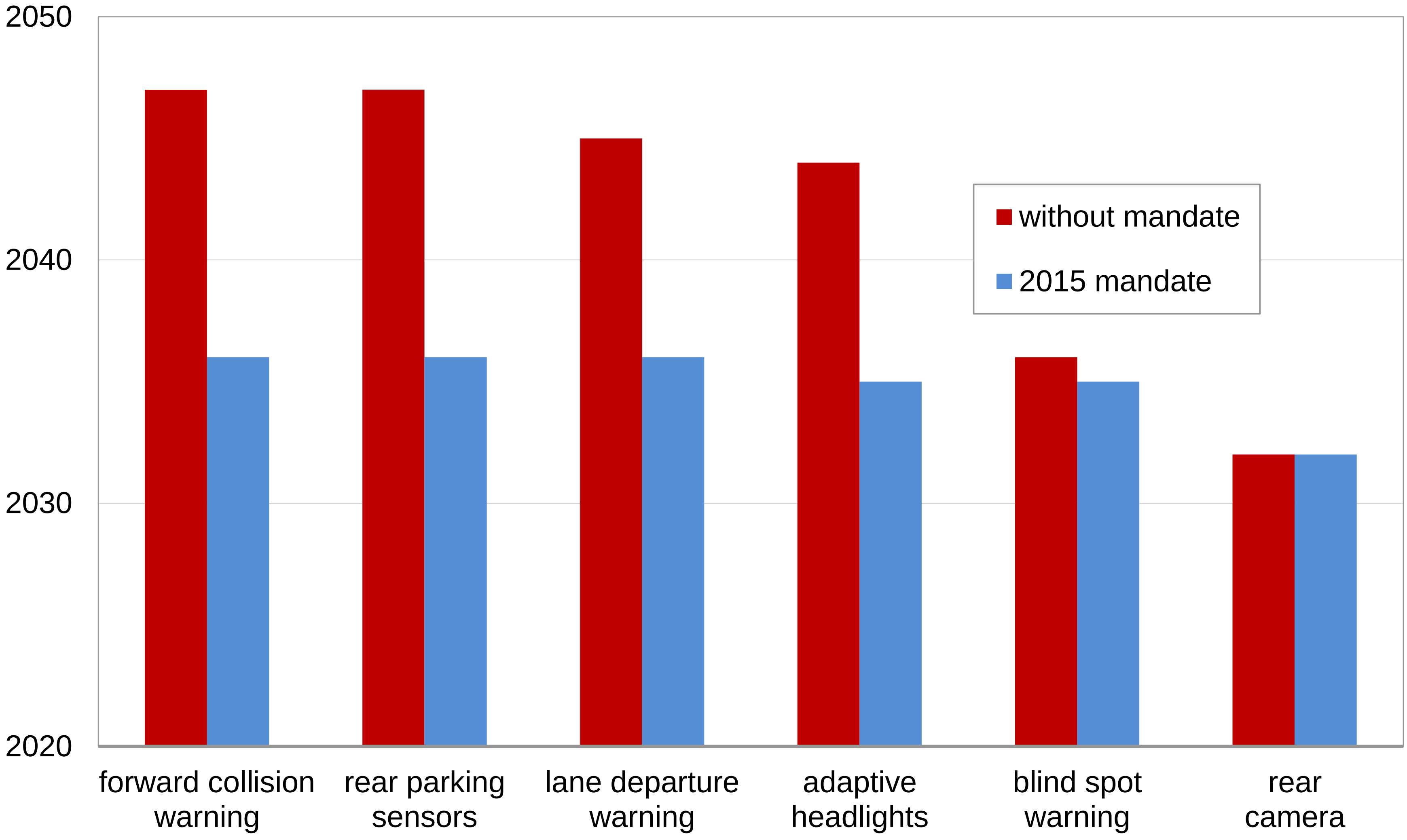


Registered vehicles with forward collision warning

By calendar year



Calendar year features reach 95% of registered vehicle fleet with and without mandate



Other potential speed bumps on road to automated driving

Laws regulating autonomous vehicle control

- 1968 Vienna Convention of Road Traffic (40 countries, excluding U.S.)
  - Article 8(1) and 8(5): "*Every moving vehicle shall have a driver*" [who] "*shall at all times be able to control his vehicle….*"
  - Article 13(1): *"[e]very driver of a vehicle shall in all circumstances have his vehicle under control. . . .*"
  - Proposed amendment (March 2014) (Austria, Belgium, France, Germany and Italy) to Article 8:

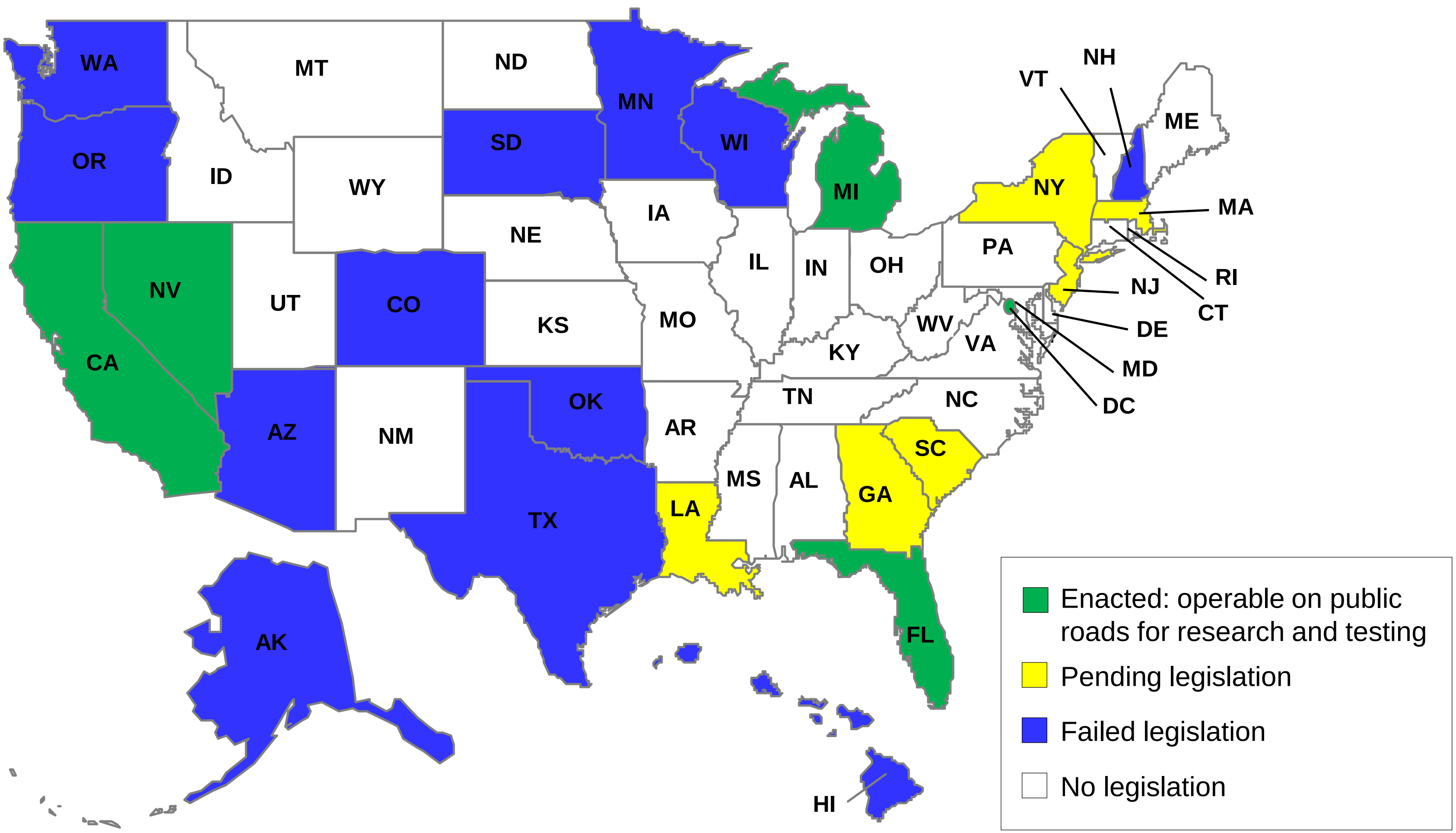
    Vehicle systems which influence the way vehicles are driven . . . shall be deemed in conformity with 8(1) and 13(1)

    when they are in conformity with … international legal instruments concerning wheeled vehicles" OR

    "when such systems can be overridden or switched off by the driver."
  - Equivalent amendments proposed for 1949 Geneva Convention on Road Traffic (94 countries, plus U.S.)
- The proposed amendments specify the conditions under which autonomous vehicle control is acceptable
  - Any level of autonomy appears acceptable if there are internationally agreed specifications for the control system
  - Autonomy levels 2 and 3 appear acceptable if there is a driver and the driver can override/turn off the system
- The amendments do not address Article 8(6): " A driver … shall … minimize any activity other than driving."
- In the US, federal and state laws neither envision nor specifically prohibit any level of autonomy on public roads, but
  - Every state has laws specifying requirements for licensure to operate a motor vehicle and laws requiring a licensed operator be in control of motor vehicles on public roads

Status of autonomous vehicle legislation in US

June 2014



NHTSA statement on vehicle automation

May 30, 2013

- NHTSA will conduct a 4-year study on the safety implications of autonomous driving technology
  - Human factors research and ESC safety
  - Develop system performance requirements
- Provide regulatory guidance to states
  - Licensing
    - Ensure that the driver understands how to operate the vehicle
  - Testing
    - Minimize risk to other road users
    - Limit testing to conditions that are suitable to driverless cars
    - Reporting requirements to monitor performance
    - Transition to self-driving mode to driver mode is safe, simple and timely
    - Capability of detecting, recording and informing driver of system malfunction
    - Installation and operation does not disable any FMVSS
    - Record information in the event of crash or loss of vehicle control
  - Operation other than testing
    - Do not recommend operation for purposes other than testing

Summary – Advanced vehicle technology

- Where are we now?
  - Mature crashworthiness science

    But recent advances still entering fleet and will continue to drive down serious injury and fatality rates over next decade

  - Newborn crash avoidance science

    Low penetration rates with exception of ESC

    Uncertain real-world effectiveness for many technologies

- Where are we going?
  - Goal is zero deaths and injuries
  - Path includes crashworthiness improvements but low hanging fruit has been harvested
  - Crash avoidance technologies promise big returns but driver acceptance and reaction will affect results
  - Autonomous driving is the ultimate vision

Summary – Advanced vehicle technology

- When will we get there?
  - We will get there when we get there
  - Advances will be evolutionary, not revolutionary

    Possible exception of autonomous vehicles for special populations with fixed routes
  - Much research is needed

    How do we make increasing amounts of “driver assistance” fit driving behavior? People are not waiting for their car to tell them how to drive.

    How do we assure fail-safe performance of increasingly automated functions? It cannot be expected that a disengaged driver will take over control in an emergency declared by the vehicle.

    As functions are introduced, the first requirement is to understand the real world effects so that we know when we are making progress.

What can we do while technology develops?

Haddon matrix shows many roads to Vision Zero

Recognizing opportunities to make a difference

changes in…	crash phase before	during	after
people	•licensing laws •graduated licensing •impaired driving laws •red light cameras •speed camera	•belt use •helmets •speed cameras	•alcohol
vehicles	•lane departure warning •daytime running lights •electronic stability control	•airbags •vehicle structure •bumpers	•crash notification systems •fuel system integrity
environment	•roundabouts •trouble spot treatment •rumble strips	•roundabouts •breakaway poles	•emergency medical services


STATUS REPORT
INSURANCE INSTITUTE FOR HIGHWAY SAFETY
Vol. 46, No. 7, Aug. 18, 2011

LOW-HANGING FRUIT

Oftentimes saving a life on the road is as basic as getting people to slow down, buckle up, or don a helmet. Tried and true countermeasures like these usually don't grab headlines, but if they were more widely propagated across the nation they would yield an immediate reduction in motor vehicle crash deaths.
The number of people who die in crashes in the United States is at a record low. Still, there were an estimated 32,788 motor vehicle crash deaths last year, according to a preliminary projection by the National Highway Traffic Safety Administration (NHTSA). Vehicles are safer than ever, and emerging technologies

August 2011

Low hanging fruit in the US

- Roundabouts
- Primary belt use laws
- Mandatory helmet use for all motorcyclists
- Strengthen graduated driver licensing laws
- Lower speed limits
- Automated enforcement of red light running and speeding
- Sobriety checkpoints

These all are proven countermeasures that can begin to reduce deaths and injuries on our highways as soon as implemented.

A common question

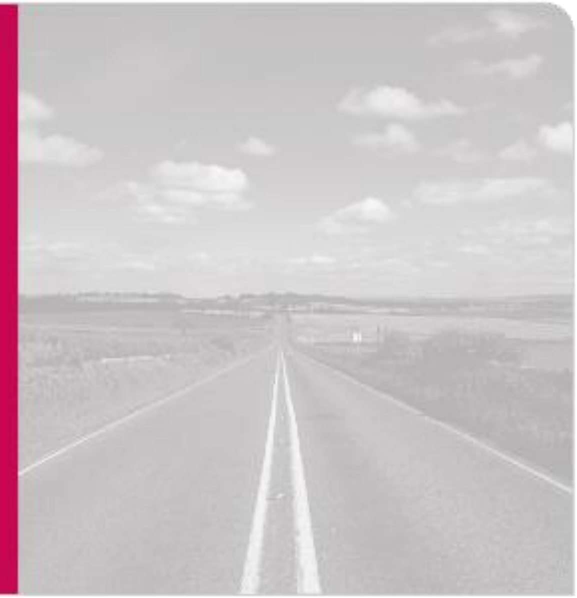
With fatality rates so low, can motor vehicle travel safety still improve?

- Absolutely - all crash deaths and serious injuries are preventable
- Advanced safety technology will be a key part to locking in improved travel safety, as in the past, but
  - Lead time for effectiveness is long as the fleet turns over slowly
  - Crashworthiness improvements are more difficult than in past
  - Crash avoidance technology is just developing and pace of progress is uncertain

    Key issue is the driver
- Vision zero in the near term requires that we apply other strategies
  - We will never achieve Vision Zero but we already know strategies that can take us closer, ahead of vehicle design changes

INSURANCE INSTITUTE FOR HIGHWAY SAFETY

HIGHWAY LOSS DATA INSTITUTE

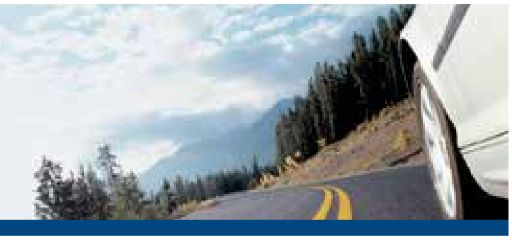


www.iihs.org

Dedicated to reducing deaths, injuries, and property damage on the highway

HIGHWAY LOSS DATA INSTITUTE

Bulletin | Vol. 29, No. 23 : December 2012



Volvo City Safety loss experience – an update

An earlier study reported that Volvo XC60s fitted with City Safety, a low-speed collision avoidance technology, had lower than expected loss frequencies for property damage liability (-27 percent), bodily injury liability (-51 percent) and collision (-22 percent). Updated results for the XC60 as well as initial results for the Volvo S60 confirm that City Safety is reducing losses substantially, although the effects are somewhat smaller than in the initial XC60 report. In the new study, property damage liability loss frequency was estimated to be 15 percent lower than relevant control vehicles for the XC60 and 16 percent lower for the S60. Collision frequencies were reduced by an estimated 20 percent for the XC60 and 9 percent for the S60. Both vehicles also showed reductions in collision claim severity and reductions in overall losses for collision and property damage liability. Under bodily injury liability, frequency was 33 percent lower for the XC60 and 18 percent lower for the S60.

Introduction

This Highway Loss Data Institute (HLDI) bulletin provides an updated look at the effects of Volvo's City Safety technology on insurance losses for the XC60. It also provides an initial look at the results for the S60, newly equipped with City Safety. Prior HLDI results found that Volvo's City Safety system on the XC60 appeared to be preventing crashes (Vol. 28, No. 6). For this bulletin the loss experiences for Volvo XC60s and S60s equipped with City Safety were compared with losses for comparable vehicles without the system. Losses under property damage liability, bodily injury liability, and collision coverage were examined. A supplementary analysis using Volvo vehicles as the comparison group was also conducted and served to verify City Safety's effect.

City Safety, a low-speed collision avoidance system, was released as standard equipment on the 2010 Volvo XC60, a midsize luxury SUV and on the 2011 S60, a midsize luxury car. The system was developed by Volvo to reduce low-speed front-to-rear crashes, which commonly occur in urban traffic, by assisting the driver in braking. According to a Volvo news release, 75 percent of all crashes occur at speeds up to 19 mph, and half of these occur in city traffic (Volvo, 2008). The City Safety system has an infrared laser sensor built into the windshield that detects other vehicles traveling in the same direction up to 18 feet in front of the vehicle. The system initially reacts to slowing or stopped vehicles by pre-charging the brakes. The vehicle will brake automatically if forward collision risk is detected and the driver does not react in time, but only at travel speeds up to 19 mph. If the relative speed difference is less than 9 mph, a collision can be avoided entirely. If the speed difference is between 9 and 19 mph, the speed will be reduced to lessen the collision severity. City Safety is automatically activated when the vehicle ignition is turned on but can be manually deactivated by the driver.

When examining the effect of City Safety on insurance losses, it is important to consider that the system is not designed to mitigate all types of crashes and that many factors can limit the system's ability to perform its intended function. City Safety works equally well during the day and at night, but fog, heavy rain, or snow may limit the ability of the system's infrared laser to detect vehicles. The driver is advised if the sensor becomes blocked by dirt, ice, or snow.

Methods

Insurance data

Automobile insurance covers damage to vehicles and property as well as injuries to people involved in crashes. Different insurance coverages pay for vehicle damage versus injuries, and different coverages may apply depending on who is at fault. The current study is based on property damage liability, bodily injury liability, and collision coverages. Data are supplied to HLDI by its member companies. Property damage liability results are based on 52,050 insured vehicle years and 1,395 claims for the XC60 and 18,033 insured vehicle years and 365 claims for the S60.

Property damage liability coverage insures against physical damage that at-fault drivers cause to other people's vehicles and property in crashes. Bodily injury liability coverage insures against medical, hospital, and other expenses for injuries that at-fault drivers inflict on occupants of other vehicles or others on the road. In the current study, bodily injury liability losses were restricted to data from traditional tort states. Collision coverage insures against physical damage to an at-fault driver's vehicle sustained in a crash with an object or other vehicle.

Subject vehicles

In the main analyses, loss results for the XC60 with City Safety were compared with other midsize luxury SUVs while loss results for the S60 with City Safety were compared with other midsize luxury cars. As a check on a possible "Volvo buyer effect," secondary analyses also compared the XC60 and S60 loss experience with that of other Volvos.

Sales of the 2010 Volvo XC60 began in February 2009, when other brands still were marketing 2009 models. Consequently, the control populations for the XC60 analyses included vehicles starting in model year 2009. The total study population for the XC60 was model years 2010-12 during calendar years 2009-12 with control vehicle model years of 2009-12. The loss experience of the model year 2009 vehicles in calendar year 2008 was excluded because no XC60s were on the road during this time period.

City Safety was added as standard equipment to the Volvo S60 in model year 2011. The analyses considered model years 2011-12 for the S60 and its control vehicles during calendar years 2011-12. Calendar year 2010 was not included in the S60 analysis because of the very small number of model year 2011 S60s insured that year.

Total exposure measured as insured vehicle years and the total number of claims for the XC60 and S60 are shown by insurance coverage type in **Table 1**. **Appendix A** contains the same information for the comparison vehicles.

Table 1: Exposure and claims by coverage type

	XC60		S60	
Coverage	Exposure	Claims	Exposure	Claims
Property damage liability	52,050	1,395	18,033	365
Bodily injury liability	16,700	86	3,863	21
Collision	52,050	2,974	18,033	1,236

Because previous HLDI analyses have shown them to have different loss patterns, hybrids, convertibles, and two-door vehicles were excluded from the control groups. Additionally, the XC60 analysis excluded City Safety-equipped S60s from the Volvo control group while the S60 analysis excluded XC60s from the Volvo comparison vehicles. For both the XC60 and S60, the Volvo comparison groups did not include the 2012 S80 or the 2012 XC70. Both these vehicles were excluded because they had standard City Safety beginning in the 2012 model year. Vehicle models with two and four-wheel drive versions were combined to provide sufficient data for analysis.

The study and control vehicles in this analysis can also be equipped with optional collision avoidance features that have been shown to affect frequency and severity in other studies by HLDI. It should be noted that this analysis does not account for their presence or absence because the information needed to identify the vehicles with the optional features is not available in the HLDI database. Furthermore, the take rate for these features is thought to be low.

Analysis methods

Regression analysis was used to model claim frequency per insured vehicle year and average loss payment per claim (claim severity) while controlling for various covariates. Claim frequency was modeled using a Poisson distribution, and claim severity was modeled using a Gamma distribution. Both models used a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models. They were calculated by multiplication because the estimate for the effect of City Safety on claim frequency and claim severity were in the form of ratios relative to the reference categories (baseline). The standard error for overall losses was calculated by taking the square root of the sum of the squared standard errors from the claim frequency and severity estimates. Based on the value of the estimate and the associated standard error, the corresponding two-sided p-value was derived from a standard normal distribution approximation.

The covariates included calendar year, model year, garaging state, vehicle density (number of registered vehicles per square mile), rated driver age, rated driver gender, marital status, collision deductible, and risk. To estimate the effect of City Safety, vehicle series was included as a variable in the regression models, with the Volvo XC60 or S60 assigned as the reference group. The model estimate corresponding to each comparison vehicle indicates the proportional increase or decrease in losses of that vehicle relative to the XC60 or the S60, while controlling for differences in the distributions of drivers and garaging locations. For example, in the analysis of property damage liability claim frequency, the model estimate comparing the XC60 to the BMW X5 was 0.2815, which translates to an estimated increase in claim frequency of 33 percent for the X5 compared to the XC60 ($e^{0.2815} = 1.33$). Given the actual property damage liability claim frequency for the Volvo XC60 equaled 2.7 claims per 100 insured vehicle years, the comparable claim frequency for the X5 if it had the same distribution of drivers and garaging locations as the XC60 is predicted to have been 2.7 x 1.33 = 3.6 claims per 100 insured vehicle years.

Weighted averages of the model estimates for individual vehicles in the analysis also were calculated for midsize luxury SUVs and for midsize luxury cars. The weights in the averages were proportional to the inverse variance of the respective estimates, meaning that the estimates with high variance (those with large confidence intervals, typically due to little exposure and/or claims) contributed less than estimates with low variance (those with small confidence intervals). These calculations estimate the average effect for each vehicle group of *not having* City Safety. Because it is often useful to state the results in terms of the estimated benefit of *having* a feature, the inverse of the average City Safety effect also was calculated. That is, the weighted average property damage loss frequency for other midsize luxury SUVs was 1.17 times that of the XC60; the inverse of that, (1/1.17)-1, or – 0.15, indicates that the estimated benefit of having City Safety is a 15 percent reduction in claim frequency compared to other SUVs. The estimated benefit for each overall comparison and the 95 percent confidence bounds are shown in **Tables 4-6**.

Results

Tables 2-3 illustrate the pattern of results available from the analyses performed. In **Table 2** it can be seen that all independent variables in the model had statistically significant effects on property damage liability loss frequencies of midsize luxury SUVs. **Table 3** lists estimates and significance levels for the individual values of the categorical variables from the regression model. The intercept outlines losses for the reference (baseline) categories: the estimate corresponds to the claim frequency for a 2012 Volvo XC60, garaged in a high vehicle density area in Texas, and driven by a married female age 40-49 with standard risk during calendar year 2012. The remaining estimates are in the form of multiples, or ratios relative to the reference categories. **Table 3** includes only an abbreviated list of results by state. Only states with the five highest and five lowest estimates are listed, along with the comparison state of Texas. Detailed results for all states and all regressions are available in a separate **Appendix**.

Table 2: Summary results of linear regression analysis of property damage liability claim frequencies for XC60 vs. other midsize luxury SUVs			
	Degrees of freedom	Chi-Square	P-value
Calendar year	3	105.75	<0.0001
Model year	3	46.66	<0.0001
Vehicle make and series	20	293.95	<0.0001
State	50	924.87	<0.0001
Registered vehicle density	6	681.76	<0.0001
Rated driver age	10	698.24	<0.0001
Rated driver gender	2	99.31	<0.0001
Rated driver marital status	2	194.64	<0.0001
Risk	1	203.87	<0.0001

Table 3: Detailed results of linear regression analysis of property damage liability claim frequencies for Volvo XC60 vs. other midsize luxury SUVs

Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Intercept	1	-9.4038		0.0361	-9.4746	-9.3330	67847.10	<0.0001
Calendar year								
2009	1	0.0528	5.4%	0.0182	0.0172	0.0885	8.43	0.0037
2010	1	0.0950	10.0%	0.0129	0.0696	0.1203	53.95	<0.0001
2011	1	0.1071	11.3%	0.0108	0.0858	0.1283	97.56	<0.0001
2012	0	0	0	0	0	0		
Model year								
2009	1	0.1311	14.0%	0.0212	0.0895	0.1727	38.11	<0.0001
2010	1	0.0834	8.7%	0.0204	0.0434	0.1234	16.70	<0.0001
2011	1	0.0705	7.3%	0.0207	0.0300	0.1111	11.61	0.0007
2012	0	0	0	0	0	0		
Vehicle make and series								
Acura MDX	1	0.1583	17.2%	0.0300	0.0996	0.2170	27.91	<0.0001
Acura RDX	1	0.1202	12.8%	0.0345	0.0525	0.1879	12.11	0.0005
Acura ZDX	1	0.2459	27.9%	0.0799	0.0893	0.4025	9.48	0.0021
Audi Q5 4WD	1	0.0291	3.0%	0.0338	-0.0370	0.0953	0.75	0.3880
BMW X3	1	0.0784	8.2%	0.0384	0.0031	0.1537	4.16	0.0414
BMW X5	1	0.2815	32.5%	0.0306	0.2216	0.3414	84.82	<0.0001
BMW X6	1	0.3300	39.1%	0.0457	0.2405	0.4196	52.21	<0.0001
Cadillac SRX	1	0.1474	15.9%	0.0309	0.0868	0.2080	22.75	<0.0001
Infiniti EX35	1	-0.0447	-4.4%	0.0459	-0.1346	0.0451	0.95	0.3292
Infiniti FX35	1	0.1878	20.7%	0.0364	0.1165	0.2592	26.61	<0.0001
Infiniti FX50	1	0.2131	23.8%	0.0914	0.0339	0.3923	5.43	0.0198
Land Rover LR2	1	0.2947	34.3%	0.0498	0.1970	0.3924	34.96	<0.0001
Lexus RX 350	1	0.1363	14.6%	0.0283	0.0809	0.1917	23.24	<0.0001
Lincoln MKT	1	0.0977	10.3%	0.0556	-0.0112	0.2066	3.09	0.0787
Lincoln MKX	1	0.1618	17.6%	0.0345	0.0942	0.2295	21.99	<0.0001
Mercedes-Benz GLK class	1	0.1517	16.4%	0.0324	0.0883	0.2151	21.99	<0.0001
Mercedes-Benz M class	1	0.0777	8.1%	0.0311	0.0168	0.1387	6.25	0.0124
Saab 9-4X	1	0.6464	90.9%	0.3176	0.0240	1.2688	4.14	0.0418

Table 3: Detailed results of linear regression analysis of property damage liability claim frequencies for Volvo XC60 vs. other midsize luxury SUVs								
Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Saab 9-7X	1	0.2384	26.9%	0.0882	0.0656	0.4112	7.31	0.0068
Volvo XC90	1	0.2878	33.3%	0.0354	0.2183	0.3572	65.93	<0.0001
Volvo XC60	0	0	0	0	0	0		
State								
Michigan	1	-1.4864	-77.4%	0.0617	-1.6072	-1.3655	581.18	<0.0001
Wyoming	1	-0.5156	-40.3%	0.2256	-0.9577	-0.0735	5.23	0.0223
Idaho	1	-0.3545	-29.8%	0.1454	-0.6395	-0.0695	5.94	0.0148
Nebraska	1	-0.3463	-29.3%	0.0827	-0.5084	-0.1843	17.54	<0.0001
Delaware	1	-0.3136	-26.9%	0.0851	-0.4803	-0.1469	13.60	0.0002
Arkansas	1	-0.0243	-2.4%	0.0717	-0.1649	0.1163	0.11	0.7351
Massachusetts	1	0.0183	1.8%	0.0356	-0.0513	0.0880	0.27	0.6060
Vermont	1	0.0762	7.9%	0.1314	-0.1813	0.3336	0.34	0.5622
District of Columbia	1	0.1090	11.5%	0.0681	-0.0245	0.2424	2.56	0.1094
North Dakota	1	0.3529	42.3%	0.1756	0.0087	0.6971	4.04	0.0445
Texas	0	0	0	0	0	0		
Registered vehicle density								
Unknown	1	-0.5713	-43.5%	0.4475	-1.4484	0.3057	1.63	0.2017
<50	1	-0.5130	-40.1%	0.0291	-0.5701	-0.4559	310.19	<0.0001
50-99	1	-0.3726	-31.1%	0.0229	-0.4175	-0.3276	264.17	<0.0001
100-249	1	-0.2906	-25.2%	0.0170	-0.3238	-0.2574	293.83	<0.0001
250-499	1	-0.2215	-19.9%	0.0140	-0.2490	-0.1940	248.60	<0.0001
500-999	1	-0.1156	-10.9%	0.0141	-0.1432	-0.0880	67.29	<0.0001
1,000+	0	0	0	0	0	0		
Rated driver age								
Unknown	1	-0.0311	-3.1%	0.0247	-0.0796	0.0173	1.59	0.2080
15-19	1	0.3649	44.0%	0.0370	0.2924	0.4374	97.24	<0.0001
20-24	1	0.2262	25.4%	0.0295	0.1682	0.2841	58.58	<0.0001
25-29	1	0.1170	12.4%	0.0233	0.0714	0.1625	25.29	<0.0001
30-39	1	0.0301	3.1%	0.0135	0.0037	0.0564	4.99	0.0255
50-59	1	-0.1323	-12.4%	0.0134	-0.1585	-0.1061	97.80	<0.0001
60-64	1	-0.1035	-9.8%	0.0172	-0.1372	-0.0698	36.19	<0.0001
65-69	1	-0.0027	-0.3%	0.0186	-0.0391	0.0338	0.02	0.8860
70-74	1	0.0866	9.0%	0.0224	0.0428	0.1305	15.02	0.0001
75+	1	0.3202	37.7%	0.0219	0.2772	0.3631	213.51	<0.0001
40-49	0	0	0	0	0	0		
Rated driver gender								
Male	1	-0.0891	-8.5%	0.0106	-0.1098	-0.0683	70.68	<0.0001
Unknown	1	-0.1681	-15.5%	0.0256	-0.2182	-0.1180	43.25	<0.0001
Female	0	0	0	0	0	0		
Rated driver marital status								
Single	1	0.1640	17.8%	0.0125	0.1394	0.1885	171.12	<0.0001
Unknown	1	0.1644	17.9%	0.0250	0.1155	0.2133	43.39	<0.0001
Married	0	0	0	0	0	0		
Risk								
Nonstandard	1	0.1953	21.6%	0.0137	0.1685	0.2221	203.87	<0.0001
Standard	0	0	0	0	0	0		

Property damage liability: Figures 1-2 show the results from the analyses of property damage liability claim frequency for the XC60 and the S60, respectively. In these figures, the actual property damage liability claim frequency (per 100 vehicle years exposure) for the Volvo XC60 and S60 are plotted, along with the estimated claim frequencies of each comparison vehicle and the average of all comparison vehicles derived from the regression models. The results were very similar, with the XC60 having an actual claim frequency 15 percent lower than the average of midsize luxury SUVs while the S60's claim frequency was 16 percent lower than the average of midsize luxury cars. Among comparison midsize luxury SUVs, only the Infiniti EX35 had a lower estimated claim frequency than the XC60, and that difference was not statistically significant. Analogously, only the Audi S4 4WD and the BMW M3 had lower estimated claim frequencies than the S60, and again, those differences were not statistically significant. In addition, these two vehicles are high performance variants of the Audi A4 4WD and the BMW 3 that may be driven only recreationally and therefore may have low-mileage exposure. Notably, the S60 had a claim frequency that was significantly lower than the base variants of these vehicles (Audi A4 4WD and BMW 3). Note that the vertical I-bars for each comparison group are the 95 percent confidence limits for the comparison of that group with the Volvo study vehicle, not the 95 percent confidence interval for that group's frequency estimate. This is true for all of the figures.

Figure 1: Property damage liability claim frequencies per 100 insured vehicle years for 2010-12 Volvo XC60 with City Safety vs. other 2009-12 midsize luxury SUVs

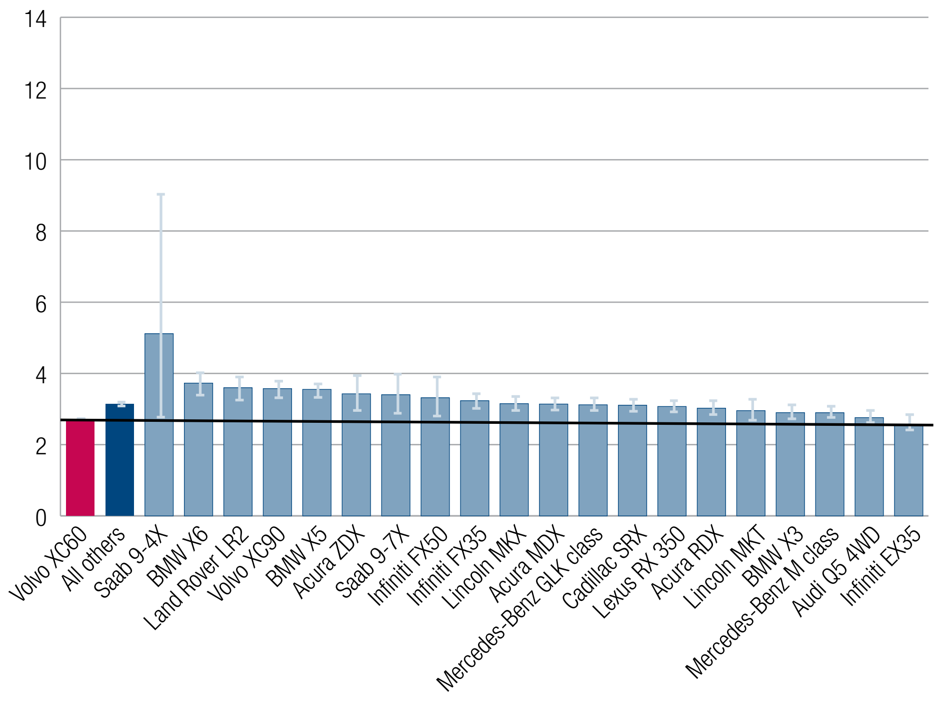
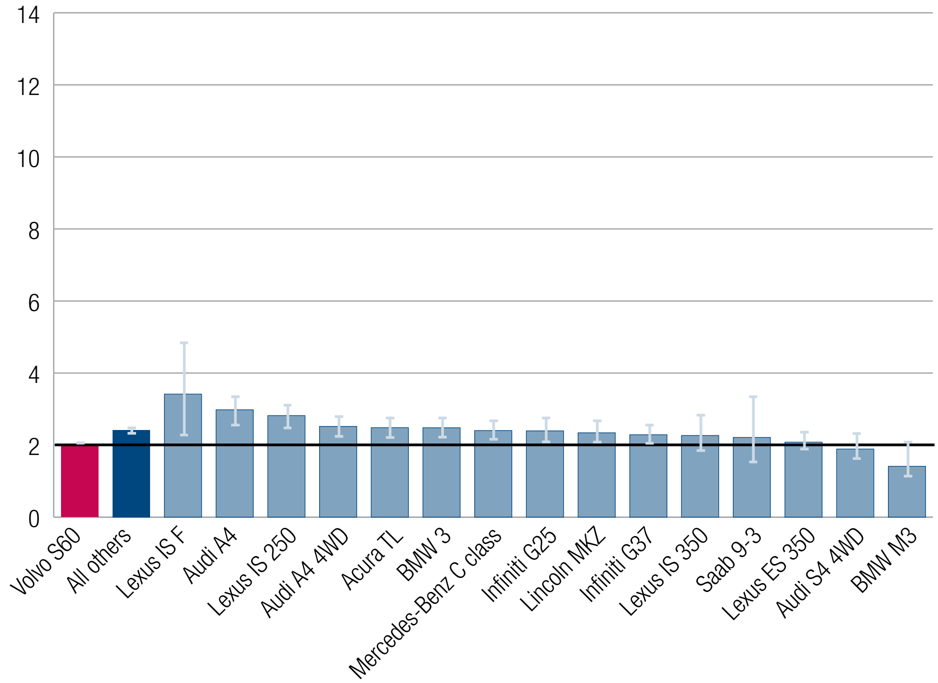


Figure 2: Property damage liability claim frequencies per 100 insured vehicle years for 2011-12 Volvo S60 with City Safety vs. other 2011-12 midsize luxury cars



Figures 3-4 show the results of the analyses of property damage liability claim severity for the Volvo XC60 and S60, respectively. As for the frequency analyses above, the actual average cost per claim is plotted for the XC60 and S60 against the model-derived estimates for each of the comparison vehicles as well as their weighted average. The XC60 average loss per claim fell near the middle of the range of other midsize luxury SUVs (1 percent lower than the average) while the S60 claim severity was typically higher than other midsize luxury cars (13 percent higher than the average).

Figure 3: Property damage liability claim severities for 2010-12 Volvo XC60 with City Safety vs. other 2009-12 midsize luxury SUVs

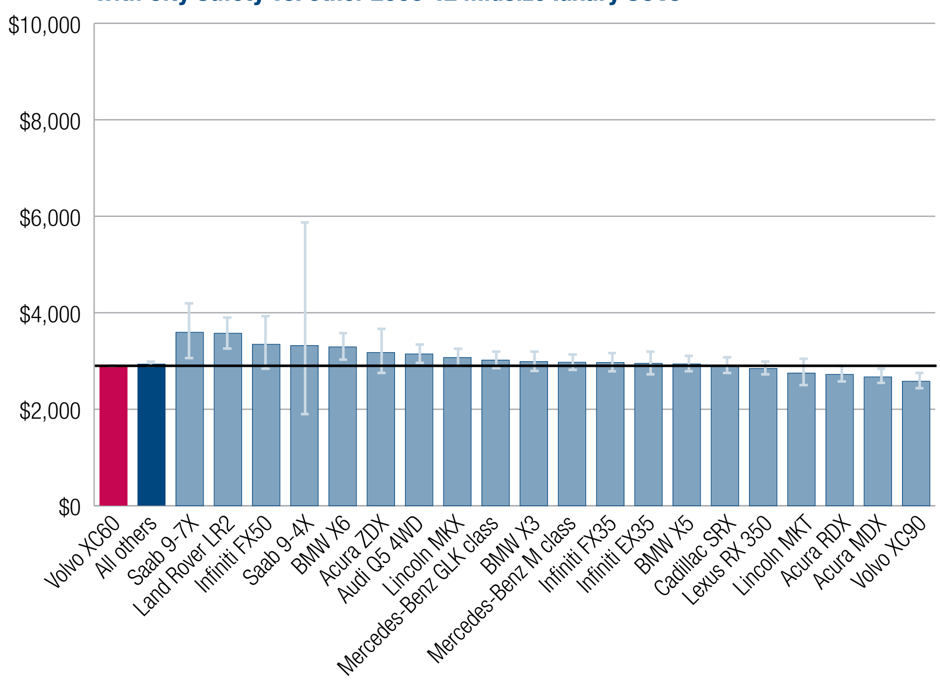
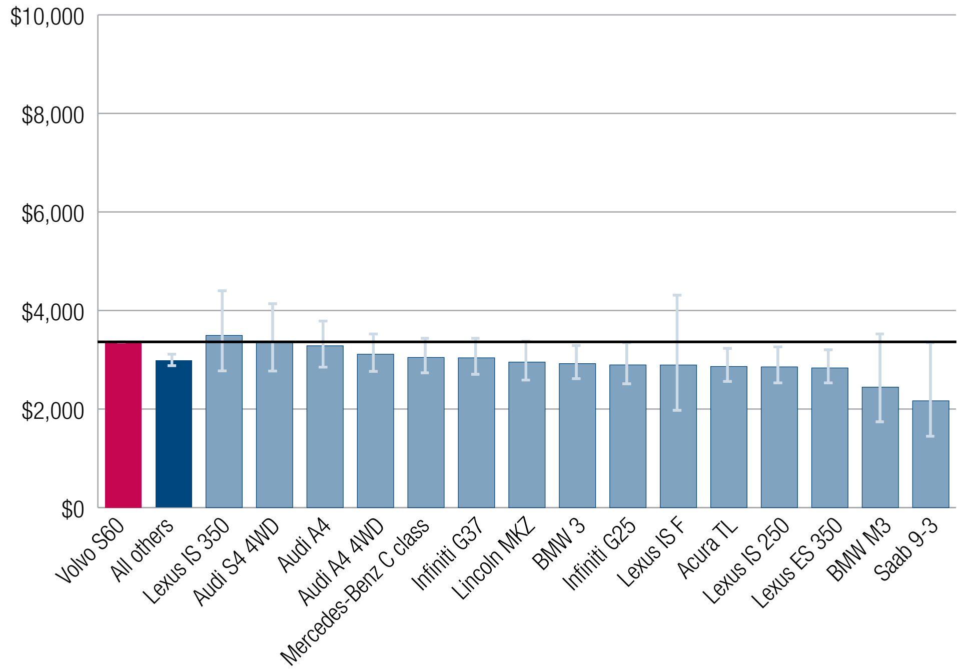


Figure 4: Property damage liability claim severities for 2011-12 Volvo S60 with City Safety vs. other 2011-12 midsize luxury cars



Figures 5-6 provide more detail about the differences in property damage liability claim severity results by examining the frequency of claims in different severity ranges. In **Figure 5**, the XC60 compared to other midsize luxury SUVs had fewer claims in low, medium and high severity ranges, with the greatest percentage reduction (21 percent) in claims costing at least $7,000. In contrast, the S60 (**Figure 6**) had lower claim frequency only in the low and medium severity ranges. For claims of at least $7,000, frequencies were slightly higher for the S60 compared to other midsize luxury cars. The claim severity results for the S60, but not the XC60, fit the pattern expected for a crash prevention system that is active only at low speeds (<20 mph) and indicates that the increase in average severity is the result of mean shifting associated with the elimination of many inexpensive claims. The differences at all claim severity ranges were statistically significant.

Figure 5: Property damage liability claim frequencies by claim severity range, Volvo XC60 vs. other midsize luxury SUVs

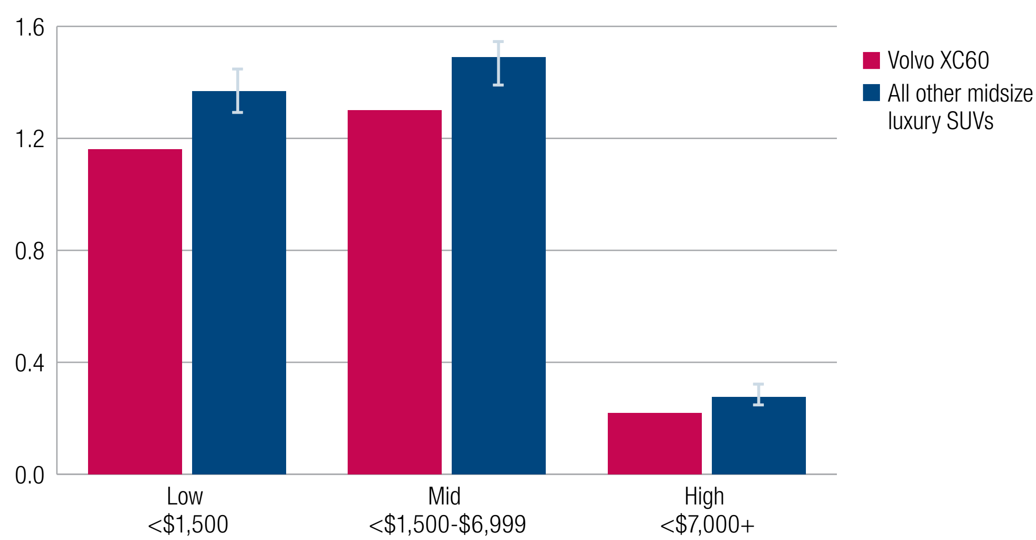
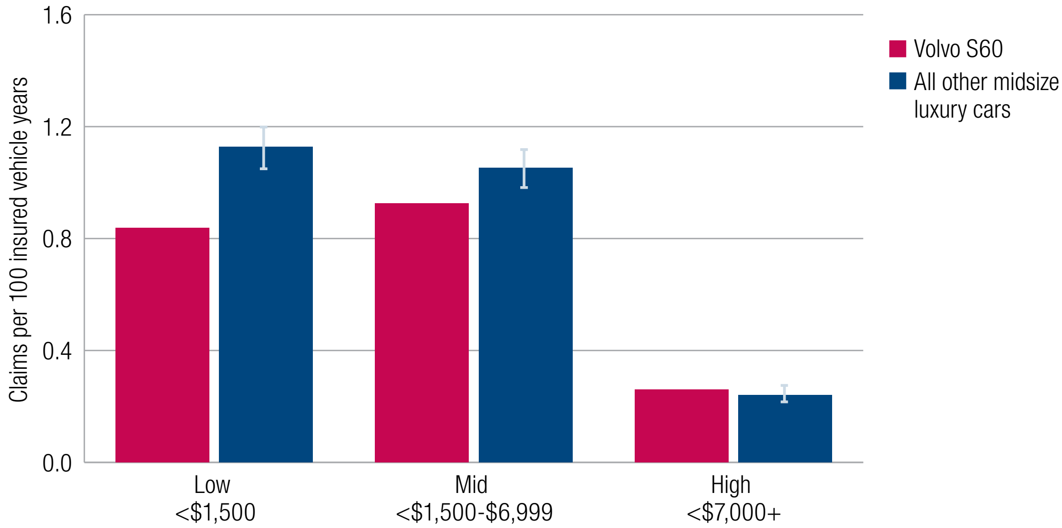


Figure 6: Property damage liability claim frequencies by claim severity range, Volvo S60 vs. other midsize luxury cars



Figures 7-8 show the result of combining the regression results from the frequency and severity analyses to obtain a comparison of overall property damage liability losses for the Volvo XC60 and S60 and their respective comparison vehicles. At $78 per insured vehicle year, the actual overall loss for the Volvo XC60 (**Figure 7**) was lower than almost all other midsize luxury SUVs and 16 percent lower than the weighted average of those vehicles. The actual overall loss for the Volvo S60 ($68 per insured vehicle year) was only 6 percent lower than that for all other midsize four-door luxury cars combined (**Figure 8**), as the decrease in claim frequency was offset somewhat by the fact that the more expensive claims had not decreased.

Figure 7: Property damage liability overall losses for 2010-12 Volvo XC60 with City Safety vs. other 2009-12 midsize luxury SUVs

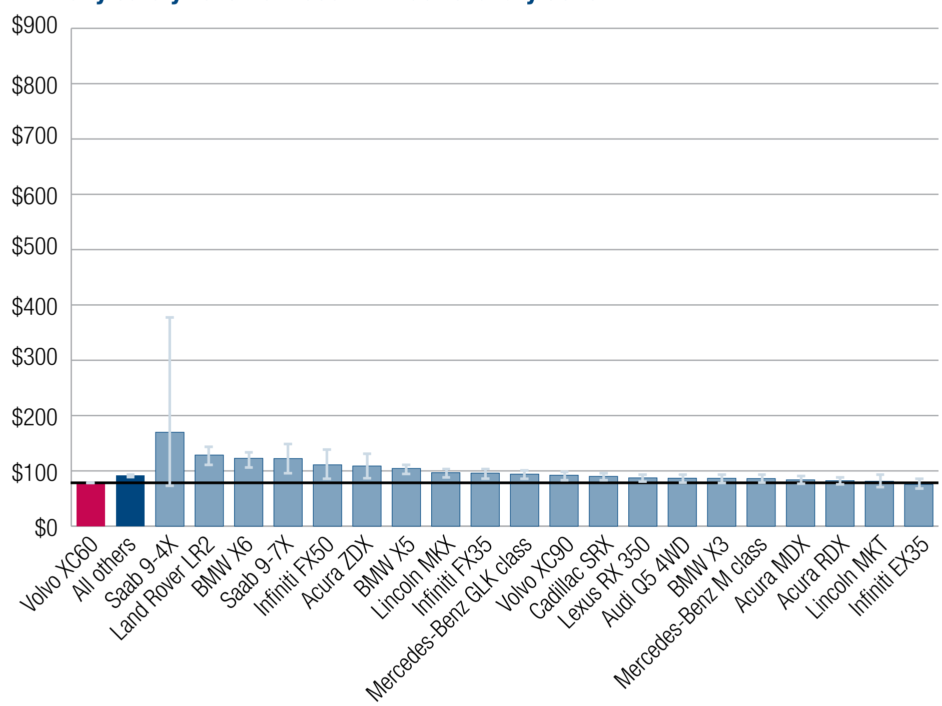


Figure 8: Property damage liability overall losses for 2011-12 Volvo S60 with City Safety vs. other 2011-12 midsize luxury cars

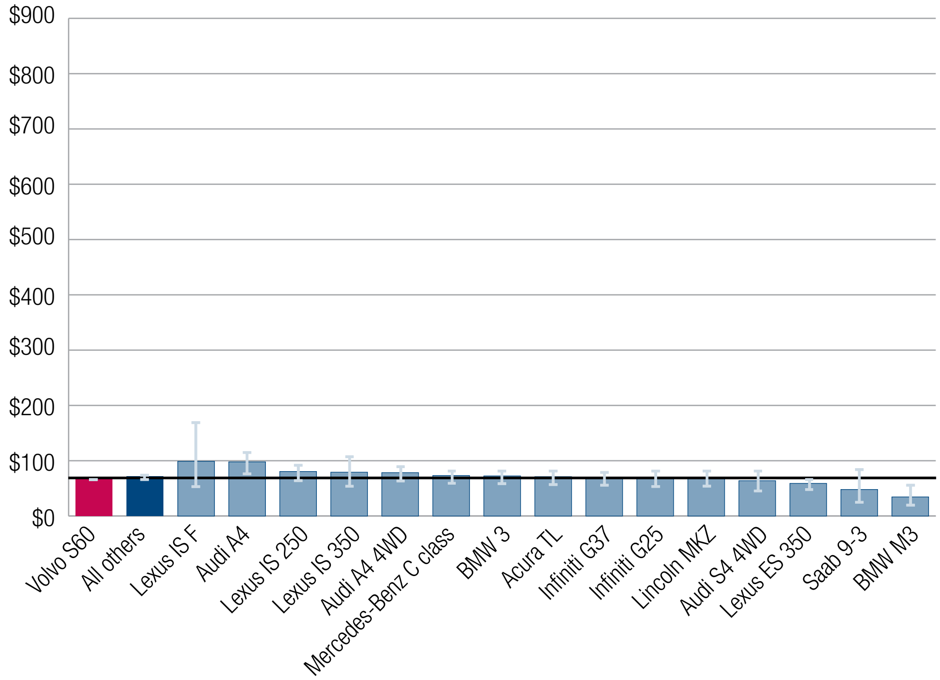


Table 4 summarizes the property damage liability results for the Volvo XC60 and S60 with City Safety. Note that the first two columns provide the weighted average estimates from the regressions and the standard error of those estimates. The third column is the effect estimate expressed as the percent increase or decrease in claim frequency, severity and overall losses (e**estimate); this is the effect of not having City Safety. In the final two columns, the effect of City Safety is expressed in terms of the estimated percent benefit of the technology (i.e., 100 x (1/$e^{estimate}$ - 1)) and the 95 percent confidence bounds of the estimated benefit.

Table 4: Property damage liability loss results - City Safety versus weighted average of comparison vehicles

				City Safety benefit	
	Estimate	Standard Error	Estimated change of control vehicles relative to study vehicles	Estimate	95% confidence interval
XC60 vs. midsize luxury SUVs					
Claim frequency	-0.1575	0.0087	17%	-15%	-16%, -13%
Claim severity	-0.0145	0.0081	1%	-1%	-3%, 0%
Overall loss	-0.1720	0.0119	19%	-16%	-18%, -14%
Claims <$1,500	-0.1654	0.0132	18%	-15%	-17%, -13%
Claims $1,500-$6,999	-0.1360	0.0124	15%	-13%	-15%, -11%
Claims $7,000+	-0.2342	0.0297	26%	-21%	-25%, -16%
S60 vs. midsize luxury cars					
Claim frequency	-0.1778	0.0200	19%	-16%	-20%, -13%
Claim severity	0.1179	0.0196	-11%	13%	8%, 17%
Overall loss	-0.0598	0.0280	6%	-6%	-11%, -1%
Claims <$1,500	-0.2984	0.0304	35%	-26%	-30%, -21%
Claims $1,500-$6,999	-0.1289	0.0298	14%	-12%	-17%, -7%
Claims $7,000+	0.0809	0.0590	-8%	8%	-3%, 22%

Bodily injury liability: Figures 9-10 show the results for the analyses of bodily injury liability claim frequency. The actual bodily injury claim frequency for the XC60 and S60 are typically lower than the estimated frequencies for their comparison vehicles. However, for the S60, most individual comparison cars were not significantly different. As with property damage liability, the Audi S4 4WD and the BMW M3 had lower claim rates than the S60.

Figure 9: Bodily injury liability claim frequencies per 1,000 insured vehicle years for 2010-12 Volvo XC60 with City Safety vs. other 2009-12 midsize luxury SUVs

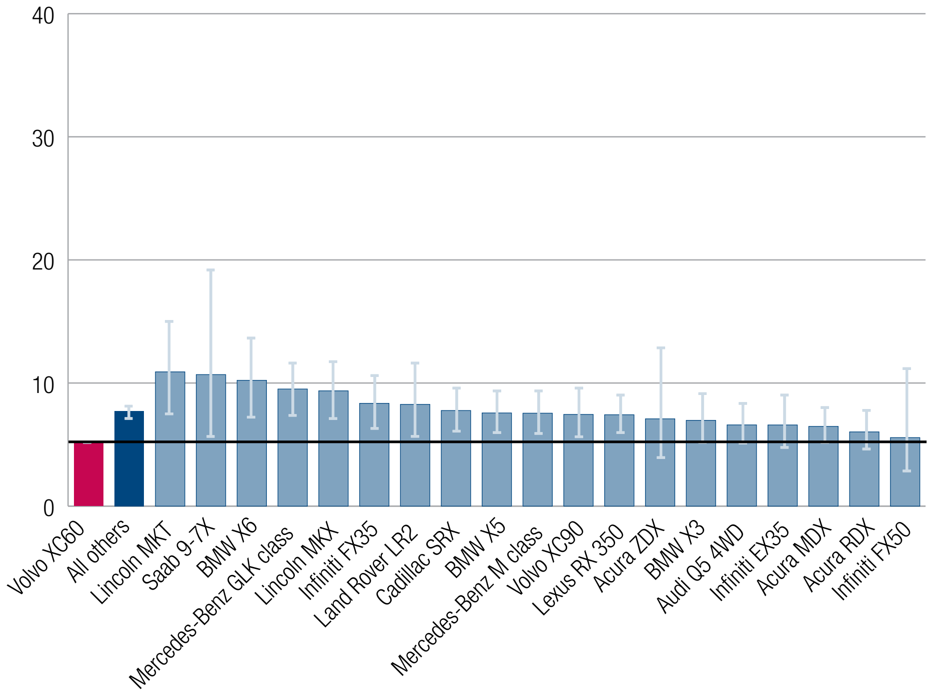


Figure 10: Bodily injury liability claim frequencies per 1,000 insured vehicle years for 2011-12 Volvo S60 with City Safety vs. other 2011-12 midsize luxury cars

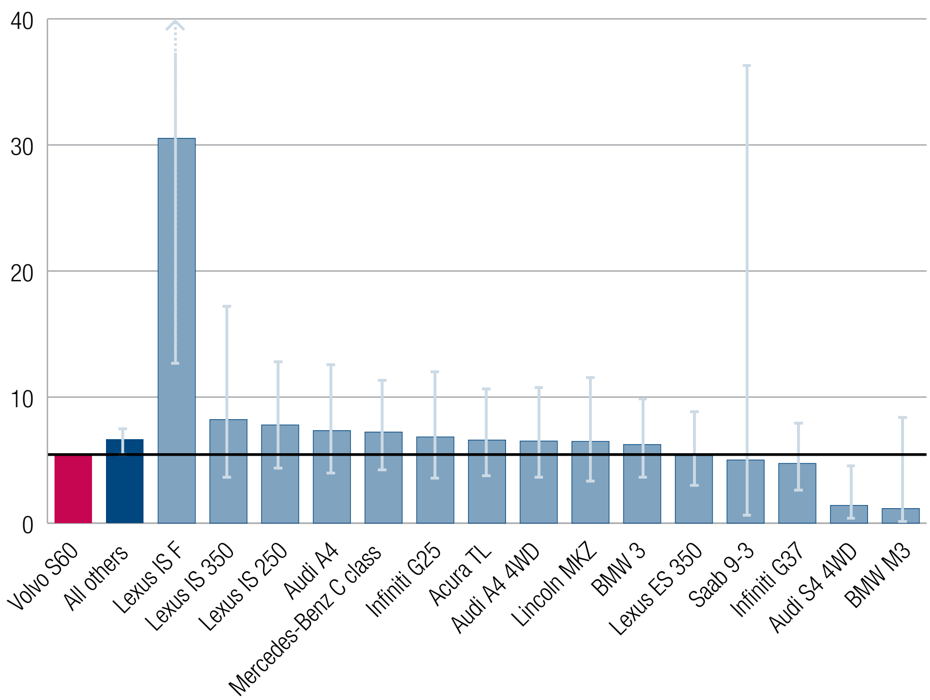


Table 5 summarizes results of the regression analysis conducted for bodily injury liability coverage. Note that analyses of claim severity were not conducted because of the relative recency of these claims and the length of time it takes for claims costs to fully develop. The layout of **Table 5** is analogous to **Table 4**, with the estimated benefits of City Safety in the Volvo XC60 and S60 shown in the final two columns. Compared to other midsize luxury SUVs, it is estimated that the XC60 bodily injury liability claims frequency was reduced by 33 percent with City Safety. For the S60, bodily injury claims frequency was 18 percent lower than would have been expected based on the weighted average experience of other midsize luxury cars.

Table 5: Bodily injury liability loss frequency results - City Safety versus weighted average of comparison vehicles

				City Safety benefit	
	Estimate	Standard Error	Estimated change of control vehicles relative to study vehicles	Estimate	95% confidence interval
XC60 vs. midsize luxury SUVs	-0.4050	0.0337	50%	-33%	-38%, -29%
S60 vs. midsize luxury cars	-0.2005	0.0827	22%	-18%	-30%, -4%

Collision damage: Figures 11-16 show the results for the analyses of collision damage claim frequency, claim severity, and overall losses for the XC60 and S60. For both vehicles fitted with City Safety, the actual loss frequency and severity are lower than the estimated frequencies and severities associated with most of the comparison vehicles. As a result, overall losses for the City Safety vehicles also are lower than the overall losses of most comparison vehicles.

Figure 11: Collision claim frequencies per 100 insured vehicle years for 2010-12 Volvo XC60 with City Safety vs. other 2009-12 midsize luxury SUVs

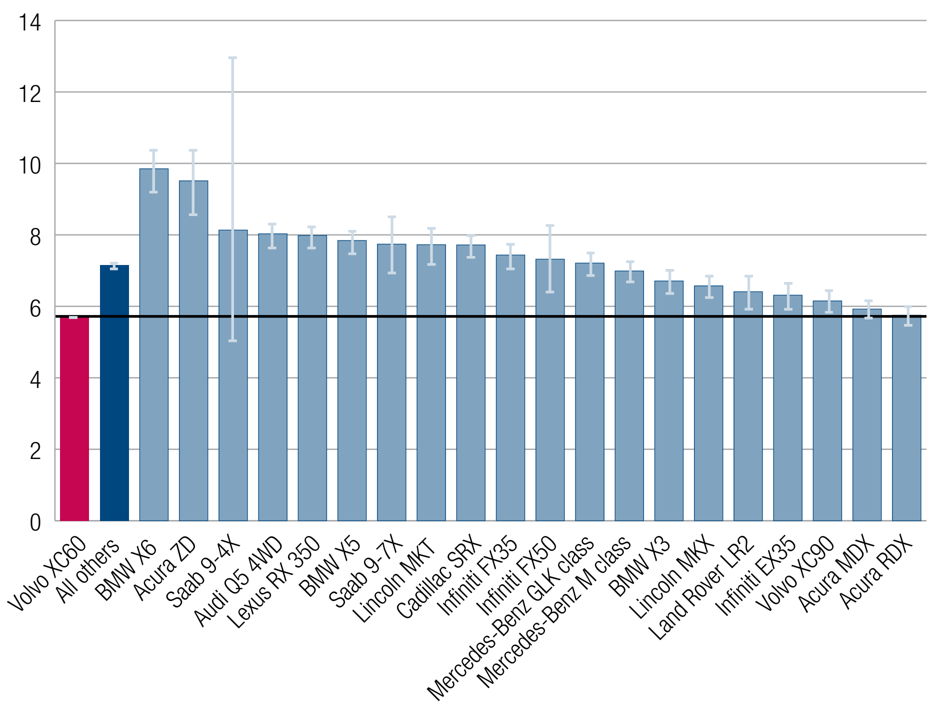


Figure 12: Collision claim frequencies per 100 insured vehicle years for 2011-12 Volvo S60 with City Safety vs. other 2011-12 midsize luxury cars

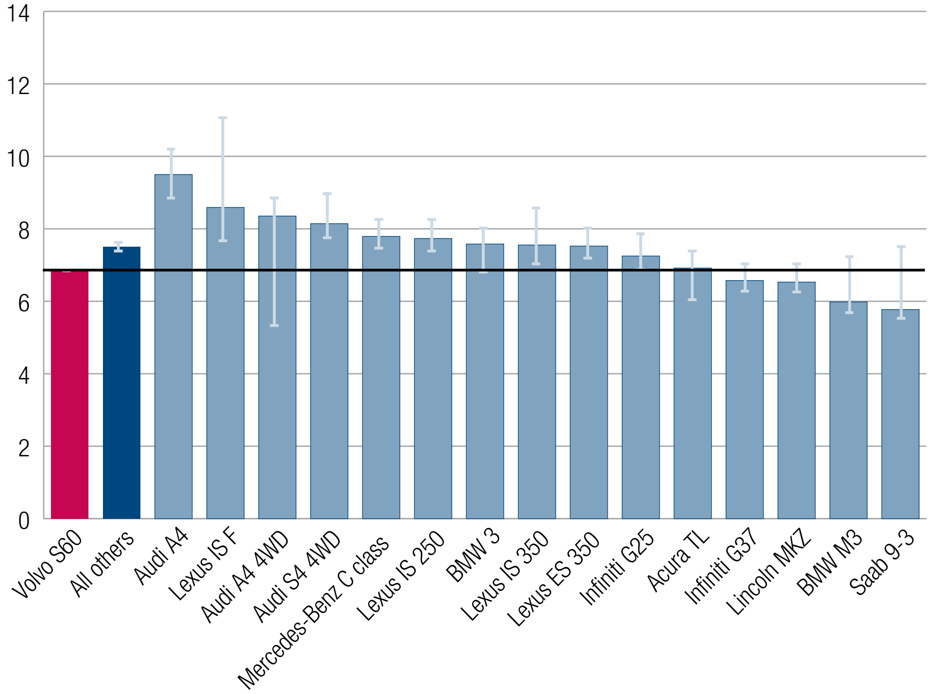


Figure 13: Collision claim severities for 2010-12 Volvo XC60 with City Safety vs. other 2009-12 midsize luxury SUVs

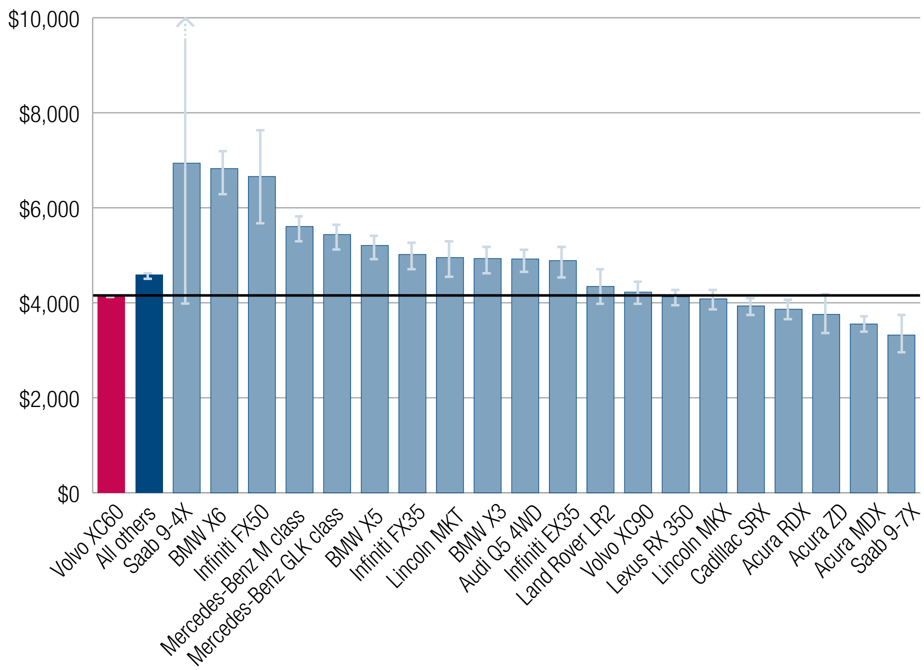


Figure 14: Collision claim severities for 2011-12 Volvo S60 with City Safety vs. other 2011-12 midsize luxury cars

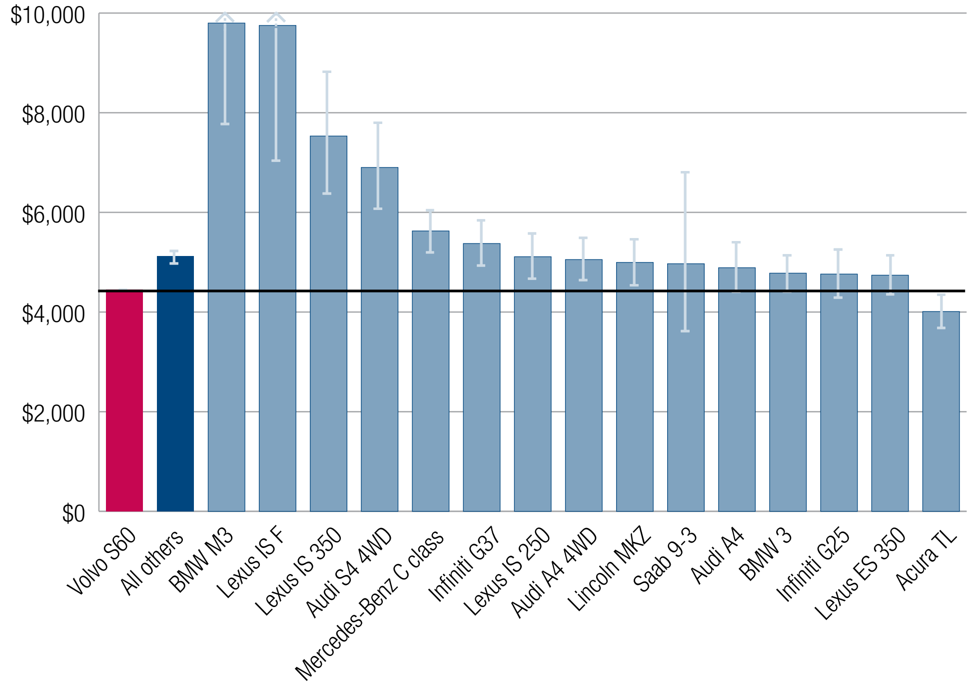


Figure 15: Collision overall losses for 2010-12 Volvo XC60 with City Safety vs. other 2009-12 midsize luxury SUVs

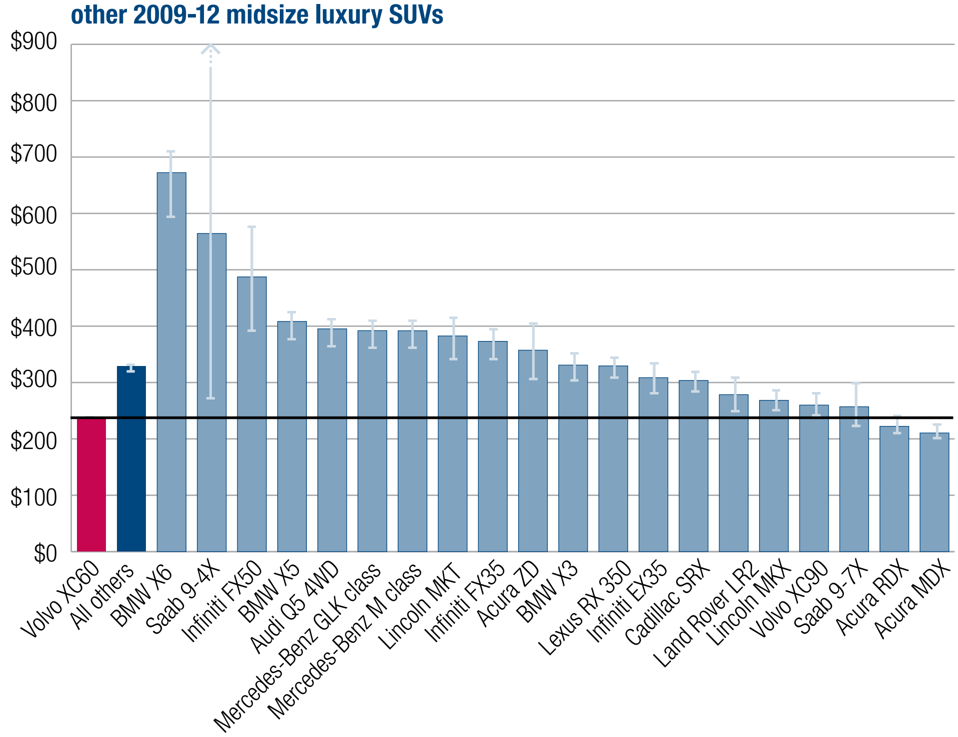


Figure 16: Collision overall losses for 2011-12 Volvo S60 with City Safety vs. other 2011-12 midsize luxury cars

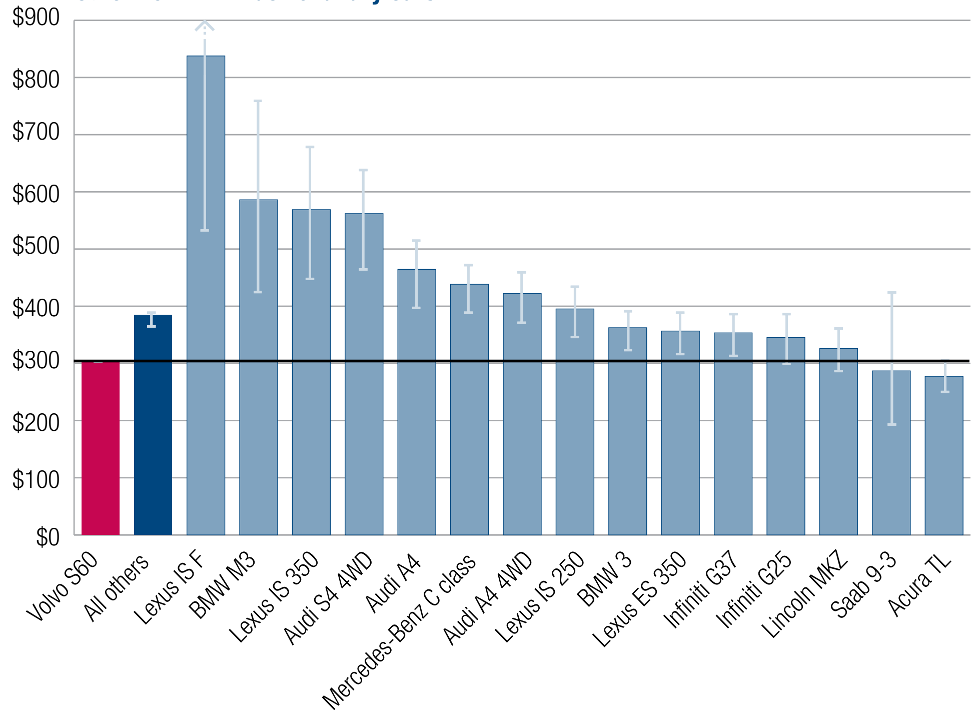


Table 6 summarizes the collision coverage results in an analogous manner to the property damage liability results. Compared to the weighted average estimate of comparison vehicles, the Volvo XC60's actual collision frequency was 20 percent lower, claim severity was 10 percent lower, and overall losses were reduced by 28 percent. Similarly, the S60's actual collision frequency was 9 percent lower than the weighted average of other midsize luxury cars, claim severity was 13 percent lower, and overall losses were 21 percent lower. Reductions in claims appear to have occurred across most of the severity spectrum, although the reductions in claims costing less than $2,000 are much less (only 13 percent for the XC60 and a 2 percent increase – not significant – for the S60).

Table 6: Collision loss results - City Safety versus weighted average of comparison vehicles

				City Safety benefit	
	Estimate	Standard Error	Estimated change of control vehicles relative to study vehicles	Estimate	95% confidence interval
XC60 vs. midsize luxury SUVs					
Claim frequency	-0.2256	0.0059	25%	-20%	-21%, -19%
Claim severity	-0.1031	0.0068	11%	-10%	-11%, -9%
Overall loss	-0.3287	0.0090	39%	-28%	-29%, -27%
Claims <$2,000	-0.1403	0.0082	15%	-13%	-14%, -12%
Claims $2,000-$4,999	-0.2689	0.0122	31%	-24%	-25%, -22%
Claims $5,000-$11,999	-0.3885	0.0160	47%	-32%	-34%, -30%
Claims $12,000+	-0.2846	0.0184	33%	-25%	-27%, -22%
S60 vs. midsize luxury cars					
Claim frequency	-0.0907	0.0112	9%	-9%	-11%, -7%
Claim severity	-0.1397	0.0132	15%	-13%	-15%, -11%
Overall loss	-0.2304	0.0173	26%	-21%	-23%, -18%
Claims <$2,000	0.0182	0.0158	-2%	2%	-1%, 5%
Claims $2,000-$4,999	-0.2186	0.0246	24%	-20%	-23%, -16%
Claims $5,000-$11,999	-0.1924	0.0291	21%	-18%	-22%, -13%
Claims $12,000+	-0.1966	0.0306	22%	-18%	-23%, -13%

Discussion

The updated loss experience for the Volvo XC60 equipped with standard City Safety, coupled with these first results for the S60 similarly fitted, strengthen the conclusion that City Safety is preventing front to rear crashes in these vehicles. The benefit of City Safety is reflected in fewer claims for property damage liability (15 percent and 16 percent for the XC60 and S60, respectively), for bodily injury (33 percent and 18 percent), and for collision (20 percent and 9 percent). Overall losses for the XC60 and S60 were lower for both property damage liability (16 percent and 6 percent, respectively) and collision (28 percent and 21 percent). Although some of these effects are not as large as those reported initially for the XC60 in 2011, they still represent quite large reductions in claims. Also, the pattern of results for the XC60 and S60 was reasonably similar, suggesting these findings are robust.

Nevertheless, there were some differences and some unexpected findings. One unexpected finding was the large benefit of City Safety for collision coverage. This substantial effect could indicate that City Safety is preventing collisions with some nonvehicle objects as well as vehicle-to-vehicle collisions. This is feasible considering that City Safety sometimes is demonstrated with nonvehicle crash targets even though it is designed to address vehicle-to-vehicle collisions.

However, the updated effects of City Safety on collision experience of the XC60 are not only large but they are larger than those for property damage liability. In the early results for the XC60 (2011), property damage liability claim frequency was reduced more than collision claim frequency. Although the difference was not large (27 percent and 22 percent), that pattern was consistent with the greater representation of front-to-rear collisions in property damage liability claims. Past HLDI (2007) research has shown that in multiple-vehicle collisions, the most common configuration is front-to-rear (49.3 percent). The next most frequent configuration is front-to-front at only 13.5 percent. In the current update, City Safety is associated with greater reductions in property damage liability claim frequency only for the S60, while the collision claim reduction is greater for the XC60. The overall loss reductions are larger for collision coverage for both vehicles. At this time, all that can be said with confidence is that City Safety is having larger than expected benefits for collision claims experience, and further research is needed to understand the mechanism of those benefits.

Another unexpected finding was that City Safety appeared to reduce property damage liability claim frequency across the severity spectrum for the XC60, with the result being a statistically significant reduction in average claim severity. This is a change from the early XC60 findings (2011) when only claims costing less than $7,000 were reduced. The reduction in lower cost claims is the expected finding with City Safety, given the low speed at which it is operative (<20 mph), and the reversal was unexpected. It is especially surprising because the property damage liability claims severity results for the S60 did follow the expected pattern, similar to the early results from the XC60. It could be that the shift in pattern of the XC60 results is a statistical aberration that additional data will correct even though the 95 percent confidence interval for the claim severity analysis is fairly tight. Alternatively, it is possible that this pattern of results is characteristic for vehicles that are newly designed, and that longer-term S60 results will follow those of the XC60.

Loss results for City Safety compared with other Volvos: Loss results for the XC60 and S60 were also compared with other Volvo vehicles to test for the possibility of a "Volvo effect." For claim frequency, the results were largely similar to those found when comparing the XC60 and S60 to their comparable vehicles. The main exception was an increase in collision claim frequency for the S60 compared to the weighted average of other midsize luxury cars. Summary results of the Volvo analysis along with the other comparison groups are found in **Appendix B**. These results are not discussed further here as this analysis was conducted primarily to assure that the subject vehicles with City Safety appeared generally to have lower loss experience versus other Volvos as well as compared to other similar vehicles. Further development of comparisons with other Volvos would require more investigation into how Volvo vehicles typically differ in loss experience than was included here.

Limitations

All of the XC60s and S60s included in the current study were equipped with the City Safety technology, but there was no way to know whether any drivers in the crash-involved vehicles had manually turned off the system prior to the crash. Also, most of the vehicles in this study, including the XC60 and S60, can be equipped with a variety of collision avoidance features that might also affect claim frequencies, and it was not possible, based on data available to HLDI at the time of the study, to control for the presence of these other features. The study and control vehicles may have other collision avoidance features that could be influencing the results. To fully understand the benefits of City Safety, subsequent analysis will be required as additional loss data become available involving more and potentially different drivers. This analysis controlled for a variety of possible demographic differences (rated driver age, gender, marital status, and risk) between the study and control populations. It still is possible that rated drivers that chose to purchase vehicles with City Safety differ in other ways that could affect crash likelihood – perhaps drivers who are more concerned about safety or who have experienced front-to-rear collisions in the past and want to avoid them in the future.

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Appendix A: Exposure and claims by coverage type for comparison vehicles						
	Property damage liability		Bodily injury liability		Collision	
	Exposure	Claims	Exposure	Claims	Exposure	Claims
Midsize luxury SUVs						
Acura MDX	194,960	6,364	64,118	411	194,960	10,982
Acura RDX	67,090	2,174	21,069	131	67,090	3,878
Acura ZDX	5,037	177	1,516	11	5,037	478
Audi Q5 4WD	83,698	2,424	26,910	186	83,698	6,620
BMW X3	45,411	1,351	12,891	87	45,411	2,938
BMW X5	139,991	5,220	44,149	343	139,991	10,284
BMW X6	18,481	749	5,489	61	18,481	1,727
Cadillac SRX	156,871	4,548	46,675	327	156,871	11,564
Infiniti EX35	26,799	726	8,437	58	26,799	1,691
Infiniti FX35	50,995	1,745	16,258	141	50,995	3,537
Infiniti FX50	3,837	132	1,443	8	3,837	246
Land Rover LR2	14,464	578	4,637	41	14,464	909
Lexus RX 350	481,315	15,389	161,053	1192	481,315	36,724
Lincoln MKT	15,986	426	4,929	47	15,986	1,194
Lincoln MKX	79,826	2,261	22,556	181	79,826	5,083
Mercedes-Benz GLK class	95,219	3,074	31,765	322	95,219	6,825
Mercedes-Benz M class	144,237	4,403	40,655	321	144,237	9,582
Saab 9-4X	223	10	43	0	223	17
Saab 9-7X	5,237	145	1,177	11	5,237	423
Volvo XC90	51,456	1,915	16,549	123	51,456	3,042
Midsize luxury cars						
Acura TL	32,079	833	7,206	50	32,079	2,239
Audi A4	9,454	384	2,856	37	9,454	1,019
Audi A4 4WD	26,798	783	6,245	50	26,798	2,491
Audi S4 4WD	5,758	125	1,596	3	5,758	504
BMW 3	92,996	2,821	23,655	204	92,996	7,856
BMW M3	1,832	31	618	1	1,832	117
Infiniti G25	12,143	364	2,883	27	12,143	991
Infiniti G37	34,584	927	7,581	46	34,584	2,465
Lexus ES 350	42,313	1,048	9,947	64	42,313	3,323
Lexus IS 250	21,953	793	5,105	61	21,953	1,916
Lexus IS 350	3,127	84	929	10	3,127	253
Lexus IS F	606	25	177	8	606	55
Lincoln MKZ	22,649	547	3,826	25	22,649	1,683
Mercedes-Benz C class	65,034	1,890	14,734	147	65,034	5,585
Saab 9-3	876	21	181	1	876	57

Appendix B: Summary loss results

XC60 summary loss results relative to other midsize luxury SUVs									
Vehicle damage coverage type	Lower bound	Claim frequency	Upper bound	Lower bound	Claim severity	Upper bound	Lower bound	Overall losses	Upper bound
Property damage liability	-16%	**-15%**	-13%	-$89	-$42	$4	-$17	**-$15**	-$12
Bodily injury	-38%	**-33%**	-29%						
Collision	-21%	**-20%**	-19%	-$512	**-$450**	-$389	-$98	**-$92**	-$86

XC60 summary loss results relative to other Volvos									
Vehicle damage coverage type	Lower bound	Claim frequency	Upper bound	Lower bound	Claim severity	Upper bound	Lower bound	Overall losses	Upper bound
Property damage liability	-9%	**-6%**	-3%	$219	**$304**	$386	$0	**$4**	$7
Bodily injury	-41%	**-34%**	-25%						
Collision	-14%	**-12%**	-10%	-$278	**-$164**	-$53	-$51	**-$41**	-$32

S60 summary loss results relative to other midsize luxury cars									
Vehicle damage coverage type	Lower bound	Claim frequency	Upper bound	Lower bound	Claim severity	Upper bound	Lower bound	Overall losses	Upper bound
Property damage liability	-20%	**-16%**	-13%	$257	**$373**	$486	-$8	**-$4**	$0
Bodily injury	-30%	**-18%**	-4%						
Collision	-11%	**-9%**	-7%	-$802	**-$668**	-$537	-$92	**-$79**	-$66

S60 summary loss results relative to other Volvos									
Vehicle damage coverage type	Lower bound	Claim frequency	Upper bound	Lower bound	Claim severity	Upper bound	Lower bound	Overall losses	Upper bound
Property damage liability	-20%	**-13%**	-5%	$581	**$811**	$1,021	$1	**$9**	$16
Bodily injury	-46%	-22%	13%						
Collision	6%	**12%**	19%	-$2	$281	$546	$28	**$51**	$72

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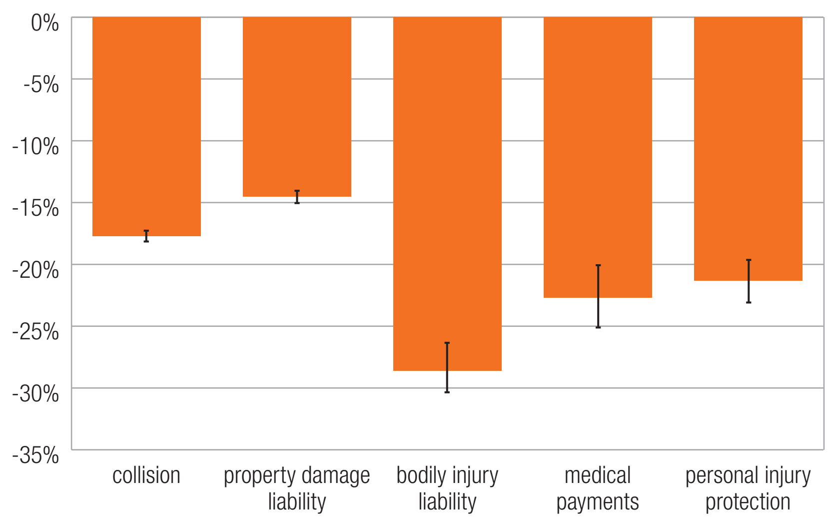
Volvo City Safety loss experience – a long-term update

This Highway Loss Data Institute (HLDI) report updates two prior bulletins on the Volvo City Safety system. Benefits have been consistent across all three reports, and for the first time pooled estimates have been calculated that combine the XC60 and S60 results. This combined, or pooled, estimate is the best estimate of a general effect for City Safety. The earlier HLDI studies reported that Volvo XC60 and S60 models with City Safety, a low-speed collision avoidance technology, had lower loss frequencies for property damage liability, bodily injury liability, and collision coverages than similar models without such a system. In the latest study, updated results for the XC60 and S60 confirm that City Safety is reducing losses substantially. Property damage liability loss frequency was estimated to be 14 percent lower for the XC60 than for relevant control vehicles and 15 percent lower for the S60. Collision claim frequencies were reduced by an estimated 21 percent for the XC60 and 12 percent for the S60. Both vehicles also showed reductions in collision claim severity and overall losses for collision and property damage liability. Under bodily injury liability, claim frequency was 28 percent lower for the XC60 and 31 percent lower for the S60.

This report also examines the effect City Safety is having on personal injury protection (PIP) and medical payment (MedPay) coverages. Under PIP, claim frequency was 21 percent lower for the XC60 and 23 percent lower for the S60. Under MedPay, claim frequency was 19 percent lower for the XC60 and 30 percent lower for the S60.

Pooled claim frequency for XC60 and S60 relative to comparison vehicles



Introduction

This Highway Loss Data Institute (HLDI) bulletin provides the third look at the effects of Volvo's City Safety technology on insurance losses for the XC60 and an updated look at the results for the S60. Prior HLDI results found that Volvo's City Safety system on the XC60 and S60 appeared to be preventing crashes (Vol. 28, No. 6 and Vol. 29, No. 23). For this bulletin, the loss experiences for Volvo XC60 and S60 models equipped with City Safety were compared with losses for comparable vehicles without the system. Updated losses under property damage liability, bodily injury liability, and collision coverages were examined and, for the first time, personal injury protection and medical payment. A supplementary analysis using Volvo vehicles as the comparison group was also conducted and served to verify City Safety's effect.

City Safety, a low-speed collision avoidance system, was released as standard equipment on the 2010 Volvo XC60, a midsize luxury SUV, and on the 2011 S60, a midsize luxury car. The system was developed by Volvo to reduce low-speed front-to-rear crashes, which commonly occur in urban traffic, by assisting the driver in braking. According to a Volvo news release, 75 percent of all crashes occur at speeds up to 19 mph, and half of these occur in city traffic (Volvo, 2008). The City Safety system has an infrared laser sensor built into the windshield that detects other vehicles traveling in the same direction up to 18 feet in front of the vehicle. The system initially reacts to slowing or stopped vehicles by pre-charging the brakes. The vehicle will brake automatically if forward collision risk is detected and the driver does not react in time, but only at travel speeds up to 19 mph. If the relative speed difference is less than 9 mph, a collision can be avoided entirely. If the speed difference is between 9 and 19 mph, the speed will be reduced to lessen the collision severity. City Safety is automatically activated when the vehicle ignition is turned on but can be manually deactivated by the driver.

When examining the effect of City Safety on insurance losses, it is important to consider that the system is not designed to mitigate all types of crashes and that many factors can limit the system's ability to perform its intended function. City Safety works equally well during the day and at night, but fog, heavy rain, or snow may limit the ability of the system's infrared laser to detect vehicles. The driver is advised if the sensor becomes blocked by dirt, ice, or snow.

Methods

Insurance data

Automobile insurance covers damage to vehicles and property as well as injuries to people involved in crashes. Different insurance coverages pay for vehicle damage versus injuries, and different coverages may apply depending on who is at fault. The current study is based on property damage liability, bodily injury liability, collision, personal injury protection, and medical payment coverages. Data are supplied to HLDI by its member companies.

Property damage liability coverage insures against physical damage that at-fault drivers cause to other people's vehicles and property in crashes. Bodily injury liability coverage insures against medical, hospital, and other expenses for injuries that at-fault drivers inflict on occupants of other vehicles or others on the road. In the current study, bodily injury liability losses were restricted to data from traditional tort states. Collision coverage insures against physical damage to an at-fault driver's vehicle sustained in a crash with an object or other vehicle. Personal injury protection insures against injuries sustained in crashes to insured drivers and other people in their vehicles, regardless of who is at fault in the collision. Medical payment is sold in states with traditional tort liability laws and insures against injuries sustained by occupants of the insured vehicle in crashes for which they are responsible.

Subject vehicles

In the main analyses, loss results for the XC60 with City Safety were compared with other midsize luxury SUVs, while loss results for the S60 with City Safety were compared with other midsize luxury cars. A supplemental analysis was conducted to address the possibility that differences between the S60, XC60 and their respective comparison groups were due to the drivers of Volvo models being different from the drivers of the comparison models. Volvo cars have a reputation for safety that may attract safer drivers than its competitors. The supplemental analysis compares S60 and XC60 with contemporary Volvo models that did not have City Safety, thereby eliminating the chance of a Volvo driver effect.

Sales of the 2010 Volvo XC60 began in February 2009, when other brands still were marketing 2009 models. Consequently, the control populations for the XC60 analyses included vehicles starting in model year 2009. The total study population for the XC60 was model years 2010-12 during calendar years 2009-14, with control vehicle model years of 2009-12. The loss experience of the model year 2009 vehicles in calendar year 2008 was excluded because no XC60s were on the road during this time period.

City Safety was added as standard equipment to the Volvo S60 in model year 2011. The analyses considered model years 2011-12 for the S60 and its control vehicles during calendar years 2011-14. Calendar year 2010 was not included in the S60 analysis because of the very small number of model year 2011 S60s insured that year.

Total exposure, measured as insured vehicle years, for the XC60 and S60 are shown by insurance coverage type in **Table 1**. For comparison, exposure from the 2011 and 2012 reports are shown. Appendix A contains the current exposure and claims information for the comparison vehicles.

Table 1: Exposure and claims by coverage type

	XC60		S60	
Coverage	Claims	Exposure	Claims	Exposure
Property damage liability	3,599	129,127	1,890	76,870
Bodily injury liability	304	51,628	159	26,930
Collision	7,310	129,127	5,597	76,870
Medical payments	288	40,013	166	20,925
Personal injury protection	523	59,965	416	37,565

Because previous HLDI analyses have shown them to have different loss patterns, hybrids, convertibles, and two-door vehicles were excluded from the control groups. Additionally, the XC60 analysis excluded City Safety-equipped S60s from the Volvo control group while the S60 analysis excluded XC60s from the Volvo comparison vehicles. For both the XC60 and S60, the Volvo comparison groups did not include the 2012 S80 or the 2012 XC70. Both of these vehicles were excluded because they had standard City Safety beginning in the 2012 model year. Vehicle models with two- and four-wheel drive versions were combined to provide sufficient data for analysis.

The study and control vehicles in this analysis can also be equipped with optional collision avoidance features that have been shown to affect claim frequency and severity in other studies by HLDI. It should be noted that this analysis does not account for their presence or absence because the information needed to identify the vehicles with the optional features is not available in the HLDI database. Furthermore, the take rate for these features is thought to be low.

Analysis methods

Regression analysis was used to model claim frequency per insured vehicle year and average loss payment per claim (claim severity) while controlling for various covariates. Claim frequency was modeled using a Poisson distribution, and claim severity was modeled using a Gamma distribution. Both models used a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models. They were calculated by multiplication because the estimate for the effect of City Safety on claim frequency and claim severity were in the form of ratios relative to the reference categories (baseline). The standard error for overall losses was calculated by taking the square root of the sum of the squared standard errors from the claim frequency and severity estimates. Based on the value of the estimate and the associated standard error, the corresponding two-sided p-value was derived from a standard normal distribution approximation.

The covariates included calendar year, model year, garaging state, vehicle density (number of registered vehicles per square mile), rated driver age, rated driver gender, marital status, collision deductible, and risk. To estimate the effect of City Safety, vehicle series was included as a variable in the regression models, with the Volvo XC60 or S60 assigned as the reference group. The model estimate corresponding to each comparison vehicle indicates the proportional increase or decrease in losses of that vehicle relative to the XC60 or S60, while controlling for differences in the distributions of drivers and garaging locations. For example, in the analysis of property damage liability claim frequency, the model estimate comparing the XC60 with the BMW X5 was 0.2610, which translates to an estimated increase in claim frequency of 30 percent for the X5 compared to the XC60 ($e^{0.2610} = 1.30$). Given that the actual property damage liability claim frequency for the Volvo XC60 equaled 2.8 claims per 100 insured vehicle years, the comparable claim frequency for the X5, if it had the same distribution of drivers and garaging locations as the XC60, is predicted to have been 2.8 x 1.30 = 3.6 claims per 100 insured vehicle years.

Weighted averages of the model estimates for individual vehicles in the analysis also were calculated for midsize luxury SUVs and for midsize luxury cars. The weights in the averages were proportional to the inverse variance of the respective estimates, meaning that the estimates with high variance (those with large confidence intervals, typically due to little exposure and/or claims) contributed less than estimates with low variance (those with small confidence intervals). These calculations estimate the average effect for each vehicle group of not having City Safety. Because it is often useful to state the results in terms of the estimated benefit of having a feature, the inverse of the average City Safety effect also was calculated. That is, the weighted average property damage liability loss frequency for other midsize luxury SUVs was 1.17 times that of the XC60; the inverse of that, (1/1.17)-1, or – 0.14, indicates that the estimated benefit of having City Safety is a 14 percent reduction in claim frequency compared with other SUVs. The estimated benefit for each overall comparison and the 95 percent confidence bounds are shown in **Tables 4–8**.

The estimated effects of City Safety were calculated separately for the XC60 and S60, along with their respective standard errors. A combined, or pooled estimate was calculated as a weighted average of the two estimates, with weights proportional to the inverse variance (i.e. weigh $=1/SE^2$). Thus, if an estimate for the XC60 had a smaller standard error (tighter confidence interval) compared to that of the S60 estimate, it would have more influence on the combined estimate. The combined standard error for the weighted average was calculated based on the same assumptions.

Results

Tables 2–3 illustrate the pattern of results available from the analyses performed. In **Table 2**, it can be seen that all independent variables in the model had statistically significant effects on property damage liability loss frequencies of midsize luxury SUVs. Most of the covariates in the regressions not shown were statistically significant. **Table 3** lists estimates and significance levels for the individual values of the categorical variables from the regression model. The intercept outlines losses for the reference (baseline) categories: the estimate corresponds to the claim frequency for a 2012 Volvo XC60, garaged in a high vehicle density area in Texas, and driven by a married female age 40-49 with standard risk during calendar year 2014. The remaining estimates are in the form of multiples, or ratios relative to the reference categories. **Table 3** includes only an abbreviated list of results by state. Only states with the five highest and five lowest estimates are listed, along with the comparison state of Texas.

Table 2: Summary Wald statistics for type 3 analysis of property damage liability claim frequencies for XC60 vs. other midsize luxury SUVs			
	Degrees of freedom	Chi-Square	P-value
Calendar year	5	116.45	<0.0001
Model year	3	51.13	<0.0001
Vehicle make and series	20	554.03	<0.0001
State	50	2296.04	<0.0001
Registered vehicle density	6	1488.79	<0.0001
Rated driver age	10	1649.84	<0.0001
Rated driver gender	2	191.26	<0.0001
Rated driver marital status	2	503.19	<0.0001
Risk	1	435.65	<0.0001

Table 3: Detailed results of linear regression analysis of property damage liability claim frequencies for Volvo XC60 vs. other midsize luxury SUVs								
Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Intercept	1	-9.2792		0.0215	-9.3214	-9.2371	186003	<0.0001
Calendar year								
2009	1	0.0085	0.9%	0.0171	-0.0250	0.0420	0.25	0.6189
2010	1	0.0538	5.5%	0.0119	0.0306	0.0771	20.56	<0.0001
2011	1	0.0728	7.6%	0.0100	0.0532	0.0924	52.82	<0.0001
2012	1	0.0629	6.5%	0.0092	0.0449	0.0808	47.02	<0.0001
2013	1	0.0894	9.4%	0.0089	0.0719	0.1069	100.51	<0.0001
2014	0	0	0	0	0	0		
Model year								
2009	1	0.0472	4.8%	0.0098	0.0280	0.0664	23.28	<0.0001
2010	1	-0.0007	-0.1%	0.0088	-0.0179	0.0164	0.01	0.9326
2011	1	-0.0106	-1.1%	0.0089	-0.0280	0.0068	1.43	0.2322
2012	0	0	0	0	0	0		
Vehicle make and series								
Acura MDX	1	0.1510	16.3%	0.0187	0.1144	0.1876	65.37	<0.0001
Acura RDX	1	0.1409	15.1%	0.0220	0.0977	0.1841	40.90	<0.0001
Acura ZDX	1	0.2656	30.4%	0.0495	0.1685	0.3627	28.74	<0.0001
Audi Q5 4WD	1	0.0365	3.7%	0.0209	-0.0046	0.0775	3.03	0.0816
BMW X3	1	0.0954	10.0%	0.0233	0.0497	0.1411	16.75	<0.0001
BMW X5	1	0.2610	29.8%	0.0193	0.2232	0.2988	182.93	<0.0001
BMW X6	1	0.2768	31.9%	0.0314	0.2152	0.3383	77.62	<0.0001
Cadillac SRX	1	0.1449	15.6%	0.0191	0.1075	0.1823	57.59	<0.0001
Infiniti EX35	1	0.0001	0.0%	0.0291	-0.0569	0.0571	0.00	0.9982
Infiniti FX35	1	0.2025	22.4%	0.0234	0.1567	0.2483	75.01	<0.0001
Infiniti FX50	1	0.1870	20.6%	0.0660	0.0577	0.3163	8.04	0.0046
Land Rover LR2	1	0.2983	34.8%	0.0314	0.2367	0.3599	90.19	<0.0001
Lexus RX 350	1	0.1382	14.8%	0.0178	0.1034	0.1731	60.48	<0.0001
Lincoln MKT	1	0.0843	8.8%	0.0353	0.0150	0.1535	5.69	0.0171
Lincoln MKX	1	0.1139	12.1%	0.0219	0.0710	0.1568	27.07	<0.0001
Mercedes-Benz GLK class	1	0.1686	18.4%	0.0203	0.1288	0.2084	68.92	<0.0001
Mercedes-Benz M class	1	0.0876	9.2%	0.0196	0.0492	0.1260	19.99	<0.0001
Saab 9-4X	1	0.2053	22.8%	0.1750	-0.1377	0.5483	1.38	0.2407

Table 3: Detailed results of linear regression analysis of property damage liability claim frequencies for Volvo XC60 vs. other midsize luxury SUVs								
Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Saab 9-7X	1	0.1969	21.8%	0.0662	0.0671	0.3266	8.84	0.0029
Volvo XC90	1	0.2900	33.6%	0.0230	0.2450	0.3350	159.31	<0.0001
Volvo XC60	0	0	0	0	0	0		
State								
Michigan	1	-1.4831	-77.3%	0.0417	-1.5648	-1.4013	1263.63	<0.0001
Wyoming	1	-0.4193	-34.2%	0.1391	-0.6919	-0.1468	9.09	0.0026
Alaska	1	-0.3598	-30.2%	0.0882	-0.5327	-0.1869	16.64	<0.0001
North Carolina	1	-0.3691	-30.9%	0.0234	-0.4149	-0.3232	248.92	<0.0001
Utah	1	-0.3569	-30.0%	0.0485	-0.4520	-0.2618	54.12	<0.0001
California	1	-0.0503	-4.9%	0.0116	-0.0729	-0.0276	18.87	<0.0001
Louisiana	1	-0.0335	-3.3%	0.0266	-0.0857	0.0186	1.59	0.2079
Massachusetts	1	0.0226	2.3%	0.0219	-0.0203	0.0655	1.06	0.3023
District of Columbia	1	0.0714	7.4%	0.0459	-0.0186	0.1614	2.42	0.1199
North Dakota	1	0.1772	19.4%	0.1135	-0.0454	0.3997	2.44	0.1186
Texas	0	0	0	0	0	0		
Registered vehicle density								
Unknown	1	-0.7956	-54.9%	0.3334	-1.4491	-0.1420	5.69	0.0170
<50	1	-0.5112	-40.0%	0.0213	-0.5528	-0.4695	578.32	<0.0001
50–99	1	-0.3749	-31.3%	0.0164	-0.4070	-0.3428	523.89	<0.0001
100–249	1	-0.2926	-25.4%	0.0113	-0.3148	-0.2704	665.31	<0.0001
250–499	1	-0.2216	-19.9%	0.0103	-0.2417	-0.2015	466.89	<0.0001
500–999	1	-0.1275	-12.0%	0.0082	-0.1435	-0.1115	243.49	<0.0001
1,000+	0	0	0	0	0	0		
Rated driver age								
Unknown	1	-0.0578	-5.6%	0.0153	-0.0878	-0.0279	14.30	0.0002
15–19	1	0.3208	37.8%	0.0243	0.2732	0.3684	174.53	<0.0001
20–24	1	0.2366	26.7%	0.0190	0.1993	0.2739	154.66	<0.0001
25–29	1	0.1354	14.5%	0.0152	0.1056	0.1653	79.00	<0.0001
30–39	1	0.0384	3.9%	0.0090	0.0208	0.0560	18.36	<0.0001
50–59	1	-0.1303	-12.2%	0.0089	-0.1477	-0.1129	215.09	<0.0001
60–64	1	-0.1330	-12.5%	0.0116	-0.1557	-0.1102	131.30	<0.0001
65–69	1	-0.0291	-2.9%	0.0122	-0.0529	-0.0052	5.71	0.0169
70–74	1	0.0603	6.2%	0.0144	0.0322	0.0885	17.63	<0.0001
75+	1	0.3031	35.4%	0.0140	0.2757	0.3305	470.87	<0.0001
40-49	0	0	0	0	0	0		
Rated driver gender								
Male	1	-0.0774	-7.4%	0.0069	-0.0910	-0.0638	124.85	<0.0001
Unknown	1	-0.1689	-15.5%	0.0175	-0.2032	-0.1347	93.43	<0.0001
Female	0	0	0	0	0	0		
Rated driver marital status								
Single	1	0.1759	19.2%	0.0081	0.1600	0.1918	469.79	<0.0001
Unknown	1	0.1478	15.9%	0.0171	0.1142	0.1813	74.64	<0.0001
Married	0	0	0	0	0	0		
Risk								
Nonstandard	1	0.2100	23.4%	0.0101	0.1903	0.2297	435.65	<0.0001
Standard	0	0	0	0	0	0		

Property damage liability: Figures 1–2 show the results from the analyses of property damage liability claim frequency for the XC60 and S60, respectively. In these figures, the actual property damage liability claim frequency (per 100 vehicle years of exposure) for the Volvo XC60 and S60 are plotted, along with the estimated claim frequencies of each comparison vehicle and the average of all comparison vehicles derived from the regression models. The results were very similar, with the XC60 having an actual claim frequency 14 percent lower than the average of midsize luxury SUVs, while the S60's claim frequency was 15 percent lower than the average of midsize luxury cars. Among comparison midsize luxury SUVs, none had a lower estimated claim frequency than the XC60, but the Infiniti EX35's claim frequency was equal to that of the XC60. Analogously, only the Audi S4 4WD and the BMW M3 had lower estimated claim frequencies than the S60, and both differences were statistically significant. These two vehicles are high-performance variants of the Audi A4 4WD and the BMW 3 that may be driven only recreationally and therefore may have low-mileage exposure. Notably, the S60 had a claim frequency that was significantly lower than the base variants of these vehicles (Audi A4 4WD and BMW 3). Note that the vertical I-bars for each comparison group are the 95 percent confidence limits for the comparison of that group with the Volvo study vehicle, not the 95 percent confidence interval for that group's claim frequency estimate. This is true for all of the figures.

Figure 1: Property damage liability claim frequencies per 100 insured vehicle years for 2010–12 Volvo XC60 with City Safety vs. other 2009–12 midsize luxury SUVs

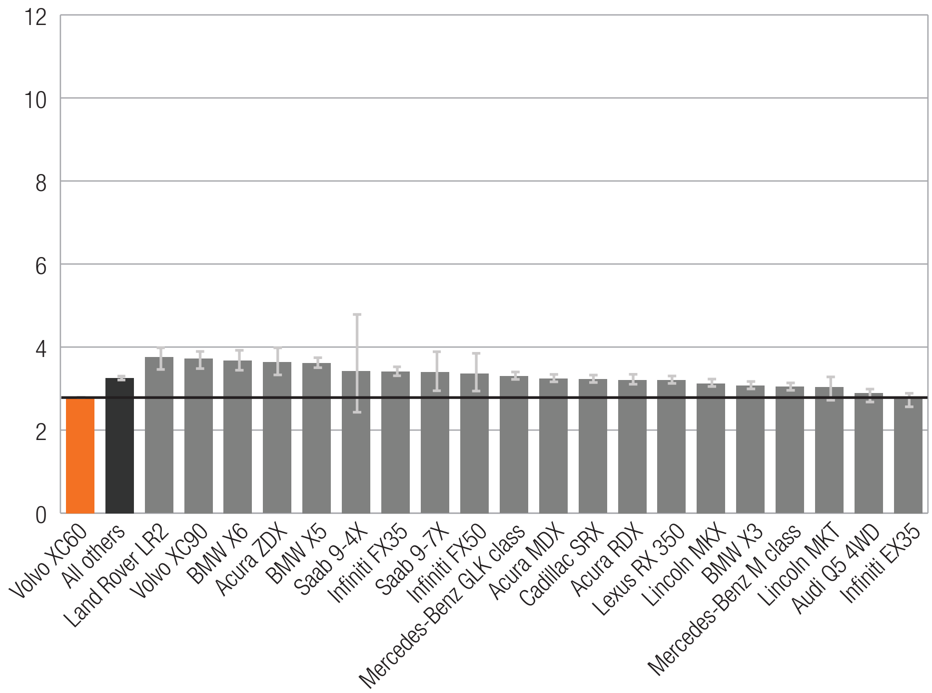
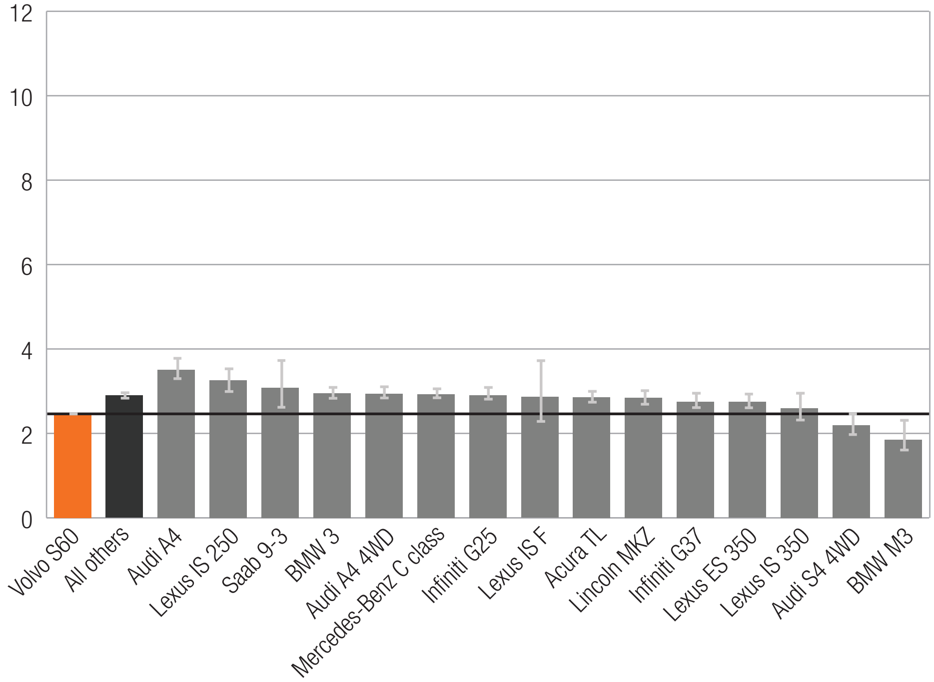


Figure 2: Property damage liability claim frequencies per 100 insured vehicle years for 2011–12 Volvo S60 with City Safety vs. other 2011–12 midsize luxury cars



Figures 3–4 show the results of the analyses of property damage liability claim severity for the Volvo XC60 and S60, respectively. As for the frequency analyses above, the actual average cost per claim is plotted for the XC60 and S60 against the model-derived estimates for each of the comparison vehicles as well as their weighted average. The XC60 average loss per claim was lower than those for the other midsize luxury SUVs (7 percent lower than the average), and the S60 claim severity was also lower than those for other midsize luxury cars (6 percent lower than the average).

Figure 3: Property damage liability claim severities for 2010–12 Volvo XC60 with City Safety vs. other 2009–12 midsize luxury SUVs

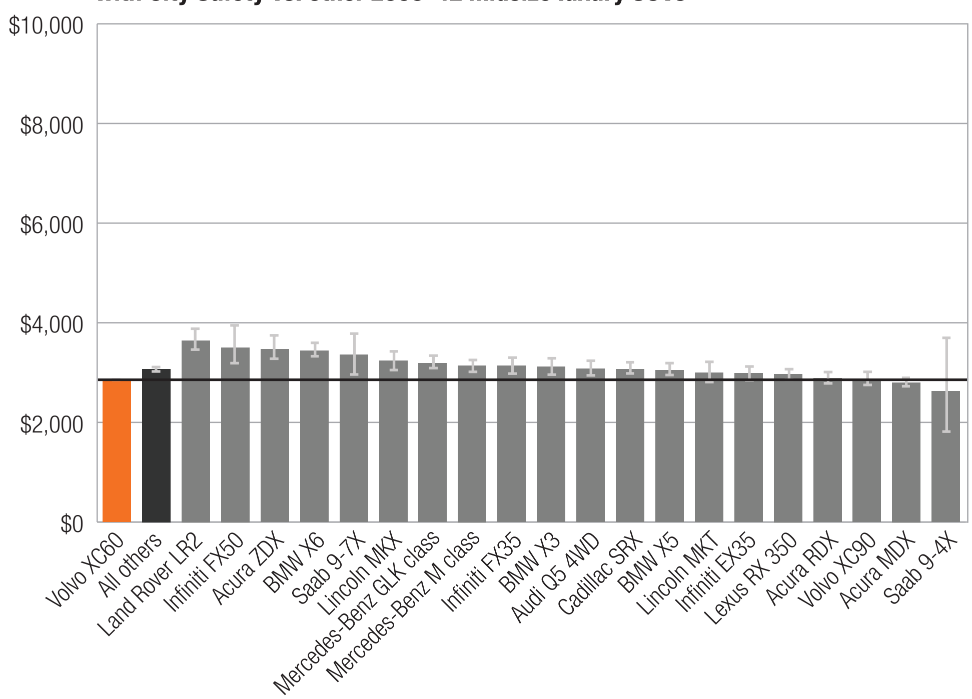
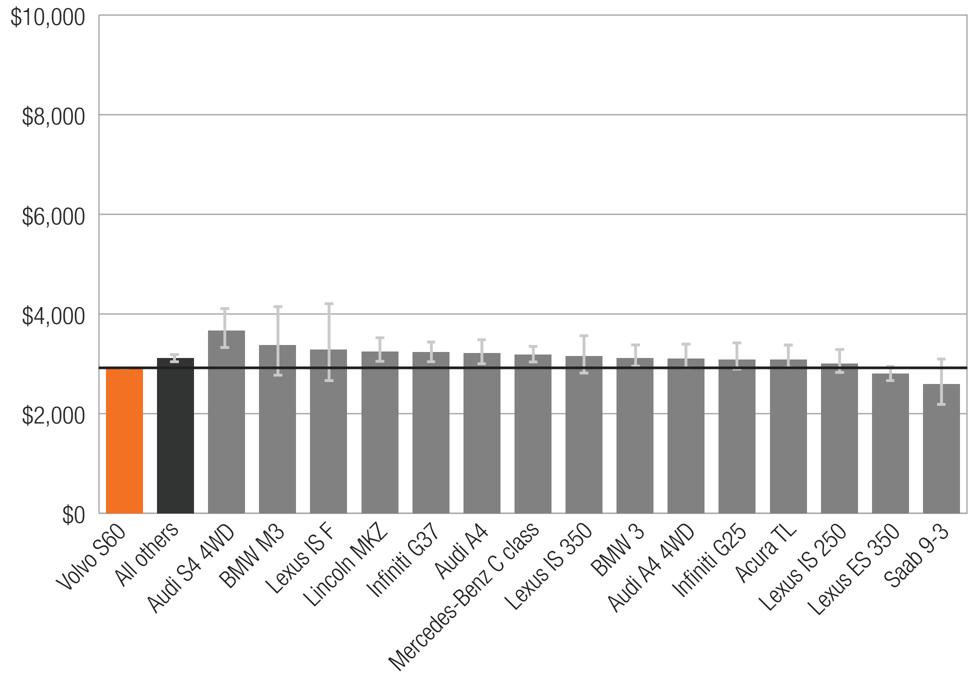


Figure 4: Property damage liability claim severities for 2011–12 Volvo S60 with City Safety vs. other 2011–12 midsize luxury cars



Figures 5–6 provide more detail about the differences in property damage liability claim severity results by examining the frequency of claims in different severity ranges. In **Figure 5**, the XC60, compared with other midsize luxury SUVs, had fewer claims in low-, medium- and high-severity ranges, with the greatest percentage reduction (26 percent) in claims costing at least $7,000. The S60 (**Figure 6**) also had lower claim frequencies in all three severity ranges, with the greatest reduction (27 percent) in claims costing at least $7,000. The differences at all claim severity ranges were statistically significant.

Figure 5: Property damage liability claim frequencies by claim severity range, Volvo XC60 vs. other midsize luxury SUVs

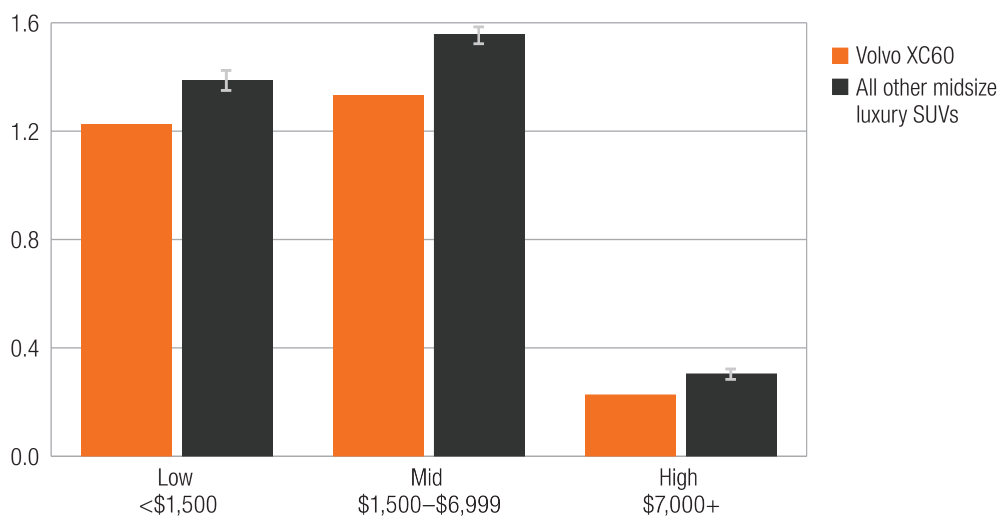
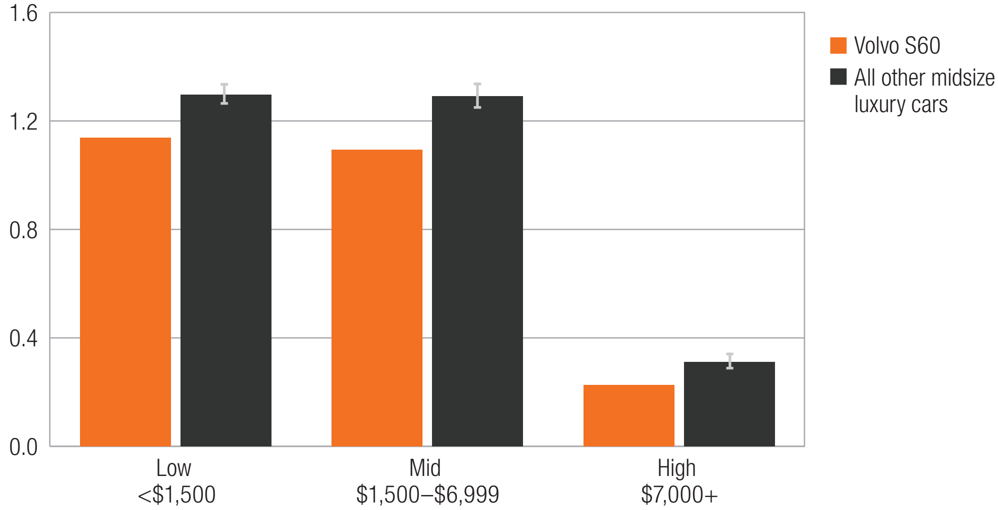


Figure 6: Property damage liability claim frequencies by claim severity range, Volvo S60 vs. other midsize luxury cars



Figures 7–8 show the result of combining the regression results from the claim frequency and severity analyses to obtain a comparison of overall property damage liability losses for the Volvo XC60 and S60 and their respective comparison vehicles. At $80 per insured vehicle year, the actual overall loss for the Volvo XC60 (**Figure 7**) was lower than those for all other midsize luxury SUVs and 20 percent lower than the weighted average of those vehicles. The actual overall loss for the Volvo S60 ($72 per insured vehicle year) was also 20 percent lower than the weighted average for all other midsize four-door luxury cars combined (**Figure 8**). Only the BMW M3 had a lower overall loss than the S60, although the difference was not significant.

Figure 7: Property damage liability overall losses for 2010–12 Volvo XC60 with City Safety vs. other 2009–12 midsize luxury SUVs

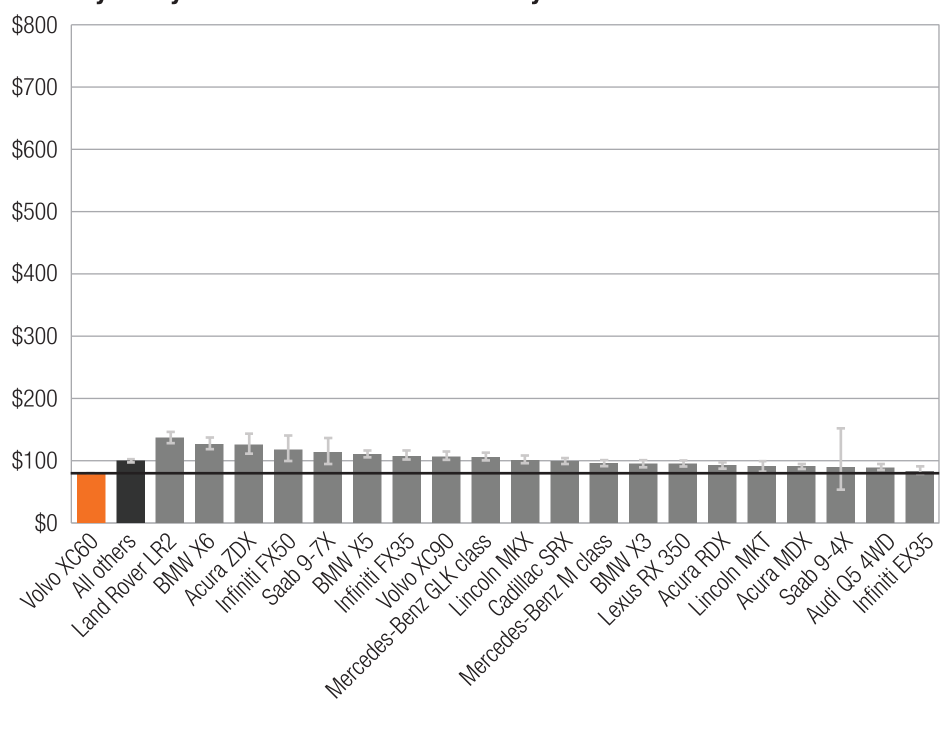


Figure 8: Property damage liability overall losses for 2011–12 Volvo S60 with City Safety vs. other 2011–12 midsize luxury cars

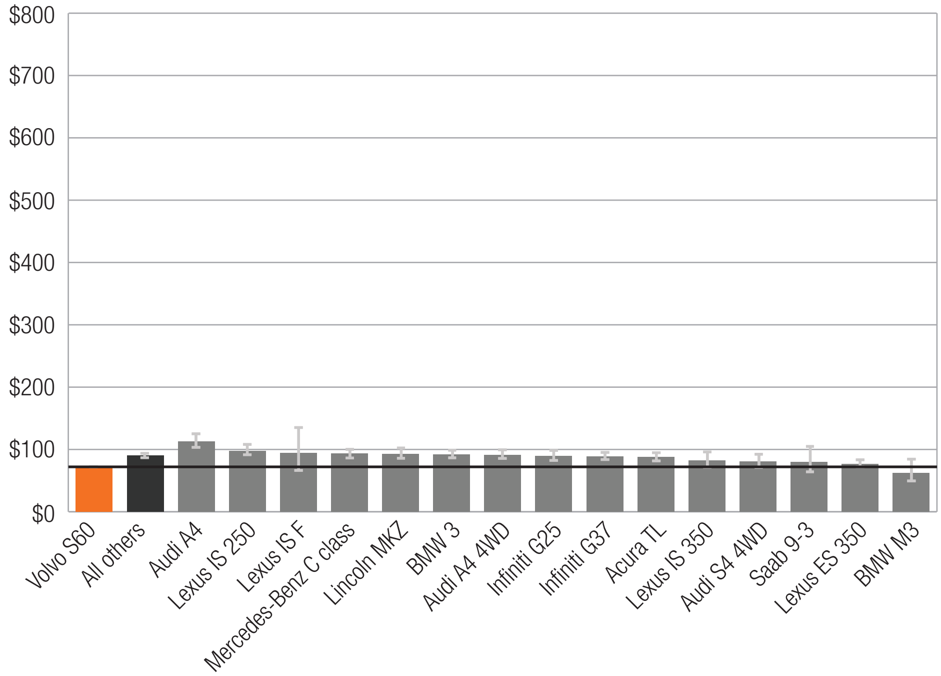


Table 4 summarizes the property damage liability results for the Volvo XC60 and S60 with City Safety. Note that the first two columns provide the weighted average estimates from the regressions and the standard error of those estimates. The third column is the effect estimate expressed as the percent increase or decrease in claim frequency, severity, and overall losses ($e^{*estimate}$); this is the effect of not having City Safety. In the final two columns, the effect of City Safety is expressed in terms of the estimated percent benefit of the technology (i.e., 100 x ($1/e^{estimate}$ - 1)) and the 95 percent confidence bounds of the estimated benefit.

Table 4: Property damage liability loss results - City Safety versus weighted average of comparison vehicles

	Estimate	Standard Error	Estimated change of control vehicles relative to study vehicles	City Safety benefit: Estimate	City Safety benefit: 95% confidence interval
XC60 vs. midsize luxury SUVs					
Claim frequency	-0.1547	0.0055	17%	-14%	-15%, -13%
Claim severity	-0.0739	0.0051	8%	-7%	-8%, -6%
Overall loss	-0.2285	0.0075	26%	-20%	-22%, -19%
Claims <$1,500	-0.1236	0.0083	13%	-12%	-13%, -10%
Claims $1,500–$6,999	-0.1566	0.0079	17%	-14%	-16%, -13%
Claims $7,000+	-0.2956	0.0185	34%	-26%	-28%, -23%
S60 vs. midsize luxury cars					
Claim frequency	-0.1647	0.0090	18%	-15%	-17%, -14%
Claim severity	-0.0646	0.0089	7%	-6%	-8%, -5%
Overall loss	-0.2293	0.0127	26%	-20%	-22%, -18%
Claims <$1,500	-0.1308	0.0134	14%	-12%	-15%, -10%
Claims $1,500–$6,999	-0.1655	0.0135	18%	-15%	-17%, -13%
Claims $7,000+	-0.3185	0.0289	38%	-27%	-31%, -23%

Bodily injury liability: Figures 9–10 show the results for the analyses of bodily injury liability claim frequency. The actual bodily injury liability claim frequency for the XC60 and S60 are typically lower than the estimated frequencies for their comparison vehicles. Only the Saab 9-4X had lower claim rates than the XC60, and the BMW M3 had lower claim rates than the S60.

Figure 9: Bodily injury liability claim frequencies per 1,000 insured vehicle years for 2010–12 Volvo XC60 with City Safety vs. other 2009–12 midsize luxury SUVs

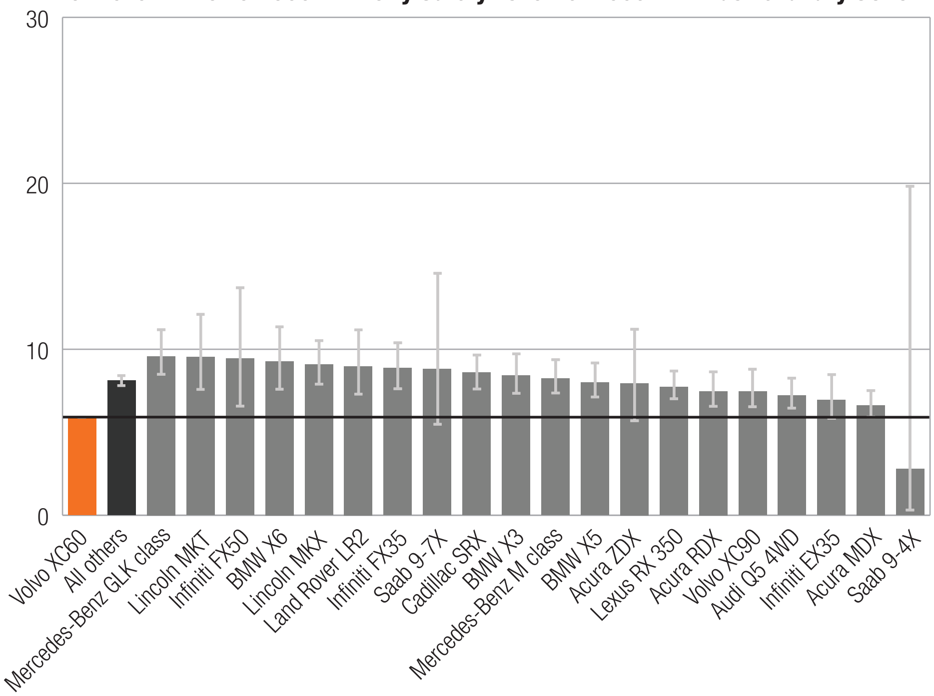


Figure 10: Bodily injury liability claim frequencies per 1,000 insured vehicle years for 2011–12 Volvo S60 with City Safety vs. other 2011–12 midsize luxury cars

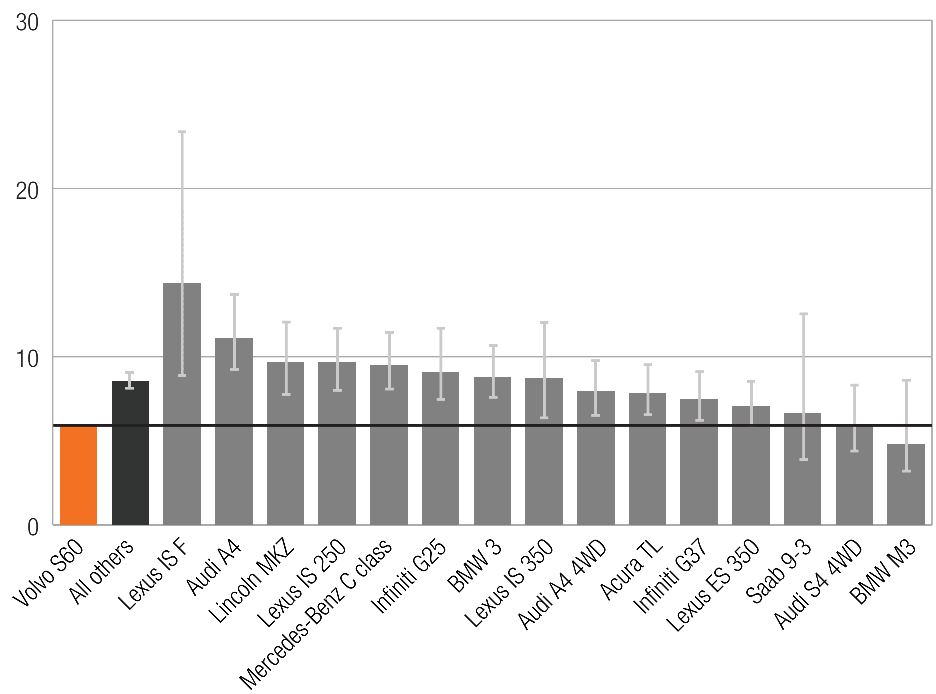


Table 5 summarizes results of the regression analysis conducted for bodily injury liability coverage. Note that analyses of claim severity were not conducted because of the relative recency of these claims and the length of time it takes for claims costs to fully develop. The layout of **Table 5** is analogous to **Table 4**, with the estimated benefits of City Safety in the Volvo XC60 and S60 shown in the final two columns. Compared with other midsize luxury SUVs, it is estimated that the XC60 bodily injury liability claim frequency was reduced by 28 percent with City Safety. For the S60, bodily injury liability claim frequency was 31 percent lower than would have been expected based on the weighted average experience of other midsize luxury cars.

Table 5: Bodily injury liability loss frequency results — City Safety versus weighted average of comparison vehicles

				City Safety benefit	
	Estimate	Standard Error	Estimated change of control vehicles relative to study vehicles	Estimate	95% confidence interval
XC60 vs. midsize luxury SUVs	-0.3219	0.0183	38%	-28%	-30%, -25%
S60 vs. midsize luxury cars	-0.3733	0.0294	45%	-31%	-35%, -27%

Collision damage: Figures 11–16 show the results for the analyses of collision damage claim frequency, claim severity, and overall losses for the XC60 and S60. For both vehicles fitted with City Safety, the actual loss frequency and severity are lower than the estimated frequencies and severities associated with most of the comparison vehicles. As a result, overall losses for the City Safety vehicles also are lower than the overall losses of most comparison vehicles.

Figure 11: Collision claim frequencies per 100 insured vehicle years for 2010–12 Volvo XC60 with City Safety vs. other 2009–12 midsize luxury SUVs

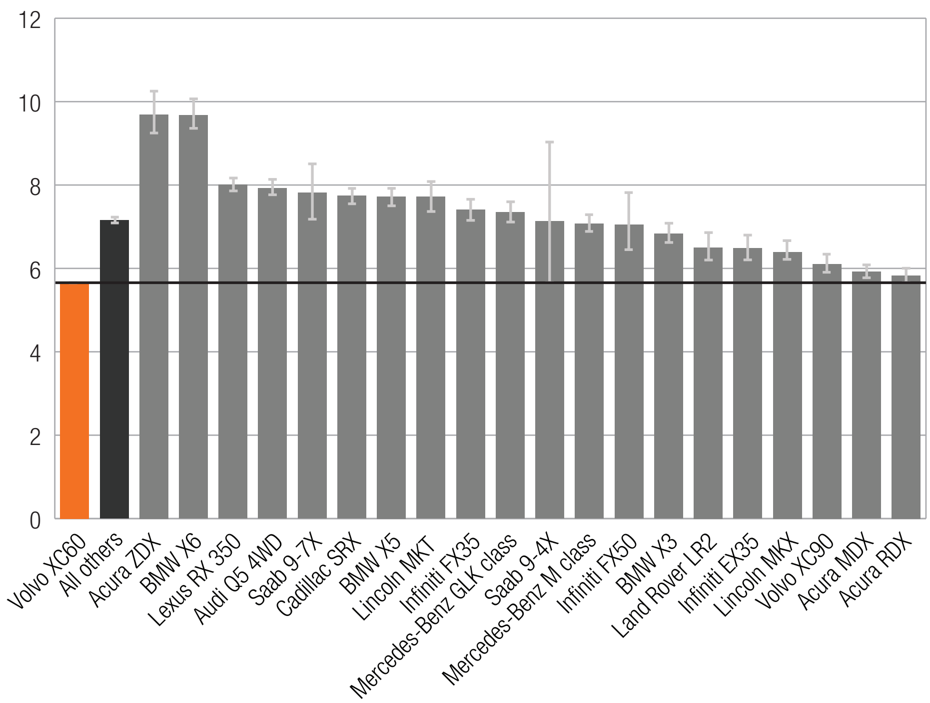


Figure 12: Collision claim frequencies per 100 insured vehicle years for 2011–12 Volvo S60 with City Safety vs. other 2011–12 midsize luxury cars

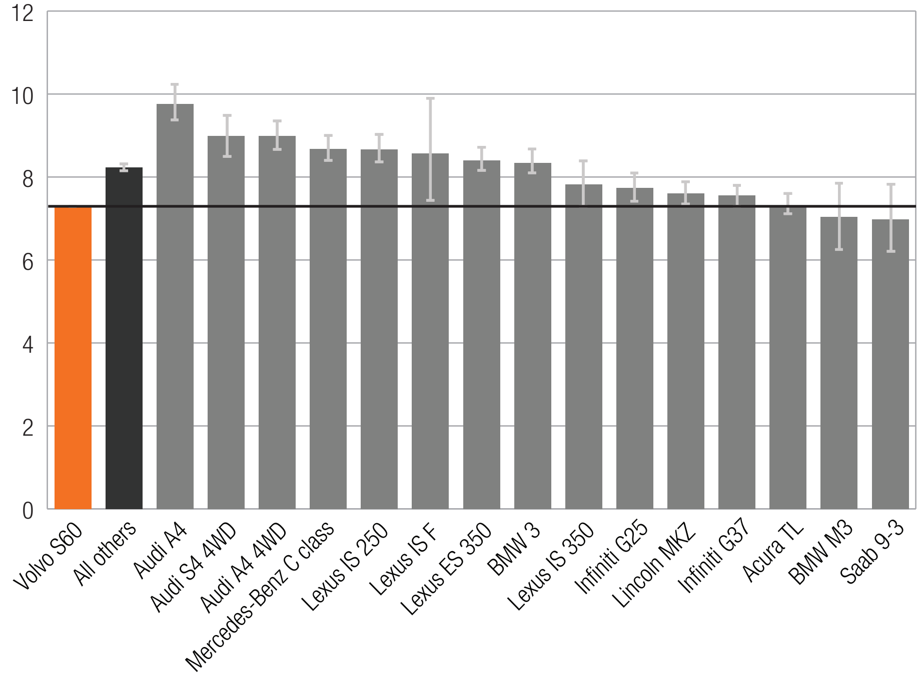


Figure 13: Collision claim severities for 2010–12 Volvo XC60 with City Safety vs. other 2009–12 midsize luxury SUVs

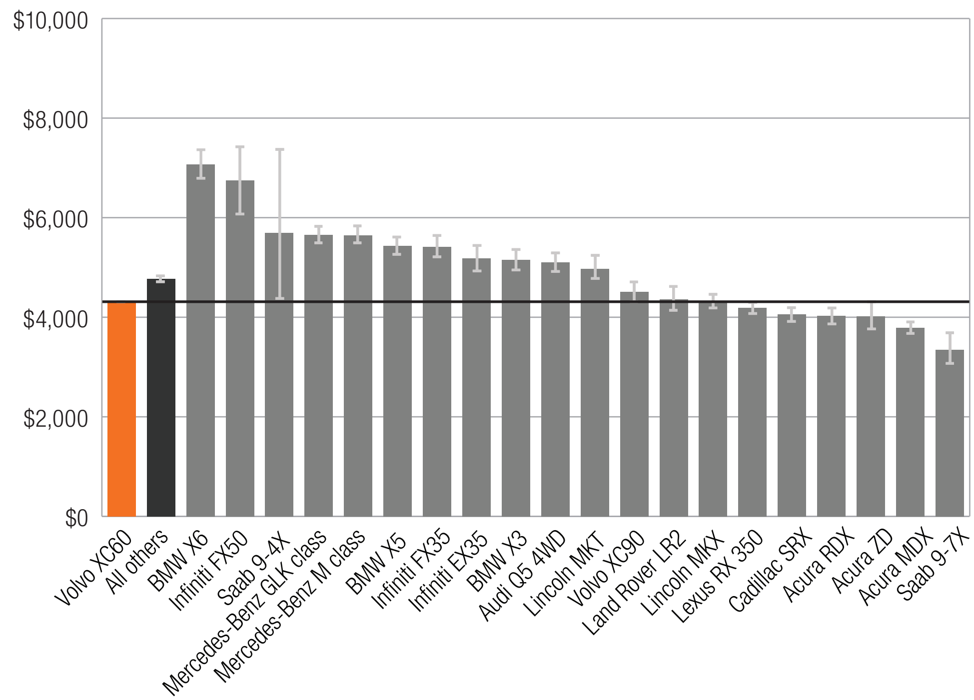


Figure 14: Collision claim severities for 2011–12 Volvo S60 with City Safety vs. other 2011–12 midsize luxury cars

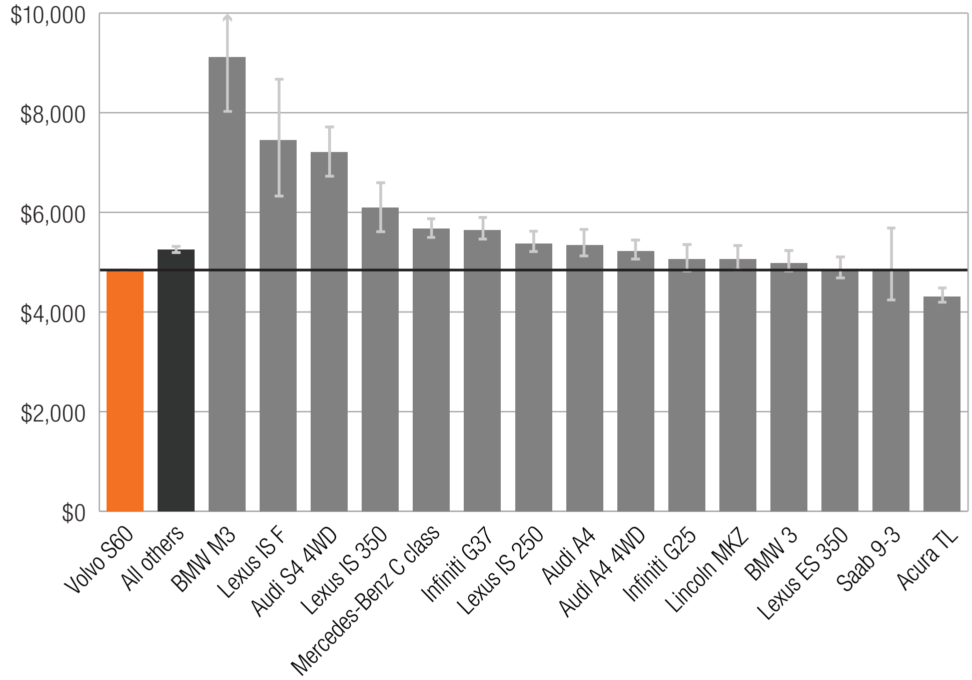


Figure 15: Collision overall losses for 2010–12 Volvo XC60 with City Safety vs. other 2009–12 midsize luxury SUVs

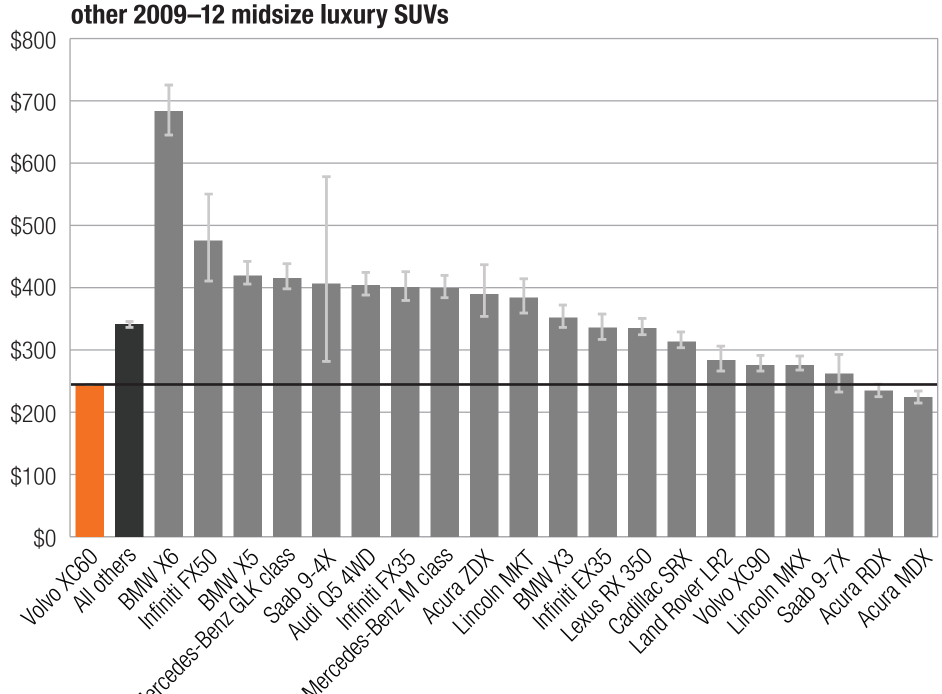


Figure 16: Collision overall losses for 2011–12 Volvo S60 with City Safety vs. other 2011–12 midsize luxury cars

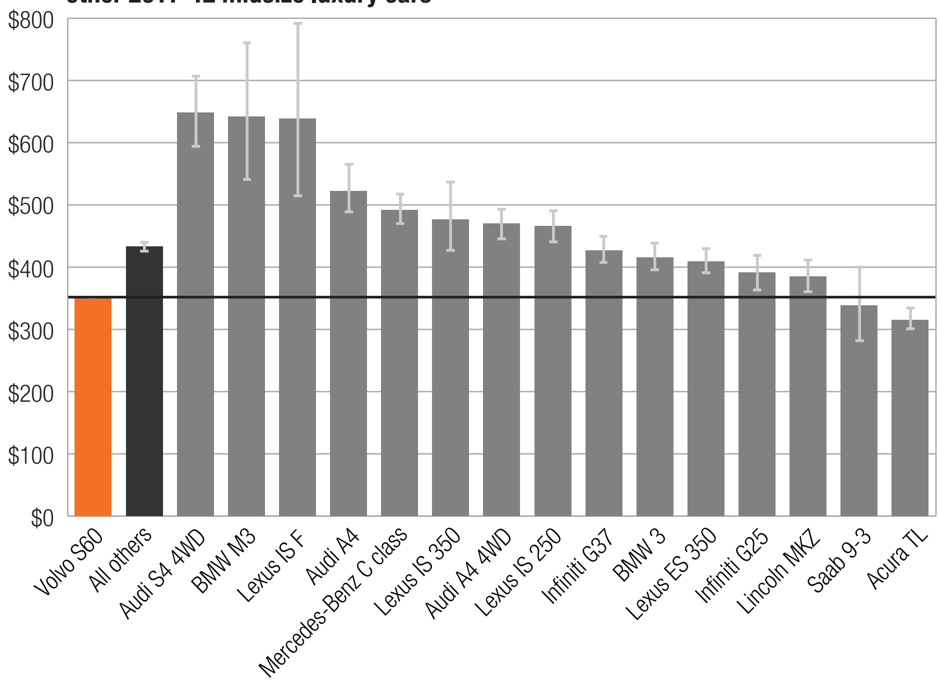


Table 6 summarizes the collision coverage results in an analogous manner to the property damage liability results. Compared with the weighted average estimate of comparison vehicles, the Volvo XC60's actual collision claim frequency was 21 percent lower, claim severity was 9 percent lower, and overall losses were reduced by 28 percent. Similarly, the S60's actual collision claim frequency was 12 percent lower than the weighted average of other midsize luxury cars, claim severity was 8 percent lower, and overall losses were 19 percent lower. Reductions in claims appear to have occurred across all of the severity spectrum, although the reductions in claims costing less than $2,000 are much less (only 13 percent for the XC60 and 1 percent for the S60).

Table 6: Collision loss results - City Safety versus weighted average of comparison vehicles

				City Safety benefit	
	Estimate	Standard Error	Estimated change of control vehicles relative to study vehicles	Estimate	95% confidence interval
XC60 vs. midsize luxury SUVs					
Claim frequency	-0.2348	0.0038	26%	-21%	-22%, -20%
Claim severity	-0.0993	0.0043	10%	-9%	-10%, -9%
Overall loss	-0.3341	0.0058	40%	-28%	-29%, -28%
Claims <$2,000	-0.1351	0.0054	14%	-13%	-14%, -12%
Claims $2,000–$4,999	-0.2912	0.0078	34%	-25%	-26%, -24%
Claims $5,000–$11,999	-0.3864	0.0100	47%	-32%	-33%, -31%
Claims $12,000+	-0.3114	0.0115	37%	-27%	-28%, -25%
S60 vs. midsize luxury cars					
Claim frequency	-0.1232	0.0053	13%	-12%	-13%, -11%
Claim severity	-0.0816	0.0062	8%	-8%	-9%, -7%
Overall loss	-0.2048	0.0082	23%	-19%	-20%, -17%
Claims <$2,000	-0.0085	0.0077	1%	-1%	-2%, 1%
Claims $2,000–$4,999	-0.2122	0.0113	24%	-19%	-21%, -17%
Claims $5,000–$11,999	-0.3565	0.0139	43%	-30%	-32%, -28%
Claims $12,000+	-0.1156	0.0141	12%	-11%	-13%, -8%

Personal injury protection: Figures 17–18 show the results for the analyses of personal injury protection claim frequency. The actual personal injury protection claim frequency for the XC60 and S60 are typically lower than the estimated frequencies for their comparison vehicles. Only the Volvo XC90 and the Acura MDX had lower claim rates than the XC60 and neither difference was significant. The Audi A4 4WD, the BMW M3, and the Audi S4 4WD had lower claim rates than the S60, with only the Audi S4 4WD difference being significant.

Figure 17: Personal injury protection claim frequencies per 1,000 insured vehicle years for 2010–12 Volvo XC60 with City Safety vs. other 2009–12 midsize luxury SUVs

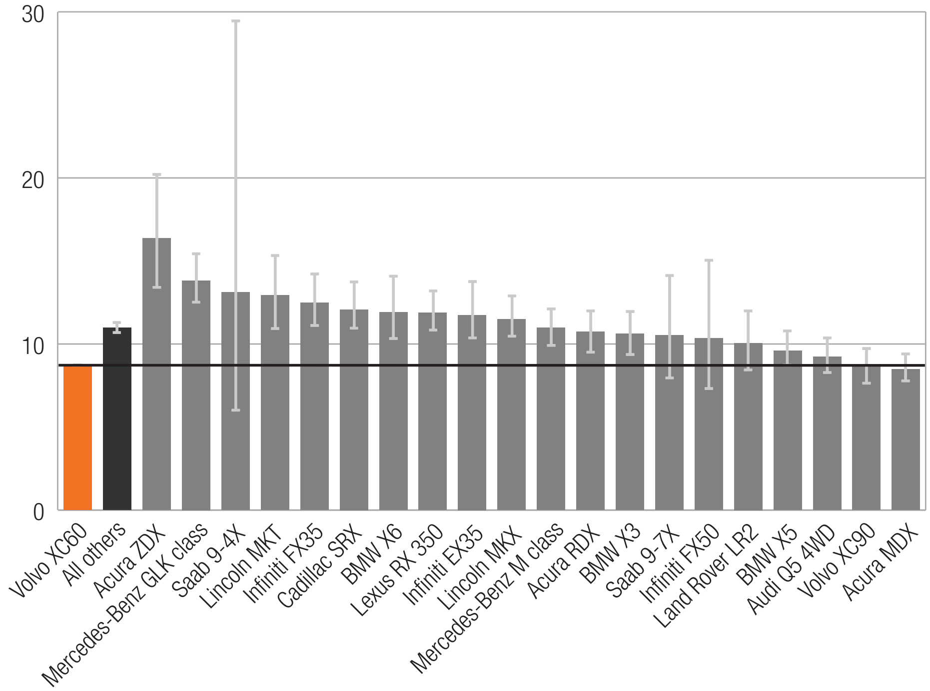


Figure 18: Personal injury protection claim frequencies per 1,000 insured vehicle years for 2011–12 Volvo S60 with City Safety vs. other 2011–12 midsize luxury cars

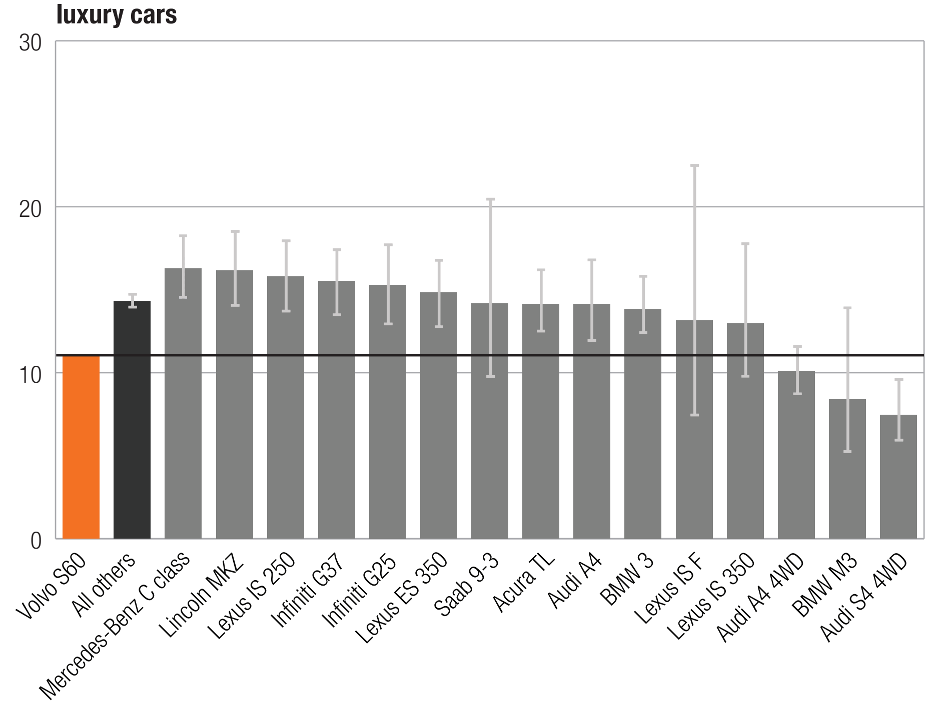


Table 7 summarizes results of the regression analysis conducted for personal injury protection coverage. Note that analyses of claim severity were not conducted because of the relative recency of these claims and the length of time it takes for claims costs to fully develop. Compared with other midsize luxury SUVs, it is estimated that the XC60 personal injury protection claim frequency was reduced by 21 percent with City Safety. For the S60, personal injury protection claim frequency was 23 percent lower than would have been expected based on the weighted average experience of other midsize luxury cars.

Table 7: Personal injury protection loss frequency results — City Safety versus weighted average of comparison vehicles

				City Safety benefit	
	Estimate	Standard Error	Estimated change of control vehicles relative to study vehicles	Estimate	95% confidence interval
XC60 vs. midsize luxury SUVs	-0.2297	0.0140	26%	-21%	-23%, -18%
S60 vs. midsize luxury cars	-0.2569	0.0192	29%	-23%	-26%, -20%

Medical payment: Figures 19–20 show the results for the analyses of medical payment claim frequency. The actual medical payment claim frequency for the XC60 and S60 are typically lower than the estimated frequencies for their comparison vehicles. Four vehicles had lower claim rates than the XC60, with only one difference being significant. The BMW M3, the Lexus IS F, and the Audi S4 4WD had lower claim rates than the S60, with only the Audi S4 4WD difference being significant.

Figure 19: Medical payment claim frequencies per 1,000 insured vehicle years for 2010–12 Volvo XC60 with City Safety vs. other 2009–12 midsize luxury SUVs

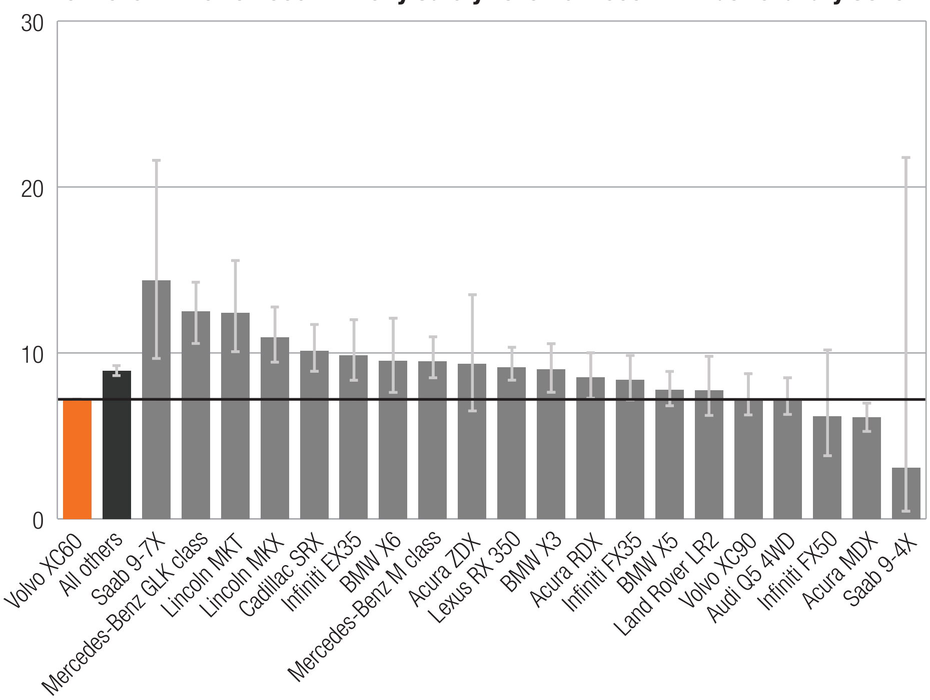


Figure 20: Medical payment claim frequencies per 1,000 insured vehicle years for 2011–12 Volvo S60 with City Safety vs. other 2011–12 midsize luxury cars

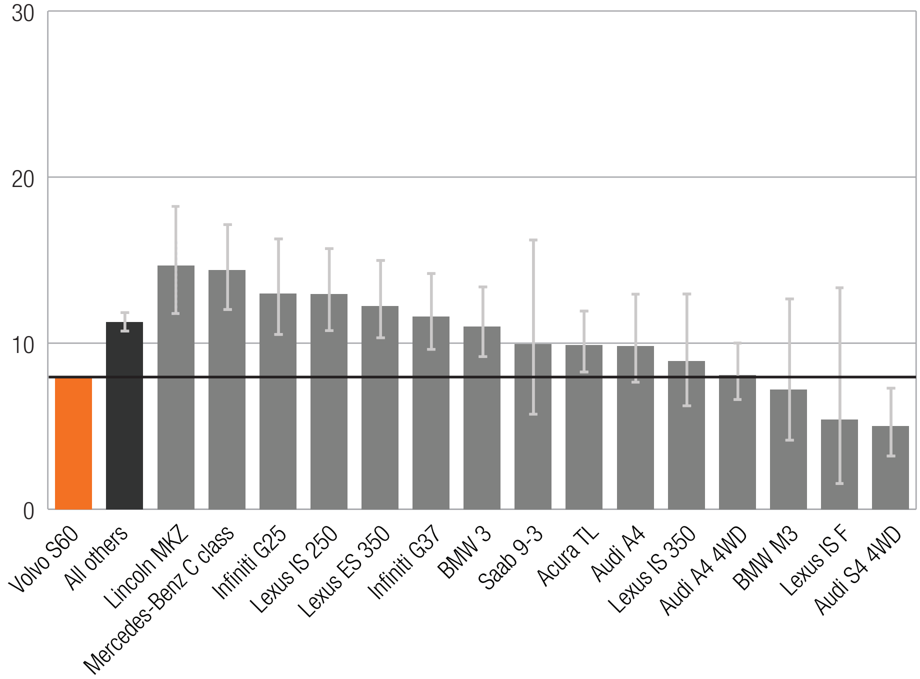


Table 8 summarizes results of the regression analysis conducted for medical payment coverage. Note that analyses of claim severity were not conducted because of the relative recency of these claims and the length of time it takes for claims costs to fully develop. Compared with other midsize luxury SUVs, it is estimated that the XC60 medical payment claim frequency was reduced by 19 percent with City Safety. For the S60, medical payment claim frequency was 30 percent lower than would have been expected based on the weighted average experience of other midsize luxury cars.

Table 8: Medical payment loss frequency results — City Safety versus weighted average of comparison vehicles

				City Safety benefit	
	Estimate	Standard Error	Estimated change of control vehicles relative to study vehicles	Estimate	95% confidence interval
XC60 vs. midsize luxury SUVs	-0.2169	0.0194	24%	-19%	-22%, -16%
S60 vs. midsize luxury cars	-0.3523	0.0297	42%	-30%	-34%, -25%

Pooled results: Table 9 shows the combined, or pooled, XC60 and S60 estimates by coverage type. When the results are presented in this manner, it allows for easy interpretation. Insurance losses for the pooled results show significant reductions across all coverage types.

Table 9: Combined XC60 and S60 summary loss results

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-18.2%	**-17.7%**	-17.2%	-$474	**-$440**	-$405	-$96	**-$93**	-$89
Property damage liability	-15.3%	**-14.5%**	-13.8%	-$240	**-$213**	-$186	-$21	**-$19**	-$18

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-30.7%	**-28.6%**	-26.4%	-38.9%	**-35.4%**	-31.7%	-32.0%	**-28.3%**	-24.4%
Medical payment	-25.1%	**-22.7%**	-20.2%	-28.3%	**-21.8%**	-14.7%	-31.4%	**-28.1%**	-24.6%
Personal injury protection	-23.0%	**-21.3%**	-19.5%	-15.3%	**-11.0%**	-6.5%	-28.5%	**-26.3%**	-24.0%

Discussion

This is the second update for Volvo XC60 and the first for S60 of analyses of the effects of the City Safety system on collision, property damage liability and bodily injury liability losses. In addition, the effects on losses under personal injury protection and medical payments coverage types are reported for the first time. **Tables 10-11** show that the effects on collision and liability claim frequencies have been stable over time. Differences between the most recent results and those reported earlier are likely due to uncertainty associated with lower exposure and smaller claim counts in the earlier analyses. The property damage claim frequency estimates for XC60 suggest there is no diminution of the City Safety effect as vehicles age, since the oldest vehicles in the present analysis are now 4-7 years old.

The consistency of the results between analyses for both the S60 and XC60 suggests that the best estimate for a general effect of City Safety for all vehicle types would be the pooled estimates reported in **Table 9**. As with the underlying estimates for the individual models, these show significant reductions in all measures of loss for all coverage types analyzed. These results suggest that if all vehicles were equipped with a system like City Safety, more than one-sixth of all physical damage claims and more than one-fifth of all injury claims would be eliminated. This reduction in crashes and injuries could be achieved without increasing the cost to repair those vehicles that become crash damaged. This contrasts with the earliest HLDI report on City Safety in which an increase in property damage liability claim severity was found. Analysis of frequency reductions by claim size suggested that the increased severity was due to mean shifting associated with the elimination of a large number of the least expensive claims and little change in the frequency of more expensive claims. The present results, which are based on nearly 18 times the exposure and 21 times the number of PDL claims do not show an increase in average physical claim costs indicating that City Safety is preventing damage across the entire range analyzed.

Unlike the earlier analyses of City Safety on the XC60, the present one shows a larger reduction in claim frequency for collision coverage than for property damage liability. This is unexpected given that City Safety is intended to prevent front-to-rear collisions between two vehicles. Such crashes are a much larger proportion of the property damage claim universe than they are among collision claims since the collision universe would include many single-vehicle crashes. This would suggest that City Safety is preventing some single vehicle crashes, which is plausible as tests show that City Safety will activate automated braking when driven toward non-vehicle objects.

Table 10: Change in claim frequencies for Volvo XC60, initial vs. updated results

Vehicle damage coverage types	Initial 2011 results	Updated 2012 results	Updated 2015 results
Collision	-22.0%	-20.2%	-20.9%
Property damage liability	-26.6%	-14.6%	-14.3%

Injury coverage types	Initial 2011 results	Updated 2012 results	Updated 2015 results
Bodily injury liability	-51.1%	-33.3%	-27.5%

Table 11: Change in claim frequencies for Volvo S60, initial vs. updated results

Vehicle damage coverage types	Initial 2012 results	Updated 2015 results
Collision	-8.7%	-11.6%
Property damage liability	-16.3%	-15.2%

Injury coverage types	Initial 2012 results	Updated 2015 results
Bodily injury liability	-18.2%	-31.2%

Loss results for City Safety compared with other Volvos: As in past reports on City Safety, the present one compares S60 and XC60 to other Volvo models that were not yet equipped with City Safety. This was included to answer concerns that by comparing the S60 and the XC60 with similar models from other automakers, the results reported for City Safety may actually be due to a difference between drivers of Volvos and drivers of the models in the comparison groups that are not fully accounted for by the inclusion of rated driver covariates in the analyses. As before, nearly every measure of loss in every coverage type is lower for the S60 and XC60 than for other Volvo models without City Safety. The only exceptions are increases in the frequency of personal injury protection claims and high severity medical payments claims, but neither of these estimates is statistically significant. Thus, it seems that the reductions in losses associated with City Safety in the main analyses are not likely due to a Volvo driver effect. These results are summarized in **Appendix B**.

Limitations

All of the XC60s and S60s included in the current study were equipped with the City Safety technology, but there was no way to know whether any drivers in the crash-involved vehicles had manually turned off the system prior to the crash. Also, most of the vehicles in this study, including the XC60 and S60, can be equipped with a variety of collision avoidance features that might also affect claim frequencies, and it was not possible, based on data available to HLDI at the time of the study, to control for the presence of these other features.

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Appendix A: Exposure and claims by coverage type for comparison vehicles										
	Property damage liability		Bodily injury liability		Collision		Personal injury protection		Medical payments	
	Exposure	Claims	Exposure	Claims	Exposure	Claims	Exposure	Claims	Exposure	Claims
Midsize luxury SUVs										
Acura MDX	470,005	15,614	191,324	1,282	470,005	26,809	217,881	2,022	146,948	933
Acura RDX	144,986	4,945	56,592	445	144,986	8,571	70,845	845	43,361	380
Acura ZDX	12,282	461	4,769	40	12,282	1,200	5,872	107	3,586	34
Audi Q5 4WD	210,105	6,371	85,982	676	210,105	16,620	96,956	971	63,289	501
BMW X3	122,167	3,853	48,199	414	122,167	8,198	57,943	642	36,707	337
BMW X5	306,557	11,541	122,446	1,043	306,557	22,569	147,938	1,563	88,338	763
BMW X6	36,044	1,435	13,406	144	36,044	3,392	18,936	262	9,055	100
Cadillac SRX	419,965	12,576	160,216	1,231	419,965	31,070	200,259	2,100	136,511	1,092
Infiniti EX35	60,872	1,773	24,250	179	60,872	3,946	29,097	359	17,789	180
Infiniti FX35	108,882	3,889	42,771	405	108,882	7,646	52,693	734	31,325	275
Infiniti FX50	7,193	247	3,311	32	7,193	451	3,136	35	2,611	17
Land Rover LR2	35,283	1,433	13,907	135	35,283	2,256	16,619	186	10,754	87
Lexus RX 350	969,669	31,845	398,145	3,044	969,669	74,406	457,025	5,293	311,076	2,659
Lincoln MKT	38,366	1,042	15,026	122	38,366	2,836	18,386	197	13,013	120
Lincoln MKX	188,276	5,276	69,275	528	188,276	11,522	94,828	924	60,650	491
Mercedes-Benz GLK class	220,877	7,539	92,759	959	220,877	16,196	98,527	1,358	66,425	860
Mercedes-Benz M class	319,744	10,107	119,339	1,041	319,744	21,743	163,878	1,942	88,153	897
Saab 9-4X	1,055	33	413	1	1,055	72	498	6	380	1
Saab 9-7X	8,939	248	2,419	19	8,939	712	5,883	61	2,118	25
Volvo XC90	107,244	4,103	42,424	318	107,244	6,315	51,432	480	31,884	240
Midsize luxury cars										
Acura TL	137,298	3,919	50,421	385	137,298	9,894	65,301	943	38,905	371
Audi A4	29,519	1,246	13,498	213	29,519	3,065	11,753	211	7,202	109
Audi A4 4WD	89,931	2,795	31,939	269	89,931	8,447	45,757	488	23,540	199
Audi S4 4WD	18,439	426	7,690	50	18,439	1,681	8,107	64	5,620	32
BMW 3	308,736	9,796	121,616	1,218	308,736	26,526	140,918	2,159	81,335	1,062
BMW M3	4,992	98	2,410	13	4,992	347	1,873	17	1,561	14
Infiniti G25	43,441	1,400	15,239	159	43,441	3,517	22,135	389	10,360	149
Infiniti G37	141,256	4,124	48,638	389	141,256	10,857	71,273	1,196	35,314	440
Lexus ES 350	160,968	4,710	60,036	419	160,968	13,332	76,703	1,051	48,352	548
Lexus IS 250	89,446	3,326	34,679	421	89,446	8,190	40,694	763	22,326	385
Lexus IS 350	11,447	317	5,360	51	11,447	902	4,229	60	3,928	40
Lexus IS F	2,342	72	1,064	18	2,342	198	896	13	761	5
Lincoln MKZ	90,668	2,416	24,349	201	90,668	7,290	53,970	689	22,140	225
Mercedes-Benz C class	251,357	7,989	95,972	1,048	251,357	22,545	118,067	2,071	65,018	1,105
Saab 9-3	4,798	142	1,777	11	4,798	339	2,278	31	1,519	13

Appendix B: Summary loss results

XC60 summary loss results relative to other midsize luxury SUVs

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-22%	**-21%**	-20%	-$492	**-$451**	-$410	-$101	**-$97**	-$93
Property damage liability	-15%	**-14%**	-13%	-$250	**-$219**	-$188	-$22	**-$20**	-$19

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-30%	**-28%**	-25%	-40%	**-36%**	-32%	-30%	**-25%**	-21%
Medical payment	-22%	**-19%**	-16%	-21%	**-12%**	-3%	-30%	**-26%**	-22%
Personal injury protection	-23%	**-21%**	-18%	-11%	-5%	1%	-33%	**-30%**	-27%

S60 summary loss results relative to other midsize luxury cars

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-13%	**-12%**	-11%	-$476	**-$412**	-$348	-$87	**-$80**	-$73
Property damage liability	-17%	**-15%**	-14%	-$249	**-$195**	-$141	-$21	**-$18**	-$16

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-35%	**-31%**	-27%	-40%	**-33%**	-26%	-44%	**-37%**	-30%
Medical payment	-34%	**-30%**	-25%	-53%	**-44%**	-33%	-38%	**-33%**	-27%
Personal injury protection	-26%	**-23%**	-20%	-29%	**-23%**	-15%	-24%	**-20%**	-16%

XC60 summary loss results relative to other Volvos

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-15%	**-14%**	-12%	-$144	-$68	$7	-$49	**-$43**	-$36
Property damage liability	-9%	**-7%**	-5%	$35	**$94**	$152	-$6	**-$3**	$0

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-28%	**-23%**	-17%	-45%	**-37%**	-29%	-25%	**-15%**	-3%
Medical payment	-16%	**-9%**	-2%	-35%	**-21%**	-4%	-17%	-6%	6%
Personal injury protection	-18%	**-13%**	-8%	-32%	**-24%**	-14%	-21%	**-14%**	-7%

S60 summary loss results relative to other Volvos

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	6%	**9%**	12%	$359	**$507**	$651	$50	**$63**	$76
Property damage liability	-19%	**-16%**	-12%	$30	**$149**	$263	-$14	**-$9**	-$4

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-37%	**-27%**	-15%	-42%	**-25%**	-3%	-56%	**-41%**	-22%
Medical payment	-23%	-10%	6%	-59%	-35%	2%	-18%	5%	34%
Personal injury protection	-2%	10%	22%	-38%	**-22%**	-1%	16%	**34%**	56%

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The Highway Loss Data Institute is a nonprofit public service organization that gathers, processes, and publishes insurance data on the human and economic losses associated with owning and operating motor vehicles. DW201412 SK

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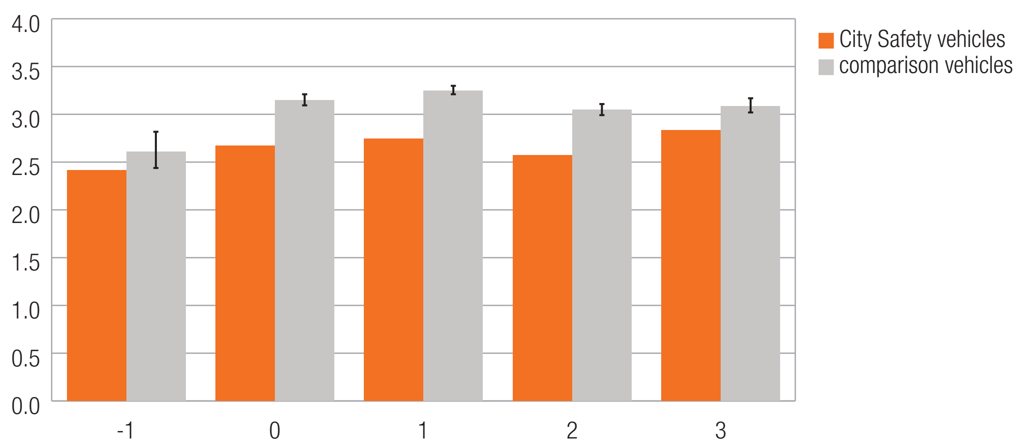
Volvo City Safety loss experience by vehicle age

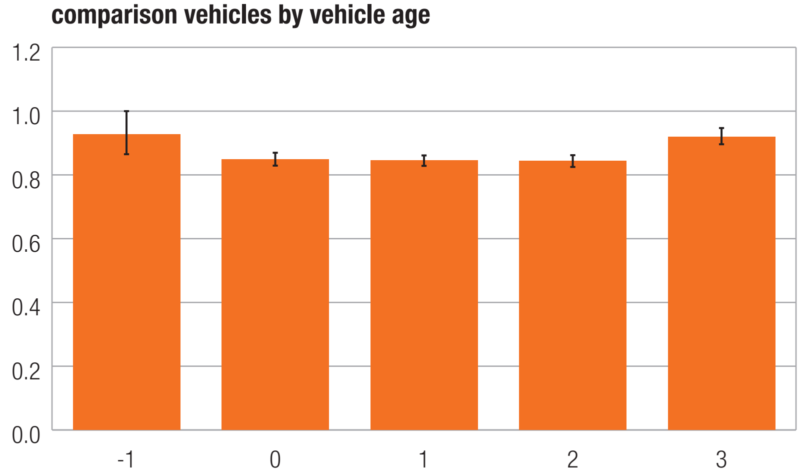
Summary

City Safety technology was first introduced by Volvo to the U.S. market with the 2010 XC60 as standard equipment. The Highway Loss Data Institute (HLDI) published bulletins in 2011 and 2012 presenting the relationship of this technology and insurance losses. The results showed that the City Safety system was associated with reductions in insurance losses. The purpose of this report is to see if the benefits of City Safety persist over time. To examine this, claim frequencies for City Safety-equipped vehicles and comparison vehicles were evaluated by vehicle age. There is some variability in the results by vehicle age but there is not an indication that there is a pattern of diminished benefits as the vehicles age.

PDL claim frequencies for City Safety-equipped vehicles and comparison vehicles by vehicle age



Ratio of PDL claim frequencies for City Safety-equipped vehicles to comparison vehicles by vehicle age



Introduction

This Highway Loss Data Institute (HLDI) bulletin provides a look at the impact of vehicle age on the insurance loss benefits of Volvo City Safety technology previously presented by HLDI. For this bulletin, the loss experience for Volvo XC60s and S60s equipped with City Safety were compared with losses for comparable vehicles without the system by vehicle age.

City Safety is a low-speed collision avoidance system first released as standard equipment on the 2010 Volvo XC60, a midsize luxury SUV, and on the 2011 S60, a midsize luxury car. The system was developed by Volvo to reduce low-speed front-to-rear crashes, which commonly occur in urban traffic, by assisting the driver in braking. According to a Volvo news release, 75 percent of all crashes occur at speeds up to 19 mph, and half of these occur in city traffic (Volvo, 2008). The City Safety system has an infrared laser sensor built into the windshield that detects other vehicles traveling in the same direction up to 18 feet in front of the vehicle. The system initially reacts to slowing or stopped vehicles by pre-charging the brakes. The vehicle will brake automatically if forward collision risk is detected and the driver does not react in time, but only at travel speeds up to 19 mph. If the relative speed difference is less than 9 mph, a collision can be avoided entirely. If the speed difference is between 9 and 19 mph, the speed will be reduced to lessen the collision severity. The City Safety system studied in this analysis operates at speeds up to 19 mph but a newer version of the system operates at speeds up to 31 mph. City Safety is automatically activated when the vehicle ignition is turned on but can be manually deactivated by the driver.

When examining the effect of City Safety on insurance losses, it is important to consider that the system is not designed to mitigate all types of crashes and that many factors can limit the system's ability to perform its intended function. City Safety works equally well during the day and at night, but fog, heavy rain, or snow may limit the ability of the system's infrared laser to detect vehicles. The driver is advised if the sensor becomes blocked by dirt, ice, or snow.

Method

Vehicles

In the initial analysis, loss results for the XC60 were compared with other midsize luxury SUVs, while loss results for the S60 were compared with other midsize luxury cars. For the results presented here, the XC60 and S60 were pooled, as were the comparison vehicles.

Sales of the 2010 Volvo XC60 began in February 2009, when other brands still were marketing 2009 models. Consequently, the control populations for the XC60 analyses included vehicles starting in model year 2009. The total study population for the XC60 was model years 2010–12 during calendar years 2009–14 with control vehicle model years of 2009–14. The loss experience of the model year 2009 vehicles in calendar year 2008 was excluded because no XC60s were on the road during this time period.

City Safety was added as standard equipment to the Volvo S60 in model year 2011. The analyses considered model years 2011–12 for the S60 and its control vehicles during calendar years 2010–14. Calendar year 2010 was not included in the S60 analysis because of the very small number of model year 2011 S60s insured that year.

Total exposure measured as insured vehicle years and the total number of claims for the XC60 and S60 are shown by insurance coverage type in **Table 1**. Because previous HLDI analyses have shown them to have different loss patterns, hybrids, convertibles, and two-door vehicles were excluded from the control groups.

Table 1: Exposure and claims by coverage type

	XC60		S60	
Coverage	Claims	Exposure	Claims	Exposure
Property damage liability	3,360	120,800	1,890	76,870
Bodily injury liability	298	50,524	159	26,930
Collision	6,880	120,800	5,597	76,870
Medical payment	270	38,005	166	20,925
Personal injury protection	491	57,144	416	37,565

The study and control vehicles in this analysis can also be equipped with optional collision avoidance features that have been shown to affect claim frequency in other studies by HLDI. It should be noted that this analysis does not account for their presence or absence because the information needed to identify the vehicles with the optional features is not available. Furthermore, the take rate for these features is thought to be low.

Insurance Data

Automobile insurance covers damages to vehicles and property as well as injuries to people involved in crashes. Different insurance coverages pay for vehicle damage versus injuries, and different coverages may apply depending on who is at fault. The current study is based on property damage liability, collision, bodily injury liability, personal injury protection, and medical payment coverages. Data are supplied to HLDI by its member companies.

Collision coverage insures against vehicle damage to an at-fault driver's vehicle sustained in a crash with an object or other vehicle; this coverage is common to all 50 states. Property damage liability (PDL) coverage insures against vehicle damage that at-fault drivers cause to other people's vehicle and property in crashes; this coverage exists in all states except Michigan, where vehicle damage is covered on a no-fault basis (each insured vehicle pays for its own damage in a crash, regardless of who is at fault).

Coverage of injuries is more complex. Bodily injury (BI) liability coverage insures against medical, hospital, and other expenses for injuries that at-fault drivers inflict on occupants of other vehicles or others on the road; although motorists in most states may have BI coverage, this information is analyzed only in states where the at-fault driver has first obligation to pay for injuries (33 states with traditional tort insurance systems). Medical payment (MedPay) coverage, also sold in the 33 states with traditional tort insurance systems, covers injuries to insured drivers and the passengers in their vehicles, but not injuries to people in other vehicles involved in the crash. Seventeen other states employ no-fault injury systems (personal injury protection coverage, or PIP) that pay up to a specified amount for injuries to occupants of involved-insured vehicles, regardless of who is at fault in a collision. The District of Columbia has a hybrid insurance system for injuries and is excluded from the injury analysis.

Statistical methods

Regression analysis was used to model claim frequency per insured vehicle year while controlling for various covariates. Claim frequency was modeled using a Poisson distribution. This model used a logarithmic link function.

The covariates included calendar year, model year, garaging state, vehicle density (number of registered vehicles per square mile), rated driver age, rated driver gender, marital status, collision deductible, and risk. A separate regression was performed for each vehicle age, study vehicle (XC60 and S60), and coverage type for a total of 50 models. To illustrate the analysis, the **Appendix** contains full model results for collision claim frequency for the XC60 at vehicle age 0.

Vehicle age in this study is defined as vehicles aged -1 to 3. For example, a 2012 model year vehicle in calendar year 2012 would have a vehicle age of 0, while a 2013 vehicle in the same calendar year would be aged -1. The results of this study are presented as ratios of claim frequency of City Safety-equipped vehicles to claim frequency of comparison vehicles. If the ratio is 1, there is no difference between the two types of vehicles being compared. If the ratio is less than 1, it means there are fewer claims made on vehicles with City Safety technology than those without.

The estimated effects of City Safety by age were calculated separately for the XC60 and S60, along with their respective standard errors. A combined, or pooled estimate was calculated as a weighted average of the two estimates, with weights proportional to the inverse variance (i.e. weight =1/SE2). Thus, if an estimate for the XC60 had a smaller standard error (tighter confidence interval) compared to that of the S60 estimate, it would have more influence on the combined estimate. The combined standard error for the weighted average was calculated based on the same assumptions.

Results

Results for this study are broken down by coverage type. **Figure 1** shows the PDL claim frequencies for City Safety-equipped vehicles and comparison vehicles by vehicle age. **Figure 2** shows the ratio of PDL claim frequencies for City Safety-equipped vehicles to comparison vehicles by vehicle age. At each vehicle age, the PDL claim frequency is significantly lower for City Safety-equipped vehicles than for comparison vehicles. Estimated effects range from 7 to 16 percent benefits for the City Safety-equipped vehicles. Vehicles from ages -1 to 3 indicate an increased benefit while age 3 is slightly less benefical than ages 0-2.

Figure 1: PDL claim frequencies for City Safety-equipped vehicles and comparison vehicles by vehicle age

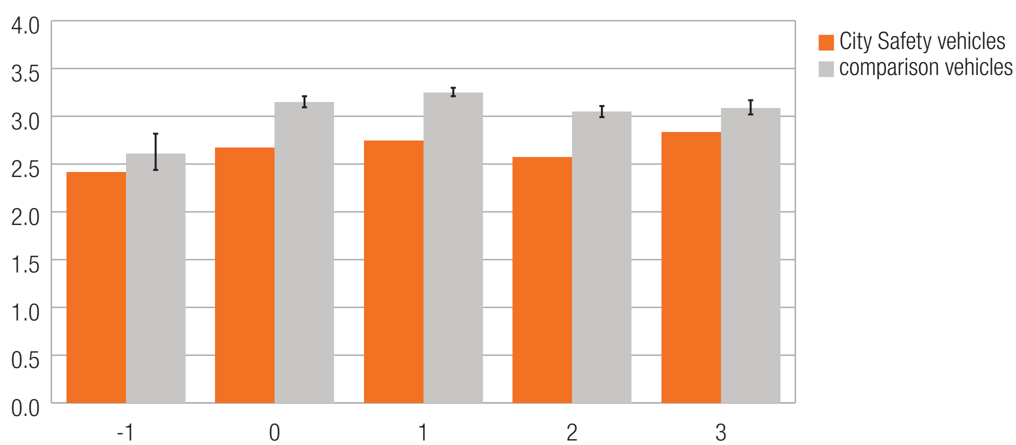


Figure 2: Ratio of PDL claim frequencies for City Safety-equipped vehicles to comparison vehicles by vehicle age

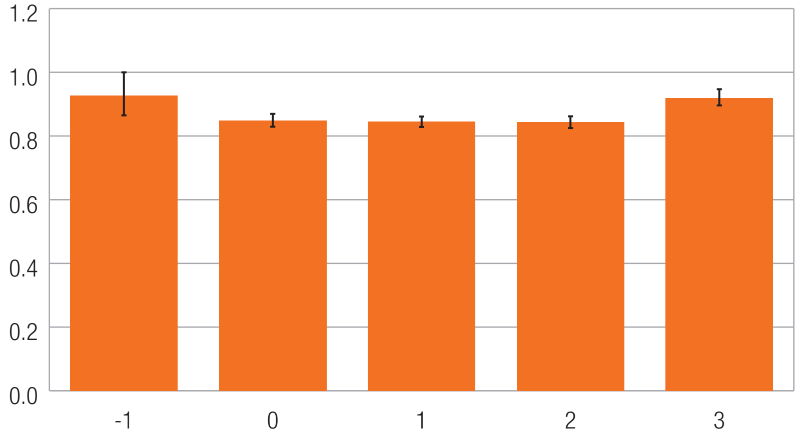
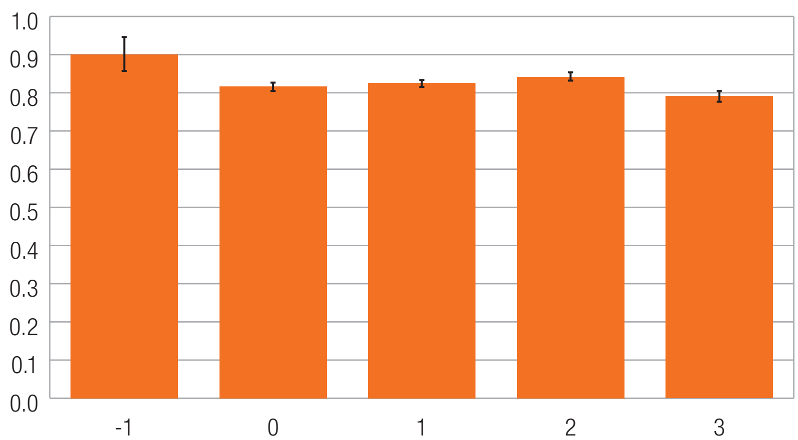


Figure 3 shows the collision claim frequency ratios of City Safety-equipped vehicles to comparison vehicles by vehicle age, and all ratios are below 1. For the newest vehicles, collision claim frequencies are about 10 percent lower for City Safety-equipped vehicles. For older vehicles (ages 0–3), the collision claim frequency ratios are similar to each other, at around 0.8.

Figure 3: Ratio of collision claim frequencies for City Safety-equipped vehicles to comparison vehicles by vehicle age



Figures 4–6 show the BI, PIP, and MedPay claim frequency ratios of City Safety-equipped vehicles to their comparison vehicles by vehicle age, respectively. All ratios are below 1, indicating that there are fewer injury claims made for City Safety-equipped vehicles than comparison vehicles at every vehicle age, and there does not appear to be a relationship between vehicle age and injury claims. In general, there are fewer injury claims in the HLDI database compared with collision and PDL claims, creating larger confidence intervals.

Figure 4: Ratio of bodily injury liability claim frequencies for City Safety-equipped vehicles to comparison vehicles by vehicle age

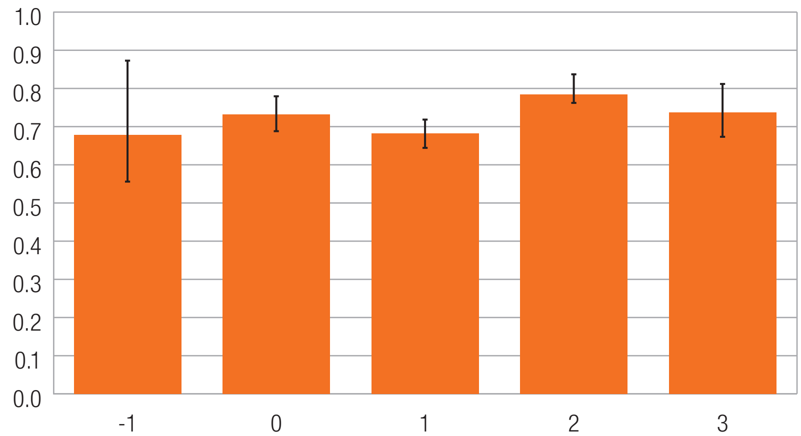


Figure 5: Ratio of personal injury protection claim frequencies for City Safety-equipped vehicles to comparison vehicles by vehicle age

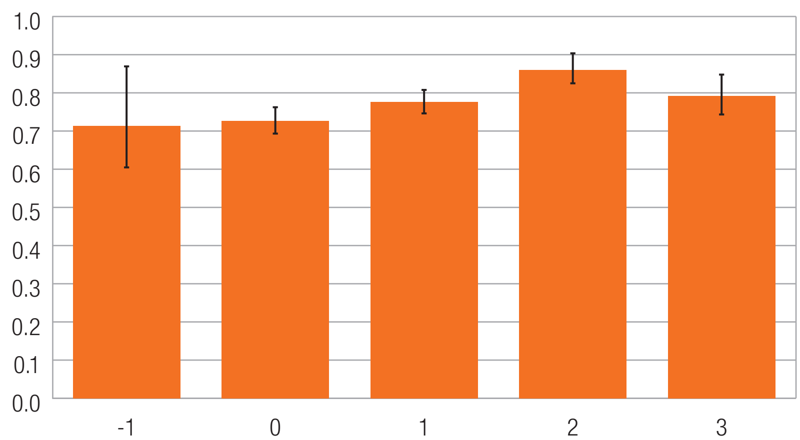
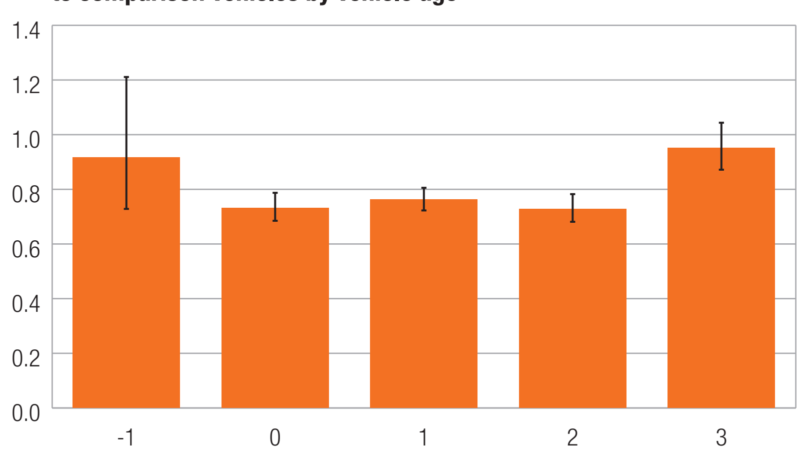


Figure 6: Ratio of MedPay claim frequencies for City Safety-equipped vehicles to comparison vehicles by vehicle age



Discussion

This is the first opportunity for HLDI to evaluate if the benefits of crash avoidance systems degrade over time. This is because collision avoidance systems are relatively new technologies to the vehicle fleet. For example, for the 2013 model year, front crash prevention was available on about 30 percent of vehicle series and will not reach 95 percent of the vehicle fleet until 2048 (HLDI, 2014).

The results presented here for the Volvo City Safety system are promising as there does not appear to be a clear change in the benefits of the system by vehicle age. This suggests no significant degradation of the City Safety system during the 3–5 years it has been available. Because the City Safety system uses the vehicle's brakes to prevent crashes, tire wear or brake aging could affect the City Safety system. As these vehicles age, these possibilities do not appear to be negatively impacting the success of the system.

Limitations

All of the XC60s and S60s included in the current study were equipped with the City Safety technology, but there was no way to know whether any drivers in the crash-involved vehicles had manually turned off the system prior to the crash. Also, most of the vehicles in this study, including the XC60 and S60, can be equipped with a variety of collision avoidance features that might also affect claim frequencies, and it was not possible, based on data available to HLDI at the time of the study, to control for the presence of these other features. The study and control vehicles may have other collision avoidance features that could be influencing the results. To fully understand the benefits of City Safety, subsequent analysis will be required as additional loss data become available involving more and potentially different drivers. This analysis controlled for a variety of possible demographic differences (rated driver age, gender, marital status, and risk) between the study and control populations. It still is possible that rated drivers who chose to purchase vehicles with City Safety differ in other ways that could affect crash likelihood — perhaps drivers who are more concerned about safety or who drive more cautiously because they have experienced prior collisions.

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Appendix

Appendix: Illustrative regression results - collision frequency for Volvo XC60 age 0									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Intercept		1	-8.8162		0.0320	-8.8788	-8.7535	76103.60	<0.0001
Calendar year	2009	1	-0.1242	-11.7%	0.0150	-0.1536	-0.0949	69.02	<0.0001
	2010	1	0.0284	2.9%	0.0117	0.0055	0.0513	5.91	0.0151
	2011	1	0.0140	1.4%	0.0116	-0.0088	0.0368	1.45	0.2292
	2012	0	0	0	0	0	0		
Vehicle make and series	Acura MDX 4dr	1	0.0223	2.3%	0.0297	-0.0360	0.0806	0.56	0.4530
	Acura RDX 4dr	1	0.0052	0.5%	0.0359	-0.0651	0.0755	0.02	0.8839
	Acura ZDX 4dr	1	0.5933	81.0%	0.0834	0.4299	0.7567	50.66	<0.0001
	Audi Q5 QUATTRO 4dr	1	0.3403	40.5%	0.0304	0.2806	0.3999	125.05	<0.0001
	BMW X3 4dr	1	0.1507	16.3%	0.0366	0.0790	0.2223	16.99	<0.0001
	BMW X5 4dr	1	0.3140	36.9%	0.0295	0.2563	0.3717	113.64	<0.0001
	BMW X6 4dr	1	0.6046	83.1%	0.0433	0.5196	0.6896	194.55	<0.0001
	Cadillac SRX 4dr	1	0.3038	35.5%	0.0288	0.2473	0.3603	**111.20**	**<0.0001**
	Infiniti EX35 4dr	1	0.1221	13.0%	0.0485	0.0271	0.2172	6.34	0.0118
	Infiniti FX35 4dr	1	0.2500	28.4%	0.0391	0.1734	0.3267	40.87	<0.0001
	Infiniti FX50 4dr	1	0.3170	37.3%	0.1178	0.0861	0.5479	7.24	0.0071
	Land Rover LR2 4dr	1	0.2462	27.9%	0.0754	0.0985	0.3939	10.67	0.0011
	Lexus RX 350 4dr	1	0.3807	46.3%	0.0270	0.3278	0.4337	198.48	<0.0001
	Lincoln MKT 4dr	1	0.3242	38.3%	0.0526	0.2212	0.4273	38.06	<0.0001
	Lincoln MKX 4dr	1	0.1107	11.7%	0.0343	0.0436	0.1778	10.45	0.0012
	Mercedes-Benz GLK Class 4dr	1	0.2635	30.1%	0.0309	0.2029	0.3241	72.63	<0.0001
	Mercedes-Benz M Class 4dr	1	0.2236	25.1%	0.0297	0.1655	0.2818	56.79	<0.0001
	Saab 9-4X 4dr	1	-0.3371	-28.6%	0.7061	-1.7211	1.0470	0.23	0.6331
	Saab 9-7X 4dr	1	0.0827	8.6%	0.1310	-0.1741	0.3395	0.40	0.5278
	Volvo XC90 4dr	1	0.0677	7.0%	0.0391	-0.0089	0.1443	3.00	0.0832
	Volvo XC60 4dr	0	0	0	0	0	0		
State	Alabama	1	0.1554	16.8%	0.0487	0.0600	0.2507	10.19	0.0014
	Arizona	1	0.1091	11.5%	0.0398	0.0311	0.1870	7.51	0.0061

Appendix: Illustrative regression results - collision frequency for Volvo XC60 age 0									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	Arkansas	1	0.1775	19.4%	0.0729	0.0346	0.3204	5.93	0.0149
	California	1	0.2678	30.7%	0.0191	0.2303	0.3053	196.05	<0.0001
	Colorado	1	0.0776	8.1%	0.0379	0.0033	0.1519	4.19	0.0407
	Connecticut	1	0.1021	10.7%	0.0345	0.0346	0.1697	8.78	0.0030
	Delaware	1	0.0294	3.0%	0.0802	-0.1279	0.1867	0.13	0.7141
	District of Columbia	1	0.3739	45.3%	0.0682	0.2402	0.5076	30.02	<0.0001
	Florida	1	-0.1252	-11.8%	0.0212	-0.1667	-0.0837	**35.01**	**<0.0001**
	Georgia	1	-0.0854	-8.2%	0.0330	-0.1501	-0.0206	6.67	0.0098
	Hawaii	1	0.1084	11.4%	0.0673	-0.0235	0.2402	2.59	0.1072
	Idaho	1	-0.1488	-13.8%	0.1442	-0.4313	0.1338	1.06	0.3021
	Illinois	1	0.0869	9.1%	0.0242	0.0396	0.1343	12.95	0.0003
	Indiana	1	0.1296	13.8%	0.0508	0.0301	0.2290	6.52	0.0107
	Iowa	1	0.0425	4.3%	0.0802	-0.1147	0.1997	0.28	0.5962
	Kansas	1	0.0611	6.3%	0.0600	-0.0564	0.1786	1.04	0.3084
	Kentucky	1	-0.0438	-4.3%	0.0617	-0.1647	0.0772	0.50	0.4783
	Louisiana	1	0.1609	17.5%	0.0422	0.0783	0.2436	14.57	0.0001
	Maine	1	0.1782	19.5%	0.1314	-0.0793	0.4357	1.84	0.1749
	Maryland	1	0.0737	7.6%	0.0305	0.0138	0.1335	5.83	0.0158
	Massachusetts	1	0.2296	25.8%	0.0417	0.1479	0.3113	30.30	<0.0001
	Michigan	1	0.4318	54.0%	0.0309	0.3712	0.4923	195.37	<0.0001
	Minnesota	1	-0.0423	-4.1%	0.0473	-0.1351	0.0504	0.80	0.3712
	Mississippi	1	-0.0733	-7.1%	0.0827	-0.2355	0.0889	0.79	0.3756
	Missouri	1	0.0113	1.1%	0.0473	-0.0813	0.1040	0.06	0.8105
	Montana	1	-0.4565	-36.7%	0.2254	-0.8982	-0.0147	4.10	0.0428
	Nebraska	1	-0.1700	-15.6%	0.0867	-0.3400	-0.0001	3.85	0.0499
	Nevada	1	0.0895	9.4%	0.0559	-0.0200	0.1990	2.57	0.1090
	New Hampshire	1	0.2652	30.4%	0.0714	0.1253	0.4051	13.80	0.0002
	New Jersey	1	0.0963	10.1%	0.0223	0.0526	0.1400	18.68	<0.0001
	New Mexico	1	-0.0533	-5.2%	0.0839	-0.2178	0.1112	0.40	0.5255
	New York	1	0.1488	16.0%	0.0194	0.1107	0.1869	58.65	<0.0001
	North Carolina	1	-0.2851	-24.8%	0.0397	-0.3629	-0.2073	51.63	<0.0001
	North Dakota	1	0.2208	24.7%	0.1976	-0.1665	0.6080	1.25	0.2638
	Ohio	1	-0.0596	-5.8%	0.0330	-0.1242	0.0050	3.27	0.0704
	Oklahoma	1	0.0382	3.9%	0.0554	-0.0703	0.1467	0.48	0.4903
	Oregon	1	0.0451	4.6%	0.0564	-0.0655	0.1557	0.64	0.4244
	Pennsylvania	1	0.2225	24.9%	0.0240	0.1754	0.2696	85.68	<0.0001
	Rhode Island	1	0.2203	24.6%	0.0718	0.0796	0.3610	9.42	0.0021
	South Carolina	1	-0.1366	-12.8%	0.0534	-0.2412	-0.0320	6.55	0.0105
	South Dakota	1	0.2593	29.6%	0.1639	-0.0620	0.5805	2.50	0.1137
	Tennessee	1	0.1367	14.6%	0.0420	0.0543	0.2190	10.57	0.0011
	Utah	1	0.0509	5.2%	0.0749	-0.0958	0.1977	0.46	0.4964
	Vermont	1	0.2176	24.3%	0.1351	-0.0472	0.4823	2.59	0.1073
	Virginia	1	0.1440	15.5%	0.0272	0.0907	0.1974	27.99	<0.0001
	Washington	1	0.1634	17.8%	0.0371	0.0908	0.2361	19.44	<0.0001

Appendix: Illustrative regression results - collision frequency for Volvo XC60 age 0									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	West Virginia	1	0.0933	9.8%	0.0909	-0.0849	0.2715	1.05	0.3049
	Wisconsin	1	0.0866	9.0%	0.0518	-0.0149	0.1880	2.80	0.0944
	Wyoming	1	0.1283	13.7%	0.1771	-0.2188	0.4754	0.52	0.4688
	Alaska	1	0.2433	27.5%	0.1136	0.0207	0.4658	4.59	0.0322
	Texas	0	0	0	0	0	0		
Registered vehicle density	Unknown	1	-0.5253	-40.9%	0.4085	-1.3260	0.2753	1.65	0.1984
	<50	1	-0.2783	-24.3%	0.0313	-0.3396	-0.2169	79.03	<0.0001
	50–99	1	-0.2390	-21.3%	0.0247	-0.2874	-0.1906	93.65	<0.0001
	100–249	1	-0.2363	-21.0%	0.0178	-0.2711	-0.2014	176.64	<0.0001
	250–499	1	-0.1984	-18.0%	0.0161	-0.2300	-0.1669	152.04	<0.0001
	500–999	1	-0.0987	-9.4%	0.0129	-0.1241	-0.0734	58.29	<0.0001
	1,000+	0	0	0	0	0	0		
Deductible range	0 to 100	1	-0.0625	-6.1%	0.0190	-0.0997	-0.0253	10.83	0.0010
	101 to 250	1	0.2716	31.2%	0.0128	0.2465	0.2968	447.94	<0.0001
	501+	1	-0.3174	-27.2%	0.0122	-0.3412	-0.2936	682.52	<0.0001
	251 to 500	0	0	0	0	0	0		
Rated driver age group	15–19	1	0.0922	9.7%	0.0433	0.0073	0.1771	4.53	0.0333
	20–24	1	0.1255	13.4%	0.0314	0.0639	0.1870	15.95	<0.0001
	25–29	1	0.1150	12.2%	0.0233	0.0694	0.1606	24.42	<0.0001
	30–39	1	0.0684	7.1%	0.0138	0.0415	0.0954	24.72	<0.0001
	50–59	1	-0.1121	-10.6%	0.0136	-0.1388	-0.0854	67.80	<0.0001
	60–64	1	-0.0778	-7.5%	0.0172	-0.1116	-0.0440	20.40	<0.0001
	65–69	1	0.0152	1.5%	0.0186	-0.0213	0.0517	0.67	0.4135
	70–74	1	0.0769	8.0%	0.0225	0.0328	0.1210	11.67	0.0006
	75+	1	0.2087	23.2%	0.0229	0.1638	0.2535	83.18	<0.0001
	Unknown	1	-0.0438	-4.3%	0.0236	-0.0901	0.0025	3.44	0.0636
	40–49	0	0	0	0	0	0		
Rated driver gender	Male	1	-0.0542	-5.3%	0.0107	-0.0752	-0.0332	25.51	<0.0001
	Unknown	1	-0.1042	-9.9%	0.0274	-0.1579	-0.0504	14.44	0.0001
	Female	0	0	0	0	0	0		
Rated driver marital status	Single	1	0.1903	21.0%	0.0126	0.1657	0.215	229.92	<0.0001
	Unknown	1	0.1545	16.7%	0.0268	0.102	0.2071	33.20	<0.0001
	Married	0	0	0	0	0	0		
Risk	Nonstandard	1	0.1705	18.6%	0.0143	0.1426	0.1985	142.80	<0.0001
	Standard	0	0	0	0	0	0		

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Honda Accord collision avoidance features

This is the third look at the collision avoidance features on the Honda Accord. The Honda Accord is a popular passenger car and is one of the best-selling vehicles in America. With many Honda Accords on the road, equipping them with a crash prevention system that works could potentially have a large and beneficial impact on insurance losses. Interestingly, Honda has equipped most of the Accords with a camera-based front crash prevention system while one Honda Accord trim is equipped with a radar-based one.

This Highway Loss Data Institute (HLDI) report updates two prior analyses of Honda Accord collision avoidance features. Forward Collision Warning (FCW) paired with Lane Departure Warning (LDW) is on most Honda Accord trims as well as the Crosstour and uses a single camera mounted behind the windshield for sensing. The Honda Accord four-door Touring trim is studied for the first time in this bulletin and is equipped with FCW, LDW and Adaptive Cruise Control (ACC). This system utilizes a radar unit mounted in the front grille, similar to most other forward collision warning systems studied by HLDI. Despite similar FCW function, these systems are evaluated separately. LaneWatch, a passenger-side blind spot information system, utilizes a camera mounted on the passenger-side mirror and is available on some of the studied vehicles.

There is nearly twice as much exposure in this study as in the prior one. All of the estimates in this study are within the confidence bounds of the prior study. The updated results for the FCW/LDW system continue to be associated with reductions in claim frequency for all five coverage types examined. With this update the insurance losses for FCW/LDW are now more in line with results from previously evaluated FCW systems. The Honda Accord Touring trim with the radar-based FCW/ACC system has much less exposure but the magnitude of the property damage liability and bodily injury liability benefits are similar to the camera-based FCW/LDW system. The claim frequency benefits for the radar-based system are slightly larger than the camera system but the confidence bounds overlap. Alternative analysis for the camera-based system using data from 2012 model year vehicles to control for differences in trim levels yields similar results. This is an indication that the benefits for the camera-based system can be attributed to the feature and not variability associated with the trim level.

The camera-based system resulted in a decline in collision claim severity while the radar based Touring system resulted in a significant increase. This is in line with previous HLDI findings and the increased claim severity is likely associated with the replacement cost of the radar units in crashes not avoided.

The updated claim frequency loss results for LaneWatch continue to be favorable. The Accord Touring trim is also equipped with LaneWatch and is evaluated for the first time. Results for all vehicles equipped with LaneWatch were consitent with expectations. Incursion into an occupied adjacent lane would be expected to result in a two-vehicle crash that would lead to a PDL claim against the encroaching driver. The estimated reductions in PDL claims is much larger than the reductions estimated for collision claims. This is consistent with the fact that the reductions in collision claims from such crashes would be diluted by the many single-vehicle crashes that result in collision claims and are unaffected by the LaneWatch system. However, alternative analysis using data from 2012 model year vehicles to control for differences in trim levels indicates an increase in claim frequency for the system. At this point the LaneWatch results should be viewed as preliminary.

Change in claim frequencies by collision avoidance feature, initial vs. updated results				
	Forward Collision Warning & Lane Departure Warning			Forward Collision Warning, Lane Departure Warning & Adaptive Cruise Control
Vehicle damage coverage type	**April 2014**	**September 2014**	**Current**	**Current**
Collision	-3.8%	-3.6%	-1.7%	2.0%
Property damage liability	**-14.0%**	**-9.9%**	**-11.7%**	**-15.8%**
Injury coverage type	**April 2014**	**September 2014**	**Current**	**Current**
Bodily injury liability	**-39.5%**	**-29.2%**	**-26.8%**	**-39.4%**
Medical payment	**-27.3%**	**-29.7%**	**-22.3%**	-25.7%
Personal injury protection	-10.7%	**-16.8%**	-6.3%	10.4%

Introduction

This Highway Loss Data Institute (HLDI) bulletin provides an updated look at the effects of available Honda Accord collision avoidance systems on insurance losses. Earlier HLDI studies found encouraging results (HLDI, 2014a, 2014b). Prior HLDI results indicate these systems are having some benefit. This HLDI bulletin updates prior analyses with significantly more exposure and adds a separate analysis for the Honda Accord Touring trim. The features included in this analysis are as follows:

Forward Collision Warning (FCW) uses a camera system located behind the windshield to assess the risk of a collision with leading traffic. The warning system has three driver-selectable range settings. When a potential crash is detected, lights flash in the heads-up display, the FCW indicator blinks, and there is continuous beeping. The system is active only at speeds more than 10 mph and can be deactivated by the driver. At each ignition cycle, the system defaults to the previous on/off setting. Vehicles with FCW also have Lane Departure Warning.

Lane Departure Warning (LDW) utilizes the same camera as forward collision warning to also identify traffic lane markings. Audio and visual warnings will indicate if the vehicle path deviates from the intended lane. The system is functional at speeds between 40 and 90 mph but does not warn if the turn signal is on or the movement is determined to be sufficiently sudden as to be evasive. The system can be deactivated by the driver. At each ignition cycle, the system defaults to the previous on/off setting.

Adaptive Cruise Control (ACC) uses radar sensors mounted in the front bumper to monitor traffic ahead and maintain the driver's selected following distance. As traffic conditions dictate, the system employs braking force to maintain the set following distance. Adaptive cruise control is available at speeds over 10 mph. Forward Collision Warning remains active even when adaptive cruise control is turned off.

LaneWatch is Honda's term for a passenger-side-only blind spot monitor. A camera mounted behind the external passenger side rearview mirror monitors the passenger side of the vehicle and displays an 80-degree field of view on the console-mounted information screen when the turn signal indicator is activated. Reference lines are also provided to indicate proximity. Both the turn signal indicator and reference lines are driver-controllable settings and can be deactivated. An upcoming navigation system maneuver can also be given priority over the LaneWatch display. LaneWatch can be deactivated by the driver. At each ignition cycle, it will default to the previous on/off setting.

All of the vehicles in this study were equipped with rear cameras. As there are no vehicles without this feature, their effectiveness cannot be evaluated in this analysis. The vehicles in this analysis may also have been equipped with optional rear parking sensors. This feature was not controlled for in the analysis, as the availability of rear parking sensors on a vehicle was not discernible from the vehicle identification number (VIN).

Method

Vehicles

Several trim levels are offered on the vehicles included in this study. Trim levels are bundles of vehicle options such as interior materials, engines, and comfort, convenience, and safety features. For example, the Honda Accord EX-L V6 is equipped with a 6-cylinder motor, leather seats, and several collision avoidance technologies. The less expensive LX is equipped with cloth seats, a 4-cylinder motor, and no collision avoidance technologies. For the Honda vehicles included in this study, the trim levels can be determined in the first 10 positions of the VIN. The collision avoidance features in this study are either standard or not available at the trim level. Consequently, by knowing the trim level, the presence of the collision avoidance features is known. LaneWatch and the combination of FCW and LDW are offered as standard equipment on several 2013–14 Honda Accord models (trims). LaneWatch and the combination of FCW, LDW, and ACC are offered on the Touring trim of the four-door Honda Accord. Honda Accord vehicles without these features served as the control vehicles in the analysis. **Table 1** lists total exposure, measured in insured vehicle years, and the exposure of each feature as a percentage of total exposure. Also included in **Table 1** is the exposure from the two prior reports.

Table 1: Feature exposure by vehicle series

Make	Series	Model year range	Forward Collision Warning (includes Lane Departure Warning)	Forward Collision Warning (includes Lane Departure Warning and Adaptive Cruise Control)	LaneWatch	Total exposure	September report exposure	April report exposure
Honda	Accord 2dr	2013–14	67%		67%	56,381	29,915	15,183
Honda	Accord 4dr	2013–14	38%		49%	569,785	283,665	157,309
Honda	Accord 4dr Touring	2013–14		100%	100%	11,662	-	-
Honda	Accord Crosstour 4dr	2013–14	70%		77%	10,767	5,750	2,408
Honda	Accord Crosstour 4dr 4WD	2013–14	100%		100%	8,671	4,474	1,968

Insurance Data

Automobile insurance covers damages to vehicles and property as well as injuries to people involved in crashes. Different insurance coverages pay for vehicle damage versus injuries, and different coverages may apply depending on who is at fault. The current study is based on property damage liability, collision, bodily injury liability, personal injury protection, and medical payment coverages. Exposure is measured in insured vehicle years. An insured vehicle year is one vehicle insured for 1 year, two vehicles for 6 months, etc.

Because different crash avoidance features may affect different types of insurance coverage, it can be important to understand how coverages vary among the states and how this affects inclusion in the analyses. Collision coverage insures against vehicle damage to an at-fault driver's vehicle sustained in a crash with an object or other vehicle; this coverage is common to all 50 states. Property damage liability (PDL) coverage insures against vehicle damage that at-fault drivers cause to other people's vehicle and property in crashes; this coverage exists in all states except Michigan, where vehicle damage is covered on a no-fault basis (each insured vehicle pays for its own damage in a crash, regardless of who is at fault).

Coverage of injuries is more complex. Bodily injury (BI) liability coverage insures against medical, hospital, and other expenses for injuries that at-fault drivers inflict on occupants of other vehicles or others on the road; although motorists in most states may have BI coverage, this information is analyzed only in states where the at-fault driver has first obligation to pay for injuries (33 states with traditional tort insurance systems). Medical payment (MedPay) coverage, also sold in the 33 states with traditional tort insurance systems, covers injuries to insured drivers and the passengers in their vehicles, but not injuries to people in other vehicles involved in the crash. Seventeen other states employ no-fault injury systems (personal injury protection coverage, or PIP) that pay up to a specified amount for injuries to occupants of involved-insured vehicles, regardless of who is at fault in a collision. The District of Columbia has a hybrid insurance system for injuries and is excluded from the injury analysis.

Statistical methods

Regression analysis was used to quantify the effect of each vehicle feature while controlling for other covariates. The covariates included calendar year, model year, garaging state, vehicle density (number of registered vehicles per square mile), rated driver age group, rated driver gender, rated driver marital status, deductible range (collision coverage only), and risk. For each safety feature studied, a variable was included.

Claim frequency was modeled using a Poisson distribution, whereas claim severity (average loss payment per claim) was modeled using a Gamma distribution. Both models used a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models. Estimates for frequency, severity, and overall losses are presented for collision and property damage liability. For PIP, BI, and MedPay, three frequency estimates are presented. The first frequency is the frequency for all claims, including those that already have been paid and those for which money has been set aside for possible payment in the future, known as claims with reserves. The other two frequencies include only paid claims separated into low- and high-severity ranges. Note that the percentage of all injury claims for the Honda Accord that were paid by the date of analysis varies by coverage: 71.7 percent for PIP, 54.0 percent for BI, and 57.7 percent for MedPay. The low-severity range was <\$1,000 for PIP and MedPay, <\$5,000 for BI; high severity covered all loss payments greater than that.

A separate regression was performed for each insurance loss measure for a total of 15 regressions (5 coverages x 3 loss measures each). For space reasons, only the estimates for the individual crash avoidance features are shown on the following pages. To illustrate the analyses, however, **Appendix A** contains full model results for Honda Accord collision claim frequencies. To further simplify the presentation here, the exponent of the parameter estimate was calculated, 1 was subtracted, and the resultant multiplied by 100. The resulting number corresponds to the effect of the feature on that loss measure. For example, the estimate of the effect of Forward Collision Warning (including Lane Departure Warning) on PDL claim frequency was -0.0166; thus, vehicles with the feature had 1.7 percent fewer collision claims than without FCW/LDW ((exp(-0.0166)-1)*100=-1.7).

Results

Results for Honda Accord's Forward Collision Warning System including Lane Departure Warning are summarized in **Table 2**. The lower and upper bounds represent the 95 percent confidence limits for the estimates. For vehicle damage losses, the frequency and severity of claims as well as overall losses are down. Half of the reductions are significant (indicated in bold in the table).

For the injury-related coverage types, bodily injury liability and medical payment claim frequencies for paid and unpaid claims show significant reductions. Among paid claims, claim frequency shows a benefit with half of the estimates being significant.

Table 2: Change in insurance losses for Forward Collision Warning and Lane Departure Warning

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-4.7%	-1.7%	1.5%	-\$300	-\$145	\$17	-\$35	**-\$18**	\$0
Property damage liability	-16.2%	**-11.7%**	-6.9%	-\$215	-\$66	\$91	-\$20	**-\$13**	-\$7

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-37.9%	**-26.8%**	-13.8%	-49.6%	**-32.1%**	-8.6%	-54.6%	**-36.7%**	-11.7%
Medical payment	-32.5%	**-22.3%**	-10.6%	-48.7%	-24.0%	12.7%	-36.9%	**-22.0%**	-3.5%
Personal injury protection	-16.1%	-6.3%	4.7%	-25.2%	-4.1%	23.0%	-17.9%	-4.3%	11.6%

Results for Honda Accord's LaneWatch system are summarized in **Table 3**. Again, the lower and upper bounds represent the 95 percent confidence limits for the estimates. Reductions in claim frequency are estimated for both first- and third-party vehicle damage coverages. Both collision and property damage liability claim frequency reductions are statistically significant. Losses per insured vehicle year (overall losses) declined significantly under both property damage liability and collision coverage.

Under injury coverages, the frequency of claims is lower for all three coverages. The 12.7 percent reduction under personal injury protection is statistically significant. Among paid claims, there is a significant reduction in high severity PIP claims, yet no clear pattern emerges.

Table 3: Change in insurance losses for LaneWatch

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-7.9%	**-5.0%**	-2.0%	-$215	-$60	$101	-$40	**-$24**	-$6
Property damage liability	-13.2%	**-8.8%**	-4.0%	-$119	$28	$183	-$14	**-$8**	-$1

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-19.4%	-6.0%	9.5%	-26.1%	-2.5%	28.6%	-32.0%	-7.4%	26.0%
Medical payment	-15.6%	-3.5%	10.3%	-23.8%	11.4%	62.8%	-30.4%	-14.9%	4.1%
Personal injury protection	-21.4%	**-12.7%**	-3.0%	-15.3%	7.8%	37.1%	-29.6%	**-18.6%**	-5.8%

Table 4 shows the differences in the claim frequency estimates between the initial results published in April 2014, September 2014, and the updated results included in this report. The updated results for the combined FCW/LDW system continue to show frequency benefits for all coverage types. The PDL claim frequency reduction remains significant, although the size of the effect is between the two prior estimates. All three injury coverages continue to show reductions in claim frequency. The effect consistently dropped for bodily injury liability across the three studies. The previous frequency estimate for personal injury protection was statistically significant, while the updated estimate is no longer significant. The benefits of LaneWatch under collision has increased over the three reports and is now statistically significant. The frequency reduction under property damage liability is significant and similar to the initial estimate. The frequency reductions under the injury-related coverages remain similar to the September 2014 estimates. However, the estimate for personal injury protection is the only statistically significant estimate.

Table 4: Change in claim frequencies by collision avoidance feature, initial vs. updated results

	Forward Collision Warning & Lane Departure Warning			LaneWatch		
Vehicle damage coverage type	April 2014	September 2014	Current	April 2014	September 2014	Current
Collision	-3.8%	-3.6%	-1.7%	-2.5%	-2.6%	**-5.0%**
Property damage liability	**-14.0%**	**-9.9%**	**-11.7%**	-7.8%	**-12.5%**	**-8.8%**

Injury coverage type	April 2014	September 2014	Current	April 2014 report	September 2014	Current
Bodily injury liability	**-39.5%**	**-29.2%**	**-26.8%**	7.9%	-5.2%	-6.0%
Medical payment	**-27.3%**	**-29.7%**	**-22.3%**	-11.1%	-8.6%	-3.5%
Personal injury protection	-10.7%	**-16.8%**	-6.3%	-15.8%	-13.1%	**-12.7%**

Honda Accord Touring:

Results for Honda Accord Touring's Forward Collision Warning System including Lane Departure Warning and Adaptive Cruise Control are summarized in **Table 5**. The lower and upper bounds represent the 95 percent confidence limits for the estimates. For property damage liability, claim frequency and overall losses are down. Under collision coverage, the Touring trim showed an increase in claim frequency, claim severity, and overall losses with severity and overall losses being significant.

For the injury-related coverage types, bodily injury liability and medical payment claim frequencies for paid and unpaid claims show reductions. Among paid claims, claim frequency also shows a benefit under bodily injury liability and medical payment.

Table 5: Change in insurance losses for Forward Collision Warning, Lane Departure Warning and Adaptive Cruise Control

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-5.0%	2.0%	9.6%	$129	**$522**	$949	$9	**$53**	$102
Property damage liability	-25.8%	**-15.8%**	-4.4%	-$211	$162	$587	-$25	-$11	$6

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-60.7%	**-39.4%**	-6.6%	-62.8%	-24.9%	51.6%	-94.9%	**-79.0%**	-13.6%
Medical payment	-46.5%	-25.7%	3.0%	-80.1%	-43.6%	59.8%	-43.9%	-11.3%	40.3%
Personal injury protection	-14.3%	10.4%	42.2%	-38.2%	11.4%	100.5%	-26.8%	4.8%	50.1%

Results for Honda Accord Touring's LaneWatch system are summarized in **Table 6**. Again, the lower and upper bounds represent the 95 percent confidence limits for the estimates. Reductions in claim frequency are estimated for both first- and third-party vehicle damage coverages. Collision and property damage liability claim frequency reductions are statistically significant. Losses per insured vehicle year (overall losses) declined significantly under these two coverage types.

Under injury coverages, the frequency of claims is lower for all three coverages. The 13.4 percent reduction under personal injury protection is statistically significant. Among paid claims, larger reductions are seen for higher severity claims.

Table 6: Change in insurance losses for Honda Accord Touring LaneWatch

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-7.7%	**-4.8%**	-1.8%	-$232	-$78	$83	-$41	**-$24**	-$7
Property damage liability	-13.3%	**-8.8%**	-4.1%	-$111	$38	$194	-$14	**-$8**	-$1

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-19.9%	-6.6%	8.9%	-26.3%	-2.7%	28.5%	-32.7%	-8.3%	25.1%
Medical payment	-15.5%	-3.4%	10.6%	-23.8%	11.7%	63.6%	-30.4%	-14.8%	4.3%
Personal injury protection	-22.1%	**-13.4%**	-3.8%	-16.0%	7.0%	36.3%	-30.7%	**-19.7%**	-7.1%

Comparison results:

Table 7 shows the differences in the claim frequency estimates for the Honda Accord/Crosstour and Honda Accord Touring. The results for the FCW/LDW (ACC on Touring) system show minimal, if any, benefit under collision coverage across the vehicle series. However, under property damage liability, claim frequency is reduced significantly. Under injury coverages, reductions are seen across all vehicle series and coverages, with the exception of personal injury protection claim frequency for the Honda Accord Touring. Several of the reductions are significant.

Table 7 also shows the differences in the claim frequency estimates for LaneWatch for the Honda Accord/Crosstour and Honda Accord Touring. The estimated reductions in claim frequency for both of these vehicles are nearly identical across all coverage types. This may in part be due to the control populations being identical. Significant reductions are seen for both vehicles under collision, property damage liability, and personal injury protection.

Table 7: Change in claim frequencies by collision avoidance feature and vehicle series

	Collision Mitigation Warning & Lane Departure Warning (ACC on Touring)		LaneWatch	
Vehicle damage coverage types	**Honda Accord/Crosstour**	**Honda Accord Touring**	**Honda Accord/Crosstour**	**Honda Accord Touring**
Collision	-1.7%	2.0%	**-5.0%**	**-4.8%**
Property damage liability	**-11.7%**	**-15.8%**	**-8.8%**	**-8.8%**
Injury coverage types	**Honda Accord/Crosstour**	**Honda Accord Touring**	**Honda Accord/Crosstour**	**Honda Accord Touring**
Bodily injury liability	**-26.8%**	**-39.4%**	-6.0%	-6.6%
Medical payments	**-22.3%**	-25.7%	-3.5%	-3.4%
Personal injury protection	-6.3%	10.4%	**-12.7%**	**-13.4%**

Discussion

The loss results for the systems included in this study continue to be favorable and fall within the bounds of the prior study. However, some of the point estimates have changed. While just a year has passed from the initial study, the exposure available for analysis has more than doubled for the Honda Accord and Crosstour. The increase in exposure has resulted from both the sale of additional vehicles and the additional time insured for the vehicles included in the previous study. The results for the combined FCW/LDW system are in-line with prior findings for comparable systems. The frequency benefits are within the confidence bounds of the estimates in the previous study, and fairly similar to the prior bulletin. The frequency estimates for LaneWatch continue to indicate reductions, and three of the estimates are statistically significant.

Forward collision warning systems are designed to prevent or mitigate front-to-rear crashes, which typically result in PDL and BI claims if injury in the struck vehicle occurs. The updated FCW/LDW system continues to be associated with reductions in claim frequency for all five coverage types examined. With this update the insurance losses are now more in line with results from previously evaluated systems. The Honda Accord Touring trim with the radar-based FCW/LDW/ACC system has much less exposure but the magnitude of the property damage liability and bodily injury liability benefits are similar to the camera-based FCW/LDW system. The claim frequency benefits for the radar-based system are slightly larger than the camera system but the confidence bounds overlap. The camera-based system resulted in a decline in collision claim severity while the radar-based Touring system resulted in a significant increase. This is in line with previous HLDI findings and the increased claim severity is likely associated with the replacement cost of the radar units in crashes not avoided.

The analysis of Honda's LaneWatch, a passenger-side blind spot detection system, showed a reduction in claims, with significant effects for collision, PDL and PIP. None of the estimates from the April 2014 report were significant, and the BI estimate suggested an increase in claims. Effects of LaneWatch are patterned as expected. Incursion into an occupied adjacent lane would be expected to result in a two-vehicle crash that would lead to a property damage liability claim against the encroaching driver. The PDL estimates for the Accord/Crosstour and Accord Touring are identical and statistically significant, and the estimated reduction in property damage liability claims is much larger than the reduction estimated for collision claims. This is consistent with the fact that the reductions in collision claims from such crashes would be diluted by the many single-vehicle crashes that result in collision claims and are unaffected by the LaneWatch system.

As previously mentioned, the collision avoidance systems are tied to the vehicle trim levels. In order to be confident that the measured differences were attributable to the collision avoidance features and not the trim levels, a supplemental analysis was conducted including loss data for model year 2012 Honda Accord vehicles. While the Honda Accord was redesigned in 2013, the trim levels in 2012-14 were comparable. The inclusion of loss data for the 2012 model year, in which no crash avoidance features were present, allowed the supplemental analysis to include the vehicle trim level in addition to the control variables used in the primary analysis. Thus, the supplemental analysis assumes that loss differences attributable to the different trim levels were the same in both model years. The summary results of the supplemental analysis are included in **Appendix B**, and the full regression analysis results for collision claim frequencies are shown in **Appendix C**. The supplemental results for the combination FCW/LDW system is consistent with the supplemental analysis from the prior 2014 bulletin. This analysis indicates larger benefits for the FCW/LDW system yet all of the estimated effects are within the confidence bounds of the main analysis presented in this report. Due to the similarity of the two analyses for FCW/LDW and uncertainty about the applicability of 2012 model trim level differences to the redesigned 2013-14 models, the analysis presented in the results section of this bulletin is expected to be the better predictor of the effects on losses of that system. The supplemental estimates for the LaneWatch system are showing increased claim frequencies. However, while the results in the main portion of this bulletin are indicating reductions, the alternative analyses suggest that LaneWatch results should be viewed as preliminary. Similar analysis could not be conducted for the Touring trim as the 2013 model year (included in this analysis) was the first year that trim was available.

Limitations

There are limitations to the data used in this analysis. At the time of a crash, the status of a feature is not known. The features in this study can be deactivated by the driver, and there is no way to know how many of the drivers in these vehicles turned off a system prior to the crash. However, surveys conducted by the Insurance Institute for Highway Safety indicate that large majorities of drivers with these types of systems leave them on. If a significant number of drivers do turn these features off, any reported reductions may actually be underestimates of the true effectiveness of these systems.

Additionally, the data supplied to HLDI does not include detailed crash information. Information on point of impact and the vehicle's transmission status is not available. The technologies in this report target certain crash types. For example, LaneWatch is designed to prevent sideswipe-type collisions. All collisions, regardless of the ability of a feature to mitigate or prevent the crash, are included in the analysis.

References

Highway Loss Data Institute. 2014a. Honda Accord collision avoidance features: initial results. *Loss Bulletin* Vol. 31, No. 2. Arlington, VA.

Highway Loss Data Institute. 2014b. Honda Accord collision avoidance features: an update. *Loss Bulletin* Vol. 31, No. 16. Arlington, VA.

Appendix A

Appendix A: Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Intercept		1	-8.9446		0.3053	-9.5430	-8.3462	858.29	<0.0001
Calendar year	2012	1	-0.5214	-40.6%	0.0480	-0.6155	-0.4272	117.84	<0.0001
	2013	1	-0.0216	-2.1%	0.0101	-0.0413	-0.0018	4.58	0.0324
	2014	0	0	0	0	0	0		
Vehicle model year and series	2013 Accord 2dr	1	0.1824	20.0%	0.1009	-0.0155	0.3802	3.26	0.0708
	2014 Accord 2dr	1	0.2399	27.1%	0.1043	0.0356	0.4443	5.29	0.0214
	2013 Accord 4dr	1	0.0666	6.9%	0.1000	-0.1294	0.2626	0.44	0.5052
	2014 Accord 4dr	1	0.0544	5.6%	0.1002	-0.1419	0.2508	0.30	0.5868
	2013 Accord Crosstour 4dr 2WD	1	0.0136	1.4%	0.1071	-0.1962	0.2234	0.02	0.8988
	2014 Accord Crosstour 4dr 2WD	1	0.1495	16.1%	0.1424	-0.1295	0.4286	1.10	0.2936
	2013 Accord Crosstour 4dr 4WD	1	0.0623	6.4%	0.1087	-0.1507	0.2753	0.33	0.5664
	2014 Accord Crosstour 4dr 4WD	0	0	0	0	0	0		
Rated driver age group	14–24	1	0.2828	32.7%	0.0198	0.2440	0.3217	203.59	<0.0001
	25–29	1	0.1870	20.6%	0.0177	0.1523	0.2217	111.57	<0.0001
	30–39	1	0.0592	6.1%	0.0151	0.0297	0.0887	15.45	<0.0001
	50–59	1	-0.0615	-6.0%	0.0154	-0.0916	-0.0313	15.97	<0.0001
	60–64	1	-0.0804	-7.7%	0.0198	-0.1192	-0.0416	16.50	<0.0001
	65–69	1	-0.0239	-2.4%	0.0203	-0.0637	0.0159	1.39	0.2390
	70+	1	0.1025	10.8%	0.0173	0.0687	0.1363	35.27	<0.0001
	Unknown	1	0.0264	2.7%	0.0239	-0.0205	0.0734	1.22	0.2696
	40–49	0	0	0	0	0	0		
Rated driver gender	Male	1	-0.0593	-5.8%	0.0103	-0.0795	-0.0392	33.26	<0.0001
	Unknown	1	-0.1820	-16.6%	0.0378	-0.2560	-0.1080	23.22	<0.0001
	Female	0	0	0	0	0	0		
Rated driver marital status	Single	1	0.1951	21.5%	0.0113	0.1729	0.2173	296.01	<0.0001
	Unknown	1	0.2132	23.8%	0.0377	0.1393	0.2871	31.99	<0.0001
	Married	0	0	0	0	0	0		
Risk	Nonstandard	1	0.2345	26.4%	0.0191	0.1970	0.2720	150.55	<0.0001
	Standard	0	0	0	0	0	0		
State	Alabama	1	0.0657	6.8%	0.2915	-0.5057	0.6371	0.05	0.8217
	Arizona	1	0.1059	11.2%	0.2909	-0.4642	0.6761	0.13	0.7157
	Arkansas	1	0.1342	14.4%	0.2957	-0.4453	0.7137	0.21	0.6499
	California	1	0.4291	53.6%	0.2890	-0.1374	0.9956	2.20	0.1377
	Colorado	1	0.1659	18.0%	0.2927	-0.4077	0.7395	0.32	0.5708
	Connecticut	1	0.0499	5.1%	0.2916	-0.5215	0.6214	0.03	0.8640
	Delaware	1	0.1750	19.1%	0.2969	-0.4069	0.7569	0.35	0.5556
	District of Columbia	1	0.6259	87.0%	0.3006	0.0366	1.2151	4.33	0.0374
	Florida	1	-0.0813	-7.8%	0.2894	-0.6484	0.4859	0.08	0.7788

Appendix A: Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	Georgia	1	0.0505	5.2%	0.2900	-0.5178	0.6189	0.03	0.8616
	Hawaii	1	0.3911	47.9%	0.2967	-0.1903	0.9726	1.74	0.1874
	Idaho	1	-0.1660	-15.3%	0.3142	-0.7818	0.4499	0.28	0.5973
	Illinois	1	0.1203	12.8%	0.2899	-0.4479	0.6884	0.17	0.6782
	Indiana	1	0.0158	1.6%	0.2919	-0.5564	0.5880	0.00	0.9568
	Iowa	1	0.0578	6.0%	0.2988	-0.5278	0.6435	0.04	0.8465
	Kansas	1	0.1013	10.7%	0.2957	-0.4784	0.6809	0.12	0.7320
	Kentucky	1	-0.1134	-10.7%	0.2946	-0.6909	0.4641	0.15	0.7004
	Louisiana	1	0.3580	43.0%	0.2902	-0.2108	0.9269	1.52	0.2174
	Maine	1	-0.0334	-3.3%	0.3135	-0.6478	0.5811	0.01	0.9153
	Maryland	1	0.2398	27.1%	0.2898	-0.3282	0.8078	0.68	0.4079
	Massachussets	1	0.2468	28.0%	0.2912	-0.3239	0.8175	0.72	0.3966
	Michigan	1	0.5284	69.6%	0.2914	-0.0428	1.0996	3.29	0.0698
	Minnesota	1	0.0760	7.9%	0.2925	-0.4973	0.6493	0.07	0.7951
	Mississippi	1	0.2545	29.0%	0.2930	-0.3198	0.8287	0.75	0.3852
	Missouri	1	-0.0412	-4.0%	0.2926	-0.6147	0.5322	0.02	0.8879
	Montana	1	-0.3104	-26.7%	0.3434	-0.9835	0.3627	0.82	0.3661
	Nebraska	1	-0.0526	-5.1%	0.3023	-0.6452	0.5400	0.03	0.8619
	Nevada	1	0.0313	3.2%	0.2950	-0.5469	0.6095	0.01	0.9155
	New Hampshire	1	0.2675	30.7%	0.2956	-0.3118	0.8468	0.82	0.3655
	New Jersey	1	0.1492	16.1%	0.2894	-0.4180	0.7164	0.27	0.6062
	New Mexico	1	0.1848	20.3%	0.2980	-0.3992	0.7688	0.38	0.5351
	New York	1	0.4253	53.0%	0.2891	-0.1414	0.9920	2.16	0.1413
	North Carolina	1	-0.1526	-14.2%	0.2901	-0.7212	0.4159	0.28	0.5988
	North Dakota	1	0.3131	36.8%	0.3173	-0.3089	0.9350	0.97	0.3238
	Ohio	1	-0.0269	-2.7%	0.2899	-0.5951	0.5412	0.01	0.9260
	Oklahoma	1	0.0885	9.3%	0.2934	-0.4866	0.6636	0.09	0.7629
	Oregon	1	0.1019	10.7%	0.2938	-0.4739	0.6776	0.12	0.7287
	Pennsylvania	1	0.2840	32.8%	0.2896	-0.2835	0.8515	0.96	0.3267
	Rhode Island	1	0.3252	38.4%	0.2950	-0.2531	0.9034	1.21	0.2704
	South Carolina	1	-0.0180	-1.8%	0.2911	-0.5886	0.5526	0.00	0.9506
	South Dakota	1	0.0106	1.1%	0.3265	-0.6294	0.6505	0.00	0.9742
	Tennessee	1	-0.0187	-1.9%	0.2911	-0.5894	0.5519	0.00	0.9487
	Texas	1	0.1180	12.5%	0.2893	-0.4489	0.6849	0.17	0.6834
	Utah	1	0.0067	0.7%	0.2974	-0.5762	0.5896	0.00	0.9819
	Vermont	1	0.2581	29.4%	0.3128	-0.3550	0.8712	0.68	0.4093
	Virginia	1	0.1924	21.2%	0.2897	-0.3754	0.7602	0.44	0.5066
	Washington	1	0.1385	14.9%	0.2912	-0.4323	0.7093	0.23	0.6344
	West Virginia	1	-0.1814	-16.6%	0.3045	-0.7782	0.4154	0.35	0.5514
	Wisconsin	1	0.1010	10.6%	0.2926	-0.4725	0.6744	0.12	0.7300
	Wyoming	1	0.0046	0.5%	0.3590	-0.6991	0.7083	0.00	0.9897
	Alaska	0	0	0	0	0	0		
Deductible range	0–250	1	0.4899	63.2%	0.0159	0.4588	0.5211	950.88	<0.0001
	1,001+	1	-0.4176	-34.1%	0.0980	-0.6095	-0.2256	18.17	<0.0001

Appendix A: Illustrative regression results — collision frequency									
Parameter		**Degrees of freedom**	**Estimate**	**Effect**	**Standard error**	**Wald 95% confidence limits**		**Chi-square**	**P-value**
	251–500	1	0.2833	32.8%	0.0137	0.2563	0.3102	424.91	<0.0001
	501–1,000	0	0	0	0	0	0		
Registered vehicle density	0–99	1	-0.2570	-22.7%	0.0173	-0.2909	-0.2230	219.70	<0.0001
	100–499	1	-0.1729	-15.9%	0.0112	-0.1949	-0.1509	237.22	<0.0001
	500+	0	0	0	0	0	0		
Forward collison warning & lane departure warning		1	-0.0166	-1.6%	0.0163	-0.0485	0.0152	1.05	0.3061
LaneWatch		1	-0.0514	-5.0%	0.0157	-0.0822	-0.0206	10.71	0.0011

Appendix B: Analysis results included model years 2012–14, accounting for vehicle series and model level loss differences

Change in insurance losses for Forward Collision Warning and Lane Departure Warning

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-10.4%	**-6.1%**	-1.7%	-$253	-$32	$202	-$44	-$23	$0
Property damage liability	-18.9%	**-12.8%**	-6.2%	-$337	-$142	$68	-$26	**-$18**	-$8

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-39.4%	**-24.7%**	-6.4%	-46.8%	-22.3%	13.4%	-52.4%	-27.8%	9.5%
Medical payment	-30.0%	-14.8%	3.7%	-45.8%	-6.0%	63.1%	-37.7%	-16.8%	11.3%
Personal injury protection	-12.7%	1.7%	18.4%	-23.1%	8.4%	52.8%	-11.6%	8.6%	33.5%

Change in insurance losses for LaneWatch

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-2.6%	1.9%	6.5%	-$251	-$38	$187	-$19	$3	$27
Property damage liability	1.0%	**8.3%**	16.1%	-$200	-$4	$205	-$2	$9	$20

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-9.3%	11.3%	36.5%	-30.7%	-1.1%	41.1%	-30.2%	3.2%	52.6%
Medical payment	-9.2%	9.5%	32.0%	-31.2%	16.3%	96.5%	-22.2%	2.5%	35.0%

Personal injury protection	-15.8%	-2.8%	12.3%	-17.8%	14.0%	57.9%	-27.2%	-11.6%	7.4%

Appendix C

Illustrative regression results for secondary analysis — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Intercept		1	-8.6458		0.1813	-9.0012	-8.2904	2273.60	<0.0001
Calendar year	2011	1	-0.3303	-28.1%	0.0426	-0.4138	-0.2468	60.15	<0.0001
	2012	1	-0.0462	-4.5%	0.0106	-0.0670	-0.0254	18.97	<0.0001
	2013	1	-0.0012	-0.1%	0.0071	-0.0151	0.0127	0.03	0.8642
	2014	0	0	0	0	0	0		
Model year	2012	1	-0.1026	-9.8%	0.0117	-0.1255	-0.0798	77.45	<0.0001
	2013	1	-0.0101	-1.0%	0.0102	-0.0301	0.0100	0.97	0.3259
	2014	0	0	0	0	0	0		
Vehicle series and trim	Accord 2dr EX	1	0.1000	10.5%	0.0325	0.0362	0.1637	9.44	0.0021
	Accord 2dr EX-L	1	0.1181	12.5%	0.0272	0.0648	0.1714	18.89	<0.0001
	Accord 2dr EX-L V6	1	0.1129	12.0%	0.0263	0.0613	0.1645	18.37	<0.0001
	Accord 2dr LX-S	1	0.1538	16.6%	0.0280	0.0989	0.2088	30.08	<0.0001
	Accord 4dr EX	1	-0.0833	-8.0%	0.0262	-0.1347	-0.0320	10.11	0.0015
	Accord 4dr EX-L	1	-0.0372	-3.7%	0.0225	-0.0813	0.0069	2.73	0.0985
	Accord 4dr EX-L V6	1	-0.0689	-6.7%	0.0230	-0.1140	-0.0238	8.97	0.0027
	Accord 4dr LX	1	-0.0076	-0.8%	0.0221	-0.0509	0.0357	0.12	0.7295
	Accord 4dr Sport	1	-0.0168	-1.7%	0.0224	-0.0607	0.0271	0.56	0.4527
	Accord Crosstour 4dr 2WD EX	1	-0.0799	-7.7%	0.0411	-0.1604	0.0007	3.78	0.0520
	Accord Crosstour 4dr 2WD EX-L	1	0.0081	0.8%	0.0400	-0.0703	0.0865	0.04	0.8388
	Accord Crosstour 4dr 2WD EX-L V6	1	0.0381	3.9%	0.0379	-0.0362	0.1125	1.01	0.3150
	Accord Crosstour 4dr 4WD EX-L V6	0	0	0	0	0	0		
Rated driver age group	14–20	1	0.3128	36.7%	0.0210	0.2717	0.3539	222.41	<0.0001
	21–24	1	0.3240	38.3%	0.0145	0.2956	0.3524	499.60	<0.0001
	25–39	1	0.1315	14.1%	0.0078	0.1161	0.1468	281.43	<0.0001
	65+	1	0.0799	8.3%	0.0091	0.0622	0.0977	77.83	<0.0001
	Unknown	1	0.0759	7.9%	0.0159	0.0447	0.1072	22.72	<0.0001
	40–64	0	0	0	0	0	0		
Rated driver gender	Male	1	-0.0467	-4.6%	0.0073	-0.0610	-0.0324	41.10	<0.0001
	Unknown	1	-0.2267	-20.3%	0.0235	-0.2728	-0.1805	92.81	<0.0001
	Female	0	0	0	0	0	0		
Rated driver marital status	Single	1	0.1992	22.0%	0.0079	0.1837	0.2147	634.16	<0.0001
	Unknown	1	0.2548	29.0%	0.0234	0.2088	0.3007	118.16	<0.0001
	Married	0	0	0	0	0	0		
Risk	Nonstandard	1	0.2253	25.3%	0.0119	0.2020	0.2487	356.69	<0.0001
	Standard	0	0	0	0	0	0		
State	Alabama	1	-0.1463	-13.6%	0.1818	-0.5026	0.2100	0.65	0.4210

Illustrative regression results for secondary analysis — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	Arizona	1	-0.1130	-10.7%	0.1814	-0.4686	0.2426	0.39	0.5335
	Arkansas	1	-0.0308	-3.0%	0.1849	-0.3931	0.3315	0.03	0.8678
	California	1	0.1873	20.6%	0.1799	-0.1653	0.5399	1.08	0.2978
	Colorado	1	-0.0733	-7.1%	0.1828	-0.4316	0.2850	0.16	0.6884
	Connecticut	1	-0.1235	-11.6%	0.1817	-0.4795	0.2326	0.46	0.4967
	Delaware	1	-0.0244	-2.4%	0.1860	-0.3889	0.3402	0.02	0.8958
	District of Columbia	1	0.4012	49.4%	0.1891	0.0307	0.7718	4.50	0.0338
	Florida	1	-0.3042	-26.2%	0.1801	-0.6573	0.0488	2.85	0.0912
	Georgia	1	-0.1965	-17.8%	0.1806	-0.5505	0.1575	1.18	0.2767
	Hawaii	1	0.1351	14.5%	0.1875	-0.2324	0.5026	0.52	0.4711
	Idaho	1	-0.3885	-32.2%	0.2017	-0.7837	0.0068	3.71	0.0540
	Illinois	1	-0.1079	-10.2%	0.1805	-0.4618	0.2459	0.36	0.5499
	Indiana	1	-0.2025	-18.3%	0.1821	-0.5594	0.1543	1.24	0.2660
	Iowa	1	-0.1530	-14.2%	0.1876	-0.5208	0.2148	0.66	0.4149
	Kansas	1	-0.2380	-21.2%	0.1862	-0.6030	0.1270	1.63	0.2012
	Kentucky	1	-0.2837	-24.7%	0.1839	-0.6441	0.0768	2.38	0.1229
	Louisiana	1	0.1056	11.1%	0.1810	-0.2491	0.4603	0.34	0.5596
	Maine	1	-0.1495	-13.9%	0.1974	-0.5365	0.2374	0.57	0.4489
	Maryland	1	0.0188	1.9%	0.1805	-0.3351	0.3726	0.01	0.9172
	Massachusetts	1	-0.0153	-1.5%	0.1813	-0.3708	0.3401	0.01	0.9326
	Michigan	1	0.2768	31.9%	0.1817	-0.0793	0.6329	2.32	0.1276
	Minnesota	1	-0.2185	-19.6%	0.1827	-0.5765	0.1395	1.43	0.2317
	Mississippi	1	-0.0540	-5.3%	0.1834	-0.4135	0.3054	0.09	0.7683
	Missouri	1	-0.2798	-24.4%	0.1827	-0.6378	0.0782	2.35	0.1256
	Montana	1	-0.1695	-15.6%	0.2087	-0.5786	0.2396	0.66	0.4167
	Nebraska	1	-0.2986	-25.8%	0.1902	-0.6714	0.0742	2.46	0.1165
	Nevada	1	-0.1340	-12.5%	0.1846	-0.4959	0.2278	0.53	0.4679
	New Hampshire	1	0.1242	13.2%	0.1842	-0.2369	0.4853	0.45	0.5004
	New Jersey	1	-0.0869	-8.3%	0.1802	-0.4400	0.2662	0.23	0.6294
	New Mexico	1	-0.0849	-8.1%	0.1880	-0.4534	0.2837	0.20	0.6518
	New York	1	0.1375	14.7%	0.1800	-0.2153	0.4902	0.58	0.4450
	North Carolina	1	-0.3662	-30.7%	0.1807	-0.7204	-0.0120	4.11	0.0427
	North Dakota	1	-0.0569	-5.5%	0.2060	-0.4606	0.3468	0.08	0.7822
	Ohio	1	-0.2856	-24.8%	0.1805	-0.6395	0.0682	2.50	0.1136
	Oklahoma	1	-0.1918	-17.5%	0.1837	-0.5519	0.1683	1.09	0.2965
	Oregon	1	-0.1363	-12.7%	0.1841	-0.4970	0.2245	0.55	0.4591
	Pennsylvania	1	0.0374	3.8%	0.1803	-0.3160	0.3907	0.04	0.8359
	Rhode Island	1	0.0949	10.0%	0.1844	-0.2665	0.4563	0.26	0.6068
	South Carolina	1	-0.2895	-25.1%	0.1816	-0.6455	0.0665	2.54	0.1109
	South Dakota	1	-0.2071	-18.7%	0.2080	-0.6147	0.2005	0.99	0.3194
	Tennessee	1	-0.2253	-20.2%	0.1814	-0.5809	0.1304	1.54	0.2144
	Texas	1	-0.1206	-11.4%	0.1801	-0.4736	0.2323	0.45	0.5029
	Utah	1	-0.2277	-20.4%	0.1870	-0.5942	0.1388	1.48	0.2234
	Vermont	1	-0.0354	-3.5%	0.1999	-0.4272	0.3564	0.03	0.8594

Illustrative regression results for secondary analysis — collision frequency									
Parameter		**Degrees of freedom**	**Estimate**	**Effect**	**Standard error**	**Wald 95% confidence limits**		**Chi-square**	**P-value**
	Virginia	1	-0.0811	-7.8%	0.1805	-0.4348	0.2727	0.20	0.6532
	Washington	1	-0.1332	-12.5%	0.1819	-0.4898	0.2234	0.54	0.4641
	West Virginia	1	-0.2894	-25.1%	0.1908	-0.6633	0.0846	2.30	0.1294
	Wisconsin	1	-0.1811	-16.6%	0.1827	-0.5391	0.1770	0.98	0.3216
	Wyoming	1	-0.1172	-11.1%	0.2287	-0.5655	0.3312	0.26	0.6085
	Alaska	0	0	0	0	0	0		
Deductible range	0–250	1	0.4788	61.4%	0.0111	0.4570	0.5007	1848.29	<0.0001
	1,001+	1	-0.4950	-39.0%	0.0753	-0.6426	-0.3475	43.27	<0.0001
	251–500	1	0.2564	29.2%	0.0096	0.2376	0.2752	712.36	<0.0001
	501–1,000	0	0	0	0	0	0		
Registered vehicle density	0–99	1	-0.2623	-23.1%	0.0125	-0.2868	-0.2378	439.50	<0.0001
	100–499	1	-0.1790	-16.4%	0.0080	-0.1947	-0.1634	502.45	<0.0001
	500+	0	0	0	0	0	0		
Forward Collision Warning & Lane Departure Warning		1	-0.0633	-6.1%	0.0237	-0.1097	-0.0169	7.14	0.0075
LaneWatch		1	0.0184	1.9%	0.0228	-0.0262	0.0631	0.65	0.4185

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The Highway Loss Data Institute is a nonprofit public service organization that gathers, processes, and publishes insurance data on the human and economic losses associated with owning and operating motor vehicles. DW201504 SK RUN171&172

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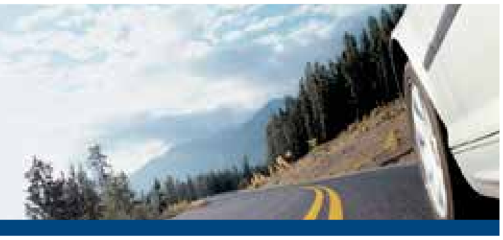

Honda Accord collision avoidance features: initial results

This analysis examines insurance loss results for two Honda Accord collision avoidance systems: Forward Collision Warning (FCW) paired with a Lane Departure Warning (LDW) system and LaneWatch, a passenger side blind spot information system. The combined FCW/LDW system is associated with reductions in claim frequency for all 5 coverage types examined—collision (4 percent), property damage liability (14 percent), bodily injury liability (40 percent), medical payments (27 percent), and personal injury protection (11 percent). Only the reductions in property damage, bodily injury liability and medical payment frequencies were statistically significant, which is consistent with FCW function to prevent front-to-rear collisions. It is also associated with statistically significant reductions in collision claim severity and overall losses, so it does not suffer the same penalty of earlier FCW systems studied by the Highway Loss Data Institute that were enabled by expensive radar units mounted near the front of the car. In contrast, the Accord's combined system uses a camera mounted behind the windshield. LaneWatch also shows reductions in physical damage claim frequencies, but the declines are not significant. There currently are not enough data to produce stable estimates for LaneWatch's effect on injury claim frequencies, but two of the three injury coverages indicate reductions. This represents the first HLDI evaluation of the effectiveness of crash avoidance systems on high-volume non-luxury vehicles.

Introduction

Collision avoidance technologies are becoming popular among U.S. passenger vehicles, and more and more automakers are touting their potential safety benefits. However, the actual benefits in terms of crash reductions still are being measured. This Highway Loss Data Institute (HLDI) bulletin examines the early insurance claims experience for Honda Accord vehicles fitted with two systems.

Forward Collision Warning uses a camera system located behind the windshield to assess the risk of a collision with leading traffic. The warning system has three driver-selectable range settings. When a potential crash is detected, lights flash in the heads-up display, the FCW indicator blinks, and there is continuous beeping. The system is active only at speeds more than 10 mph and can be deactivated by the driver. At each ignition cycle, the system defaults to the previous on/off setting. Vehicles with Forward Collision Warning also have Lane Departure Warning.

Lane Departure Warning utilizes the same camera as forward collision warning to also identify traffic lane markings. Audio and visual warnings will indicate if the vehicle path deviates from the intended lane. The system is functional at speeds between 40 and 90 mph but does not warn if the turn signal is on or the movement is determined to be sufficiently sudden as to be evasive. The system can be deactivated by the driver. At each ignition cycle, the system defaults to the previous on/off setting.

LaneWatch is Honda's term for a passenger-side-only blind spot monitor. A camera mounted behind the external passenger side rearview mirror monitors the passenger side of the vehicle and displays an 80-degree field of view on the console-mounted information screen when the turn signal indicator is activated. Reference lines are also provided to indicate proximity. Both the turn signal indicator and reference lines are driver-controllable settings and can be deactivated. An upcoming navigation system maneuver can also be given priority over the LaneWatch display. LaneWatch can be deactivated by the driver. At each ignition cycle, it will default to the previous on/off setting.

All of the vehicles in this study were equipped with rear cameras. As there are no vehicles without this feature their effectiveness cannot be evaluated in this analysis. The vehicles in this analysis may also have been equipped with optional rear parking sensors. This feature was not controlled for in the analysis as the availability of rear parking sensors on a vehicle was not discernible from the VIN. The Touring trim level of the Accord four-door was excluded from the analysis because it is equipped with a different forward collision warning system that uses a radar system instead of a camera and includes adaptive cruise control functionality. Consequently, despite similar FCW function, these systems should be evaluated separately. However, there is too little exposure to produce reliable estimates of effectiveness at this time. The total collision coverage exposure was only 3,138 years.

Method

Vehicles

Several trim levels are offered on the vehicles included in this study. Trim levels are bundles of vehicle options such as interior materials, engines and comfort, convenience and safety features. For example, the Honda Accord EX-L V6 is equipped with a 6 cylinder motor, leather seats and several collision avoidance technologies. The less expensive LX is equipped with cloth seats, a 4 cylinder motor and no collision avoidance technologies. For the Honda vehicles included in this study the trim levels can be determined in the first 10 positions of the VIN. The collision avoidance features in this study are either standard or not available at the trim level. Consequently, by knowing the trim level the presence of the collision avoidance features is known. LaneWatch and the combination of Forward Collision Warning and Lane Departure Warning are offered as standard equipment on several 2013 Honda Accord models (trims). Honda Accords without these features served as the control vehicles in the analysis. **Table 1** lists total exposure, measured in insured vehicle years, and the exposure of each feature as a percentage of total exposure.

Table 1: Feature exposure by vehicle series

Make	Series	Model year range	Forward Collision Warning (includes Lane Departure Warning)	LaneWatch	Total exposure
Honda	Accord 2dr	2013	69%	83%	15,183
Honda	Accord 4dr	2013	40%	51%	157,309
Honda	Crosstour 4dr	2013	72%	78%	2,408
Honda	Crosstour 4dr 4WD	2013	100%	100%	1,968

Insurance Data

Automobile insurance covers damages to vehicles and property as well as injuries to people involved in crashes. Different insurance coverages pay for vehicle damage versus injuries, and different coverages may apply depending on who is at fault. The current study is based on property damage liability, collision, bodily injury liability, personal injury protection, and medical payment coverages. Exposure is measured in insured vehicle years. An insured vehicle year is one vehicle insured for 1 year, two vehicles for 6 months, etc.

Because different crash avoidance features may affect different types of insurance coverage, it can be important to understand how coverages vary among the states and how this affects inclusion in the analyses. Collision coverage insures against vehicle damage to an at-fault driver's vehicle sustained in a crash with an object or other vehicle; this coverage is common to all 50 states. Property damage liability (PDL) coverage insures against vehicle damage that at-fault drivers cause to other people's vehicle and property in crashes; this coverage exists in all states except Michigan, where vehicle damage is covered on a no-fault basis (each insured vehicle pays for its own damage in a crash, regardless of who is at fault).

Coverage of injuries is more complex. Bodily injury (BI) liability coverage insures against medical, hospital, and other expenses for injuries that at-fault drivers inflict on occupants of other vehicles or others on the road; although motorists in most states may have BI coverage, this information is analyzed only in states where the at-fault driver has first obligation to pay for injuries (33 states with traditional tort insurance systems). Medical payment (MedPay) coverage, also sold in the 33 states with traditional tort insurance systems, covers injuries to insured drivers and the passengers in their vehicles, but not injuries to people in other vehicles involved in the crash. Seventeen other states employ no-fault injury systems (personal injury protection coverage, or PIP) that pay up to a specified amount for injuries to occupants of involved-insured vehicles, regardless of who is at fault in a collision. The District of Columbia has a hybrid insurance system for injuries and is excluded from the injury analysis.

Statistical methods

Regression analysis was used to quantify the effect of vehicle feature while controlling for other covariates. The covariates included calendar year, model year, garaging state, vehicle density (number of registered vehicles per square mile), rated driver age group, rated driver gender, rated driver marital status, deductible range (collision coverage only), and risk. For each safety feature studied, a variable was included.

Claim frequency was modeled using a Poisson distribution, whereas claim severity (average loss payment per claim) was modeled using a Gamma distribution. Both models used a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models. Estimates for frequency, severity, and overall losses are presented for collision and property damage liability. For PIP, BI, and MedPay, three frequency estimates are presented. The first frequency is the frequency for all claims, including those that already have been paid and those for which money has been set aside for possible payment in the future, known as claims with reserves. The other two frequencies include only paid claims separated into low and high severity ranges. Note that the percentage of all injury claims that were paid by the date of analysis varies by coverage: 70.6 percent for PIP, 49.3 percent for BI, and 53.7 percent for MedPay. The low severity range was <$1,000 for PIP and MedPay, <$5,000 for BI; high severity covered all loss payments greater than that.

A separate regression was performed for each insurance loss measure for a total of 15 regressions (5 coverages x 3 loss measures each). For space reasons, only the estimates for the individual crash avoidance features are shown on the following pages. To illustrate the analyses, however, **Appendix A** contains full model results for collision claim frequencies. To further simplify the presentation here, the exponent of the parameter estimate was calculated, 1 was subtracted, and the resultant multiplied by 100. The resulting number corresponds to the effect of the feature on that loss measure. For example, the estimate of the effect of Forward Collision Warning (including Lane Departure Warning) on PDL claim frequency was -0.15083; thus, vehicles with the feature had 14.0 percent fewer PDL claims than expected ((exp(-0.15083)-1)*100=-14.0).

Results

Results for Honda Accord's Forward Collision Warning System including Lane Departure Warning are summarized in Table 2. The lower and upper bounds represent the 95 percent confidence limits for the estimates. For vehicle damage losses, frequency and severity of claims as well as overall losses are down. The reductions are significant (indicated in blue in the table), with the exception of the decrease in collision claim frequency and property damage liability claim severity.

For the injury related coverage types, all measures of frequency for all coverage types show a reduction. The bodily injury liability and medical payment reductions are significant.

Table 2: Change in insurance losses for Forward Collision Warning and Lane Departure Warning

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-9.1%	-3.8%	1.8%	-$668	**-$409**	-$132	-$71	**-$45**	-$17
Property damage liability	-21.8%	**-14.0%**	-5.4%	-$418	-$169	$104	-$26	**-$17**	-$6

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-57.7%	**-39.5%**	-13.5%	-66.3%	-31.8%	38.1%	-75.5%	-47.3%	13.7%
Medical payments	-45.0%	**-27.3%**	-4.0%	-65.0%	-21.7%	74.9%	-52.2%	-26.0%	14.4%
Personal injury protection	-27.8%	-10.7%	10.3%	-41.1%	-5.9%	50.4%	-37.5%	-16.3%	12.1%

Results for Honda Accord's LaneWatch System are summarized in Table 3. Again, the lower and upper bounds represent the 95 percent confidence limits for the estimates. Reductions in claim frequency are estimated for both first and third-party vehicle damage coverages, yet resulting in somewhat higher claim severity. Loss per insured vehicle year (overall losses) declined under both property damage liability and collision coverage. However, none of the estimated effects for LaneWatch on collision or PDL losses are statistically significant.

Under injury coverages, the frequency of claims is lower for both MedPay and PIP, but not for BI, and none of the differences is statistically significant. Among paid claims, no clear pattern emerges.

Table 3: Change in insurance losses for LaneWatch

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-7.8%	-2.5%	3.1%	-$190	$99	$409	-$30	-$1	$31
Property damage liability	-16.0%	-7.8%	1.1%	-$162	$102	$392	-$14	-$4	$8

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-22.9%	7.9%	51.0%	-56.4%	-15.7%	63.1%	-41.8%	19.5%	145.4%
Medical payments	-32.0%	-11.1%	16.1%	-58.4%	-10.0%	95.0%	-44.1%	-14.9%	29.4%
Personal injury protection	-31.3%	-15.8%	3.3%	-34.2%	4.2%	65.1%	-33.5%	-11.9%	16.7%

Discussion

This is the first analysis of the effectiveness of crash avoidance features involving a high-volume non-luxury model. For example, in 2013 the Accord outsold the most popular Volvo model (Volvo S60) 10 to 1. It is also less expensive than midsize cars in the luxury class; $23,270 for the four-door Accord compared with a range of $32,645-$62,495 for midsize luxury cars. As such, results of this analysis may give a better estimate of the potential crash reductions associated with these features than analyses examining only luxury class vehicles.

The results for these two Honda Accord collision avoidance features — Forward Collision Warning (with Lane Departure Warning) and LaneWatch — are encouraging. The combined FCW/LDW systems show a reduction in claim frequencies across all coverages. The pattern of findings for vehicle damage coverages is consistent with the expected benefits; that is, the reduction in claims is greater for property damage liability coverage than for collision coverage. Forward Collision Warning operates in following traffic and is intended to reduce the occurrence and/or severity of front-to-rear collisions. These types of crashes are more common among property damage liability claims than among collision claims, as the latter often include single-vehicle collisions. The forward collision warning system does not have autonomous braking, yet the significant 14 percent reduction in property damage liability claim frequency is at least as large as HLDI's earlier estimates for autobraking systems from Acura and Mercedes-Benz as well as the low-speed autobraking system, City Safety, from Volvo (HLDI, 2012a, 2012b, 2013). All prior forward collision warning systems evaluated by HLDI have been bundled with adaptive cruise control (ACC). The Honda study vehicles are not equipped with ACC. While the effects of ACC could not be isolated in prior analysis, if used by drivers ACC could reduce the likelihood that drivers get into situations that lead to a crash. Given that the Honda forward collision warning system is not bundled with ACC and the favorable loss results for the Honda system, if ACC did contribute to lower claim rates for previously studied systems where FCW and ACC was bundled then it may indicate that the FCW system from Honda is even more effective than previously studied systems.

It is also interesting to note that the current estimates for the effectiveness of this combined FCW/LDW system are greater than the estimates for a Volvo combined FCW/LDW system that included autobraking (HLDI, 2012c). At the time, it was hypothesized that the presence of LDW was decreasing the effectiveness of the Volvo combined system. This was based on estimates of claim frequency increases associated with LDW presence on Buick and Mercedes-Benz vehicles compared with estimates for Acura and Mercedes-Benz FCW with autobrake systems which did not include LDW. In the context of the current results, LDW may not be as deleterious as previously hypothesized. This would be consistent with the significant reduction in property damage liability claim frequency, another effect not observed for the Volvo combined system. Alternately, the forward collision warning system on the Accord is much more effective than those previously studied. It may be the case that these warning systems are more effective for drivers of mainstream cars than drivers of luxury models.

Honda's forward collision warning system is camera-based and unlike the previously evaluated systems from other manufacturers that use a radar-based system, typically mounted in the vulnerable front grille of the vehicle. Analysis of Mercedes-Benz and Volvo forward collision systems showed increases in collision claim severity, likely associated with replacement of the radar units in crashes not avoided (HLDI, 2012a, 2012b). This analysis of Honda Accords showed a significant decrease in collision claim severity, which may be attributed to the better protected interior location of the camera.

Effects of Honda's LaneWatch, a passenger-side blind spot detection system, although not statistically significant, are patterned as expected. Incursion into an occupied adjacent lane would be expected to result in a two-vehicle crash that would lead to a property damage liability claim against the encroaching driver. Although neither estimate is statistically significant, the estimated reduction in property damage liability claims is much larger than the reduction estimated for collision claims. This is consistent with the fact that the reductions in collision claims from such crashes would be diluted by the many single-vehicle crashes that result in collision claims and are unaffected by the LaneWatch system.

As previously mentioned, the collision avoidance systems are tied to the vehicle trim levels. In order to be confident that the measured differences were attributable to the collision avoidance features and not the trim levels, a supplemental analysis was conducted including loss data for model year 2012 Honda Accord vehicles. While the Honda Accord was redesigned in 2013 the trim levels in 2012 and 2013 were comparable. The inclusion of loss data for the 2012 model year, in which no crash avoidance features were present, allowed the supplemental analysis to include the vehicle trim level in addition to the control variables used in the primary analysis. Thus the supplemental analysis assumes that loss differences attributable the different trim levels were the same in both model years. The summary results of the supplemental analysis are included in **Appendix B** and the full regression analysis results for collision claim frequencies are shown in **Appendix C**. The supplemental results for the combination FCW/LDW system are largely the same as in the original analysis with all of the estimated effects within the confidence bounds of the original. Results for the LaneWatch system are mostly similar to the original except that PDL frequency and PDL overall loss estimates did not fall within the confidence bounds of the original. They both estimated increases whereas the original analysis estimated decreases. Due to the similarity of the two analyses and uncertainty about the applicability of 2012 model trim level differences to the redesigned 2013 models, the original analysis is expected to the better predictor of the effects on losses of these two systems.

Limitations

There are limitations to the data used in this analysis. At the time of a crash, the status of a feature is not known. The features in this study can be deactivated by the driver, and there is no way to know how many of the drivers in these vehicles turned off a system prior to the crash. However, surveys conducted by the Insurance Institute for Highway Safety indicate that large majorities of drivers with these types of systems leave them on. If a significant number of drivers do turn these features off, any reported reductions may actually be underestimates of the true effectiveness of these systems.

Additionally, the data supplied to HLDI does not include detailed crash information. Information on point of impact and the vehicle's transmission status is not available. The technologies in this report target certain crash types. For example, LaneWatch is designed to prevent sideswipe-type collisions. All collisions, regardless of the ability of a feature to mitigate or prevent the crash, are included in the analysis.

References

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Appendix A

Appendix A: Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Intercept		1	-8.9726		0.5086	-9.9694	-7.9758	311.23	<0.0001
Calendar year	2012	1	-0.4699	-37.5%	0.0485	-0.5650	-0.3748	93.85	<0.0001
	2013	0	0	0	0	0	0		
Vehicle model year and series	2013 Accord 2dr	1	0.2560	29.2%	0.0951	0.0695	0.4425	7.24	0.0071
	2013 Accord 4dr	1	0.1087	11.5%	0.0920	-0.0716	0.2890	1.40	0.2375
	2013 Crosstour 4dr 2WD	1	0.0486	5.0%	0.1211	-0.1888	0.2860	0.16	0.6883
	2013 Crosstour 4dr 4WD	0	0	0	0	0	0		
Rated driver age group	14-20	1	0.3899	47.7%	0.0575	0.2771	0.5026	45.92	<0.0001
	21-24	1	0.3289	38.9%	0.0396	0.2512	0.4065	68.91	<0.0001
	25-39	1	0.1733	18.9%	0.0218	0.1306	0.2161	63.12	<0.0001
	65+	1	0.1229	13.1%	0.0245	0.0748	0.1710	25.09	<0.0001
	Unknown	1	0.1444	15.5%	0.0439	0.0584	0.2304	10.83	0.0010
	40-64	0	0	0	0	0	0		
Rated driver gender	Male	1	-0.0202	-2.0%	0.0201	-0.0595	0.0191	1.02	0.3136
	Unknown	1	-0.1513	-14.0%	0.0696	-0.2877	-0.0149	4.72	0.0297
	Female	0	0	0	0	0	0		
Rated driver marital status	Single	1	0.2342	26.4%	0.0219	0.1913	0.2771	114.50	<0.0001
	Unknown	1	0.2122	23.6%	0.0691	0.0768	0.3475	9.44	0.0021
	Married	0	0	0	0	0	0		
Risk	Nonstandard	1	0.1819	19.9%	0.0362	0.1111	0.2528	25.32	<0.0001
	Standard	0	0	0	0	0	0		
State	Alabama	1	-0.1702	-15.7%	0.5065	-1.1630	0.8225	0.11	0.7368
	Arizona	1	-0.0584	-5.7%	0.5049	-1.0480	0.9312	0.01	0.9079
	Arkansas	1	0.0571	5.9%	0.5135	-0.9493	1.0634	0.01	0.9115
	California	1	0.2529	28.8%	0.5007	-0.7285	1.2344	0.26	0.6135
	Colorado	1	-0.0399	-3.9%	0.5093	-1.0381	0.9583	0.01	0.9375
	Connecticut	1	-0.1421	-13.2%	0.5061	-1.1340	0.8499	0.08	0.7789
	Delaware	1	-0.1086	-10.3%	0.5199	-1.1277	0.9105	0.04	0.8346
	District of Columbia	1	0.4169	51.7%	0.5283	-0.6186	1.4523	0.62	0.4301
	Florida	1	-0.2386	-21.2%	0.5015	-1.2214	0.7442	0.23	0.6342
	Georgia	1	-0.1401	-13.1%	0.5029	-1.1258	0.8456	0.08	0.7805
	Hawaii	1	0.3382	40.2%	0.5162	-0.6736	1.3500	0.43	0.5124
	Idaho	1	-0.5532	-42.5%	0.5718	-1.6739	0.5675	0.94	0.3333
	Illinois	1	-0.0307	-3.0%	0.5025	-1.0156	0.9543	0.00	0.9514
	Indiana	1	-0.2169	-19.5%	0.5077	-1.2120	0.7781	0.18	0.6692
	Iowa	1	-0.1347	-12.6%	0.5245	-1.1626	0.8933	0.07	0.7974
	Kansas	1	0.0158	1.6%	0.5149	-0.9933	1.0249	0.00	0.9755
	Kentucky	1	-0.3336	-28.4%	0.5135	-1.3401	0.6729	0.42	0.5159
	Louisiana	1	0.2241	25.1%	0.5033	-0.7623	1.2105	0.20	0.6561
	Maine	1	-0.2200	-19.7%	0.5529	-1.3036	0.8636	0.16	0.6907

Appendix A: Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	Maryland	1	0.0668	6.9%	0.5025	-0.9180	1.0516	0.02	0.8943
	Massachusetts	1	0.0739	7.7%	0.5073	-0.9205	1.0682	0.02	0.8842
	Michigan	1	0.2745	31.6%	0.5062	-0.7176	1.2667	0.29	0.5876
	Minnesota	1	-0.1709	-15.7%	0.5097	-1.1699	0.8281	0.11	0.7374
	Mississippi	1	-0.0621	-6.0%	0.5104	-1.0625	0.9383	0.01	0.9032
	Missouri	1	-0.1909	-17.4%	0.5083	-1.1873	0.8054	0.14	0.7072
	Montana	1	-0.8978	-59.3%	0.6712	-2.2133	0.4177	1.79	0.1810
	Nebraska	1	-0.1166	-11.0%	0.5288	-1.1531	0.9199	0.05	0.8255
	Nevada	1	-0.2760	-24.1%	0.5160	-1.2874	0.7354	0.29	0.5928
	New Hampshire	1	-0.1079	-10.2%	0.5177	-1.1226	0.9068	0.04	0.8350
	New Jersey	1	-0.0414	-4.1%	0.5016	-1.0244	0.9417	0.01	0.9343
	New Mexico	1	-0.0671	-6.5%	0.5229	-1.0918	0.9577	0.02	0.8979
	New York	1	0.2583	29.5%	0.5009	-0.7235	1.2401	0.27	0.6061
	North Carolina	1	-0.3855	-32.0%	0.5032	-1.3718	0.6008	0.59	0.4437
	North Dakota	1	-0.3347	-28.4%	0.6013	-1.5133	0.8439	0.31	0.5778
	Ohio	1	-0.1924	-17.5%	0.5026	-1.1775	0.7927	0.15	0.7019
	Oklahoma	1	0.0427	4.4%	0.5090	-0.9550	1.0404	0.01	0.9331
	Oregon	1	0.1113	11.8%	0.5095	-0.8873	1.1098	0.05	0.8271
	Pennsylvania	1	0.0099	1.0%	0.5021	-0.9742	0.9939	0.00	0.9843
	Rhode Island	1	0.0155	1.6%	0.5161	-0.9960	1.0270	0.00	0.9761
	South Carolina	1	-0.2156	-19.4%	0.5053	-1.2060	0.7749	0.18	0.6697
	South Dakota	1	-0.4461	-36.0%	0.6124	-1.6464	0.7542	0.53	0.4663
	Tennessee	1	-0.1267	-11.9%	0.5051	-1.1166	0.8632	0.06	0.8020
	Texas	1	-0.0318	-3.1%	0.5012	-1.0142	0.9505	0.00	0.9493
	Utah	1	-0.1737	-15.9%	0.5206	-1.1941	0.8467	0.11	0.7386
	Vermont	1	-0.1491	-13.9%	0.5628	-1.2523	0.9540	0.07	0.7910
	Virginia	1	-0.0211	-2.1%	0.5023	-1.0056	0.9634	0.00	0.9665
	Washington	1	0.0784	8.2%	0.5051	-0.9115	1.0684	0.02	0.8766
	West Virginia	1	-0.4545	-36.5%	0.5359	-1.5048	0.5958	0.72	0.3963
	Wisconsin	1	-0.0208	-2.1%	0.5085	-1.0175	0.9759	0.00	0.9674
	Wyoming	1	-0.3746	-31.2%	0.6712	-1.6901	0.9408	0.31	0.5767
	Alaska	0	0	0	0	0	0		
Deductible range	0-250	1	0.4765	61.0%	0.0315	0.4148	0.5382	229.20	<0.0001
	251-500	1	-0.0776	-7.5%	0.1759	-0.4224	0.2673	0.19	0.6592
	1001+	1	0.3064	35.9%	0.0274	0.2528	0.3600	125.43	<0.0001
	501-1000	0	0	0	0	0	0		
Registered vehicle density	0-99	1	-0.2548	-22.5%	0.0339	-0.3213	-0.1883	56.38	<0.0001
	100-499	1	-0.1506	-14.0%	0.0219	-0.1936	-0.1076	47.11	<0.0001
	500+	0	0	0	0	0	0		
Forward Collision Warning & Lane Departure Warning		1	-0.0388	-3.8%	0.0288	-0.0954	0.0177	1.81	0.1782
LaneWatch		1	-0.0254	-2.5%	0.0285	-0.0812	0.0304	0.80	0.3720

Appendix B: Supplemental analysis results for Honda Accord variants with control variables included for model year, vehicle series and trim

Change in insurance losses for Forward Collision Warning and Lane Departure Warning

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-13.9%	**-7.7%**	-1.1%	-$638	**-$335**	-$6	-$75	**-$48**	-$17
Property damage liability	-26.2%	**-17.3%**	-7.4%	-$534	-$255	$57	-$36	**-$25**	-$12

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-55.9%	**-34.2%**	-2.0%	-65.1%	-24.8%	62.0%	-76.8%	-46.5%	23.2%
Medical payments	-43.6%	-21.9%	8.2%	-75.8%	-37.2%	63.2%	-46.5%	-11.9%	45.1%
Personal injury protection	-19.9%	2.7%	31.7%	-39.2%	5.7%	83.7%	-29.5%	-1.0%	38.9%

Change in insurance losses for LaneWatch

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-4.8%	1.8%	8.9%	-$250	$76	$429	-$21	$11	$47
Property damage liability	1.0%	**12.6%**	25.5%	-$325	-$36	$288	-$5	$11	$30

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-24.8%	9.1%	58.2%	-56.0%	-10.5%	82.1%	-48.1%	13.4%	147.7%
Medical payments	-26.5%	0.2%	36.5%	-51.8%	20.0%	198.7%	-41.8%	-6.5%	50.3%
Personal injury protection	-26.6%	-7.2%	17.4%	-33.5%	12.9%	91.6%	-29.0%	-2.1%	34.8%

Appendix C

Appendix C: Illustrative regression results for secondary analysis — collision frequency

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Intercept		1	-8.5425		0.2607	-9.0533	-8.0316	1074.06	<0.0001
Calendar year	2011	1	-0.3089	-26.6%	0.0428	-0.3928	-0.2249	51.98	<0.0001
	2012	1	-0.0251	-2.5%	0.0112	-0.0470	-0.0033	5.07	0.0243
	2013	0	0	0	0	0	0		
Model year	2012	1	-0.0642	-6.2%	0.0151	-0.0938	-0.0345	18.01	<0.0001
	2013	0	0	0	0	0	0		
Vehicle series and trim	Accord 2dr EX	1	0.0953	10.0%	0.0484	0.0003	0.1902	3.87	0.0492
	Accord 2dr EX-L	1	0.1744	19.1%	0.0397	0.0966	0.2523	19.28	<0.0001
	Accord 2dr EX-L V6	1	0.0957	10.0%	0.0389	0.0195	0.1719	6.06	0.0138
	Accord 2dr LX-S	1	0.1690	18.4%	0.0403	0.0900	0.2480	17.57	<0.0001
	Accord 4dr EX	1	-0.0842	-8.1%	0.0361	-0.1549	-0.0135	5.45	0.0195
	Accord 4dr EX-L	1	-0.0424	-4.2%	0.0332	-0.1074	0.0226	1.64	0.2010
	Accord 4dr EX-L V6	1	-0.0716	-6.9%	0.0337	-0.1376	-0.0056	4.52	0.0335
	Accord 4dr LX	1	-0.0318	-3.1%	0.0318	-0.0941	0.0305	1.00	0.3171
	Accord 4dr Sport	1	-0.0454	-4.4%	0.0322	-0.1085	0.0178	1.98	0.1591

Appendix C: Illustrative regression results for secondary analysis — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	Accord Crosstour 4dr 2WD EX	1	-0.1086	-10.3%	0.0606	-0.2273	0.0101	3.22	0.0730
	Accord Crosstour 4dr 2WD EX-L	1	0.0073	0.7%	0.0597	-0.1097	0.1244	0.02	0.9021
	Accord Crosstour 4dr 2WD EX-L V6	1	-0.0138	-1.4%	0.0557	-0.1230	0.0955	0.06	0.8047
	Accord Crosstour 4dr 4WD EX-L V6	0	0	0	0	0	0		
Rated driver age group	14-20	1	0.3847	46.9%	0.0308	0.3243	0.4451	155.79	<0.0001
	21-24	1	0.3195	37.6%	0.0219	0.2765	0.3624	212.51	<0.0001
	25-39	1	0.1349	14.4%	0.0119	0.1116	0.1583	128.20	<0.0001
	65+	1	0.0775	8.1%	0.0139	0.0502	0.1047	31.05	<0.0001
	Unknown	1	0.1287	13.7%	0.0244	0.0810	0.1765	27.90	<0.0001
	40-64	0	0	0	0	0	0		
Rated driver gender	Male	1	-0.0347	-3.4%	0.0111	-0.0564	-0.0130	9.80	0.0017
	Unknown	1	-0.2493	-22.1%	0.0321	-0.3123	-0.1863	60.18	<0.0001
	Female	0	0	0	0	0	0		
Rated driver marital status	Single	1	0.2076	23.1%	0.0120	0.1839	0.2312	296.80	<0.0001
	Unknown	1	0.2927	34.0%	0.0318	0.2304	0.3551	84.75	<0.0001
	Married	0	0	0	0	0	0		
Risk	Nonstandard	1	0.1961	21.7%	0.0160	0.1647	0.2274	150.27	<0.0001
	Standard	0	0	0	0	0	0		
State	Alabama	1	-0.2951	-25.6%	0.2617	-0.8080	0.2178	1.27	0.2594
	Arizona	1	-0.2500	-22.1%	0.2612	-0.7619	0.2619	0.92	0.3384
	Arkansas	1	-0.0494	-4.8%	0.2655	-0.5698	0.4710	0.03	0.8525
	California	1	0.0453	4.6%	0.2587	-0.4616	0.5523	0.03	0.8608
	Colorado	1	-0.2247	-20.1%	0.2635	-0.7411	0.2917	0.73	0.3938
	Connecticut	1	-0.2455	-21.8%	0.2613	-0.7576	0.2666	0.88	0.3475
	Delaware	1	-0.2482	-22.0%	0.2692	-0.7759	0.2795	0.85	0.3567
	District of Columbia	1	0.2620	30.0%	0.2734	-0.2740	0.7979	0.92	0.3380
	Florida	1	-0.4478	-36.1%	0.2590	-0.9555	0.0599	2.99	0.0838
	Georgia	1	-0.3466	-29.3%	0.2599	-0.8560	0.1627	1.78	0.1822
	Hawaii	1	0.0148	1.5%	0.2721	-0.5184	0.5481	0.00	0.9566
	Idaho	1	-0.6291	-46.7%	0.2990	-1.2151	-0.0430	4.43	0.0354
	Illinois	1	-0.2561	-22.6%	0.2597	-0.7651	0.2528	0.97	0.3240
	Indiana	1	-0.3606	-30.3%	0.2621	-0.8744	0.1531	1.89	0.1689
	Iowa	1	-0.2584	-22.8%	0.2714	-0.7902	0.2735	0.91	0.3411
	Kansas	1	-0.4052	-33.3%	0.2696	-0.9336	0.1231	2.26	0.1328
	Kentucky	1	-0.4197	-34.3%	0.2649	-0.9389	0.0995	2.51	0.1131
	Louisiana	1	-0.0576	-5.6%	0.2605	-0.5682	0.4530	0.05	0.8251
	Maine	1	-0.3724	-31.1%	0.2892	-0.9392	0.1944	1.66	0.1979
	Maryland	1	-0.1263	-11.9%	0.2598	-0.6354	0.3828	0.24	0.6268
	Massachusetts	1	-0.2144	-19.3%	0.2613	-0.7265	0.2976	0.67	0.4118
	Michigan	1	0.0946	9.9%	0.2615	-0.4179	0.6071	0.13	0.7175
	Minnesota	1	-0.4576	-36.7%	0.2636	-0.9744	0.0591	3.01	0.0826
	Mississippi	1	-0.3107	-26.7%	0.2648	-0.8298	0.2084	1.38	0.2407

Appendix C: Illustrative regression results for secondary analysis — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	Missouri	1	-0.3751	-31.3%	0.2629	-0.8905	0.1402	2.04	0.1536
	Montana	1	-0.3047	-26.3%	0.3030	-0.8986	0.2892	1.01	0.3147
	Nebraska	1	-0.5450	-42.0%	0.2774	-1.0887	-0.0013	3.86	0.0495
	Nevada	1	-0.3703	-30.9%	0.2673	-0.8943	0.1537	1.92	0.1660
	New Hampshire	1	-0.0001	0.0%	0.2651	-0.5197	0.5195	0.00	0.9997
	New Jersey	1	-0.2362	-21.0%	0.2591	-0.7439	0.2715	0.83	0.3619
	New Mexico	1	-0.3387	-28.7%	0.2739	-0.8756	0.1982	1.53	0.2164
	New York	1	-0.0315	-3.1%	0.2587	-0.5386	0.4757	0.01	0.9032
	North Carolina	1	-0.5197	-40.5%	0.2600	-1.0292	-0.0102	4.00	0.0456
	North Dakota	1	-0.4686	-37.4%	0.3132	-1.0824	0.1452	2.24	0.1346
	Ohio	1	-0.4561	-36.6%	0.2597	-0.9651	0.0528	3.09	0.0790
	Oklahoma	1	-0.2825	-24.6%	0.2646	-0.8011	0.2360	1.14	0.2855
	Oregon	1	-0.2437	-21.6%	0.2655	-0.7641	0.2767	0.84	0.3586
	Pennsylvania	1	-0.1477	-13.7%	0.2593	-0.6560	0.3605	0.32	0.5689
	Rhode Island	1	-0.0613	-5.9%	0.2657	-0.5822	0.4595	0.05	0.8174
	South Carolina	1	-0.4584	-36.8%	0.2615	-0.9710	0.0542	3.07	0.0797
	South Dakota	1	-0.4737	-37.7%	0.3100	-1.0813	0.1339	2.33	0.1265
	Tennessee	1	-0.3558	-29.9%	0.2611	-0.8675	0.1559	1.86	0.1730
	Texas	1	-0.2716	-23.8%	0.2589	-0.7792	0.2359	1.10	0.2941
	Utah	1	-0.3516	-29.6%	0.2709	-0.8826	0.1794	1.68	0.1943
	Vermont	1	-0.2408	-21.4%	0.2919	-0.8129	0.3313	0.68	0.4094
	Virginia	1	-0.2353	-21.0%	0.2597	-0.7442	0.2736	0.82	0.3648
	Washington	1	-0.1991	-18.1%	0.2618	-0.7123	0.3141	0.58	0.4470
	West Virginia	1	-0.3866	-32.1%	0.2748	-0.9253	0.1520	1.98	0.1595
	Wisconsin	1	-0.3599	-30.2%	0.2632	-0.8758	0.1560	1.87	0.1715
	Wyoming	1	-0.3631	-30.4%	0.3418	-1.0331	0.3068	1.13	0.2880
	Alaska	0	0	0	0	0	0		
Deductible range	0-250	1	0.4662	59.4%	0.0169	0.4330	0.4994	756.72	<0.0001
	1001+	1	-0.3305	-28.1%	0.1140	-0.5539	-0.1070	8.40	0.0037
	251-500	1	0.2462	27.9%	0.0146	0.2176	0.2748	284.42	<0.0001
	501-1000	0	0	0	0	0	0		
Registered vehicle density	0-99	1	-0.2511	-22.2%	0.0192	-0.2887	-0.2135	170.98	<0.0001
	100-499	1	-0.1751	-16.1%	0.0122	-0.1990	-0.1511	205.00	<0.0001
	500+	0	0	0	0	0	0		
Forward Collision Warning & Lane Departure Warning		1	-0.0804	-7.7%	0.0355	-0.1501	-0.0108	5.13	0.0236
LaneWatch		1	0.0178	1.8%	0.0345	-0.0497	0.0854	0.27	0.6046

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Subaru collision avoidance features: an update

This report updates a prior analysis of two Subaru collision avoidance features: EyeSight and a rear-vision camera. The EyeSight system uses dual front facing cameras to provide several collision avoidance functions. These functions include: forward collision warning with autonomous braking, adaptive cruise control with complete stop, lane departure warning, and lead vehicle start alert. There is about 40 percent more collision exposure in this study than in the prior one. Although all estimates in this study are within the confidence bounds of the prior study, the point estimates of some of the effects have shifted.

The pattern of frequency reductions, in particular the reductions for property damage liability in conjunction with a much larger reduction for bodily injury liability, is consistent with expectations for vehicles fitted with forward collision systems. Forward collision systems are designed to prevent or mitigate front-to-rear crashes, which typically result in property damage liability claims and bodily injury liability claims if an injury in the struck vehicle occurs. In initial reports, although consistent with expectations, the estimated benefits for these two coverages differed from other systems HLDI had studied. In the current analyses, the property damage liability benefit increased by nearly 5 percentage points from the prior report while the updated bodily injury liability benefit for EyeSight dropped nearly 6 percentage points. These results are comparable to other similar systems.

The updated results for the rear-vision camera are within the bounds indicated in the prior study. The updated rear-vision camera results show reductions in property damage liability, collision, and bodily injury liability claim frequencies; the result for property damage liability is statistically significant.

Change in claim frequencies by collision avoidance feature, initial vs. updated results

	EyeSight		Rear-vision camera	
Vehicle damage coverage types	**Initial results**	**Updated results**	**Initial results**	**Updated results**
Collision	3.5%	0.5%	-2.5%	-1.2%
Property damage liability	**-10.6%**	**-15.1%**	**-6.4%**	**-7.0%**
Injury coverage types	**Initial results**	**Updated results**	**Initial results**	**Updated results**
Bodily injury liability	**-40.3%**	**-34.7%**	4.1%	-1.6%
Medical payment	20.5%	22.4%	9.3%	4.8%
Personal injury protection	-10.1%	-2.9%	-2.0%	1.4%

Introduction

This Highway Loss Data Institute (HLDI) bulletin provides an updated look at the effects of two available Subaru collision avoidance systems on insurance losses. An earlier HLDI report found encouraging results (HLDI, 2014). The prior HLDI results indicate these systems are having some benefit. This HLDI bulletin updates the prior analysis with more exposure. The increase in collision exposure was 37.1 percent. The two features included in this analysis are as follows:

EyeSight uses a dual-camera system located behind the windshield to assess the risk of a collision with leading traffic. EyeSight's functionality includes the following four features:

> **Forward collision warning with autonomous braking** uses the cameras to assess the risk of a rear-end collision with an obstacle in front, and warns the driver with an audible alert. If the driver does not take evasive action, the brakes are automatically applied to reduce impact damage or, if possible, prevent the collision. EyeSight is capable of avoiding a collision with a speed difference to the obstacle in front as high as 30 mph. However, not every situation under these conditions will result in full collision avoidance. Some of the EyeSight functionality may be turned off by the driver and can be activated/deactivated via the instrument cluster controls, but will reactivate at the next ignition cycle.
>
> **Adaptive cruise control with complete stop** is a system that uses the dual cameras to monitor traffic ahead and maintain the driver's selected following distance. As traffic conditions dictate, the system employs braking force to maintain the set following distance. Adaptive cruise control is available at speeds up to 90 mph and can bring the car to a stop in traffic. Forward collision warning remains active even when adaptive cruise control is turned off.
>
> **Lane departure warning** utilizes the dual cameras to identify traffic lane markings. Audio and visual warnings will indicate if the vehicle path deviates from the lane and the turn signal is not on. The system is functional at speeds at or above 32 mph (50 km/h). The system may be deactivated by the driver, but will reactivate at the next ignition cycle.
>
> **Lead vehicle start alert** notifies the driver by means of an audible tone and the lead vehicle indicator on the multi-information display when the driver's vehicle remains stopped after the vehicle in front has started to move forward. When the EyeSight-equipped vehicle has stopped within 32 feet of a stationary vehicle and both remain stopped for several seconds, this system will alert the driver of the EyeSight vehicle if his/her car remains stationary after the lead vehicle has moved 10 feet.

Rear-vision camera is an optical parking aid that uses a rear-facing camera mounted at the rear of the vehicle to show the area behind the vehicle on a central display screen. The image includes static distance/guidance lines to aid the driver in parking maneuvers. The display is activated when the reverse gear is engaged.

Vehicles

EyeSight and the rear-vision camera are offered as optional equipment on various Subaru models. The presence or absence of these features is discernible from the information encoded in the vehicle identification numbers (VINs). EyeSight and rear-vision camera are offered as optional equipment on several 2013 and 2014 Subaru vehicles. Subaru vehicles without these features served as the control vehicles in this analysis. **Table 1** lists the total exposure, measured in insured vehicle years, and the exposure of each feature as a percentage of total exposure.

Table 1: Feature exposure by vehicle series

Make	Series	Model year range	Rear-vision camera	EyeSight	Total exposure
Subaru	Forester 4dr 4WD	2014	82%	7%	129,117
Subaru	Legacy 4dr 4WD	2013-14	22%	7%	76,402
Subaru	Outback station wagon 4WD	2013-14	58%	9%	235,219

Insurance Data

Automobile insurance covers damages to vehicles and property, as well as injuries to people involved in crashes. Different insurance coverages pay for vehicle damage versus injuries, and different coverages may apply depending on who is at fault. The current study is based on property damage liability, collision, bodily injury liability, personal injury protection, and medical payment coverages. Exposure is measured in insured vehicle years. An insured vehicle year is equivalent to one vehicle insured for 1 year, two vehicles for 6 months, etc.

Because different crash avoidance features may affect different types of insurance coverage, it is important to understand how coverages vary among the states and how this affects inclusion in the analyses. Collision coverage insures against vehicle damage to an at-fault driver's vehicle sustained in a crash with an object or other vehicle; this coverage is common to all 50 states. Property damage liability (PDL) coverage insures against vehicle damage that at-fault drivers cause to other people's vehicle and property in crashes; this coverage exists in all states except Michigan, where vehicle damage is covered on a no-fault basis (each insured vehicle pays for its own damage in a crash, regardless of who is at fault).

Coverage of injuries is more complex. Bodily injury (BI) liability coverage insures against medical, hospital, and other expenses for injuries that at-fault drivers inflict on occupants of other vehicles or others on the road. Although motorists in most states may have BI coverage, this information is analyzed only in states where the at-fault driver has first obligation to pay for injuries (33 states with traditional tort insurance systems). Medical payment (MedPay) coverage, also sold in the 33 states with traditional tort insurance systems, covers injuries to insured drivers and the passengers in their vehicles, but not injuries to people in other vehicles involved in the crash. Seventeen other states employ no-fault injury systems (personal injury protection coverage, or PIP) that pay up to a specified amount for injuries to occupants of involved-insured vehicles, regardless of who is at fault in a collision. The District of Columbia has a hybrid insurance system for injuries and is excluded from the injury analysis.

Statistical methods

Regression analysis was used to quantify the effect of vehicle features while controlling for other covariates. The covariates included calendar year, model year, garaging state, vehicle density (number of registered vehicles per square mile), rated driver age group, rated driver gender, rated driver marital status, deductible range (collision coverage only), and risk. For each safety feature studied, a variable was included.

Claim frequency was modeled using a Poisson distribution, whereas claim severity (average loss payment per claim) was modeled using a Gamma distribution. Both models used a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models. Estimates for frequency, severity, and overall losses are presented for collision and property damage liability. For PIP, BI, and MedPay, three frequency estimates are presented. The first frequency is the frequency for all claims, including those that already have been paid and those for which money has been set aside for possible payment in the future, known as claims with reserves. The other two frequencies include only paid claims separated into low and high severity ranges. Note that the percentage of all injury claims that were paid by the date of analysis varies by coverage: 73.5 percent for PIP, 52.7 percent for BI, and 62.0 percent for MedPay. The low severity range was <$1,000 for PIP and MedPay, <$5,000 for BI; high severity covered all loss payments greater than that.

A separate regression was performed for each insurance loss measure for a total of 15 regressions (5 coverages x 3 loss measures each). For space reasons, only the estimates for the individual crash avoidance features are shown on the following pages. To illustrate the analyses, however, Appendix A contains full model results for collision claim frequencies. To further simplify the presentation here, the exponent of the parameter estimate was calculated, 1 was subtracted, and the resultant multiplied by 100. The resulting number corresponds to the effect of the feature on that loss measure. For example, the estimate of the effect of EyeSight on collision claim frequency was 0.0052; thus, vehicles with the feature had 0.5 percent more collision claims than without EyeSight ((exp(0.0052)-1)*100=0.5).

Results

Results for Subaru's EyeSight system are summarized in **Table 2**. The lower and upper bounds represent the 95 percent confidence limits for the estimates. For vehicle damage losses, claim frequency is down for property damage liability and up slightly for collision coverage. The decrease in property damage liability claim frequency is significant (bold and shaded grey in the table).

For injury losses, overall claim frequency (both paid and reserved) is lower for both BI and PIP, but not for MedPay, and only the bodily injury liability benefit is statistically significant. Among low-severity paid claims, only BI shows reductions. Among high severity claims, BI and PIP show reductions, and the decrease for BI and the increase for MedPay are statistically significant.

Table 2: Change in insurance losses for EyeSight

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-4.1%	0.5%	5.4%	-$198	$4	$216	-$15	$1	$19
Property damage liability	-21.5%	**-15.1%**	-8.2%	-$155	$46	$262	-$16	**-$10**	-$3

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-52.0%	**-34.7%**	-11.2%	-67.0%	-42.5%	0.1%	-90.7%	**-74.5%**	-30.0%
Medical payment	-0.1%	22.4%	49.9%	-35.0%	8.7%	81.8%	1.5%	**35.5%**	80.7%
Personal injury protection	-19.4%	-2.9%	16.9%	-13.3%	26.6%	84.9%	-35.4%	-15.5%	10.5%

Results for Subaru's rear-vision camera are summarized in **Table 3**. Again, the lower and upper bounds represent the 95 percent confidence limits for the estimates. For vehicle damage losses, claim frequencies are down but only the property damage liability reduction is significant. Claim severities are up, resulting in minimal change in overall losses.

Under injury coverages, claim frequency is lower for BI, but not for PIP or MedPay, and none of the differences is statistically significant. Among paid claims, claim frequency is up for nearly all injury coverage types.

Table 3: Change in insurance losses for rear-vision camera

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-3.9%	-1.2%	1.7%	-$35	$88	$215	-$7	$3	$13
Property damage liability	-10.9%	**-7.0%**	-2.9%	-$84	$28	$144	-$9	**-$5**	$0

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-15.8%	-1.6%	15.1%	-21.3%	3.1%	35.0%	-25.2%	7.1%	53.1%
Medical payment	-8.5%	4.8%	20.1%	-12.4%	23.3%	73.6%	-12.3%	7.4%	31.6%
Personal injury protection	-9.2%	1.4%	13.2%	-25.2%	-4.9%	20.9%	-12.5%	1.8%	18.4%

Discussion

The loss results for the systems included in this study have changed slightly since they were first studied in December 2014. While just a few months have passed, the exposure available for analysis had increased by nearly 40 percent. The increase in exposure has resulted from both the sale of additional vehicles and the additional time insured for the vehicles included in the previous study. All of the claim frequency estimates from this analysis are within the confidence bounds of the estimates in the previous study.

Table 4 shows the differences in the claim frequency estimates between the initial results published in December 2014 and the updated results included in this report. EyeSight is showing an increased benefit for property damage liability and the collision disbenefit measured in the first study (3.5 percent) is now almost gone (0.5 percent). The previous injury benefits under BI and PIP are now smaller than previously estimated. Rear camera continues to reduce property damage liability claims and indicates some collision and bodily injury liability benefits. More data is needed to be confident in the bodily injury liability results.

Table 4: Change in claim frequencies by collision avoidance feature, initial vs. updated results

	EyeSight		Rear-vision camera	
Vehicle damage coverage types	**Initial results**	**Updated results**	**Initial results**	**Updated results**
Collision	3.5%	0.5%	-2.5%	-1.2%
Property damage liability	**-10.6%**	**-15.1%**	**-6.4%**	**-7.0%**
Injury coverage types	**Initial results**	**Updated results**	**Initial results**	**Updated results**
Bodily injury liability	**-40.3%**	**-34.7%**	4.1%	-1.6%
Medical payment	20.5%	22.4%	9.3%	4.8%
Personal injury protection	-10.1%	-2.9%	-2.0%	1.4%

Front crash prevention systems are designed to prevent front-to-rear crashes, which are the type of crashes that result in PDL and BI claims, and the Subaru EyeSight system continues to be associated with reductions for these two coverage types. In fact, the estimated reductions for the EyeSight system for PDL and BI continue to be among the highest estimated by HLDI thus far. The EyeSight system however continues to be associated with increases in both collision and Med Pay claim frequencies. All other front crash prevention systems evaluated by HLDI were associated with reductions in collision frequency, although those estimates were small and generally not statistically significant. Previously, collision claim frequency for EyeSight was associated with a 3.5 percent increase and now is down to a less than 1 percent disbenefit. Additionally, most other front crash prevention systems evaluated by HLDI were associated with reductions in MedPay claim frequencies. **Figures 1 and 2** summarize the frequency effects under five coverage types for the eight front crash prevention systems. The reductions in collision claim frequencies for other manufacturers are smaller than PDL reductions and, given that collision claims often include single-vehicle crashes, the larger reduction in PDL frequencies is expected. The reason that EyeSight is associated with a slight increase in collision claim frequency and a larger increase in MedPay claim frequency is unknown. It should be noted that the results for manufacturers other than Subaru and Honda are from reports published between 2012 and 2013, while these Subaru results are from current insurance loss data.

Figure 1: Changes in physical damage claim frequency for front crash prevention systems

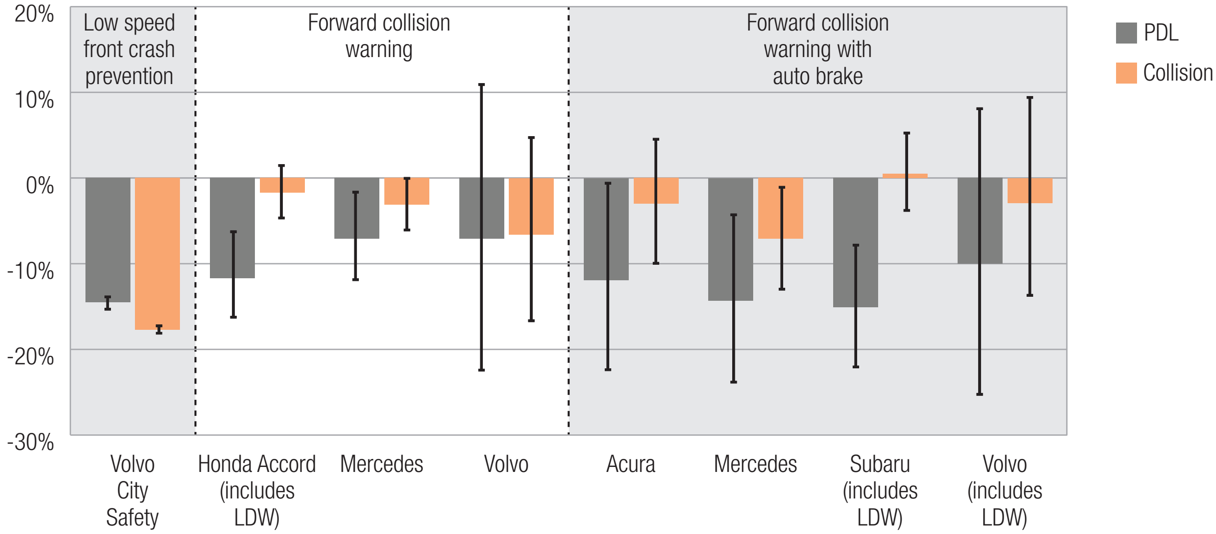
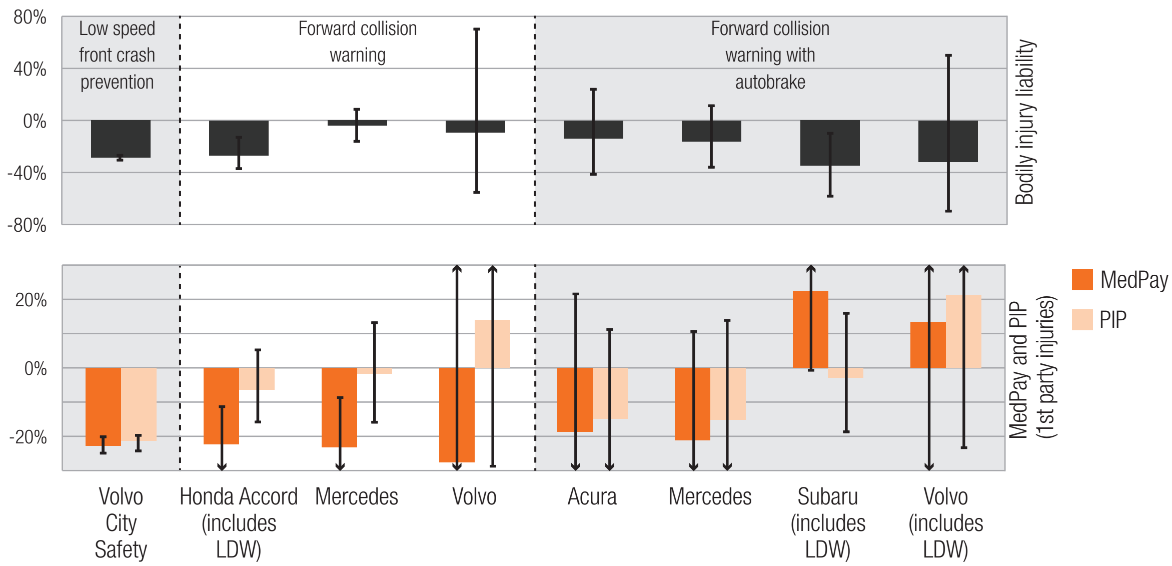


Figure 2: Changes in injury claim frequency for front crash prevention systems



In addition to EyeSight, HLDI has evaluated one lane departure warning (LDW) system as a standalone system, one LDW system paired with a blind spot system (BLIS), and two LDW systems paired with front crash prevention systems. **Figures 3 and 4** summarize the claim frequency effects under five coverage types for the five LDW systems. Both the standalone LDW system and the LDW system paired with BLIS were associated with increases in claim frequencies for all coverages except BI. However, in the two assessments of LDW paired with front crash prevention, the systems were associated with reductions in claim frequency for many of the coverages. The results for EyeSight further add to the uncertainty of the effect of LDW systems on insurance losses.

Figure 3: Changes in LDW physical damage claim frequency

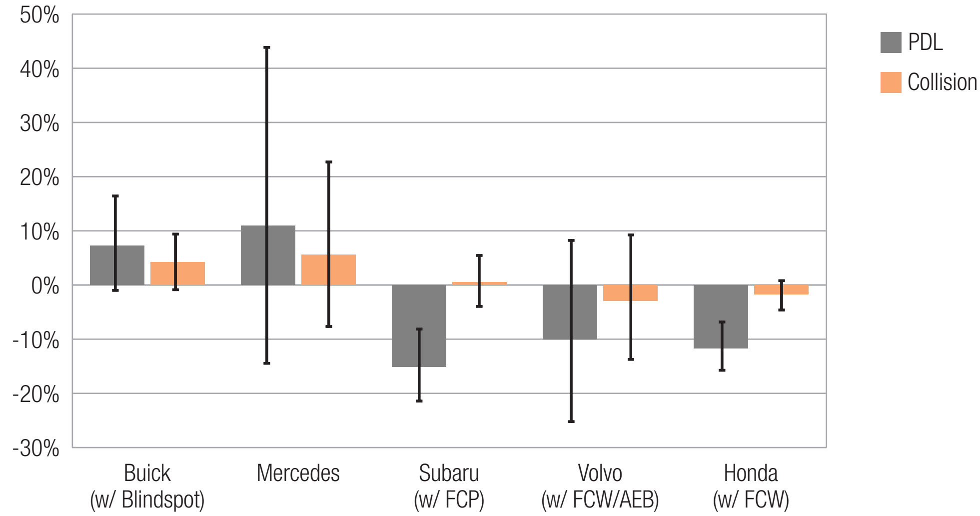
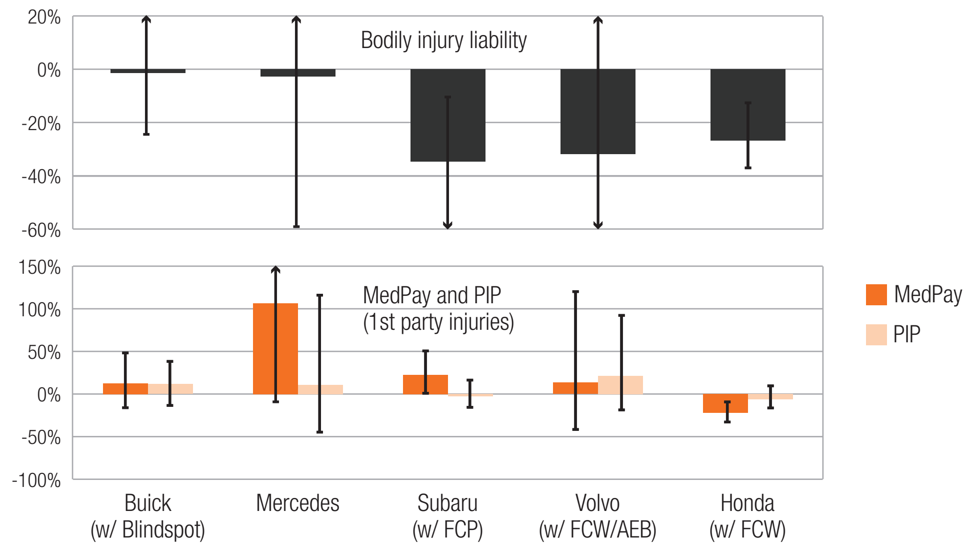


Figure 4: Changes in LDW injury claim frequency



A rear-vision camera would be expected to reduce impacts with other vehicles, objects, and some nonoccupants when operating the vehicle in reverse. This would be expected to yield reductions in collision and PDL losses and, perhaps, in BI losses. Both collision and PDL claims decreased as in the previous study, with the PDL result continuing to be significant. The current results now show small but not significant increases in claim frequency for both MedPay and PIP. The previous reduction in PIP claims is no longer found. Rear/parking collision avoidance systems were evaluated for other manufactures — Buick, Mercedes-Benz, and Mazda — and results varied by automaker as shown in **Figures 5 and 6**. The Subaru rear camera appears to be associated with reduced physical damage claims, but its effect on injury coverage losses is uncertain.

Figure 5: Changes in physical damage claim frequency for rear parking systems

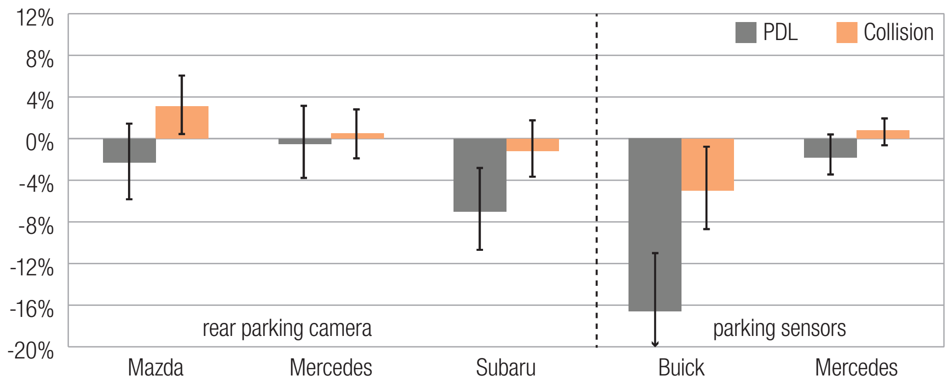
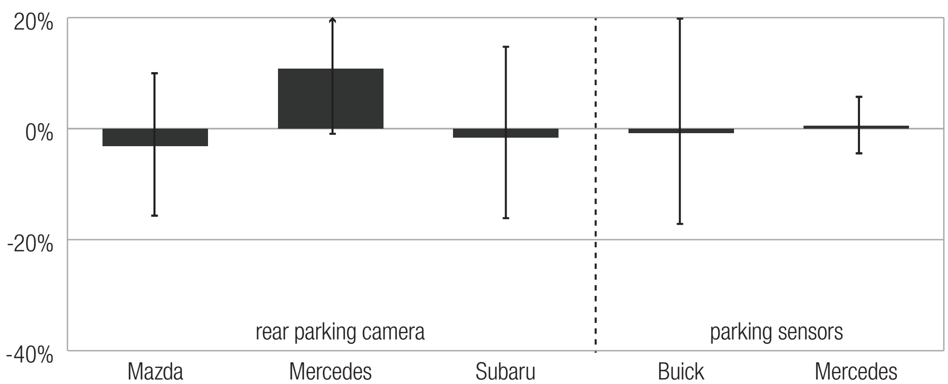


Figure 6: Changes in bodily injury liability claim frequency for rear parking systems



Limitations

There are limitations to the data used in this analysis. At the time of a crash, the status of a feature is not known. The features in this study can be deactivated by the driver, and there is no way to know how many of the drivers in these vehicles turned off a system prior to the crash. However, surveys conducted by the Insurance Institute for Highway Safety indicate that large majorities of drivers with these types of systems leave them on. If a significant number of drivers do turn these features off, any reported reductions may actually be underestimates of the true effectiveness of these systems.

Additionally, the data supplied to HLDI does not include detailed crash information. The specific crash types addressed by the different technologies cannot be isolated in these analyses. For example, it is not known how many of the crashes in the rear camera analysis involved backing-up, which is the only maneuver during which the camera is active. All collisions, regardless of the ability of a feature to mitigate or prevent the crash, are included in the analysis.

All of these features are optional and associated with increased costs. The type of person who selects these options may be different from the person who declines. While the analysis controls for several driver characteristics, there may be other uncontrolled attributes associated with people who select these features.

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Appendix A

Appendix A: Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Intercept		1	-9.0595		0.0816	-9.2194	-8.8996	12328.80	<0.0001
Calendar year	2012	1	-0.1414	-13.2%	0.0420	-0.2237	-0.0590	11.32	0.0008
	2013	1	-0.0226	-2.2%	0.0140	-0.0500	0.0049	2.59	0.1075
	2014	0	0	0	0	0	0		
Vehicle model year and series	2014 Forester	1	0.0025	0.3%	0.0199	-0.0365	0.0415	0.02	0.8994
	2013 Legacy	1	0.2198	24.6%	0.0236	0.1736	0.2661	86.92	<0.0001
	2014 Legacy	1	0.1713	18.7%	0.0314	0.1098	0.2328	29.81	<0.0001
	2013 Outback	1	0.0363	3.7%	0.0193	-0.0015	0.0742	3.54	0.0601
	2014 Outback	0	0	0	0	0	0		
Rated driver age group	14–24	1	0.2484	28.2%	0.0347	0.1804	0.3163	51.32	<0.0001
	25–29	1	0.1345	14.4%	0.0293	0.0772	0.1919	21.14	<0.0001
	30–39	1	0.0681	7.0%	0.0222	0.0246	0.1117	9.39	0.0022
	50–59	1	-0.0829	-8.0%	0.0218	-0.1256	-0.0402	14.47	0.0001
	60–64	1	-0.0332	-3.3%	0.0251	-0.0824	0.0159	1.75	0.1855
	65–69	1	0.0308	3.1%	0.0260	-0.0201	0.0817	1.40	0.2361
	70+	1	0.1397	15.0%	0.0244	0.0919	0.1875	32.79	<0.0001
	Unknown	1	0.0085	0.9%	0.0312	-0.0526	0.0696	0.07	0.7851
	40–49	0	0	0	0	0	0		
Rated driver gender	Male	1	-0.0531	-5.2%	0.0148	-0.0822	-0.0240	12.80	0.0003
	Unknown	1	-0.1979	-18.0%	0.0456	-0.2873	-0.1086	18.87	<0.0001
	Female	0	0	0	0	0	0		
Rated driver marital status	Single	1	0.1310	14.0%	0.0168	0.0980	0.1640	60.70	<0.0001
	Unknown	1	0.1630	17.7%	0.0451	0.0746	0.2515	13.05	0.0003
	Married	0	0	0.0%	0	0	0		
Risk	Nonstandard	1	0.1614	17.5%	0.0336	0.0955	0.2273	23.05	<0.0001
	Standard	0	0	0	0	0	0		
State	Alabama	1	-0.0293	-2.9%	0.1244	-0.2732	0.2146	0.06	0.8138
	Arizona	1	0.0115	1.2%	0.0929	-0.1706	0.1936	0.02	0.9017
	Arkansas	1	0.0240	2.4%	0.1252	-0.2213	0.2693	0.04	0.8481
	California	1	0.1777	19.4%	0.0774	0.0260	0.3295	5.27	0.0217
	Colorado	1	0.0040	0.4%	0.0787	-0.1503	0.1582	0.00	0.9597
	Connecticut	1	-0.1094	-10.4%	0.0827	-0.2714	0.0526	1.75	0.1858
	Delaware	1	-0.0643	-6.2%	0.1204	-0.3003	0.1717	0.29	0.5934
	District of Columbia	1	0.2939	34.2%	0.1422	0.0151	0.5727	4.27	0.0388
	Florida	1	-0.1884	-17.2%	0.0854	-0.3558	-0.0209	4.86	0.0274
	Georgia	1	-0.1845	-16.8%	0.0959	-0.3725	0.0035	3.70	0.0544
	Hawaii	1	-0.0638	-6.2%	0.1768	-0.4104	0.2828	0.13	0.7182
	Idaho	1	-0.1766	-16.2%	0.1012	-0.3749	0.0217	3.05	0.0808
	Illinois	1	-0.0596	-5.8%	0.0821	-0.2206	0.1013	0.53	0.4677
	Indiana	1	-0.1384	-12.9%	0.0954	-0.3254	0.0486	2.10	0.1469
	Iowa	1	-0.3677	-30.8%	0.1156	-0.5942	-0.1412	10.12	0.0015
	Kansas	1	-0.3424	-29.0%	0.1225	-0.5824	-0.1024	7.82	0.0052

Appendix A: Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	Kentucky	1	-0.3859	-32.0%	0.1222	-0.6255	-0.1463	9.97	0.0016
	Louisiana	1	0.0670	6.9%	0.1298	-0.1875	0.3214	0.27	0.6059
	Maine	1	0.0649	6.7%	0.0958	-0.1227	0.2526	0.46	0.4977
	Maryland	1	-0.1852	-16.9%	0.0847	-0.3513	-0.0191	4.78	0.0288
	Massachusetts	1	-0.1384	-12.9%	0.0887	-0.3122	0.0353	2.44	0.1185
	Michigan	1	0.2859	33.1%	0.0868	0.1159	0.4560	10.86	0.0010
	Minnesota	1	-0.0314	-3.1%	0.0839	-0.1959	0.1331	0.14	0.7084
	Mississippi	1	0.0554	5.7%	0.1918	-0.3205	0.4314	0.08	0.7726
	Missouri	1	-0.1436	-13.4%	0.0978	-0.3353	0.0481	2.15	0.1422
	Montana	1	0.0637	6.6%	0.1016	-0.1355	0.2629	0.39	0.5309
	Nebraska	1	-0.2381	-21.2%	0.1094	-0.4525	-0.0237	4.74	0.0295
	Nevada	1	-0.0194	-1.9%	0.0999	-0.2153	0.1764	0.04	0.8457
	New Hampshire	1	-0.0884	-8.5%	0.0933	-0.2713	0.0945	0.90	0.3434
	New Jersey	1	-0.0320	-3.1%	0.0811	-0.1909	0.1268	0.16	0.6928
	New Mexico	1	-0.0501	-4.9%	0.1057	-0.2572	0.1569	0.23	0.6351
	New York	1	-0.0050	-0.5%	0.0776	-0.1571	0.1471	0.00	0.9488
	North Carolina	1	-0.3110	-26.7%	0.0882	-0.4838	-0.1382	12.44	0.0004
	North Dakota	1	0.0499	5.1%	0.1290	-0.2031	0.3028	0.15	0.6992
	Ohio	1	-0.2415	-21.5%	0.0830	-0.4042	-0.0787	8.46	0.0036
	Oklahoma	1	-0.0326	-3.2%	0.1127	-0.2535	0.1883	0.08	0.7726
	Oregon	1	-0.1238	-11.6%	0.0830	-0.2864	0.0389	2.22	0.1358
	Pennsylvania	1	-0.0271	-2.7%	0.0776	-0.1793	0.1251	0.12	0.7270
	Rhode Island	1	0.0613	6.3%	0.1149	-0.1640	0.2865	0.28	0.5940
	South Carolina	1	-0.3011	-26.0%	0.1126	-0.5219	-0.0804	7.15	0.0075
	South Dakota	1	-0.0673	-6.5%	0.1374	-0.3366	0.2021	0.24	0.6246
	Tennessee	1	-0.0856	-8.2%	0.0964	-0.2745	0.1034	0.79	0.3747
	Texas	1	-0.0717	-6.9%	0.0825	-0.2334	0.0901	0.75	0.3851
	Utah	1	-0.1970	-17.9%	0.0920	-0.3773	-0.0167	4.59	0.0322
	Vermont	1	0.0549	5.6%	0.0994	-0.1400	0.2497	0.30	0.5810
	Virginia	1	-0.0886	-8.5%	0.0820	-0.2493	0.0722	1.17	0.2801
	Washington	1	-0.1126	-10.6%	0.0790	-0.2675	0.0423	2.03	0.1541
	West Virginia	1	-0.1098	-10.4%	0.0929	-0.2919	0.0724	1.39	0.2376
	Wisconsin	1	-0.0853	-8.2%	0.0854	-0.2527	0.0821	1.00	0.3180
	Wyoming	1	0.0164	1.7%	0.1228	-0.2243	0.2572	0.02	0.8935
	Alaska	0	0	0	0	0	0		
Deductible range	0–250	1	0.6557	92.6%	0.0240	0.6088	0.7027	749.41	<0.0001
	251–500	1	0.4193	52.1%	0.0215	0.3771	0.4615	378.87	<0.0001
	1,001+	1	-0.4636	-37.1%	0.1401	-0.7382	-0.1890	10.95	0.0009
	501–1,000	0	0	0	0	0	0		
Registered vehicle density	0–99	1	-0.2348	-20.9%	0.0196	-0.2731	-0.1964	144.09	<0.0001
	100–499	1	-0.1372	-12.8%	0.0151	-0.1668	-0.1075	82.27	<0.0001
	500+	0	0	0	0	0	0		
Rear camera		1	-0.0117	-1.2%	0.0145	-0.0400	0.0167	0.65	0.4200
EyeSight		1	0.0052	0.5%	0.0241	-0.0419	0.0524	0.05	0.8280

Highway Loss Data Institute

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iihs-hldi.org

The Highway Loss Data Institute is a nonprofit public service organization that gathers, processes, and publishes insurance data on the human and economic losses associated with owning and operating motor vehicles. DW201504 SK RUN190

www.iihs.org

Experiences of Owners of Non-Luxury Vehicles with Collision Avoidance Technology

TRB 93rd Annual Meeting
Washington, DC • January 14, 2014

Jessica B. Cicchino

Background

- Collision avoidance technologies have potential to prevent up to 20 percent of police-reported crashes
- Early look at insurance data shows reductions in claim rates associated with forward collision avoidance systems
- Full effectiveness of technologies depends on how they are used
- Previous surveys with Volvo and Infiniti owners found high acceptance of systems among drivers
- Technologies initially available in luxury vehicles, and now increasingly available in a larger variety of vehicles

Objectives

- To gather in-depth information on drivers' opinions about systems
- To understand drivers' use of systems and how they may affect driver behavior
- To assess if use of systems on luxury vehicles differs from use on more mainstream vehicles
- To examine if use of systems differs by driver age and duration of ownership


Forward collision avoidance
INSURANCE INSTITUTE
FOR HIGHWAY SAFETY
HIGHWAY LOSS
DATA INSTITUTE


Lane departure warning and prevention
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Blind spot detection
INSURANCE INSTITUTE
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HIGHWAY LOSS
DATA INSTITUTE

Adaptive cruise control

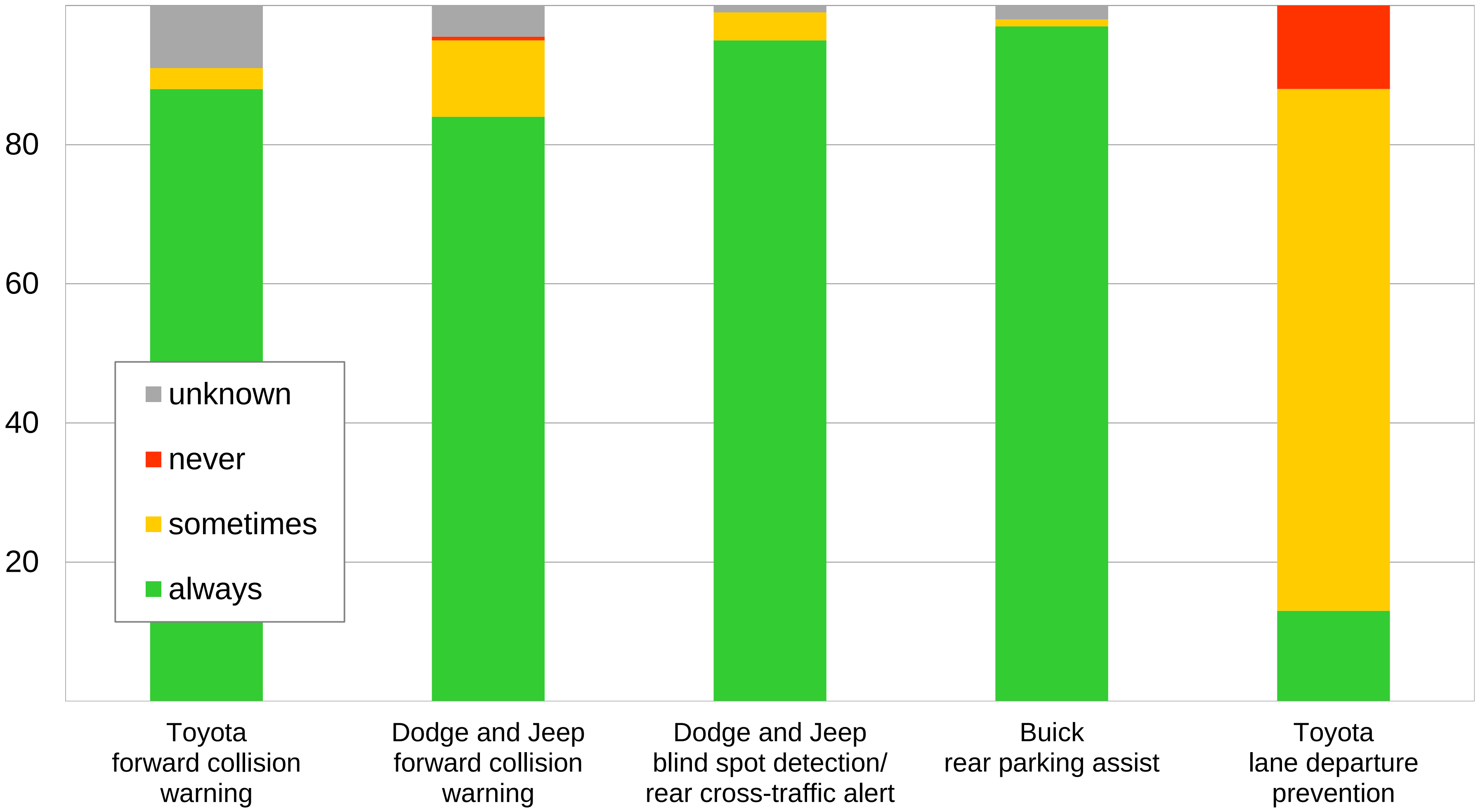
INSURANCE INSTITUTE
FOR HIGHWAY SAFETY

HIGHWAY LOSS
DATA INSTITUTE

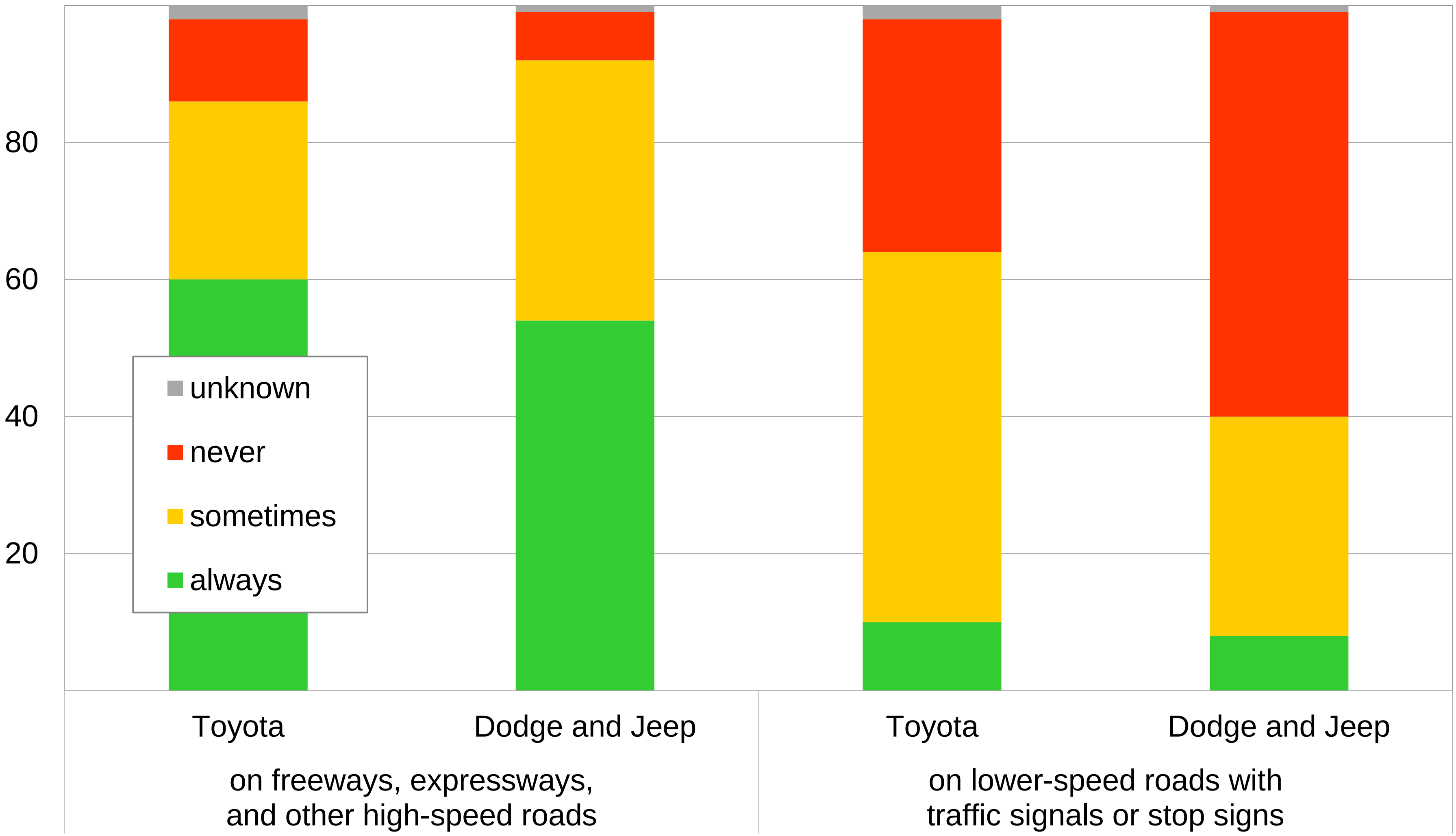
Surveys of owners of non-luxury vehicles with crash avoidance technologies

- 183 Toyota Sienna and Toyota Prius owners
  - 183 owners with adaptive cruise control and forward collision warning with autonomous braking
  - 120 Prius owners with lane departure prevention
- 430 Dodge Charger, Dodge Durango, and Jeep Grand Cherokee owners
  - 215 owners with adaptive cruise control and forward collision warning
  - 215 owners with blind spot detection and rear cross-traffic alert
- 426 Buick Lucerne owners with rear parking assist

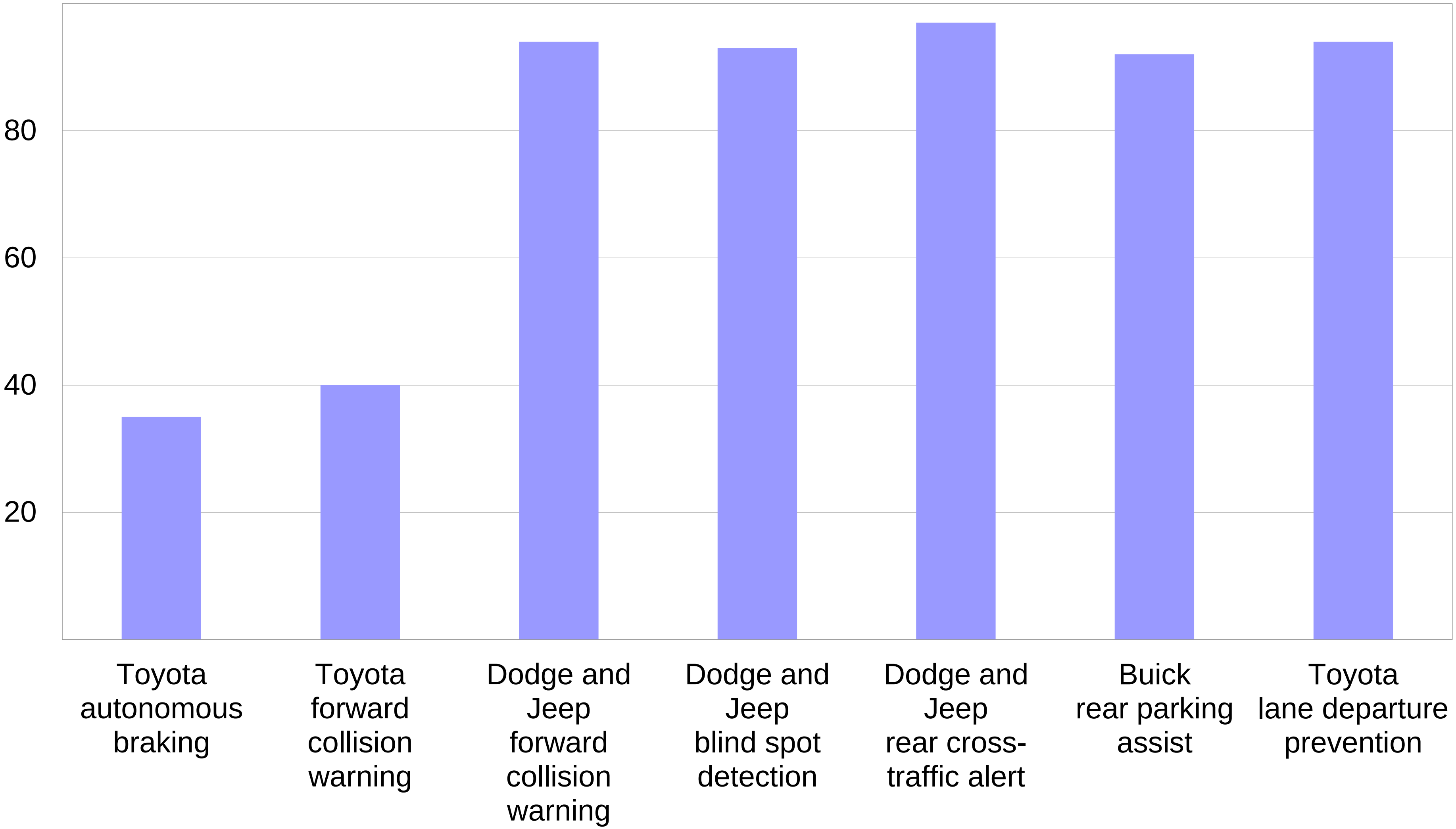
Percent of owners who drive with systems on



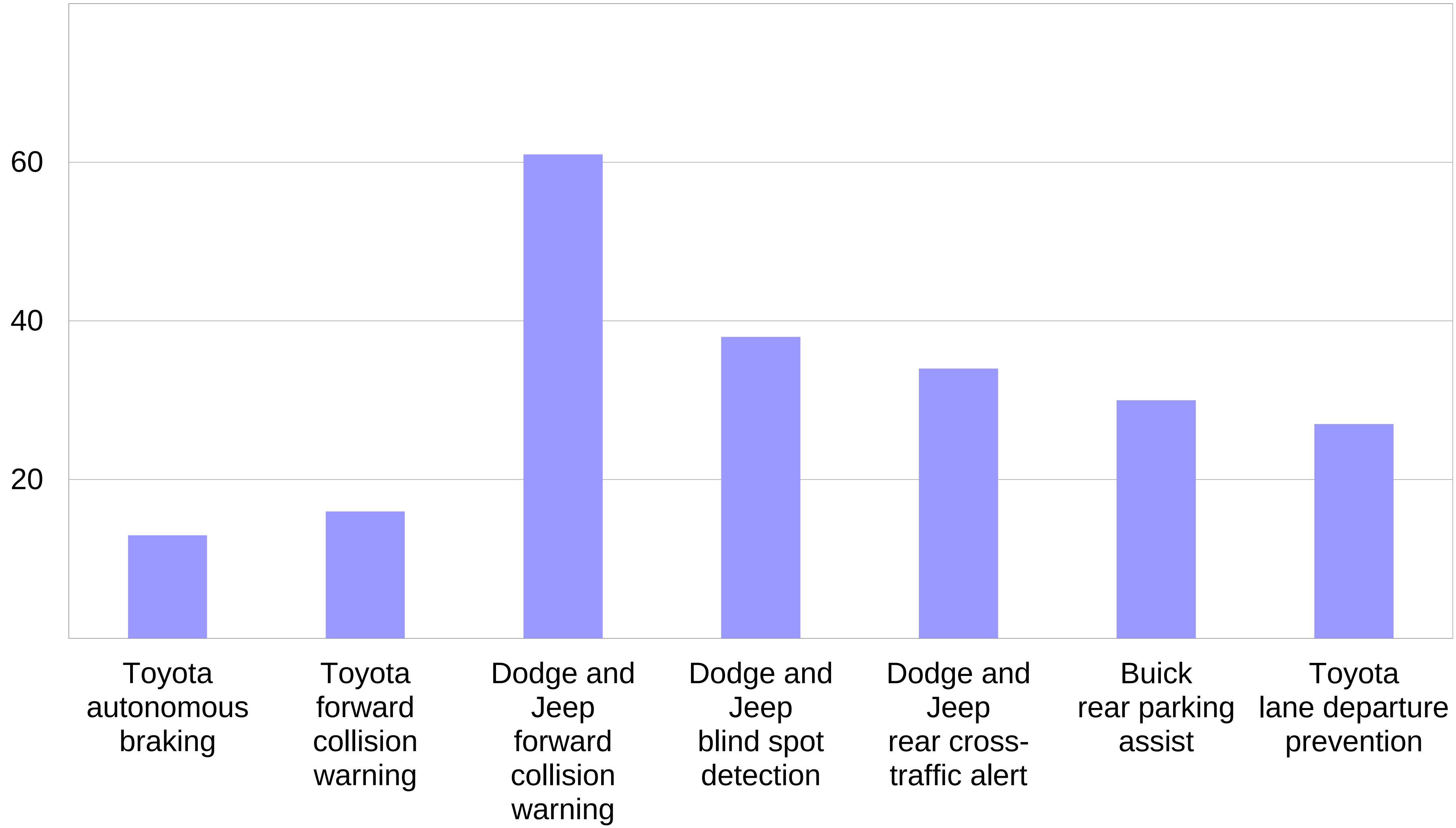
Percent of owners who use adaptive cruise control



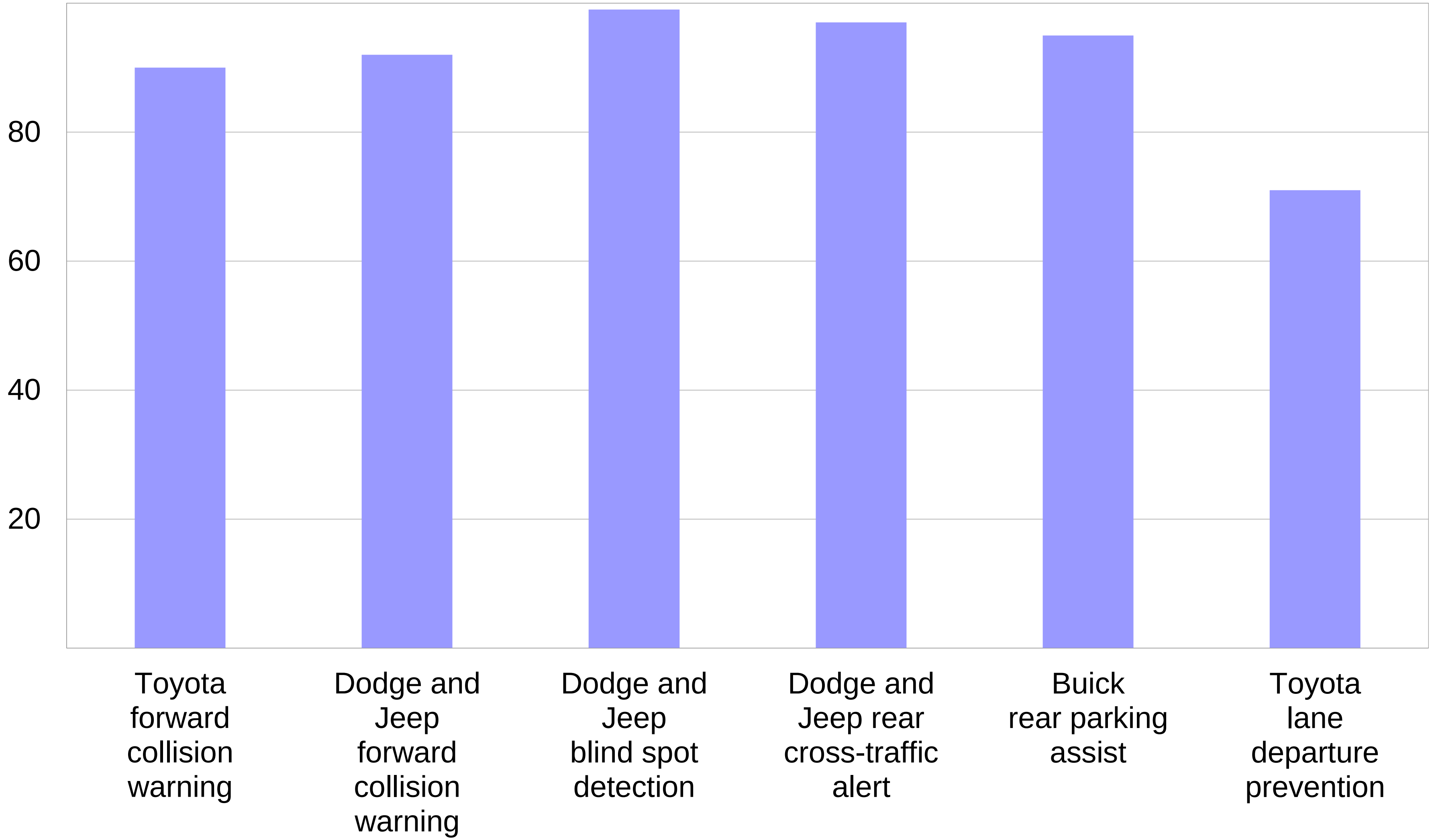
Percent of owners who report system activations



Percent of owners who report false or unnecessary activations



Percent of owners who would want systems again



Percent of drivers reporting safer driving behaviors with systems

Lane departure prevention

	Infiniti (2009)	Toyota (2013)
Drift from lane less often	68	35
Use turn signal more often	64	14

Percent of drivers reporting safer driving behaviors with systems

Adaptive cruise control and blind spot detection

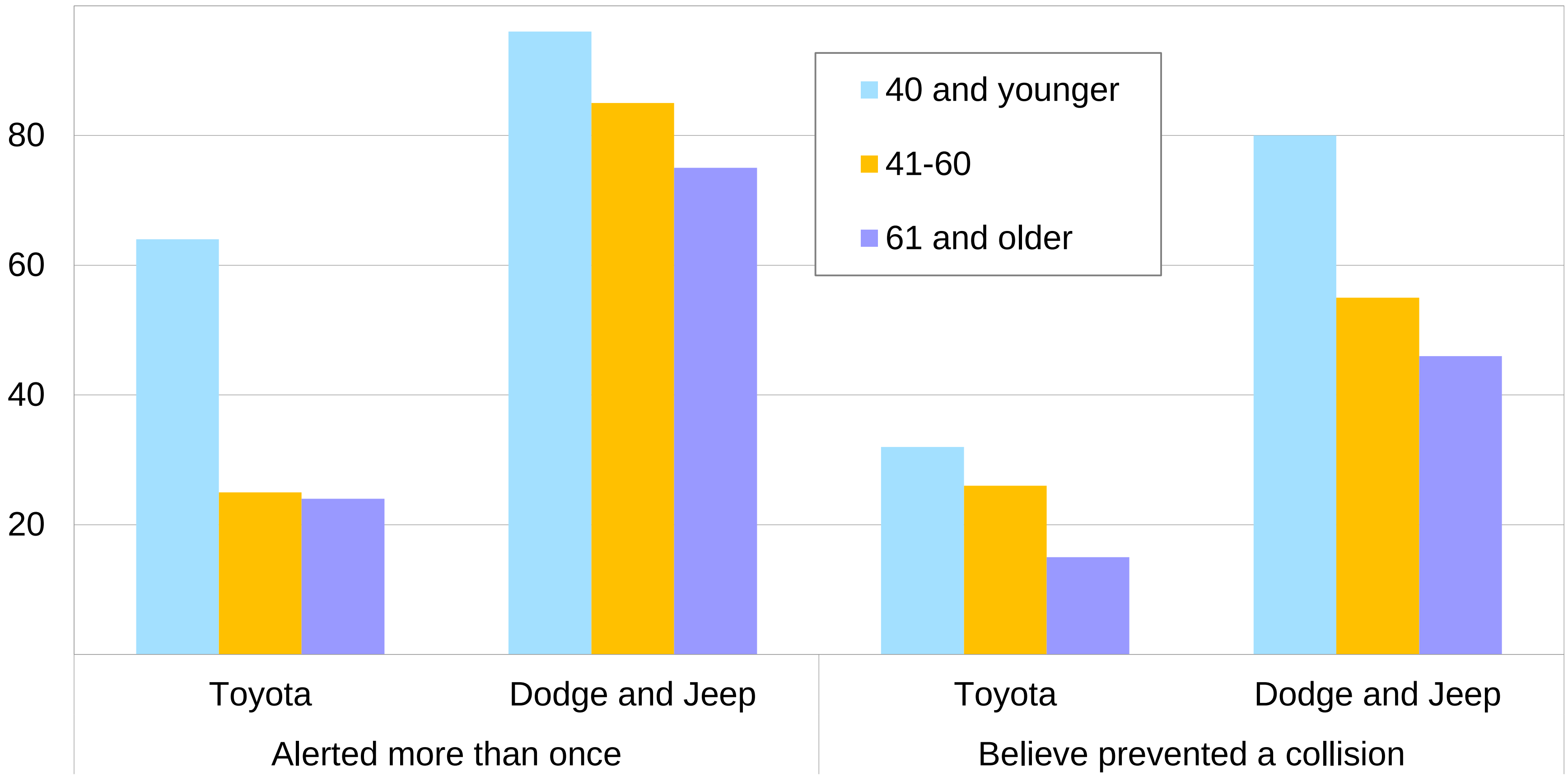
	Volvo (2009, 2012)	Toyota, Dodge, and Jeep (2013)
Follow vehicles less closely with adaptive cruise control	46	36-41
Check side mirrors more frequently with blind spot detection	25	20 for Dodge and Jeep

Percent of owners reporting less safe driving behaviors with systems

	Volvo (2009, 2012)	Toyota, Dodge, and Jeep (2013)
Follow vehicle ahead more closely with forward collision warning	2-5	16 for Toyota
Wait for the forward collision warning light or sound before slowing as they approached another vehicle	4	6-14
Turned their heads less often with blind spot detection	13	33 for Dodge and Jeep

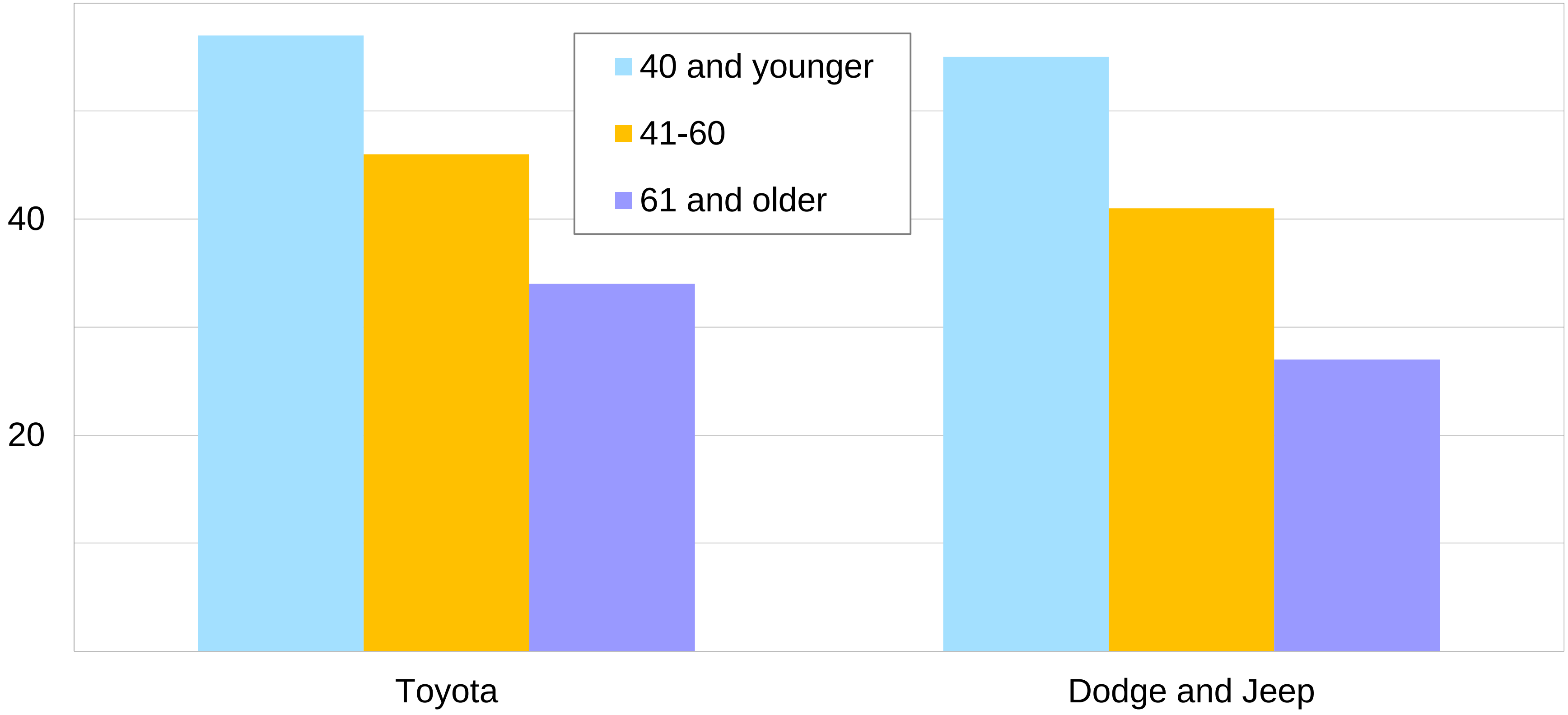
Percent of owners reporting benefit from forward collision warning

By owner age



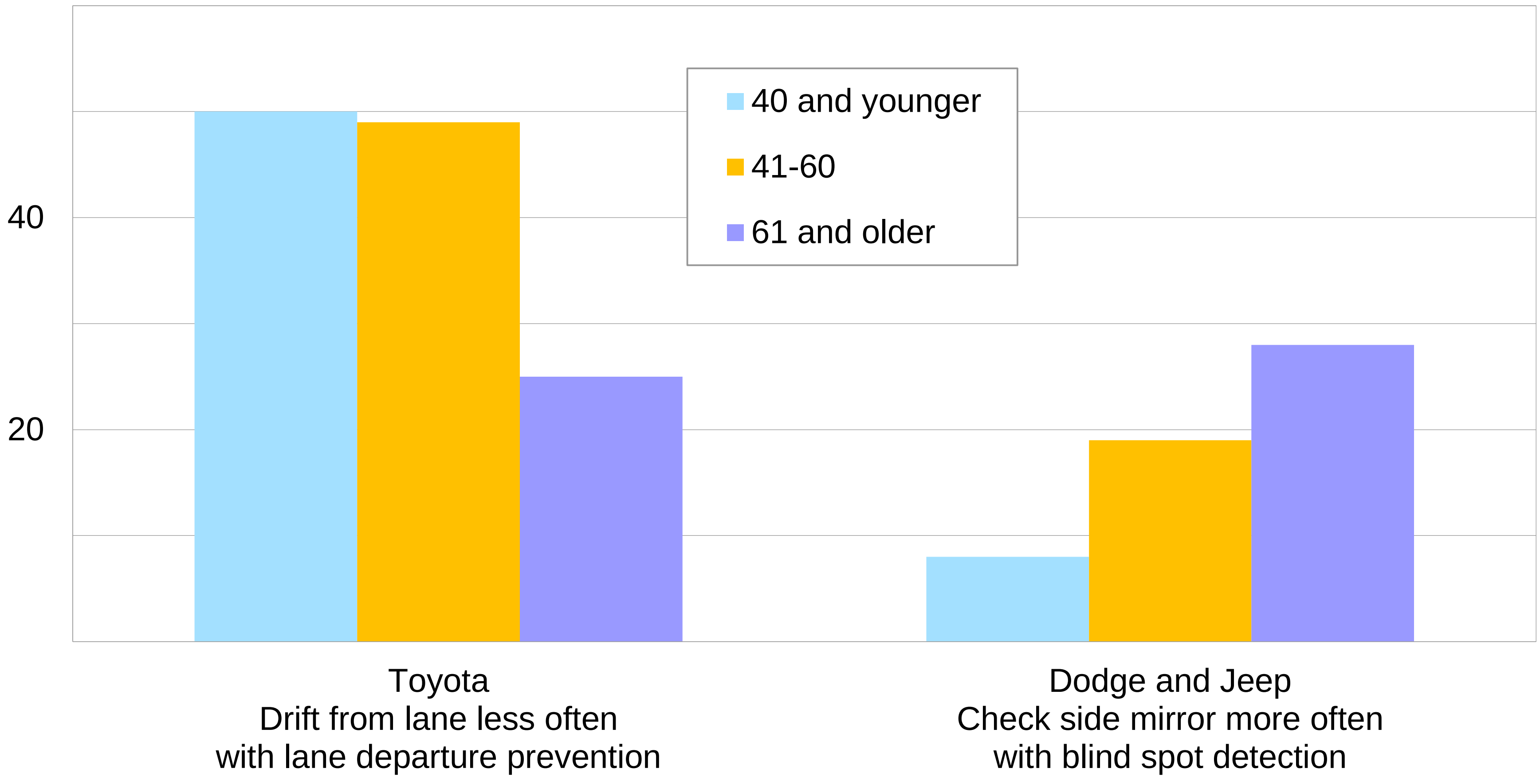
Percent of owners reporting they follow the vehicle ahead less closely with adaptive cruise control

By owner age



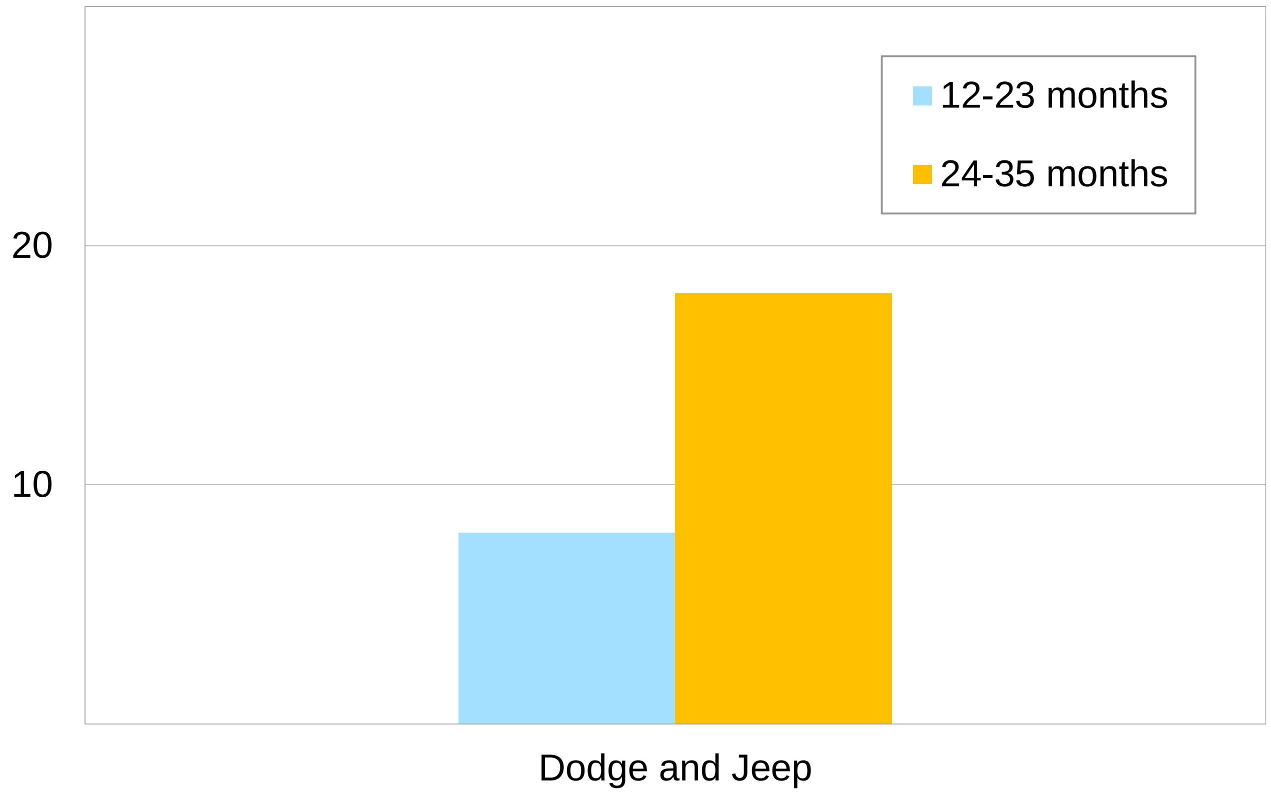
Percent of owners reporting safer driving behaviors with systems

By owner age



Percent of owners reporting at least sometimes waiting for forward collision warning before braking

By duration of ownership



Conclusions

- Use of systems is consistent with previous surveys:
  - Most owners leave systems on and would want again
  - Lane departure prevention was least likely to be used
- But reports of changes in driving habits were not as positive for non-luxury models, in comparison with previous surveys with luxury models
- Drivers ages 40 and younger experienced more warnings and generally reported the most positive impact on driving habits
- Although the current surveys focused on non-luxury models, the retail prices of models with crash avoidance options were high and substantially greater than the base models without the options

www.iihs.org

Dedicated to reducing deaths, injuries, and property damage on the highway

Insurance Institute for Highway Safety
Highway Loss Data Institute

Consumer Safety Information Programs at IIHS

24th ESV Conference
Gothenburg, Sweden
10 June, 2015

David Zuby
Executive Vice President &
Chief Research Officer

iihs.org

Booster seats

Belt-fitting boosters don’t always fit

IIHS has rated boosters since 2008

Good belt fit
lap belt flat on upper thighs;
Shoulder belt centered on chest, shoulder

Poor belt fit
Lap belt too high on abdomen;
Shoulder belt too low on shoulder

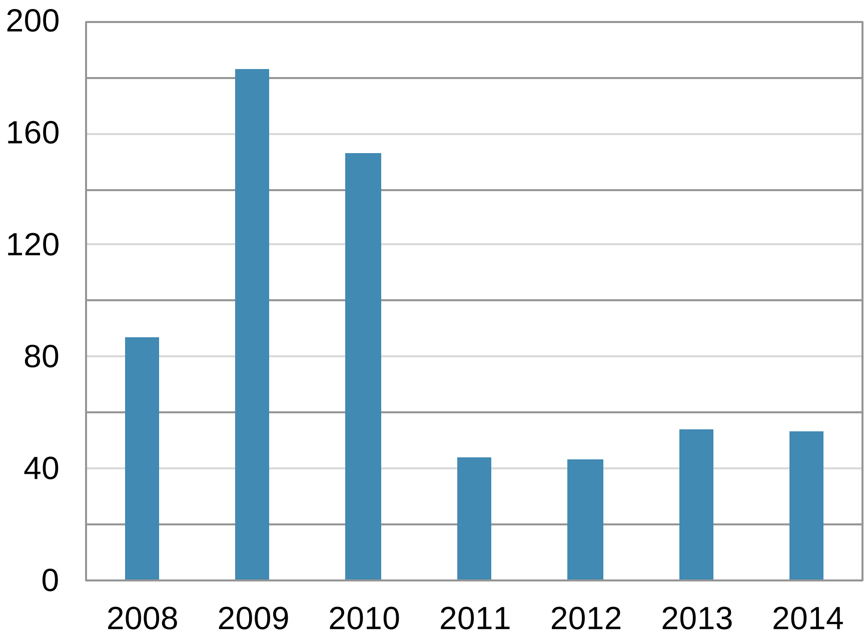
IIHS HLDI

Belt fit measurement rig

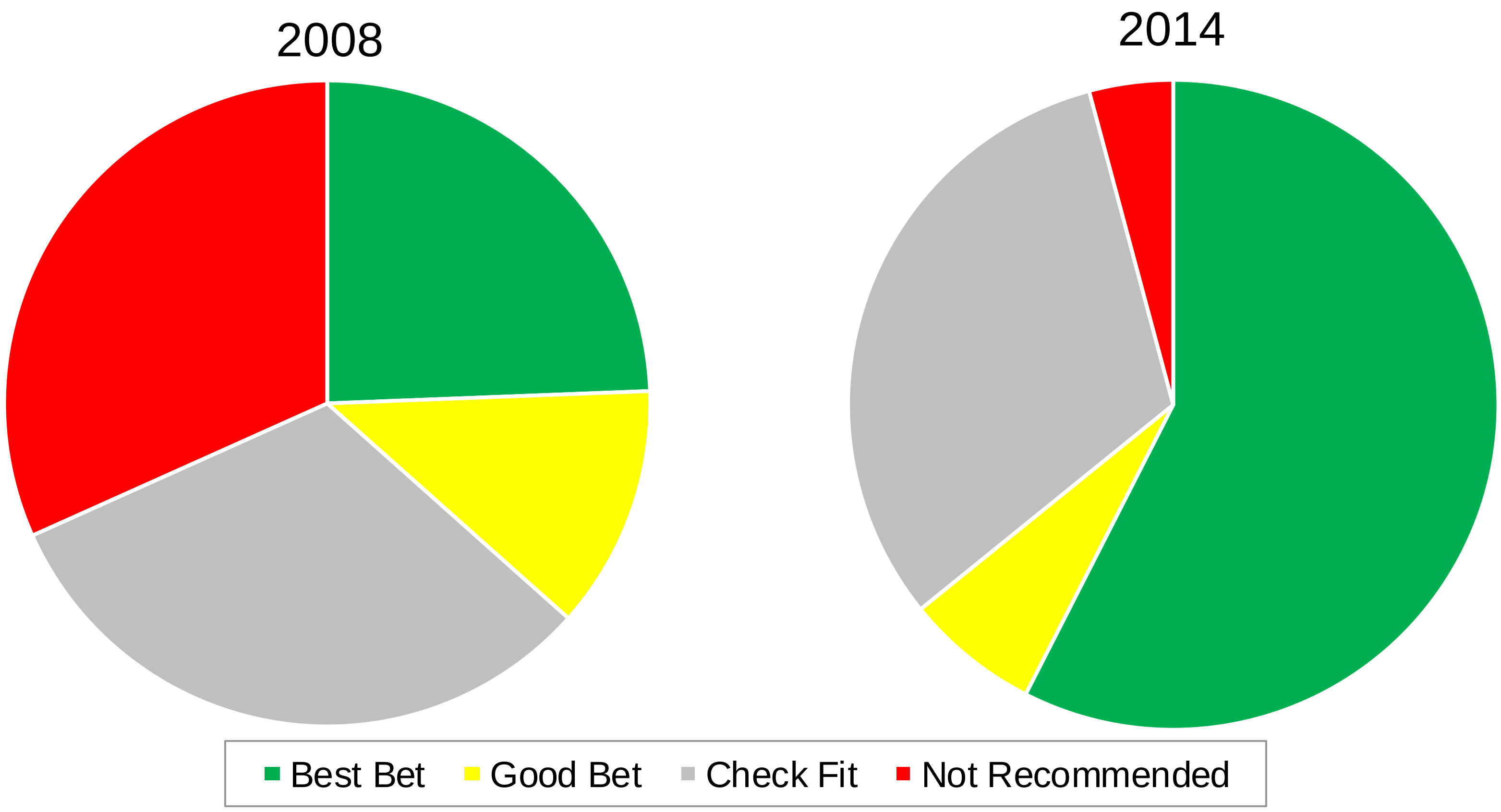
Movable anchorages to match range observed in vehicles

Publication of ratings is widely viewed

Estimated TV audience in millions



Boosters have improved



Truck underride guards

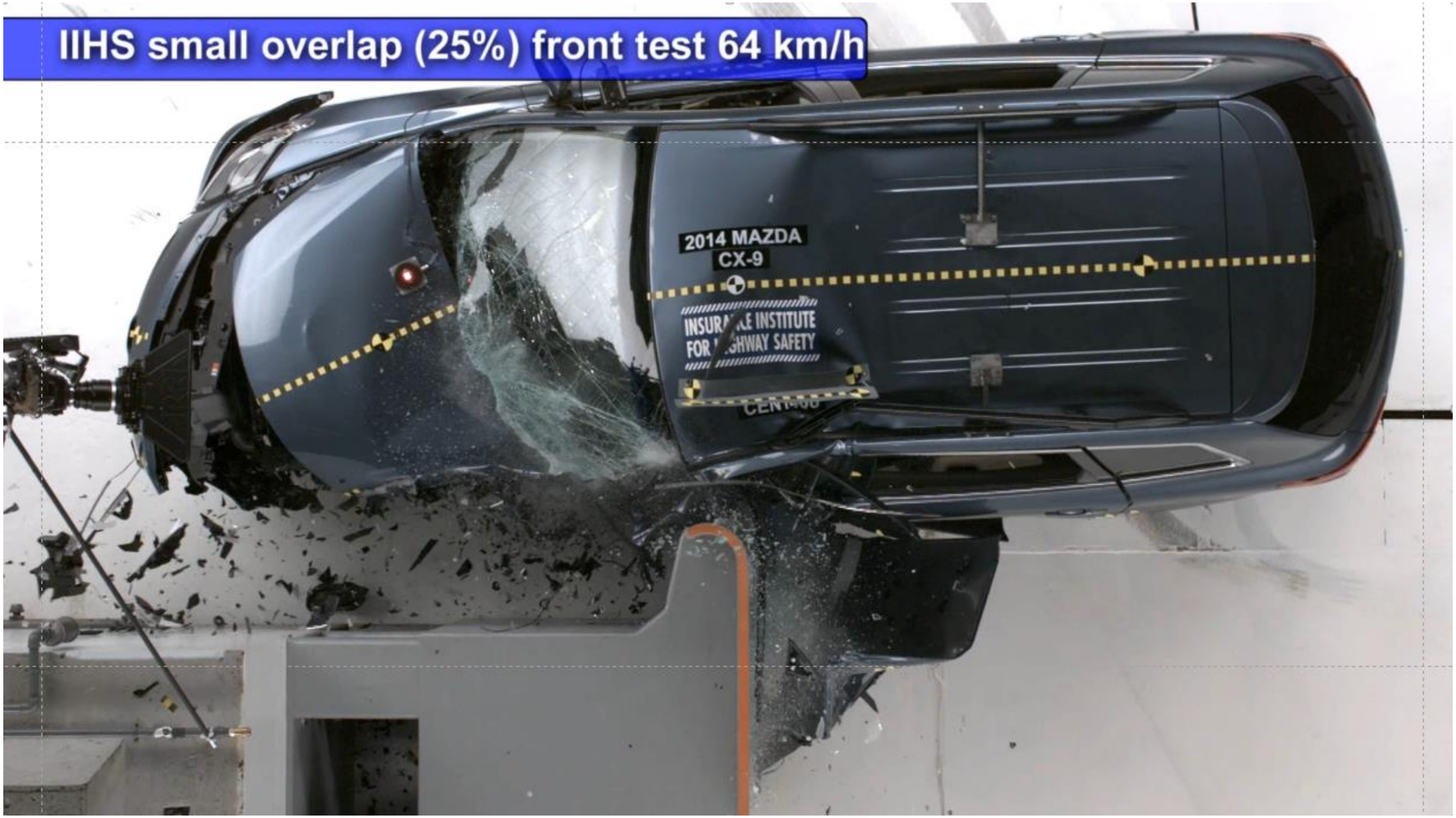
Truck underride tests

Published in 2011 and 2013

Underride guards are improving

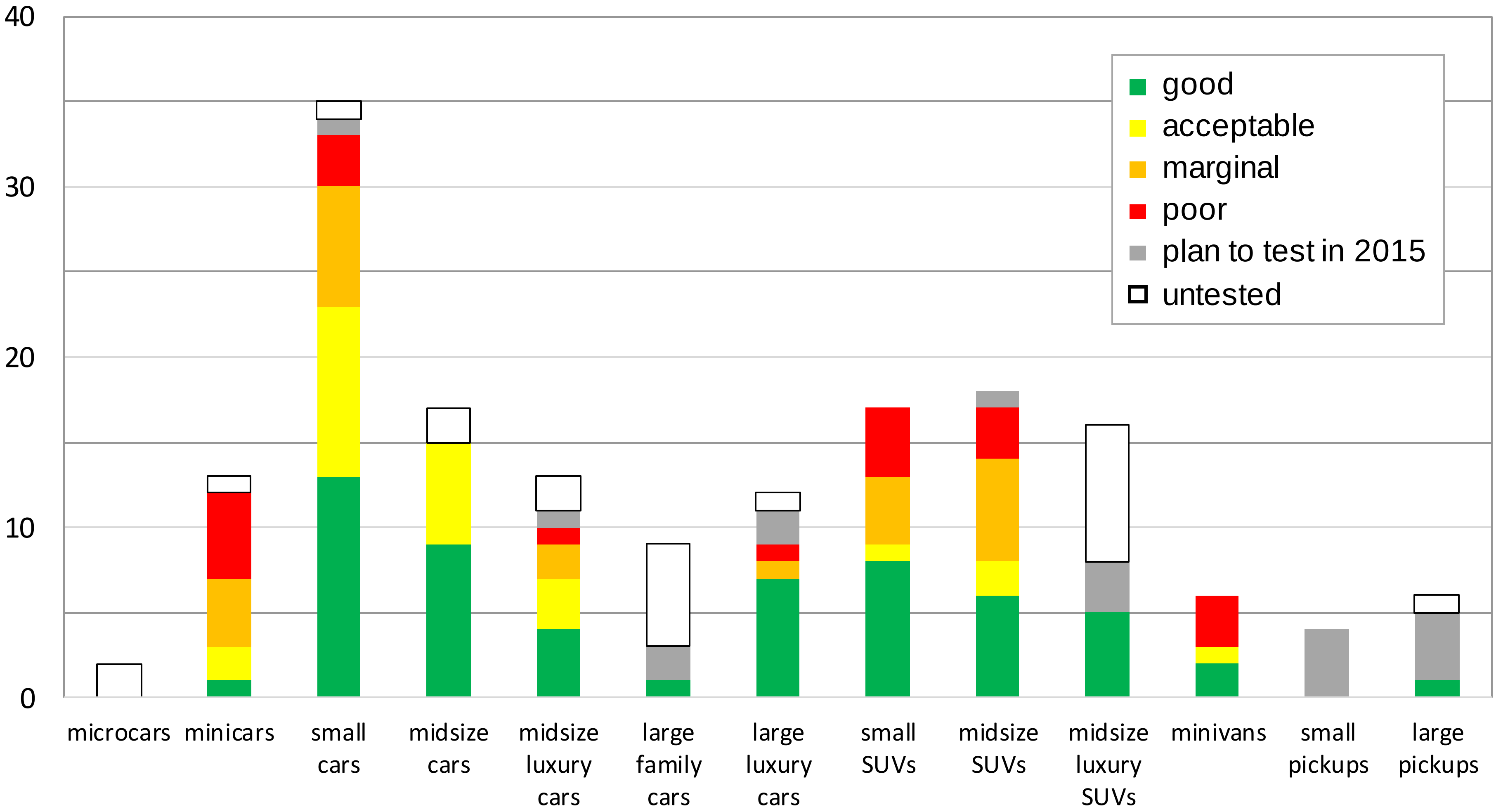
Small overlap front crashworthiness

Small overlap front crashworthiness since 2012



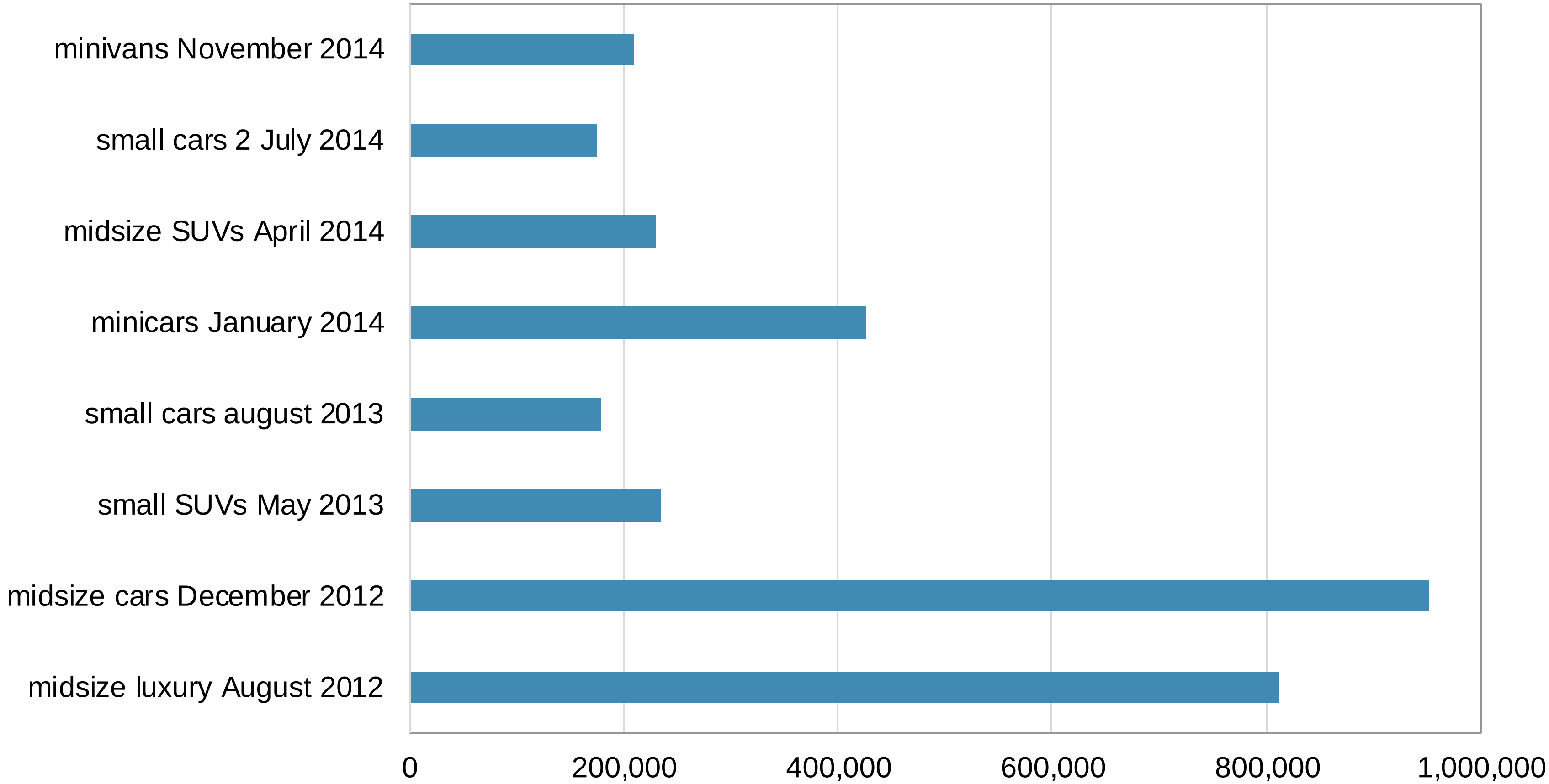
Number of vehicles tested for small overlap ratings

Evaluated 126 of 168 models on our list



IIHS using more new media

Number of views on IIHS YouTube channel as of 23 January, 2015



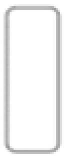
Sales before and after small overlap release

Surveys of automobile dealerships

	week before announcement	week after announcement	percent change
S60	267	376	41
all Volvo models	809	956	18
Forester	1,243	1,422	14
all Subaru models	3,970	4,397	11
Patriot	426	419	-2
all Jeep models	2,314	2,325	<1

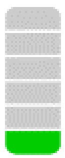
Front crash prevention

Front crash prevention ratings



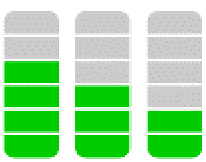
NOT AVAILABLE

vehicles without forward collision warning or autobrake; or vehicles equipped with a system that doesn't meet NHTSA or IIHS criteria



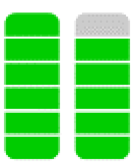
BASIC

vehicles earning 1 point for forward collision warning or 1 point in either 12 or 25 mph test



ADVANCED

vehicles with autobrake that achieve 2-4 points for forward collision warning and/or performance in autobraking tests



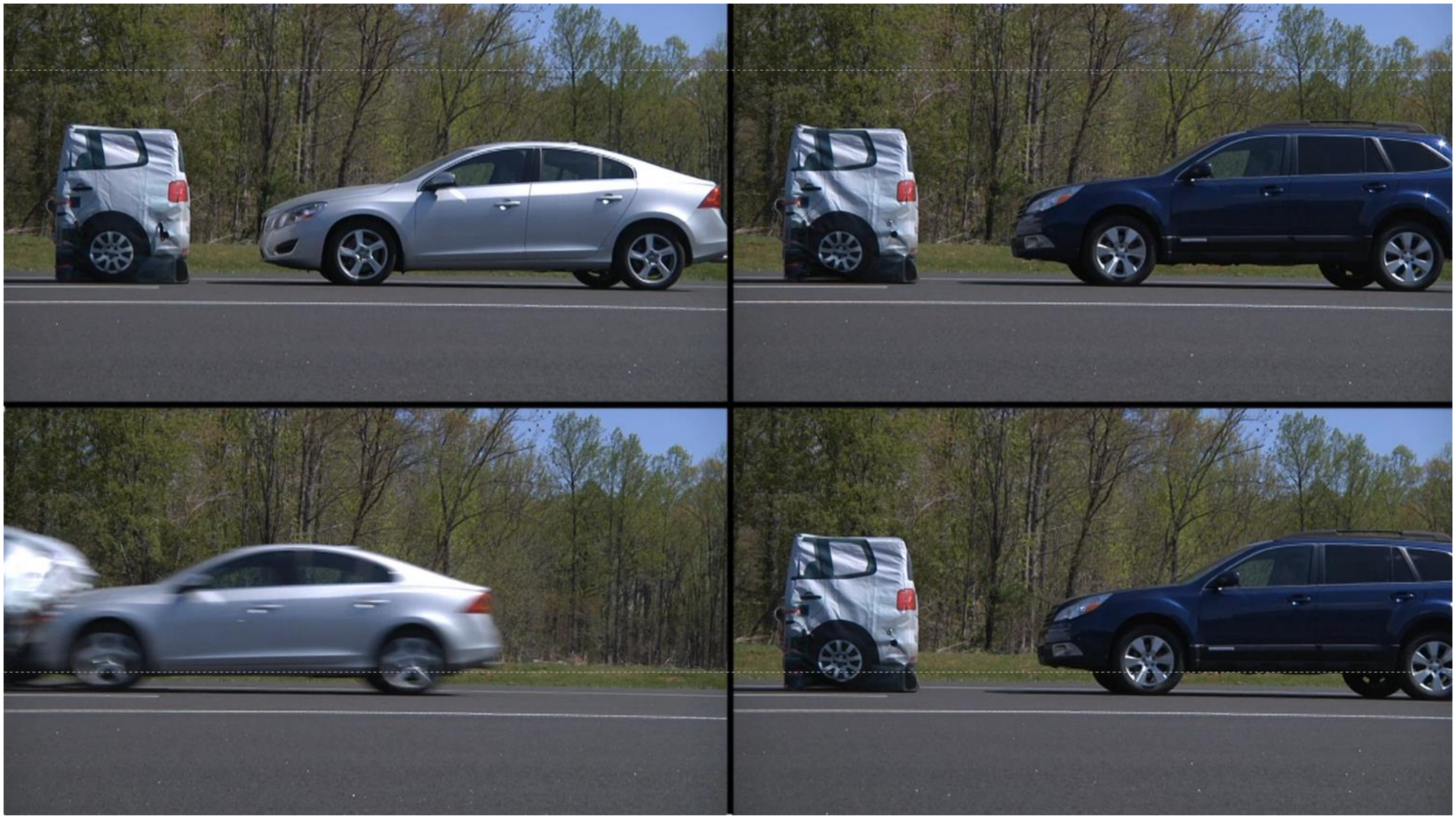
SUPERIOR

vehicles with autobrake that achieve 5-6 points for forward collision warning and/or performance in autobraking tests

Autobrake performance tests

Volvo S60 with City Safety

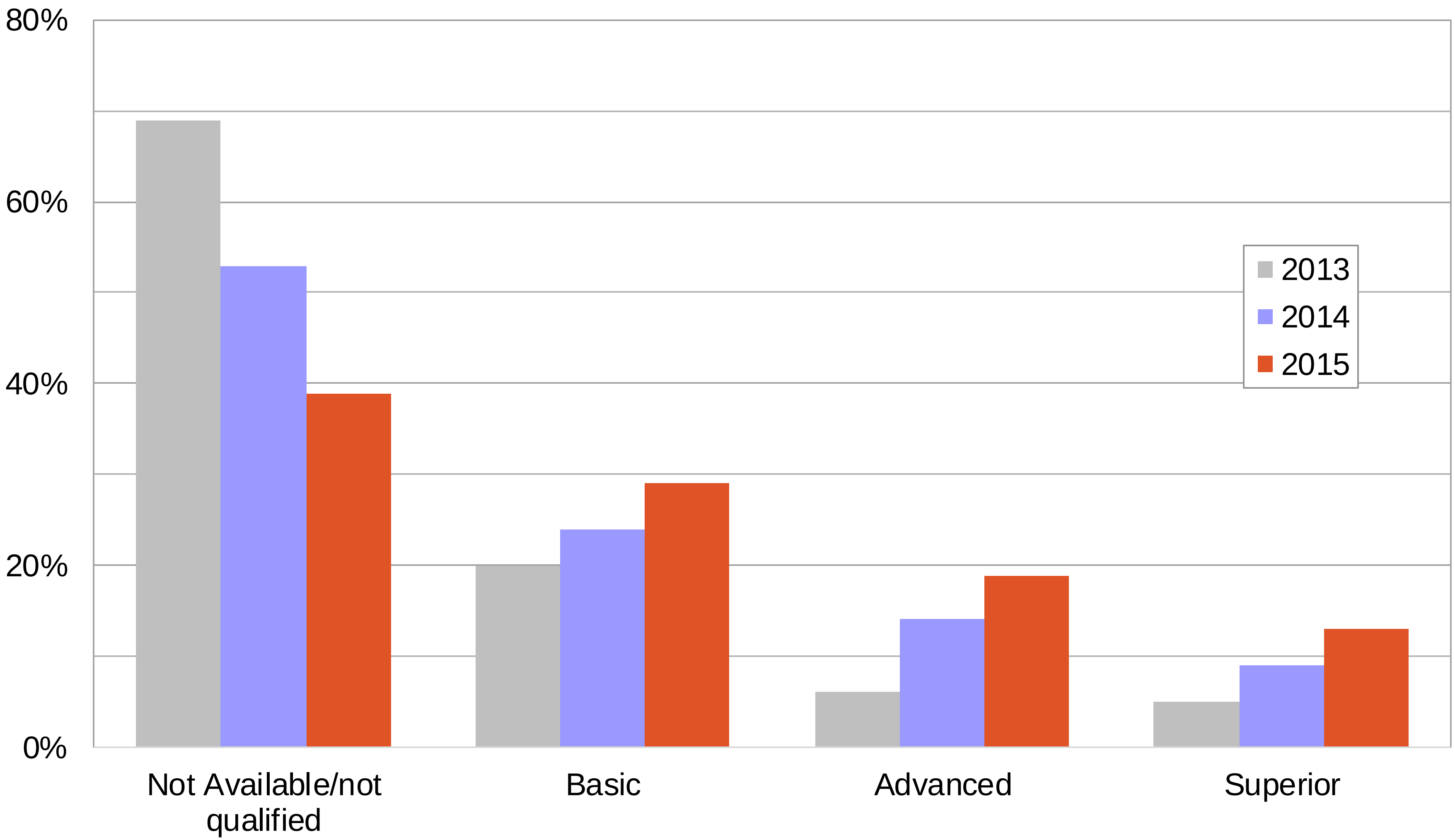
Subaru Outback with Eyesight



12 mph

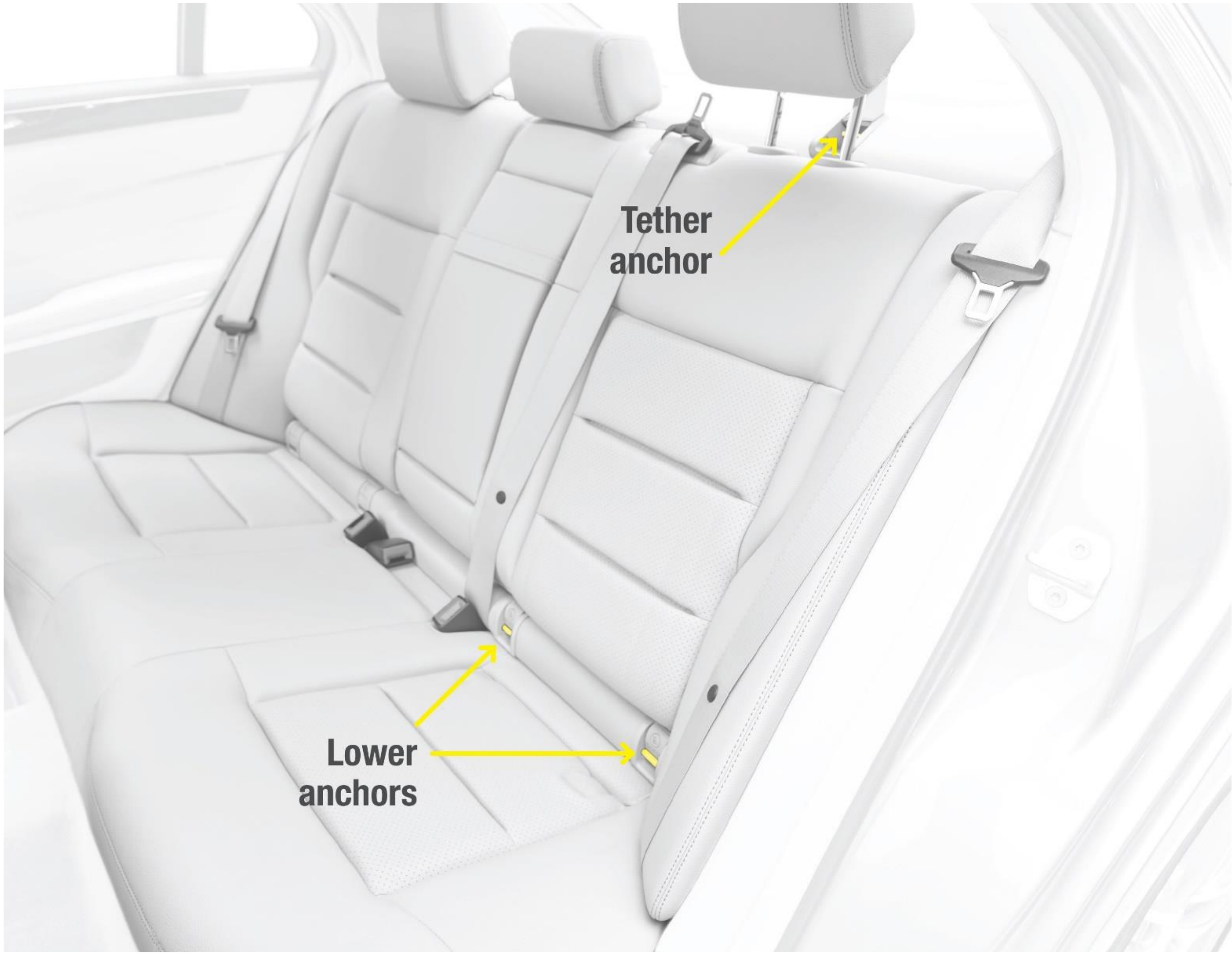
25 mph

AEB ratings by model year



Vehicle LATCH systems

Lower Anchors and Tethers for Children (LATCH)



LATCH ease-of-use criteria

- Lower anchors must
  - Not be very deep within the seat
  - Have plenty of room to maneuver around
  - Require little force to attach connectors
- Tether anchors must
  - Be located in an easy-to-find location on the rear deck in sedans or middle of the seatback in other vehicle types
  - Have no hardware that could be confused for a tether anchor or be clearly labeled

Overall vehicle rating

Based on LATCH hardware required by federal government

G GOOD	vehicle meets all ease-of-use criteria for 2 LATCH positions in 2nd row and 1 additional tether anchor
A ACCEPTABLE	2 LATCH positions meet most of the criteria
M MARGINAL	at least 1 LATCH position meets only a couple of the criteria
P POOR	at least 1 LATCH position meets only 1 or none of the criteria

IIHS HLDI

102 current passenger vehicles evaluated

	number of vehicles
G	4
A	43
M	44
P	11

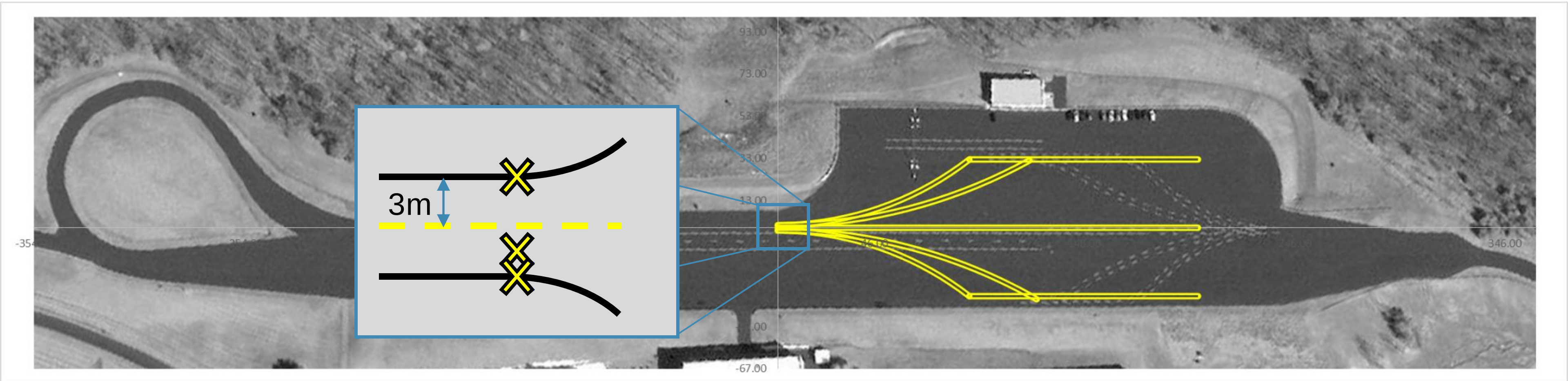
First public release of LATCH ratings

18 June, 2015

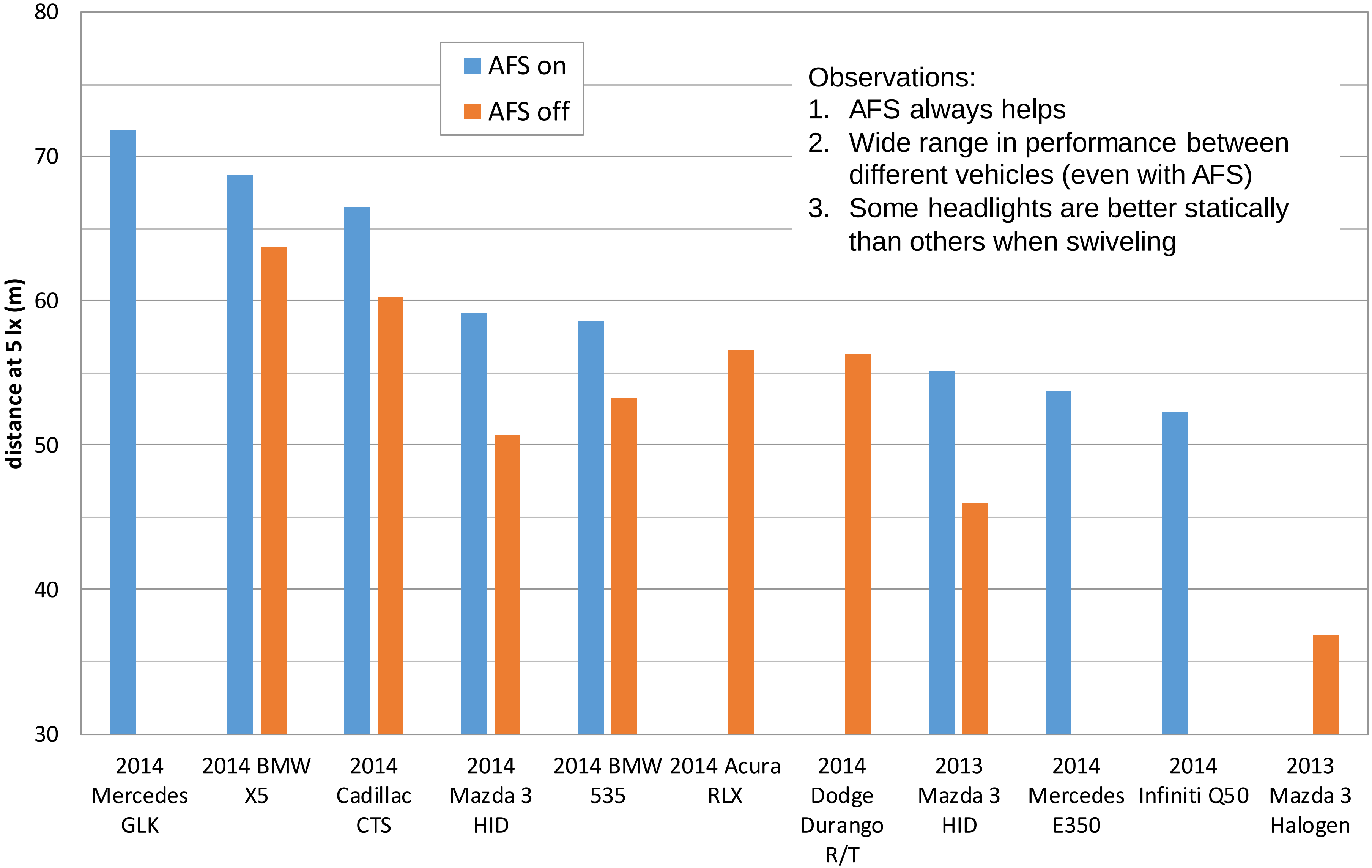
Headlights

Dynamic headlight test setup

- 150 m left and right curves at 65 km/h
- 250 m left and right curves at 80 km/h
- Straightaway at 65 km/h
- For each approach, illuminance measurements are recorded at 3 locations. At each location 3 sensors provide a pitch-corrected average.
  - Visibility: right and left edges of road, 25 cm above ground
  - Glare: center of oncoming lane, 110 cm above ground



Low beam 4 curve average—R edge of road



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More information and links to our YouTube channel and Twitter feed at iihs.org

David Zuby
EVP & Chief Research Officer
dzuby@iihs.org

INSURANCE INSTITUTE FOR HIGHWAY SAFETY

HIGHWAY LOSS DATA INSTITUTE

SAE International

www.iihs.org

Measuring Crash Avoidance System Effectiveness with Insurance Data

2013 Government/Industry Meeting
Washington, DC ● January 30, 2013

Matthew Moore, Vice President, HLDI

The Insurance Institute for Highway Safety,

founded in 1959, is an independent, nonprofit, scientific, and educational organization dedicated to reducing the losses — deaths, injuries, and property damage — from crashes on the nation's highways.

The Highway Loss Data Institute,

founded in 1972, shares and supports this mission through scientific studies of insurance data representing the human and economic losses resulting from the ownership and operation of different types of vehicles and by publishing insurance loss results by vehicle make and model.

Both organizations are wholly supported by auto insurers.

Highway Loss Data Institute

HLDI data providers have 80% share of U.S. auto insurance market

- AAA Northern California, Nevada and Utah
- AIG Agency
- Allstate
- American Family
- Amica
- ANPAC
- Auto Club Group
- Automobile Insurers Bureau of Mass.
- Chubb
- COUNTRY
- Erie
- Farm Bureau Financial Services (Iowa Farm Bureau)
- Farmers
- Foremost
- GEICO
- GMAC
- The Hartford
- High Point
- Kentucky Farm Bureau
- Liberty Mutual
- MetLife
- Nationwide
- PEMCO
- Progressive
- Rockingham
- Safeco
- Secura Insurance
- State Farm
- Tennessee Farm Bureau
- Travelers
- Unitrin
- USAA

Size of HLDI passenger vehicle database

Number of unique VINs in files, January 2013

model year	number of vehicles
2003	16,037,878
2004	15,837,777
2005	15,539,974
2006	14,555,883
2007	14,214,501
2008	12,444,140
2009	8,041,491
2010	8,984,595
2011	9,080,974
2012	8,550,880
total	123,288,093

Insurance coverages

- Collision
- Physical damage liability
- Bodily injury liability
- Medical payments
- Personal injury protection

Insurance measures

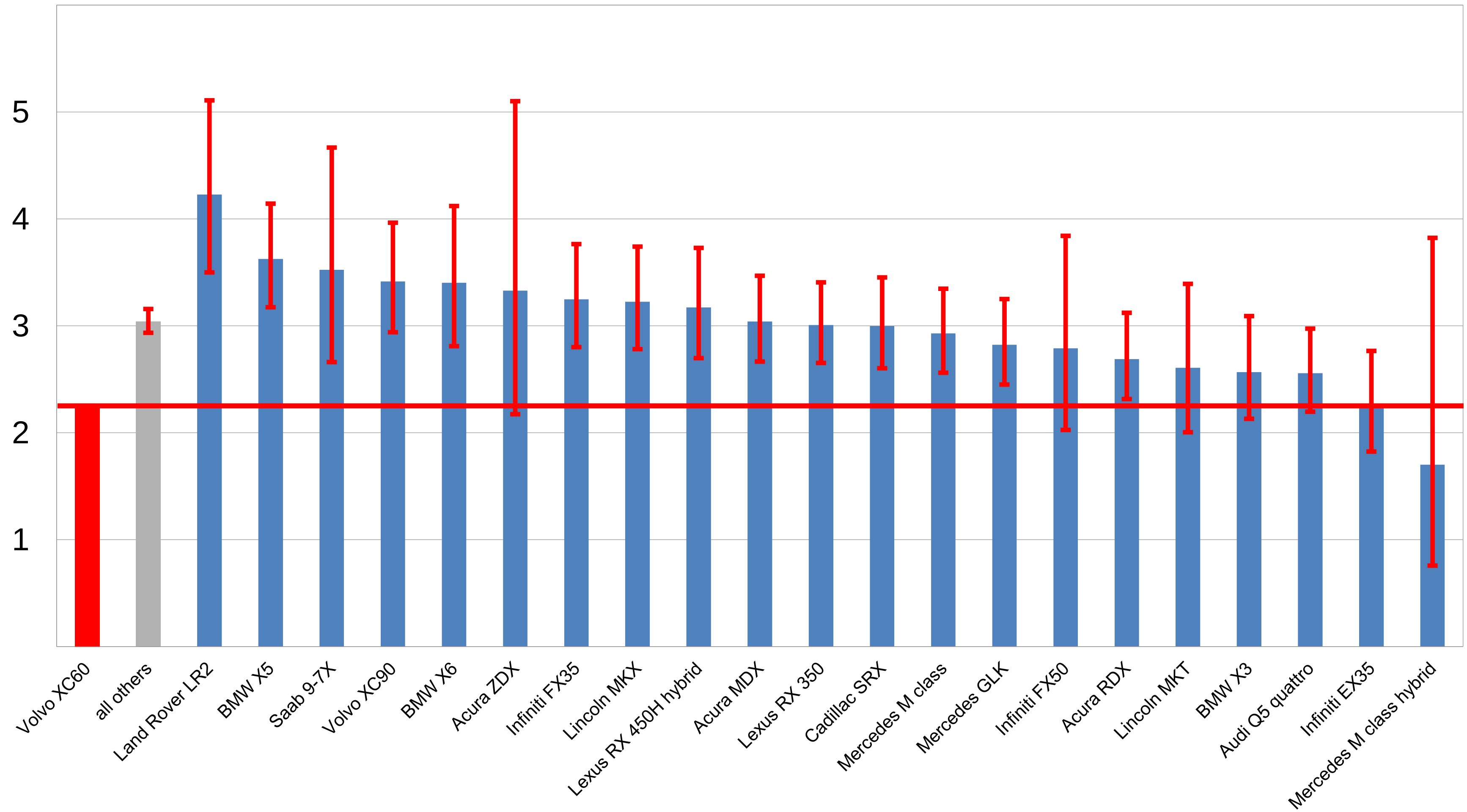
- Exposure
  - Expressed in insured vehicle years
  - One insured vehicle year represents 1 vehicle insured for 1 year or 2 vehicles insured for 6 months
- Claim frequency
  - Calculated by dividing claims by exposure
  - Expressed as the number of claims per selected number of insured vehicle years (exposure)
- Claim severity
  - Represents the average cost per claim
  - Calculated by dividing dollars paid for all claims by the claim count
- Overall losses
  - Represents the average cost per insured vehicle (year)
  - Calculated by dividing total dollars paid for claims by exposure

Evaluation of crash avoidance technologies

Volvo City Safety

Property damage liability claim frequencies for 2010 Volvo XC60

With City Safety vs. other 2009-10 midsize luxury SUVs



Early information about new technology

Example of Volvo City Safety loss reduction benefits (HLDI)

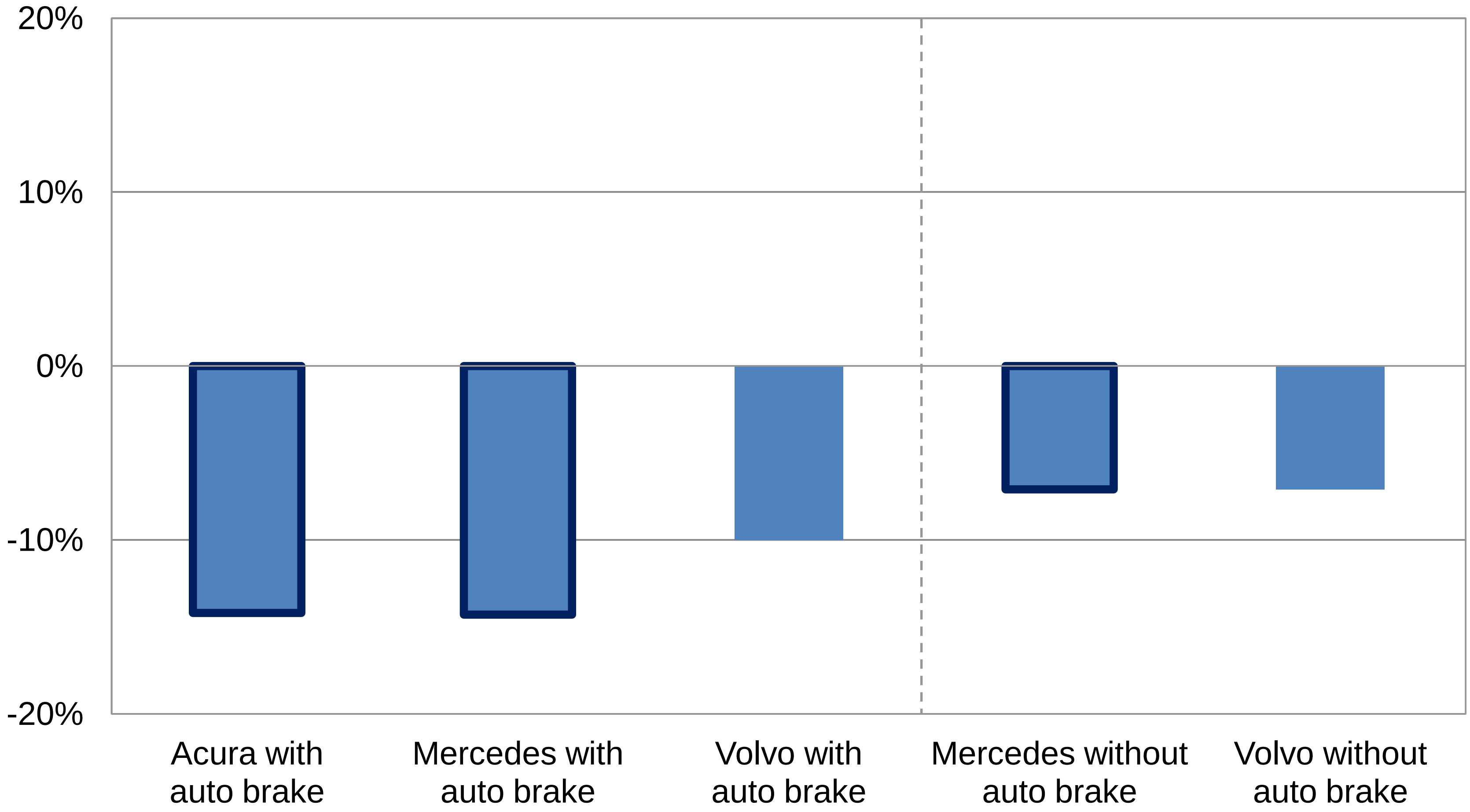
vs. other midsize luxury SUVs	claim frequency			claim severity			overall losses		
property damage liability	-29.3%	-26.6%	-23.9%	$174	$270	$362	-$21	-$166	-$125
bodily injury	-58.9%	-51.1%	-41.8%						
collision	-23.8%	-22.0%	-20.1%	-$645	-$517	-$392	-$109	-$98	-$86

vs. other Volvos	claim frequency			claim severity			overall losses		
property damage liability	-24.5%	-19.2%	-13.7%	$488	$646	$794	-$5	$2	$7
bodily injury	-62.3%	-49.2%	-31.4%						
collision	-20.2%	-16.7%	-13.0%	-$362	-$147	$58	-$72	-$53	-$36

Forward collision warning and mitigation systems

Forward collision warning with and without autonomous braking

Property damage liability claim frequency by manufacturer



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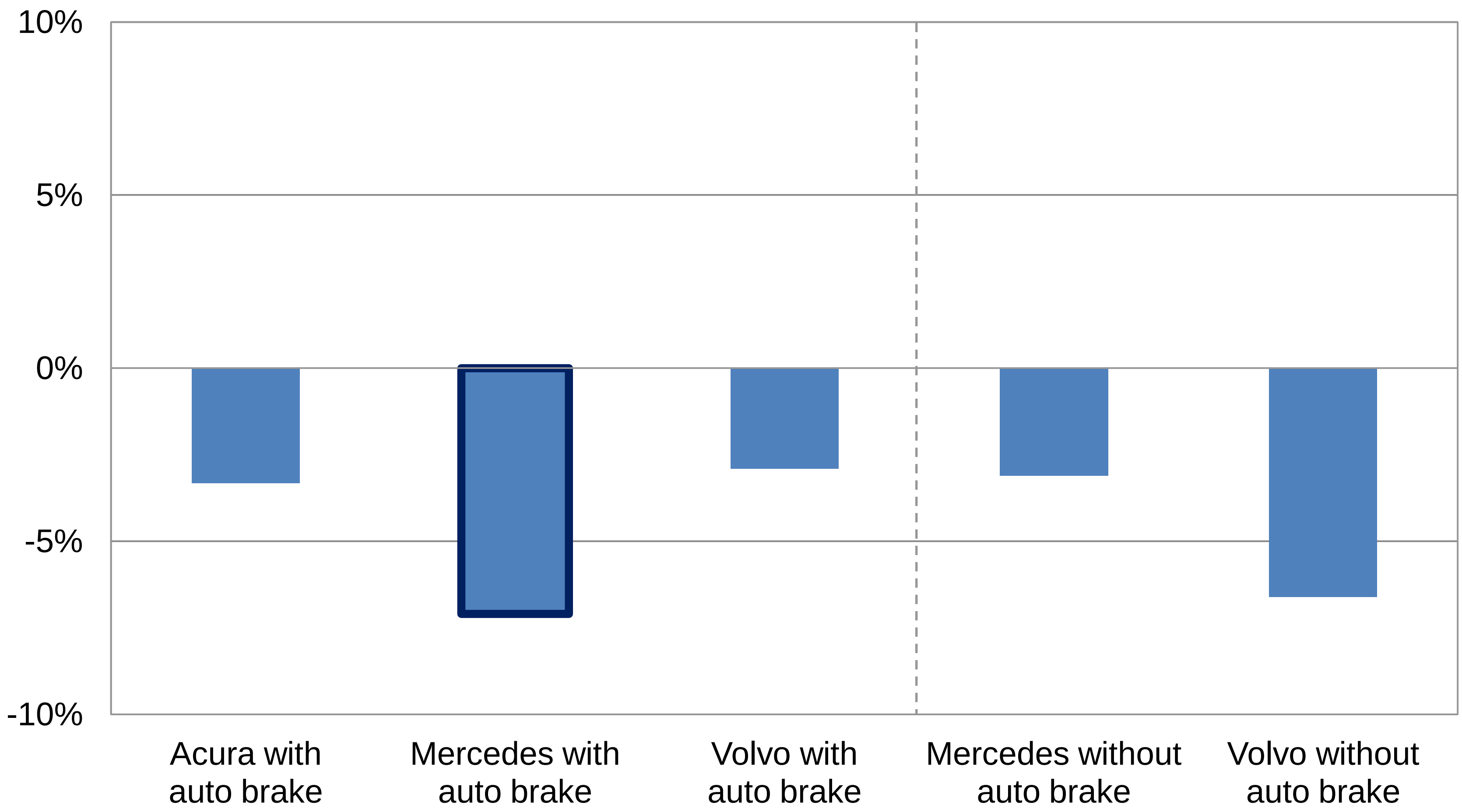
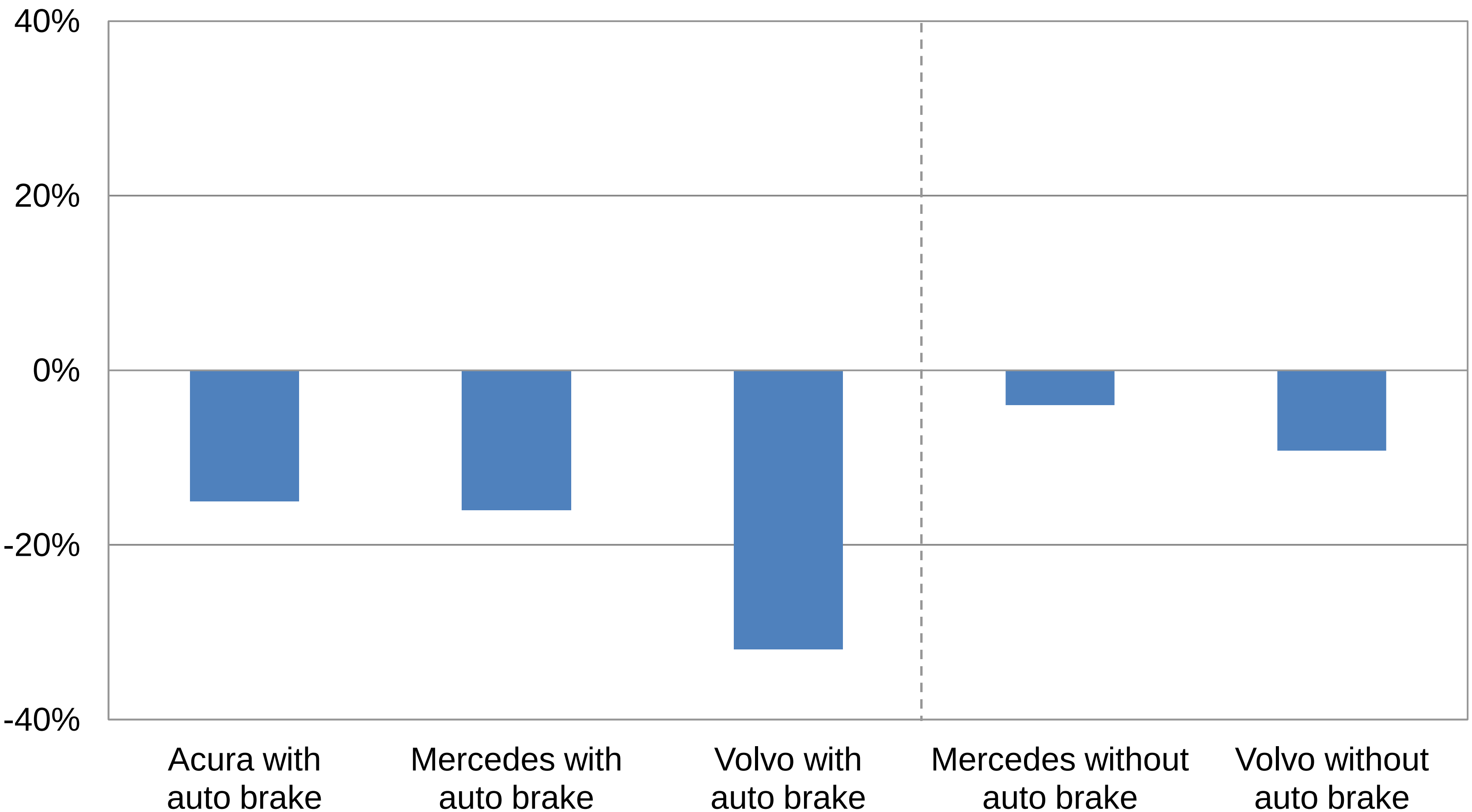
Forward collision warning with and without autonomous braking

Collision claim frequency by manufacturer



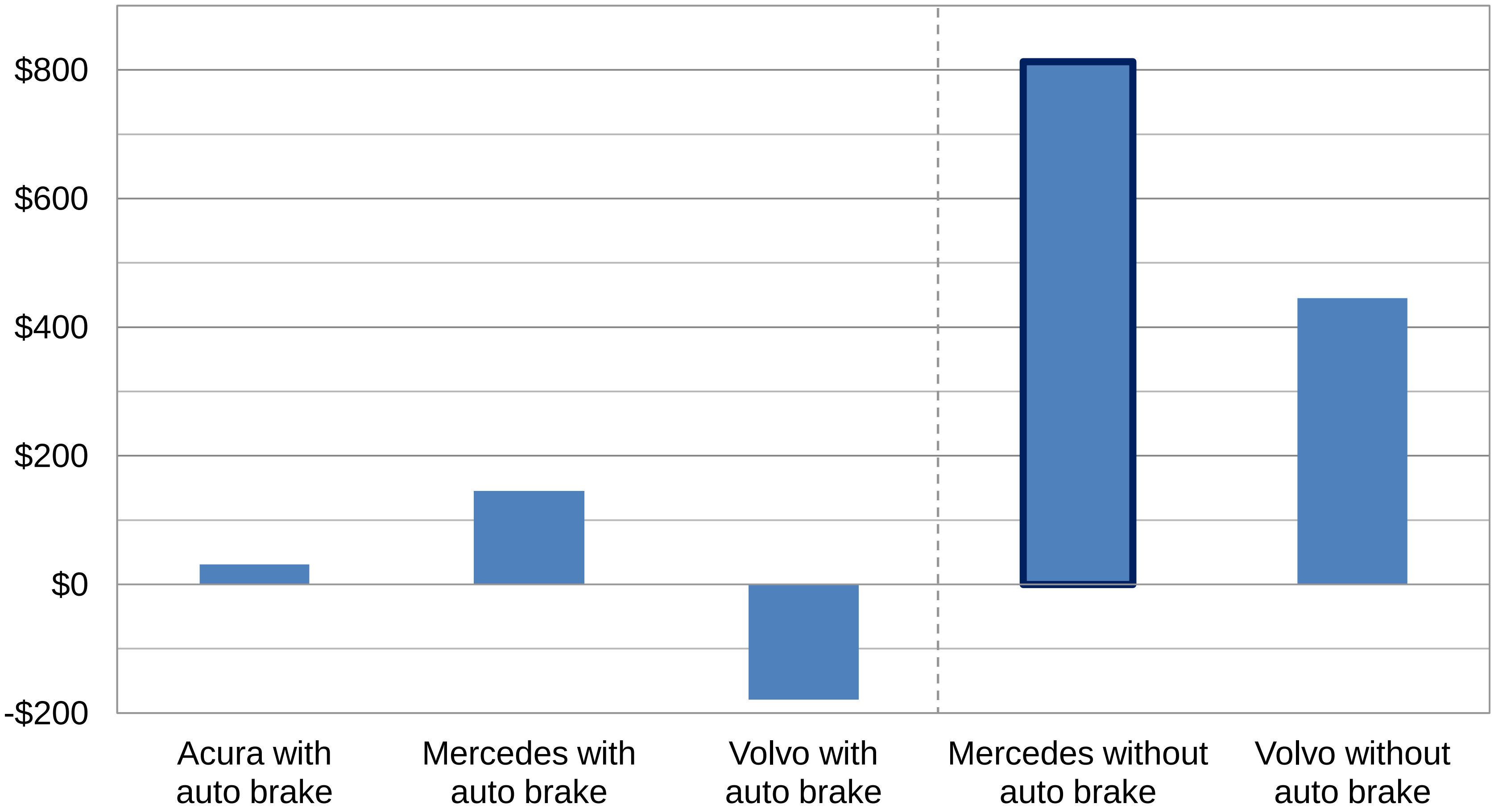
Forward collision warning with and without autonomous braking

Bodily injury claim frequency by manufacturer



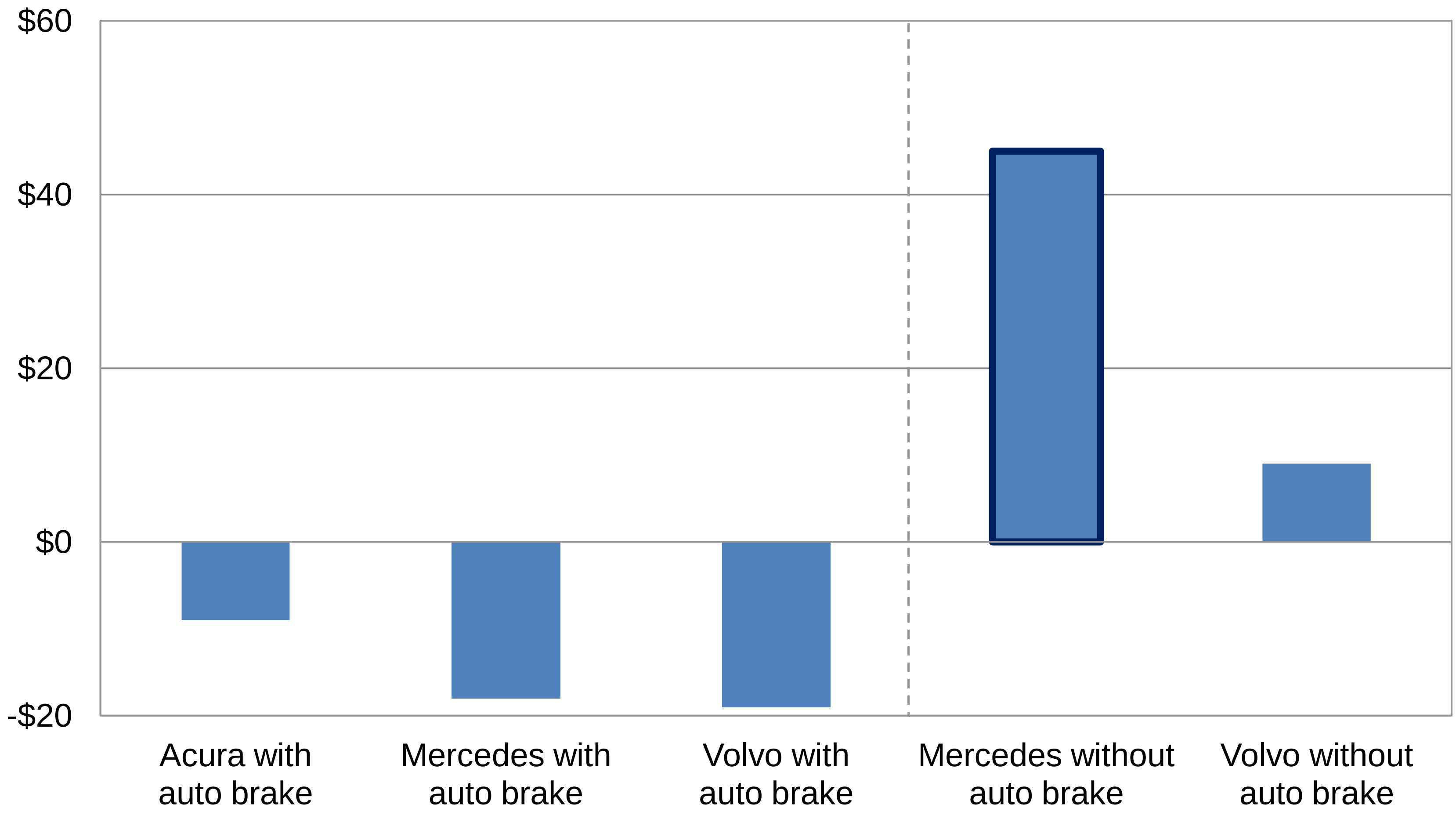
Forward collision warning with and without autonomous braking

Collision claim severity by manufacturer



Forward collision warning with and without autonomous braking

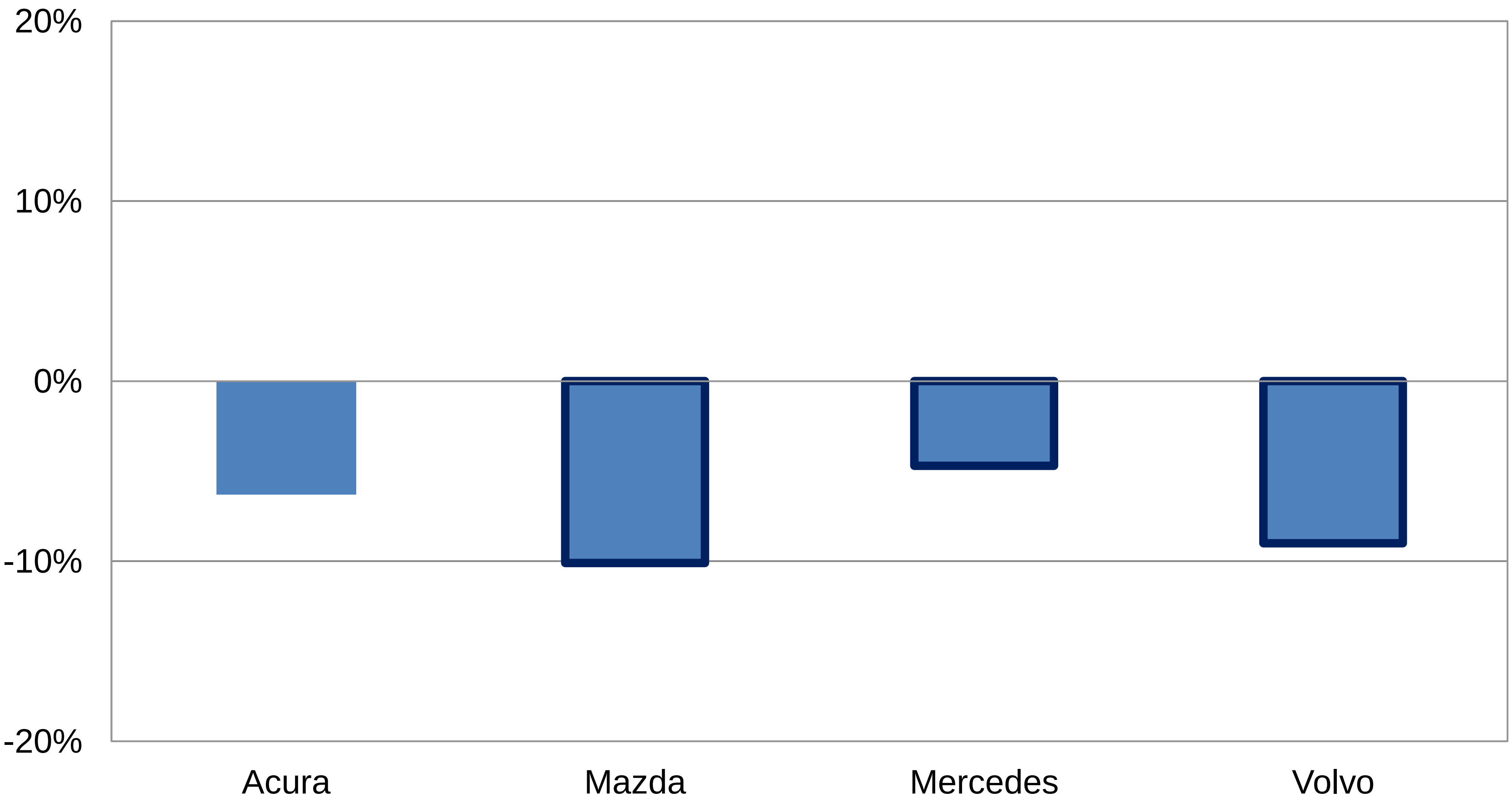
Collision overall losses per insured vehicle year by manufacturer



Adaptive headlights

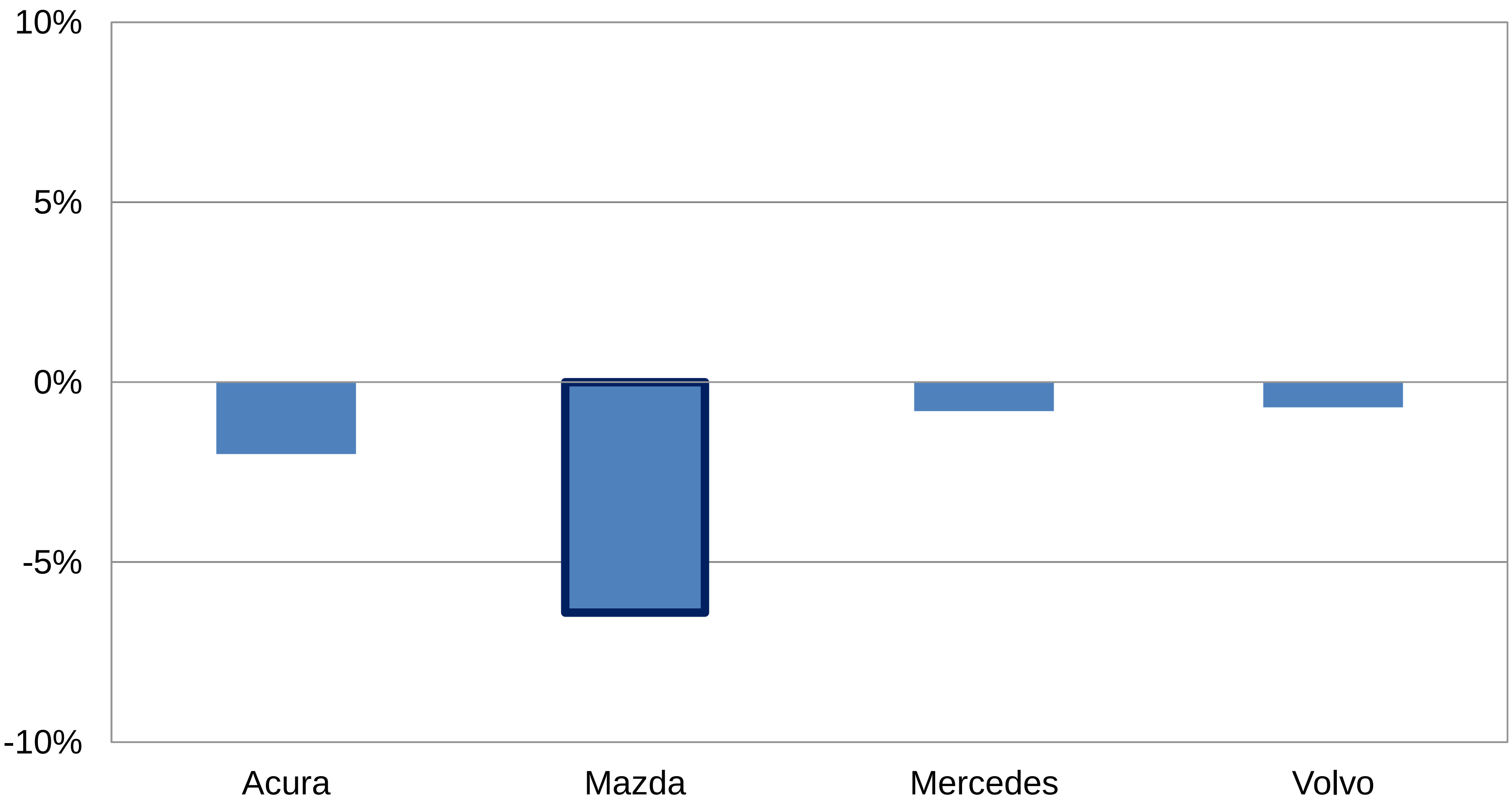
Adaptive headlights

Property damage liability claim frequency by manufacturer



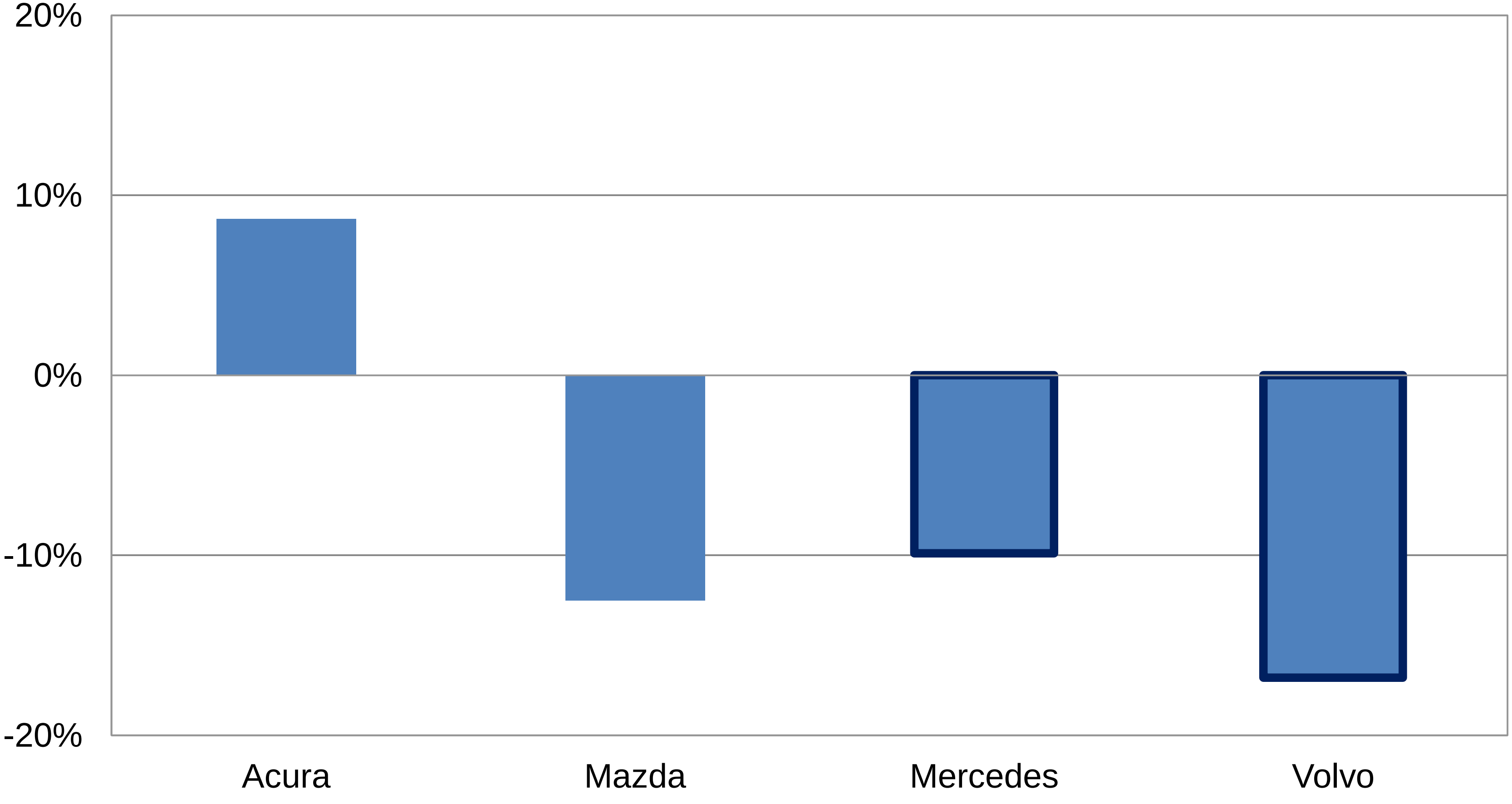
Adaptive headlights

Collision claim frequency by manufacturer



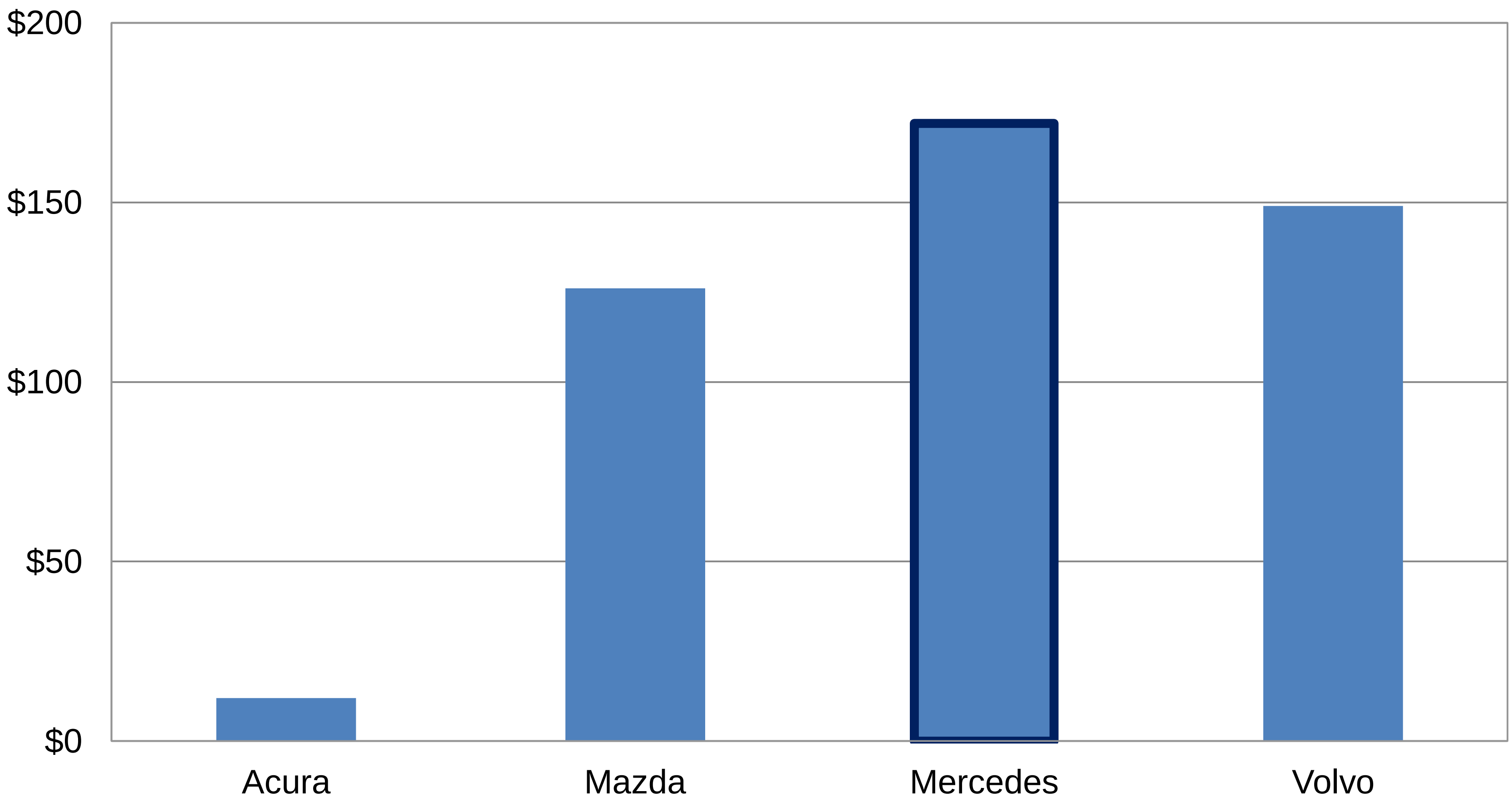
Adaptive headlights

Bodily injury claim frequency by manufacturer



Adaptive headlights

Collision claim severity by manufacturer



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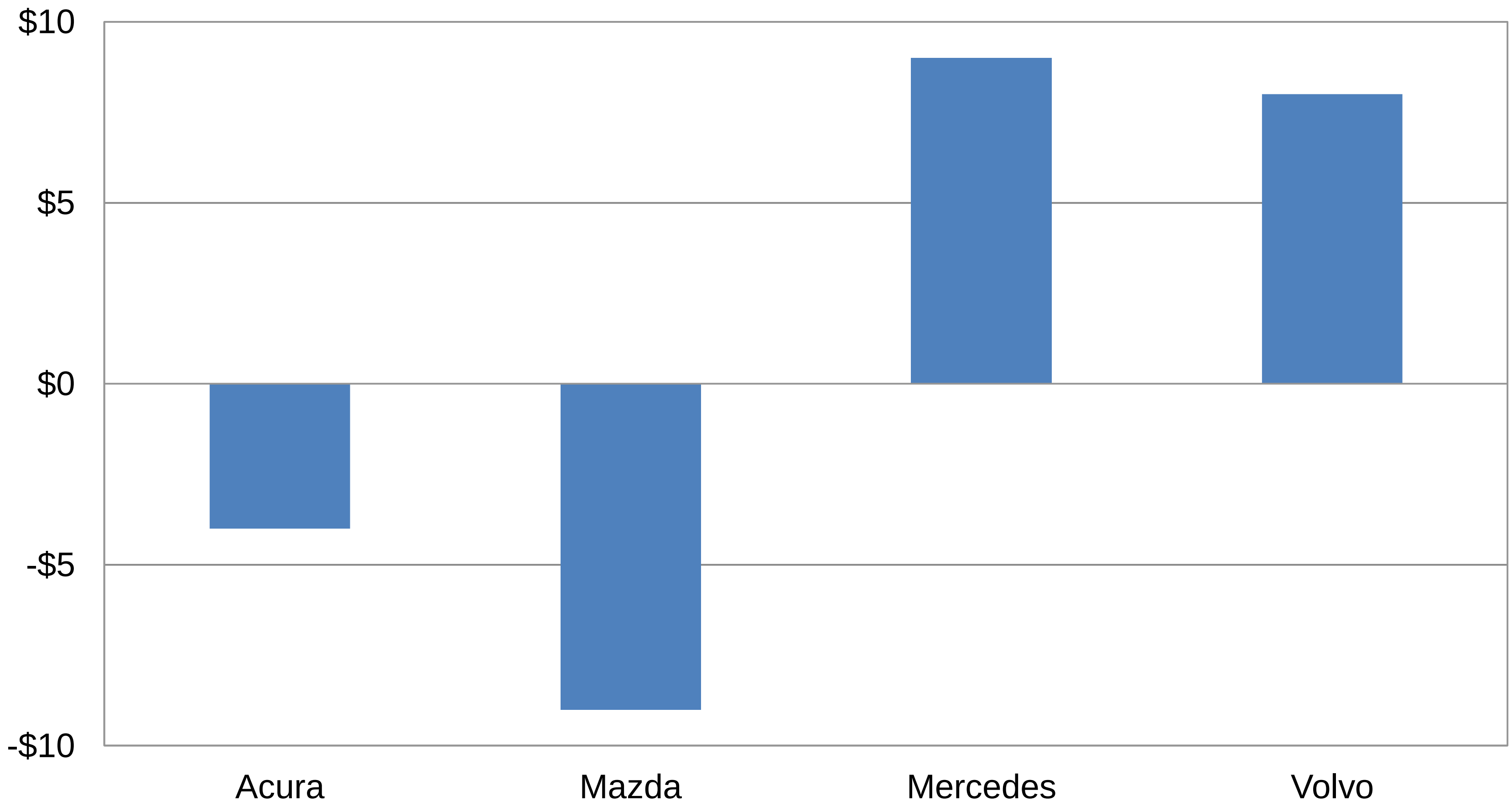
Adaptive headlights

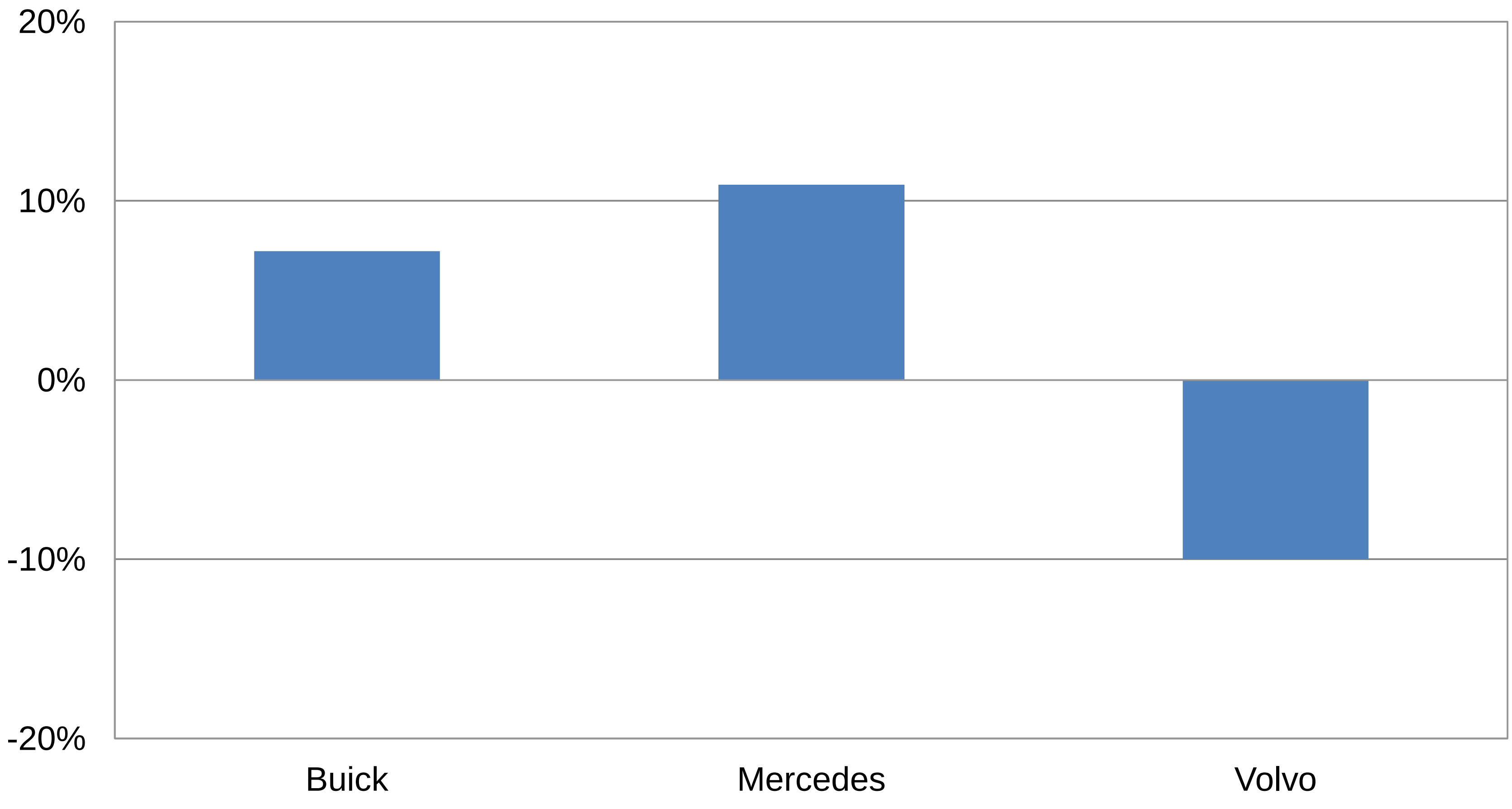
Collision overall losses by manufacturer



Lane departure warning

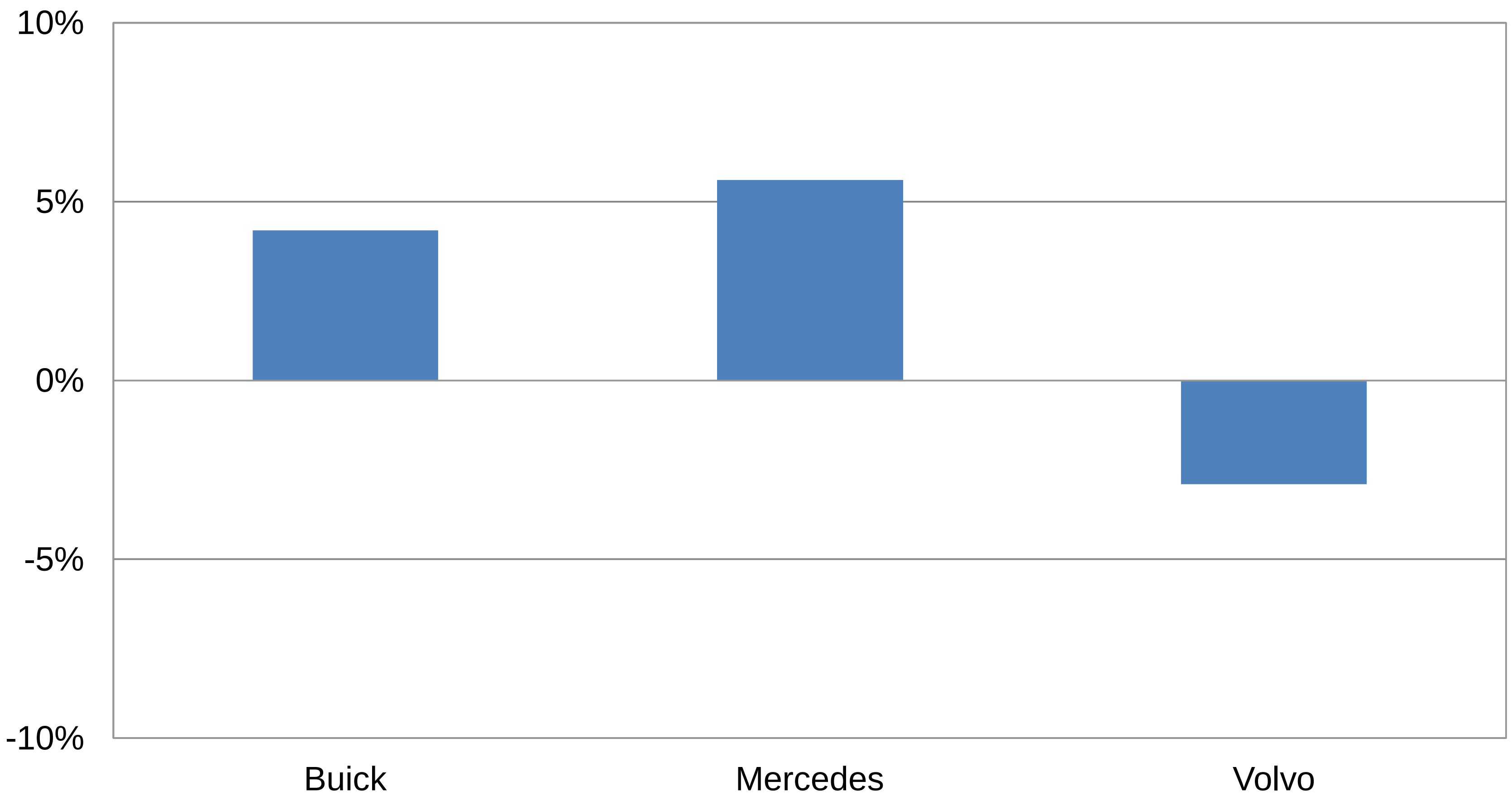
Lane departure warning without active assist

Property damage liability claim frequency by manufacturer



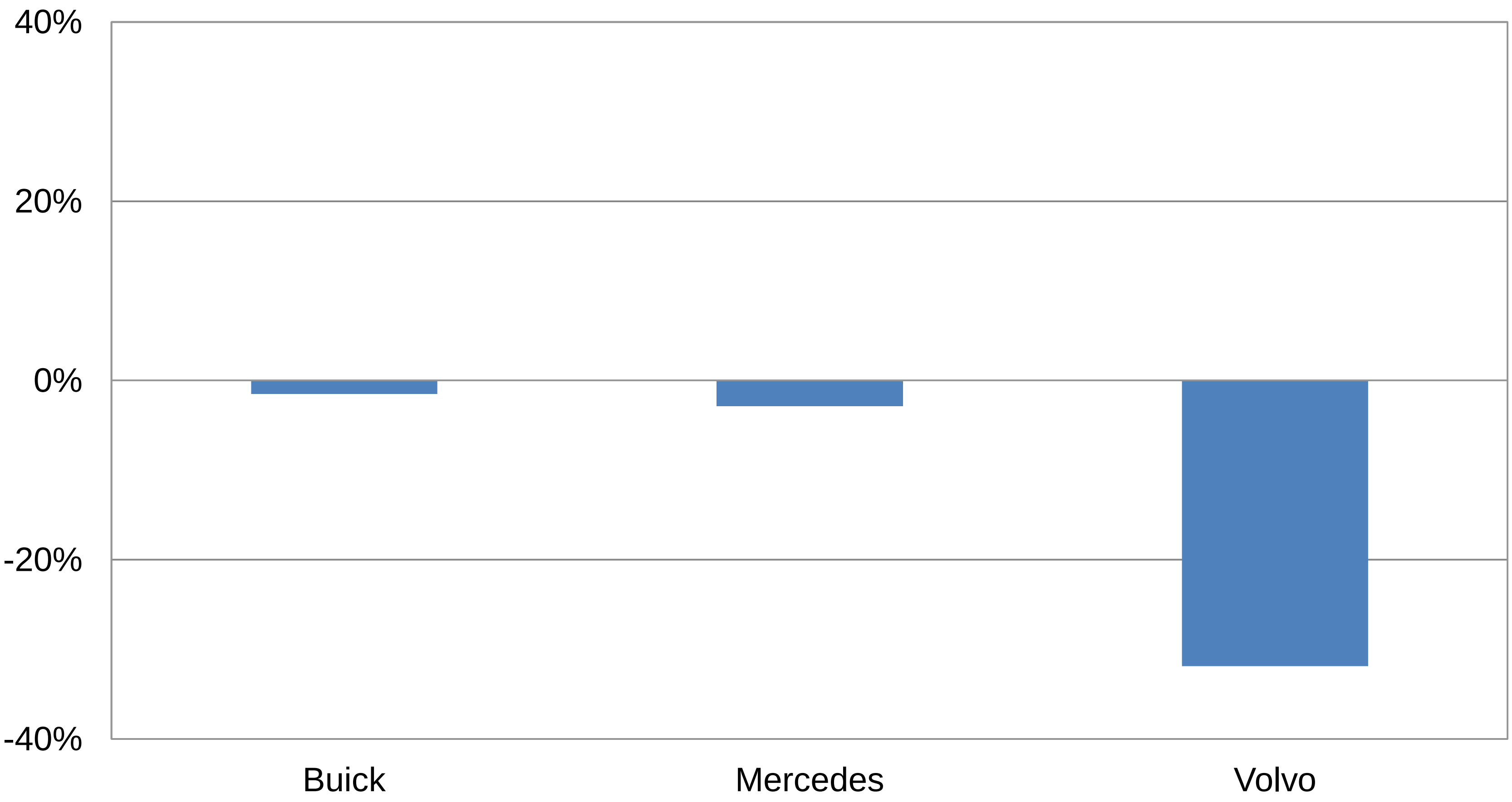
Lane departure warning without active assist

Collision claim frequency by manufacturer



Lane departure warning without active assist

Bodily injury liability claim frequency by manufacturer



INSURANCE INSTITUTE FOR HIGHWAY SAFETY

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Dedicated to reducing deaths, injuries, and property damage on the highway

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Drivers and Driver Assistance Systems: How well do they match?

2013 Driving Assessment Conference
Lake George, NY ● June 18, 2013

Adrian Lund, Ph.D., President

The Insurance Institute for Highway Safety,

founded in 1959, is an independent, nonprofit, scientific, and educational organization dedicated to reducing the losses — deaths, injuries, and property damage — from crashes on the nation's roads.

The Highway Loss Data Institute,

founded in 1972, shares and supports this mission through scientific studies of insurance data representing the human and economic losses resulting from the ownership and operation of different types of vehicles and by publishing insurance loss results by vehicle make and model.

Both organizations are wholly supported by auto insurers.

Where are we?

Location of IIHS/HLDI and Vehicle Research Center

IIHS members write 85% of private passenger market

- ACE Private Risk Services
- Affirmative Insurance
- Agency Insurance Company of Maryland
- Alfa Alliance Insurance Corporation
- Alfa Insurance
- Allstate Insurance Group
- American Family Mutual Insurance
- American National Property and Casualty Company
- Ameriprise Auto & Home
- Amica Mutual Insurance Company
- ARI Insurance Companies
- Auto Club Enterprises
- Auto Club Group
- Bankers Insurance Group
- Bituminous Insurance Companies
- California Casualty Group
- California State Auto Group
- Capital Insurance Group
- Chubb & Son
- Colorado Farm Bureau Mutual Insurance Company
- Concord Group Insurance Companies
- Cotton States Insurance
- COUNTRY Financial
- Direct General Corporation
- Discovery Insurance Company
- Driver's Insurance Group
- Erie Insurance Group
- Esurance
- Farm Bureau Financial Services
- Farm Bureau Insurance of Michigan
- Farm Bureau Mutual Insurance Company of Idaho
- Farmers Insurance Group of Companies
- Farmers Mutual Hail Insurance Company of Iowa
- Farmers Mutual of Nebraska
- Fireman's Fund Insurance Company
- First Acceptance Corporation
- Florida Farm Bureau Insurance Companies
- Frankenmuth Insurance
- Gainsco Insurance
- GEICO Group
- Georgia Farm Bureau Mutual Insurance Company
- GMAC Personal Lines Insurance
- Grange Insurance
- Hallmark Insurance Company
- Hanover Insurance Group
- The Hartford
- Haulers Insurance Company Inc.
- Homeowners of America Insurance Company
- Horace Mann Insurance Companies
- ICW Group
- Imperial Fire & Casualty Insurance Company
- Infinity Property & Casualty
- Kemper Preferred
- Kentucky Farm Bureau Insurance
- Liberty Mutual Insurance Company
- Louisiana Farm Bureau Mutual Insurance Company
- Maryland Automobile Insurance Fund
- Mercury Insurance Group
- MetLife Auto & Home
- MiddleOak
- Mississippi Farm Bureau Casualty Insurance Company
- MMG Insurance
- Mutual of Enumclaw Insurance Company
- Nationwide
- New Jersey Manufacturers Insurance Company
- NLC Insurance Companies Inc.
- Nodak Mutual Insurance Company
- Norfolk & Dedham Group
- North Carolina Farm Bureau Mutual Insurance Company
- Northern Neck Insurance Company
- Old American County Mutual Fire Insurance
- Oregon Mutual Insurance
- Pekin Insurance
- PEMCO Insurance
- Plymouth Rock Assurance
- Progressive Corporation
- The Responsive Auto Insurance Company
- Rockingham Group
- Safeco Insurance
- Samsung Fire & Marine Insurance Company
- SECURA Insurance
- Sentry Insurance
- Shelter Insurance
- Sompo Japan Insurance Company of America
- South Carolina Farm Bureau Mutual Insurance Company
- Southern Farm Bureau Casualty Insurance Company
- State Auto Insurance Companies
- State Farm
- Tennessee Farmers Mutual Insurance Company
- Texas Farm Bureau Insurance Companies
- Tower Group Companies
- The Travelers Companies
- United Educators
- USAA
- Viceroy Insurance Company
- Virginia Farm Bureau Mutual Insurance
- West Bend Mutual Insurance Company
- Young America Insurance Company
- Zurich North America

Institute activities

We do not lobby, legislate, or litigate

- Priority 1 – objective research on policy options to reduce injuries and property damage from motor vehicle crashes
- Priority 2 – effective communications to make research information attractive to news media
  - News releases (TV, print, Internet)
  - Films
  - Testimony at state and federal legislative and regulatory hearings
  - Briefings of other stakeholders, including vehicle manufacturers
- IIHS and HLDI rely on aggressive research and communications to empower people and policymakers with objective information

IIHS research and communications cover a wide array of highway safety issues

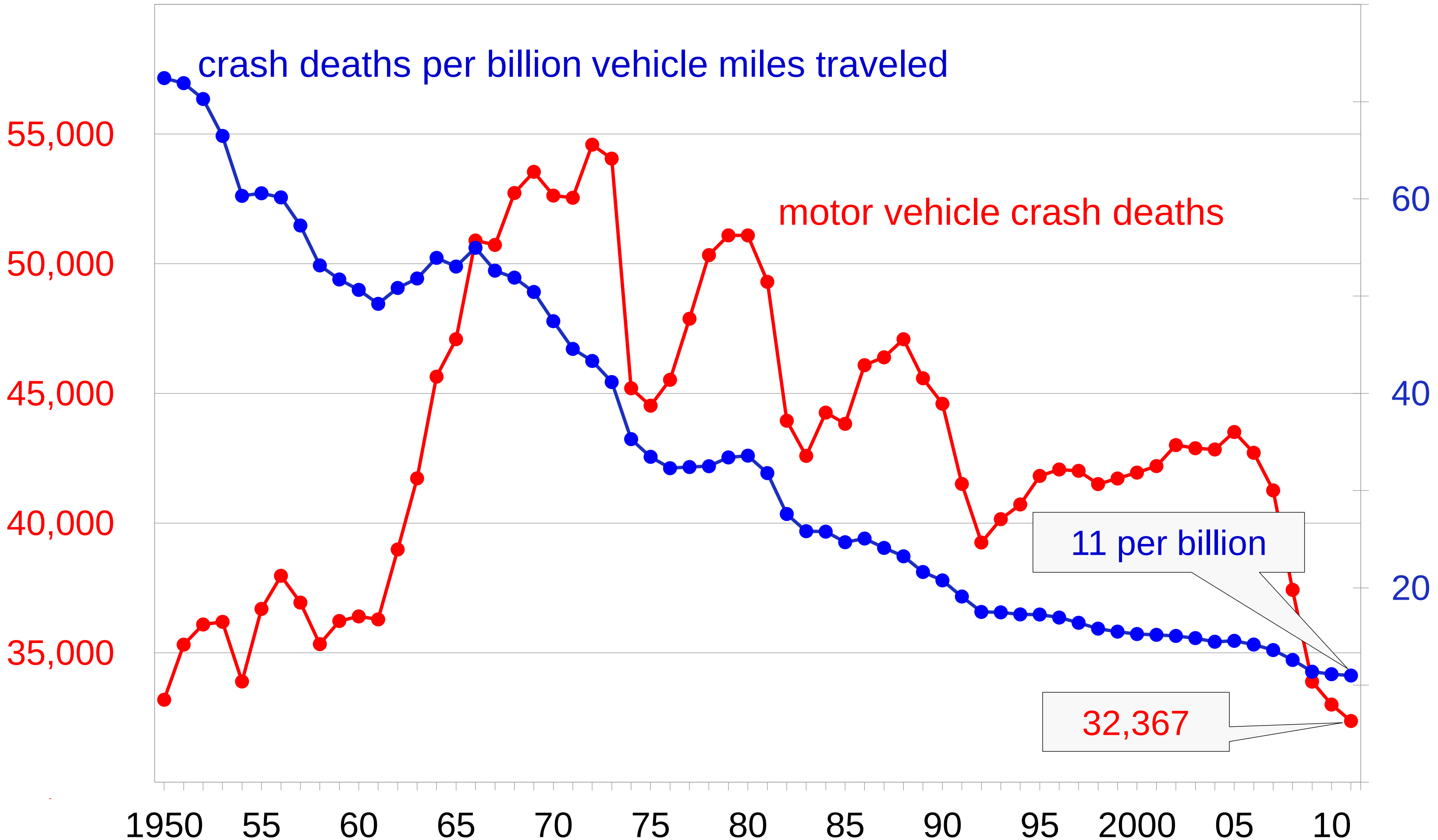
50th Anniversary crash test

1959 Bel Air vs. 2009 Malibu

Overview of presentation

- Some surprising findings about driver behavior and crashes
  - Infotainment technology
  - Advanced driver assistance systems (collision warnings, headlamps, cameras)
- Questions raised about how drivers drive
  - To what extent do drivers consciously control their actions?
  - What is attention?
- Reducing crash risk
  - Advanced technology
  - Old technology

Fatalities and fatal crash risk per mile traveled have declined steadily since peaking in the 1960s



Role of driver error has not changed

- 1979 Indiana "Tri-Level Study" estimated driver error as proximate cause of 9 out of 10 crashes
- 2008 National Motor Vehicle Crash Causation Study cited driver error as the critical reason for the crash in 95% of crashes where reason was assigned

  Critical reason attributed to driver (top 5):

    Inadequate surveillance (19%)

    Internal distraction (10%)

    Too fast for conditions (8%)

    Too fast for curve (5%)

    Overcompensation (5%)

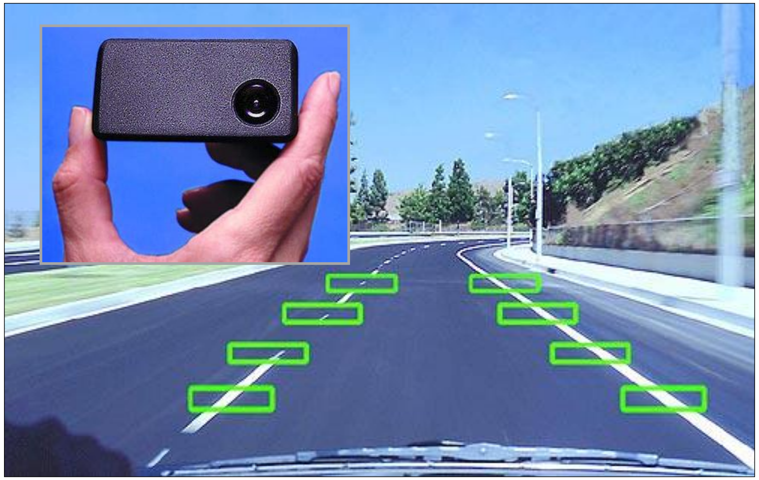
In-vehicle technologies:

New distractions or driver aids?

Infotainment features

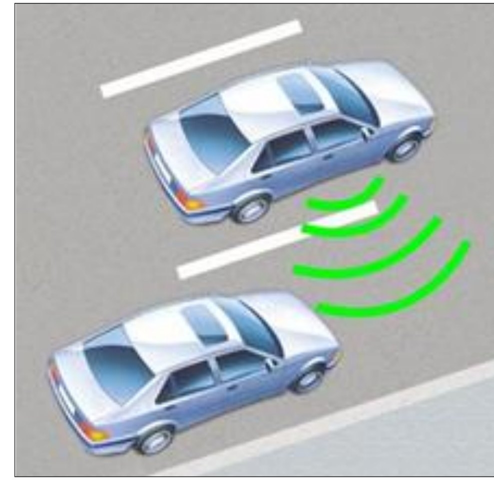
- Cellphones
- iPods
- Navigation systems
  - Mobile
  - Built-in
- Radios becoming more complex
  - Multiple bands
  - Built-in controls for iPods
  - CD/DVD players
  - Music streaming

Advanced information technology for safety

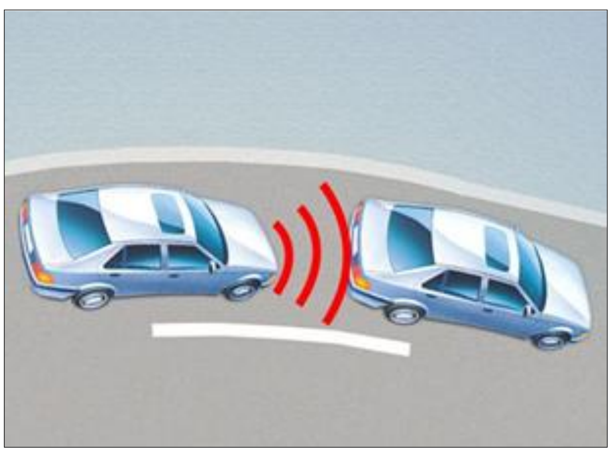


lane departure prevention

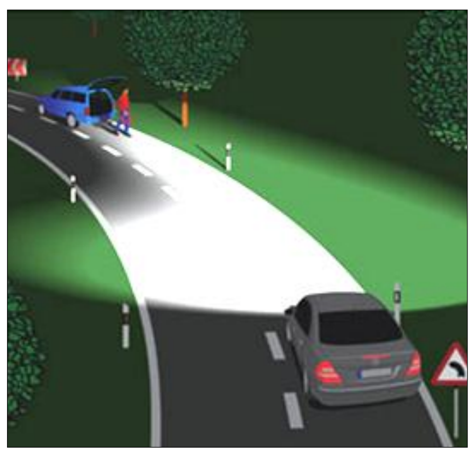
crash notification



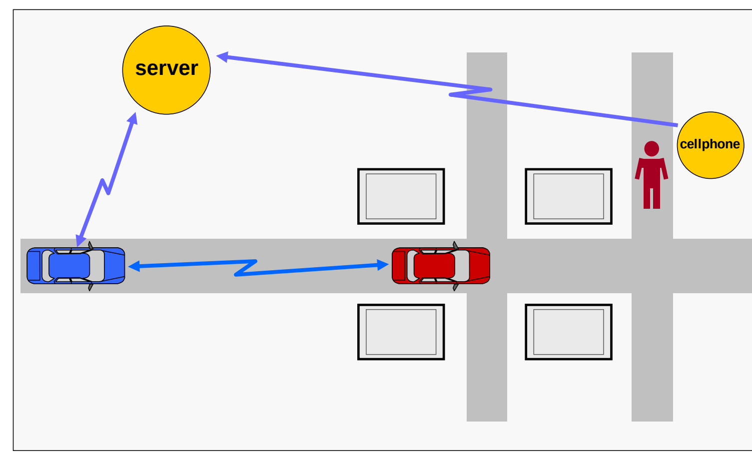
blind spot detection



forward collision warning
and auto braking



adaptive headlights



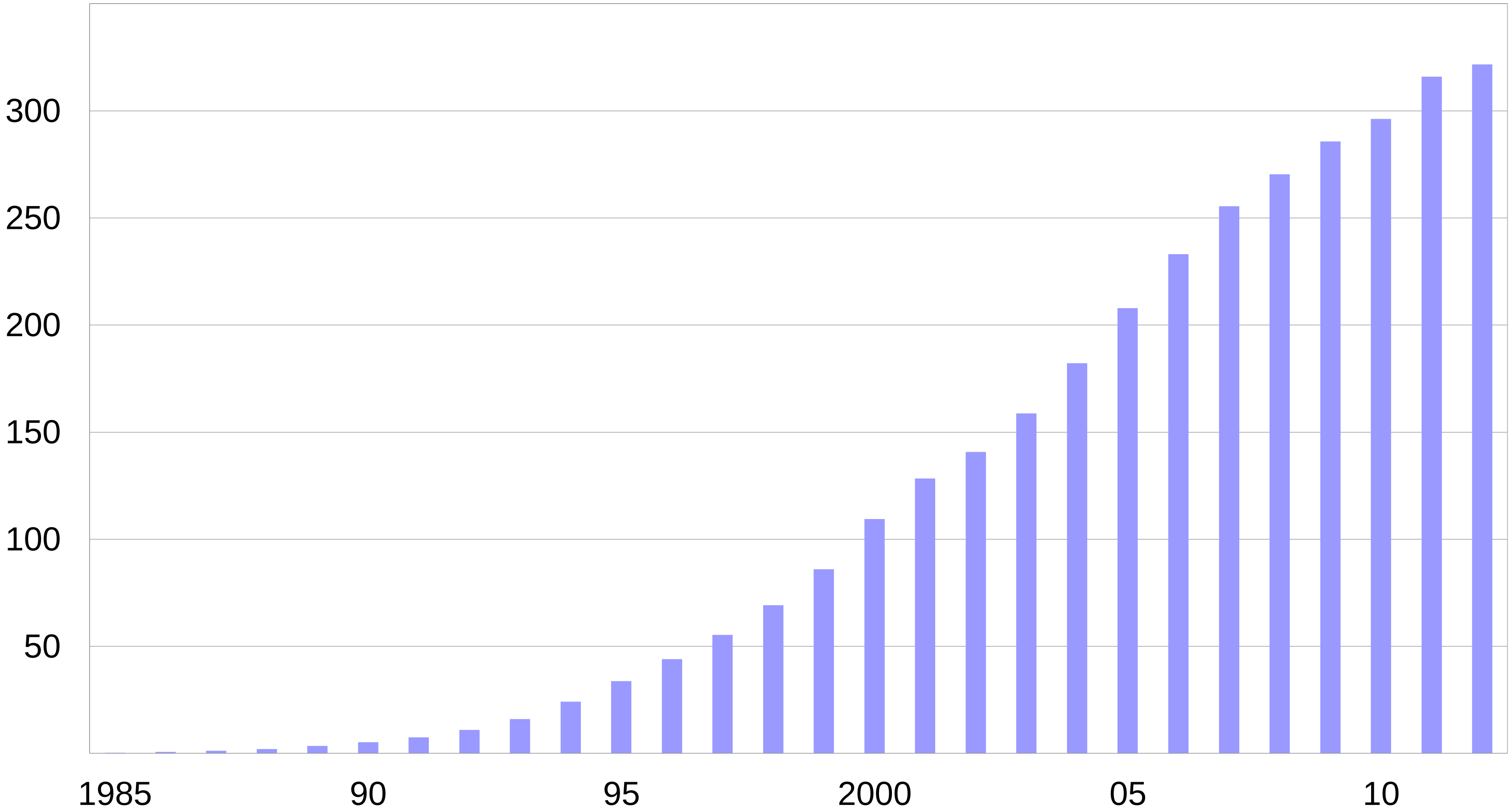
vehicle-to-vehicle communication

Infotainment usage by drivers increased greatly in the early 2000s

What is the effect on crashes?
The case of cellphones

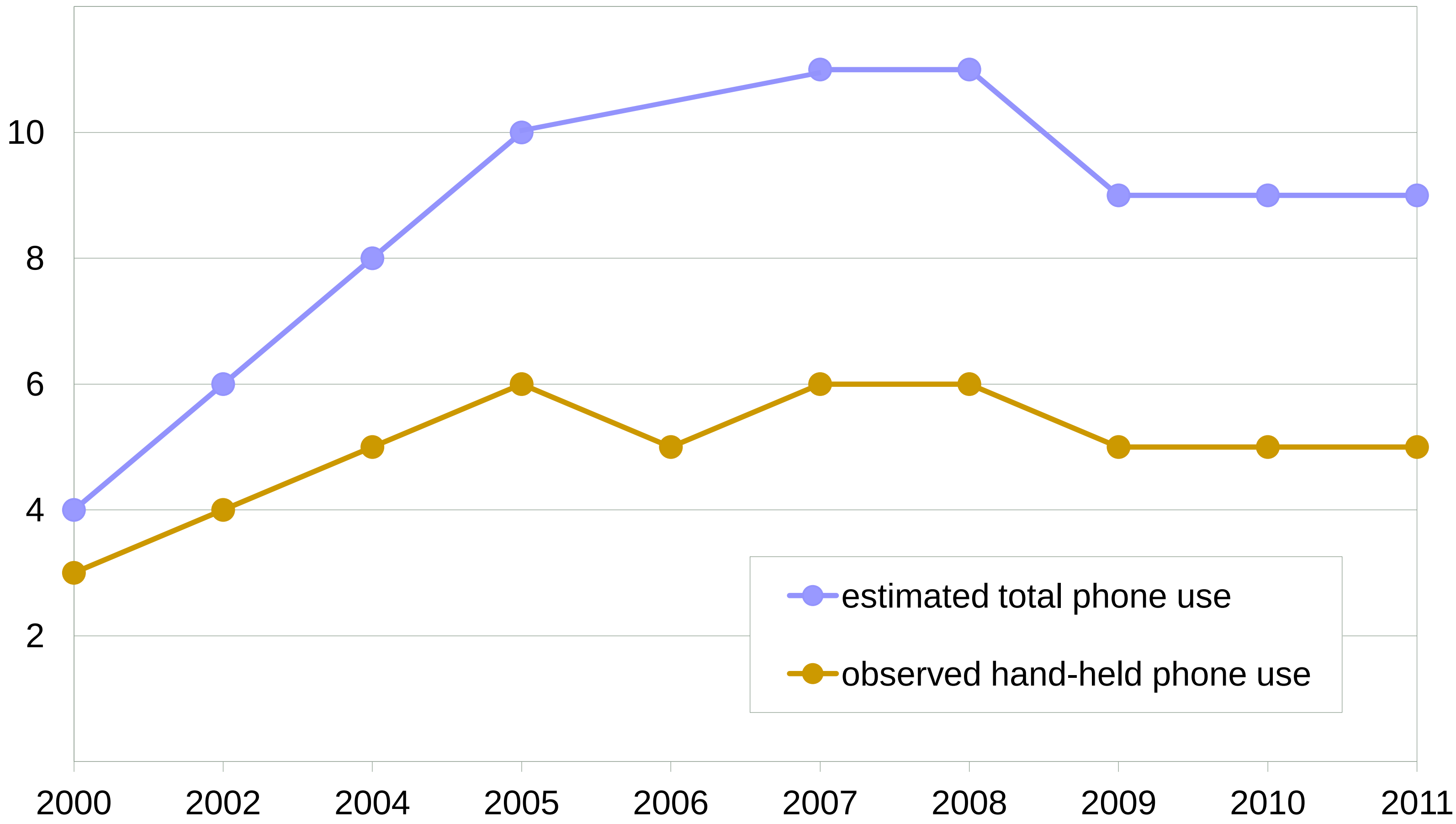
Cellphone subscribers

In millions, 1985-2012



Percent of drivers talking on phones

National observational surveys, NHTSA, 2000-11

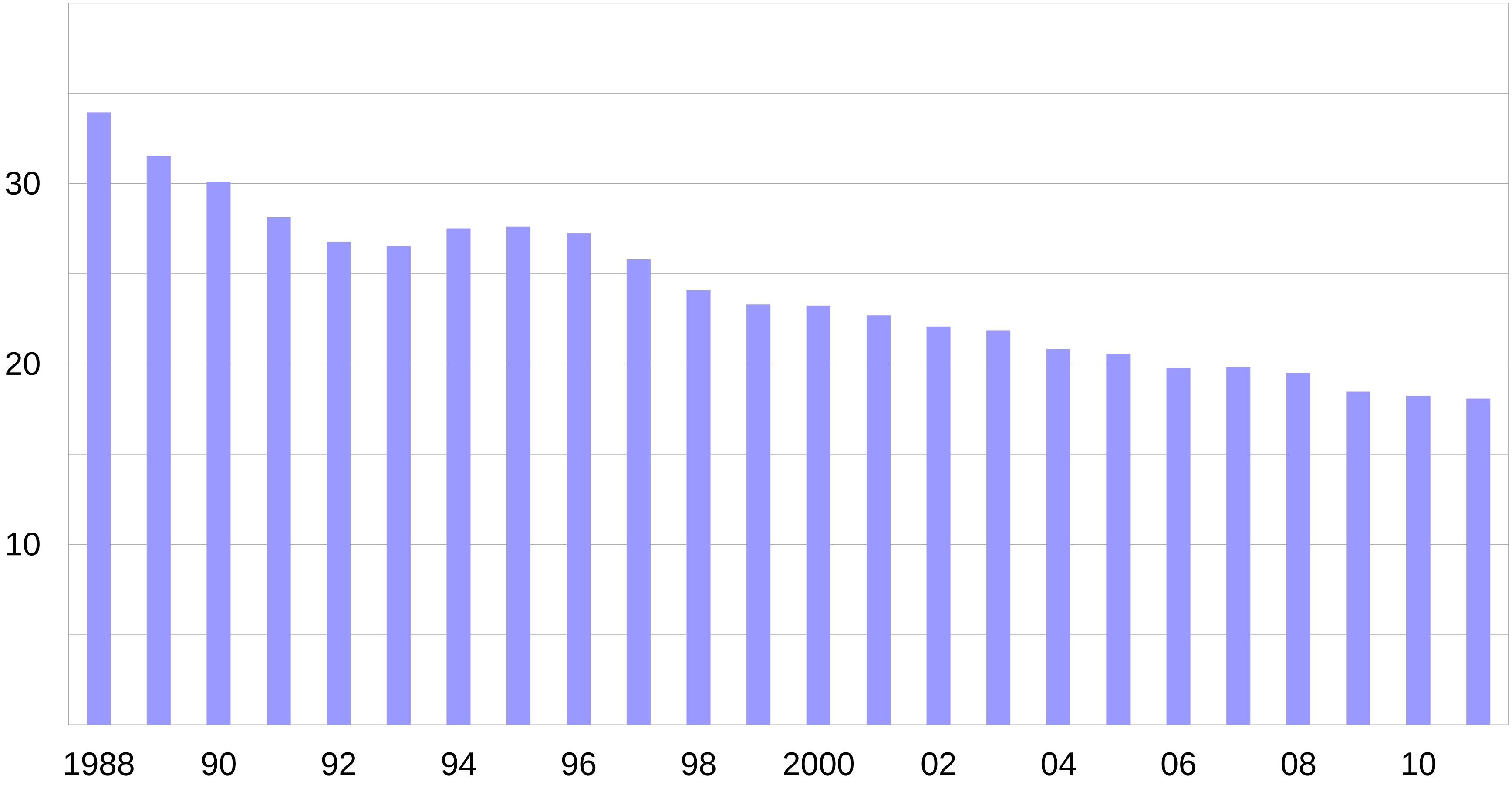


Cellphones and crash risk

- Multiple laboratory studies demonstrate that cellphone dialing and talking are distracting (i.e., reduce performance on simultaneous task)
- Case-crossover epidemiologic studies in Canada and Australia indicate four-fold crash risk when drivers are talking on their phones
- Virginia Tech naturalistic driving study (2013) suggests a smaller increase in crash risk
  - 1.39 times the risk of a safety critical event during hand-held phone use
    - No increased risk while talking
  - 1.73 times the risk of safety critical event during text messaging or browsing on cellphone

All police-reported crashes per billion miles traveled

By calendar year



Summary thoughts on infotainment and crashes

- Infotainment usage distracts
  - In some cases greatly
  - Even voice-activated systems
- Crashes have occurred because drivers were distracted by cellphones and other devices
- No dose response relationship between population cellphone use (and other electronics) and crashes

This poses a scientific conundrum:

Specifically, how can highly distracting activities that are increasing in frequency in the population not be associated with an increase in crashes for the population?

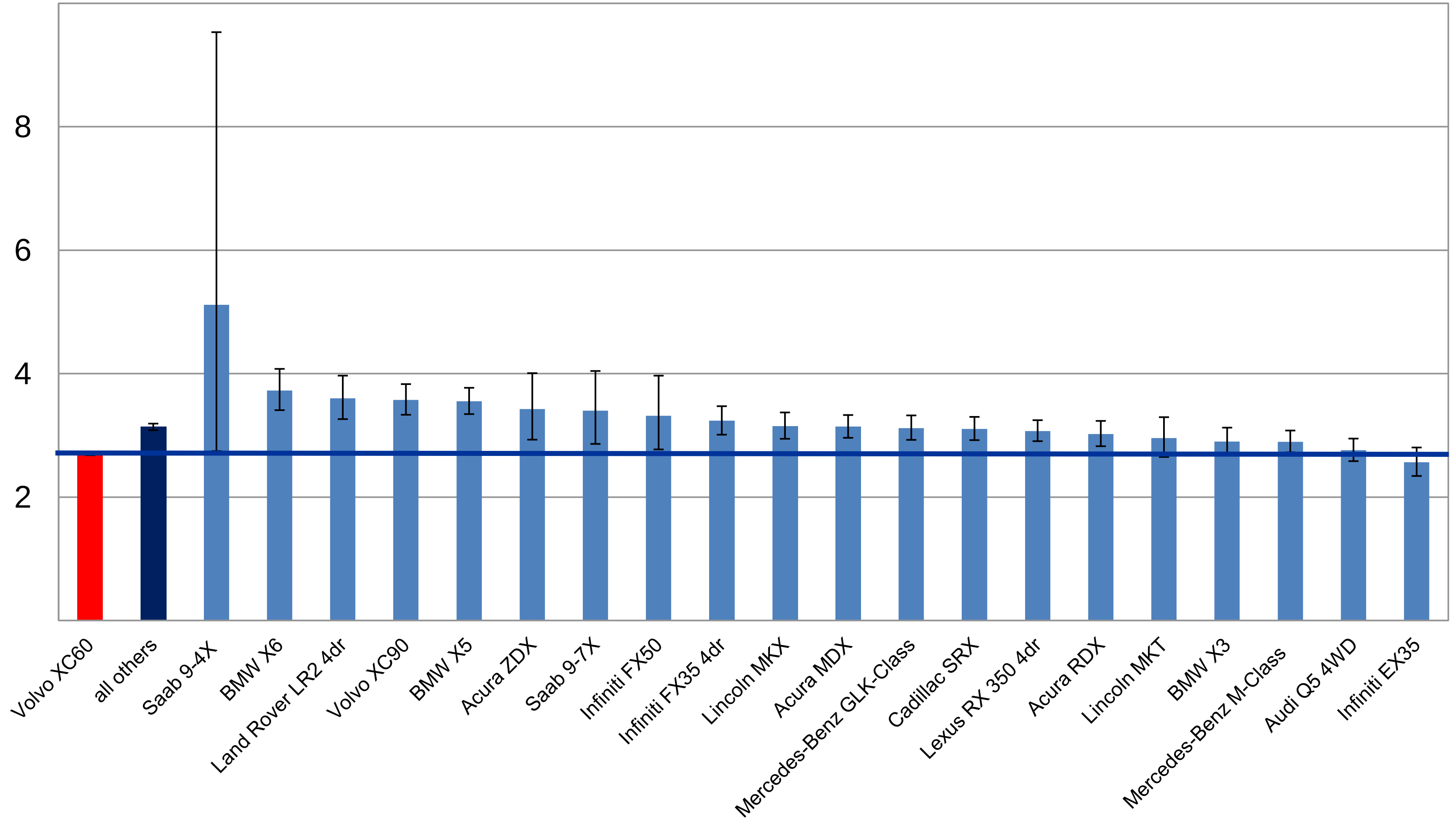
Is there a psychological issue here – another factor needed in our intuitive model of driver attention?

How are advanced driver assistance systems working?

Forward collision warning, with and without automatic braking, is working as expected

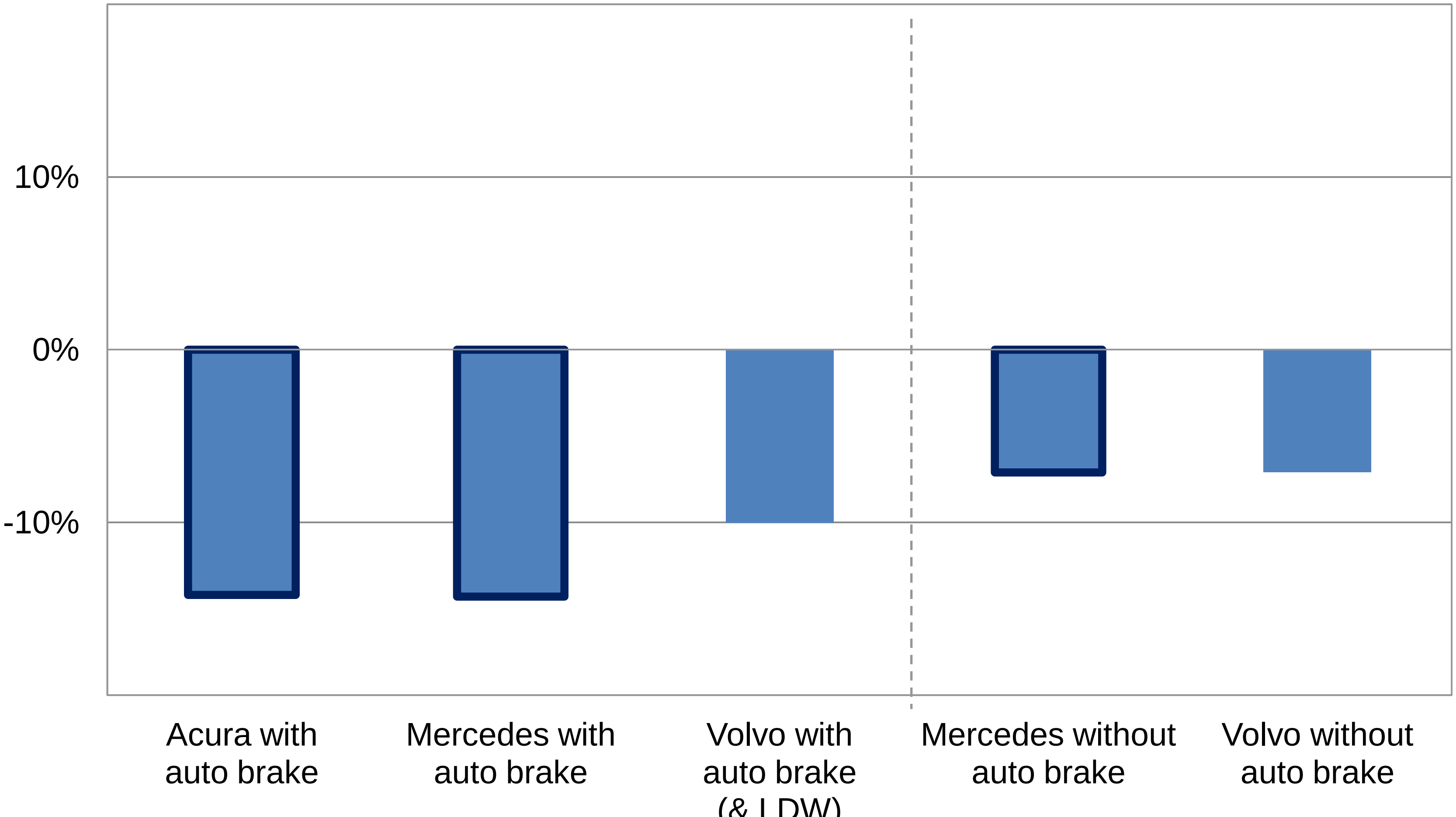
Volvo XC60 with City Safety (low speed autobrake) vs. other 2009-12 midsize luxury SUVs

Property damage liability claims per 100 vehicle years, 2009-12



High speed forward collision warning, with and without autonomous braking

Property damage liability claim frequency by manufacturer

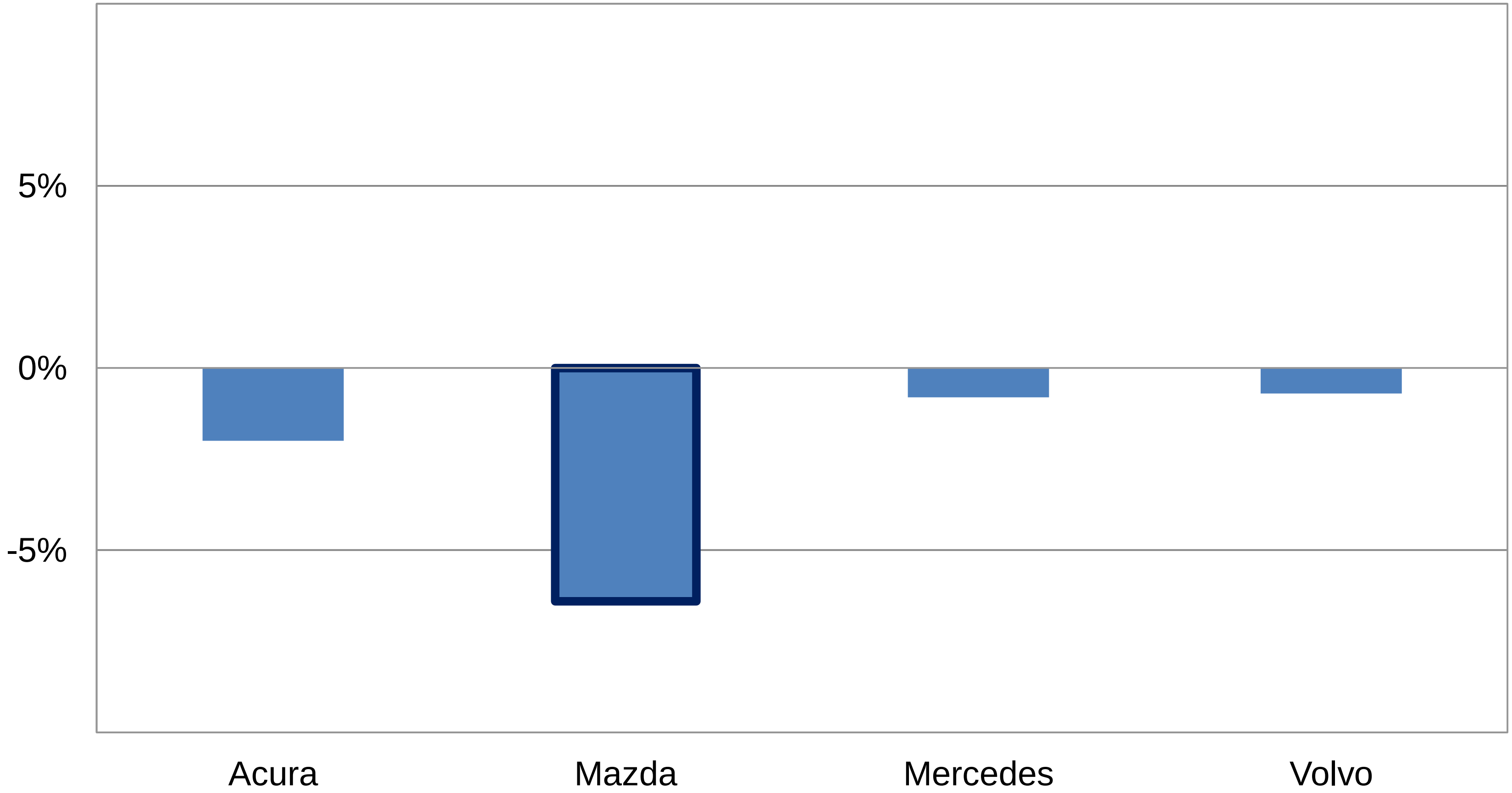


Adaptive headlights (steering responsive lamps) are working but not on single vehicle run-off-road crashes as expected

Adaptive headlights seem not to be reducing insurance collision claims, the kind of claim that would result from a single-vehicle crash (possible exception of Mazda)

Adaptive headlights

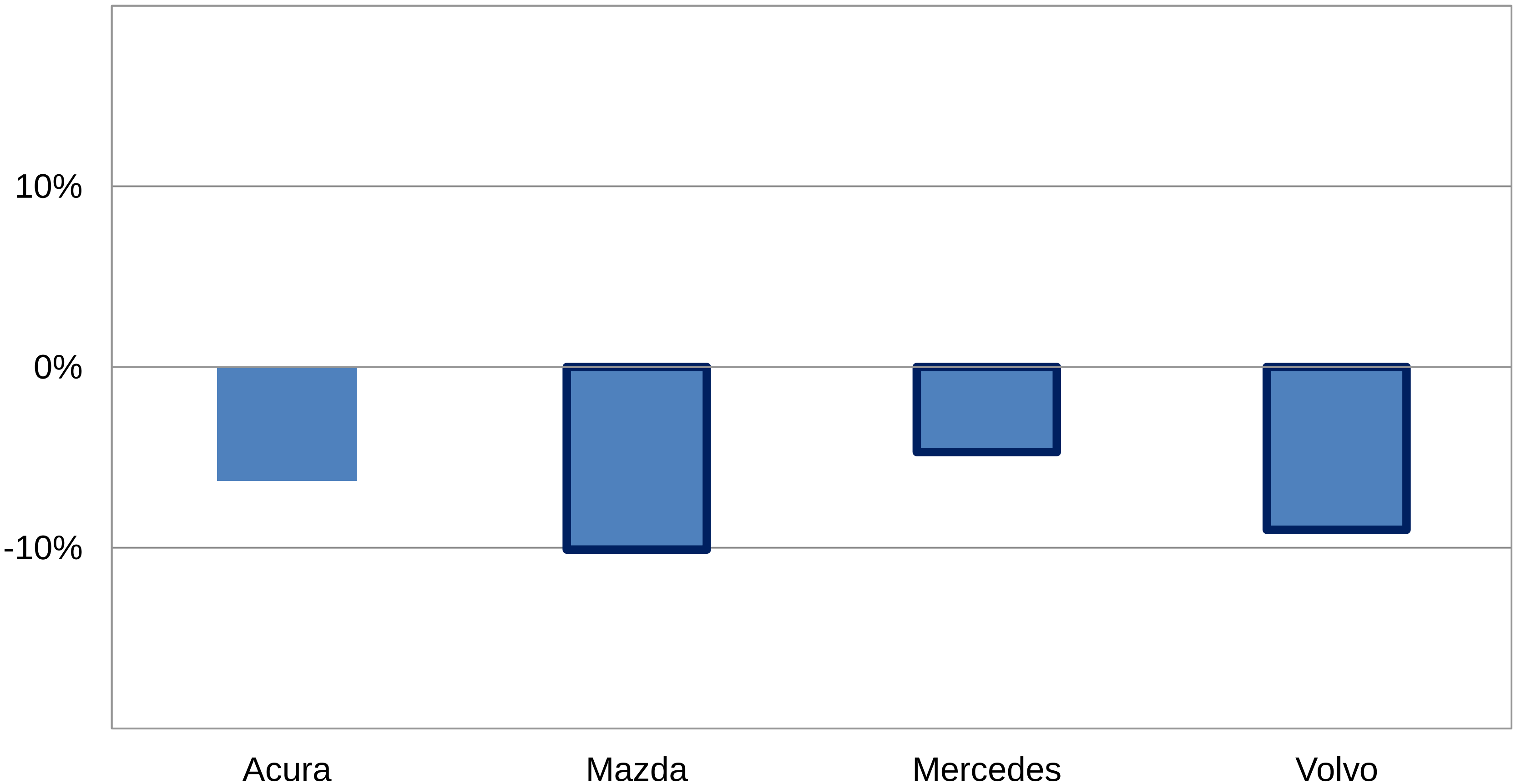
Percent change in collision claims per insured vehicle year



However, vehicles with adaptive headlights are involved in fewer crashes with other vehicles for which that vehicle is responsible, as indicated by a reduction in property damage liability claims and in claims for injuries in other vehicles

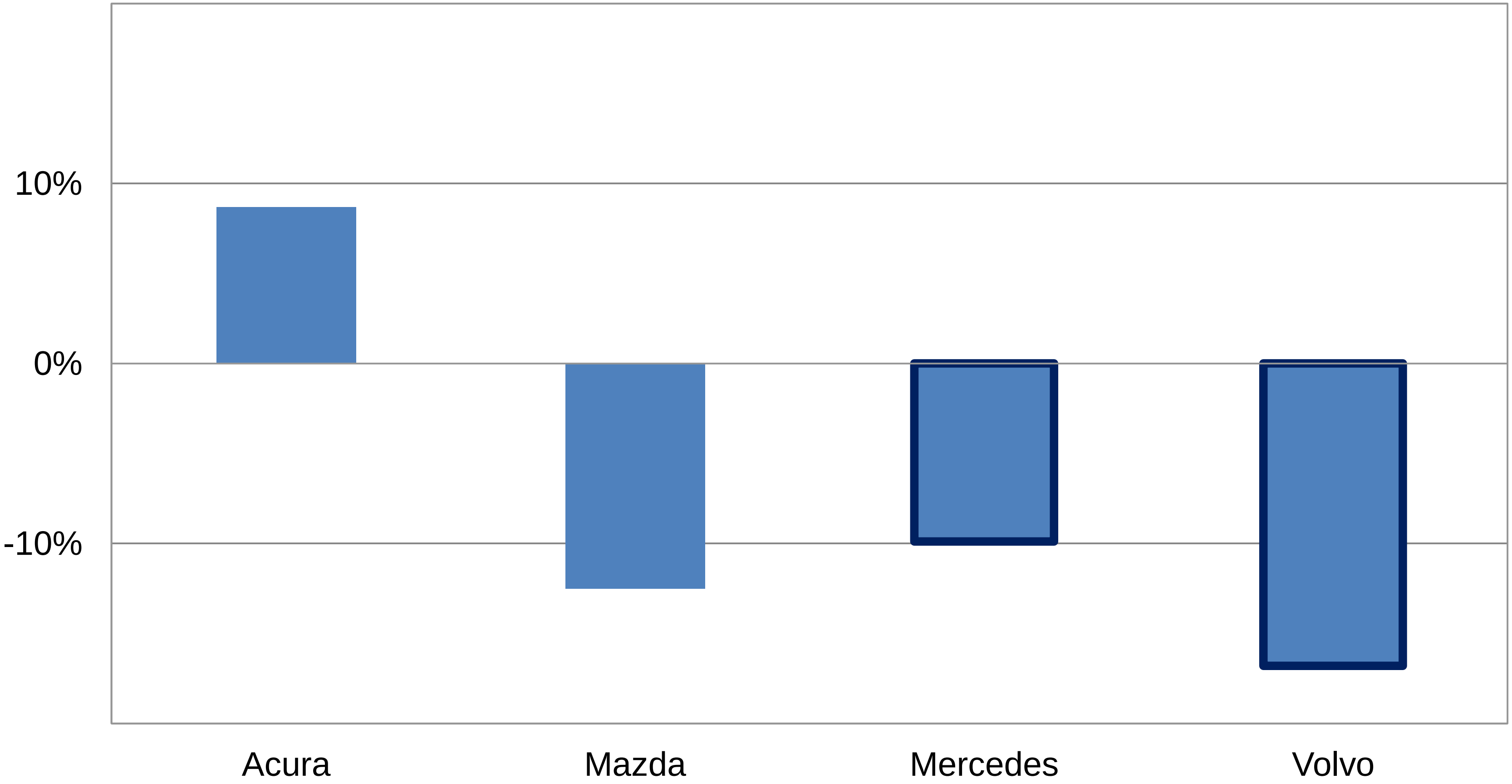
Adaptive headlights

Percent change in property damage liability claims per insured vehicle year



Adaptive headlights

Percent change in bodily injury claims per insured vehicle year

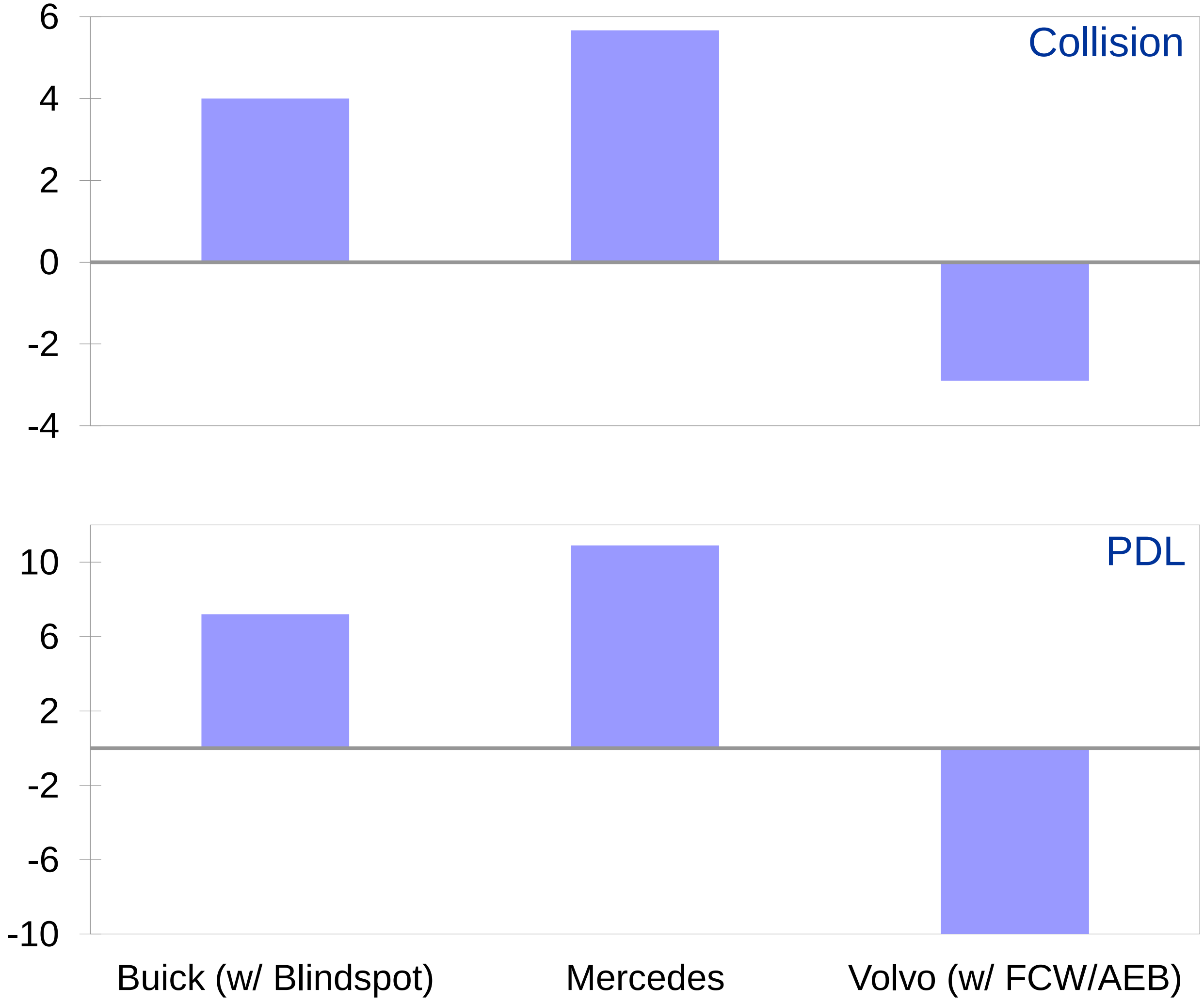


Some crash avoidance systems are showing no effectiveness

Lane departure warning (LDW, without active lane keep assistance) may be increasing crashes claimed with insurers

LDW is not reducing crash incidence

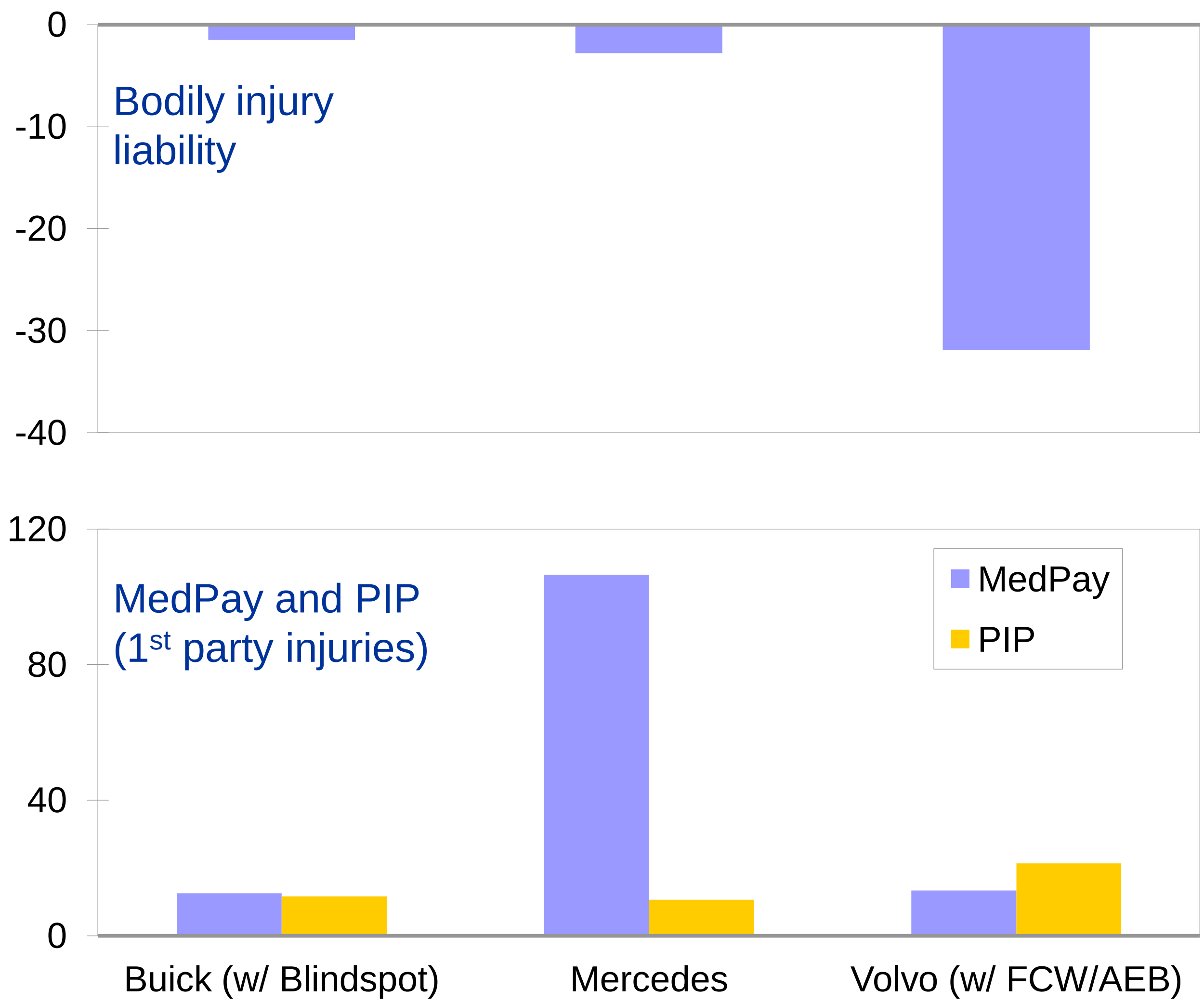
Percent change in vehicle damage claims per insured vehicle year



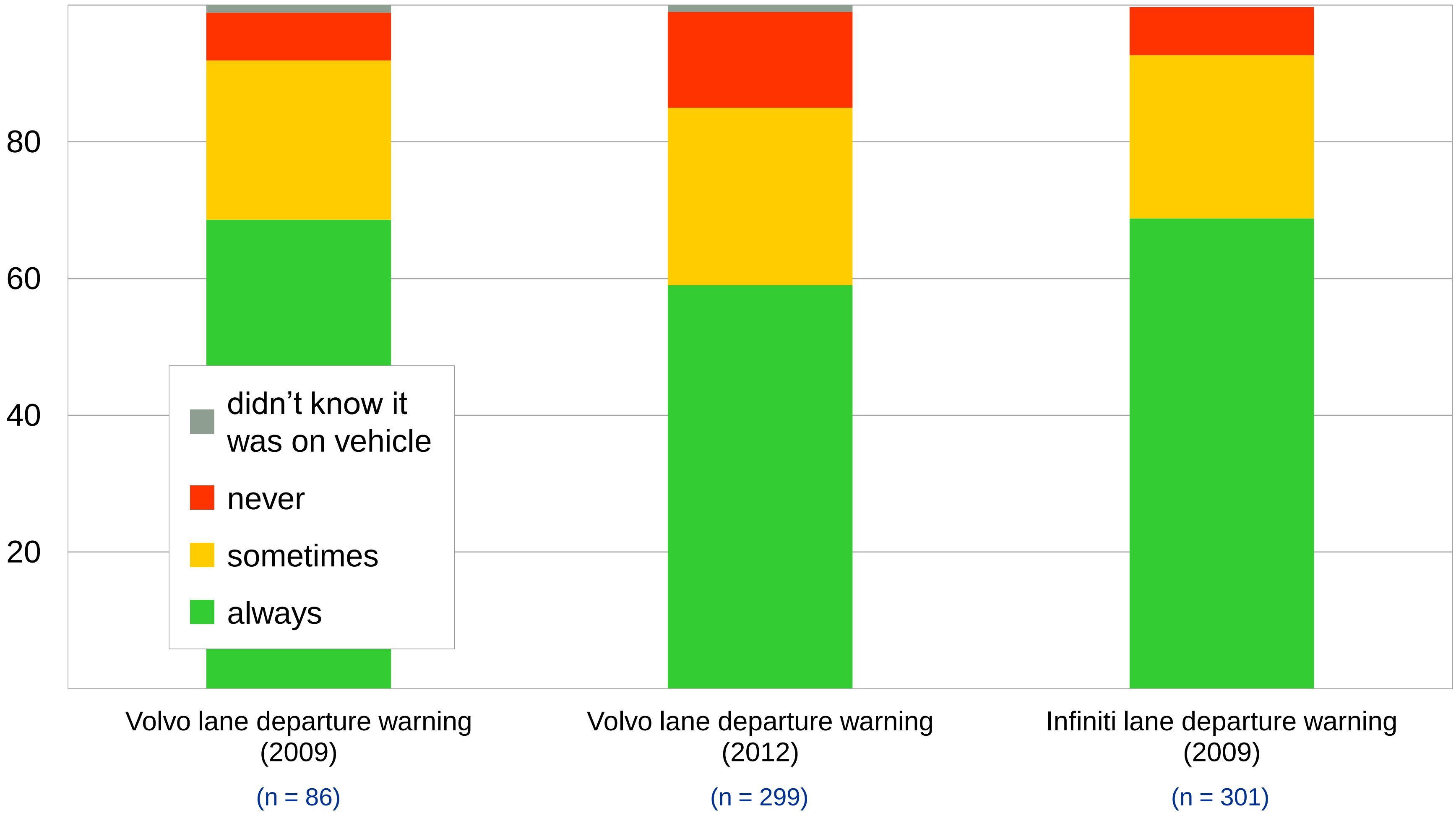
Only Volvo LDW systems are associated with decreases in claim frequency, and that is likely due to the forward collision warning with autonomous braking system, which always is paired with LDW

LDW is not reducing injury incidence

Percent change in claims per insured vehicle year



Percent of owners who drive with lane departure warning turned on



Questions raised about how drivers drive:

How much of driving is consciously controlled?

Intuitive model of driver behavior

Oversimplified but useful for this discussion

- Drivers set out to get from point A to point B without crashing
  - With rare exceptions of suicide and homicide
- Drivers (safe ones) constantly scan the road ahead and behind for risk
  - Drivers are cognitively engaged with the task unless attention is diverted to unrelated activity (distraction)
- Infotainment devices bring additional cues for behavior unrelated to the task of driving
  - These cues increase distraction from primary vehicle control task
- Crash avoidance features cue drivers when their distractions have led to danger
  - These cues return drivers’ attention to primary vehicle control task

Is cognitive engagement the default driver state?

Mind wandering is common

- "We developed a smartphone technology to sample people's ongoing thoughts, feelings, and actions and found (i) that people are thinking about what is not happening almost as often as they are thinking about what is and (ii) found that doing so typically makes them unhappy."
  - Killingsworth, M.A. and Gilbert, D.T. 2010. A wandering mind is an unhappy mind. *Science*, 330, 932.
- "… people adjust their effort to the immediate and prospective demands of tasks that are put before them."
  - Hancock, P.A. 2013. In search of vigilance: The problem of iatrogenically created psychological phenomena*.* *American Psychologist*, 68(2), 97-109.

How great are the situational demands for cognitive control of driving ?

- Driving for most of us is an overlearned behavior
- Overlearned behaviors may have limited conscious control; for example
  - Throwing a baseball does not involve calculation of parabolic trajectories but rather the exercise of brain-muscle connections developed with practice
  - Maintaining lane position and driving around curves is easier if one looks ahead to where the vehicle is going rather than nearby, trying to control distance to road edge lines precisely
- Sometimes we arrive at our destinations with little memory of how we got there
  - Do you remember your drive to the airport to come here?

What does it mean to pay attention to driving?

- Conscious attention to paying attention is not attention to the driving task
  - That's like being proud of humility
- If most driving is habitual, then driving effectiveness depends on
  - The adequacy of overlearned driving habits (hence the importance of graduated licensing)
  - The degree to which the road environment engages the driver's attention when necessary (road geometry and rules of the road)
  - Recapturing attention when unusual circumstances arise (special signing – flashing lights, crash avoidance features)

Implications for advanced driver assistance systems

- Forward collision prevention
  - Systems appear to work
  - Cues are effective

    But not always, because autonomous braking improves effectiveness
  - One surprising finding is equivalence of different alert strategies as indicated in equivalent findings across automakers
- Adaptive (steering responsive) headlamps
  - Benefits consistent with the addition of information that fits drivers' habits
  - Although data are preliminary, other lighting improvements also seem to reduce insurance crash claims

Implications for advanced driver assistance systems

- Lane departure warning
  - Cues are ineffective
  - If the negative effect is real, is it possible that exposure to non-meaningful warnings may be making drivers less sensitive to all cues?
- Implication for V2V and V2I communications
  - These can greatly increase information coming to drivers
  - What problems may occur if too much of the information has limited implications for immediate behavior?

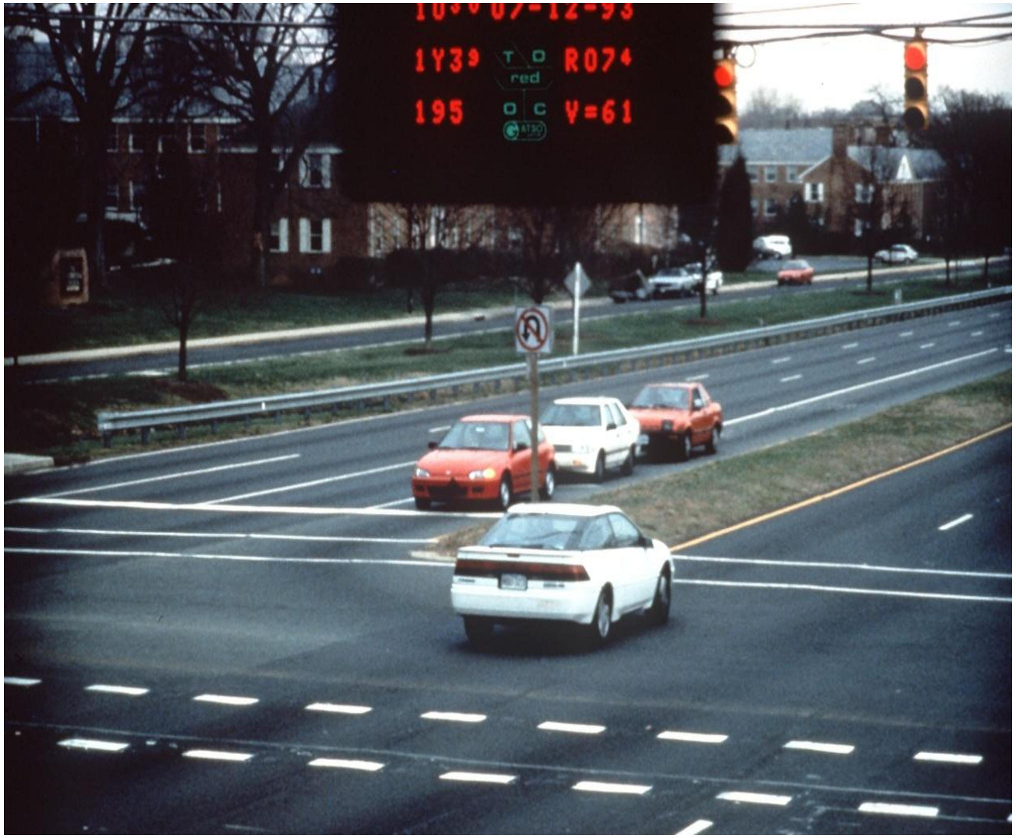
    Providing these cues hypothesizes that what the car thinks drivers should focus on is more important than what the driver is focused on

    Is information that has no immediate behavioral value distracting from the driving task?

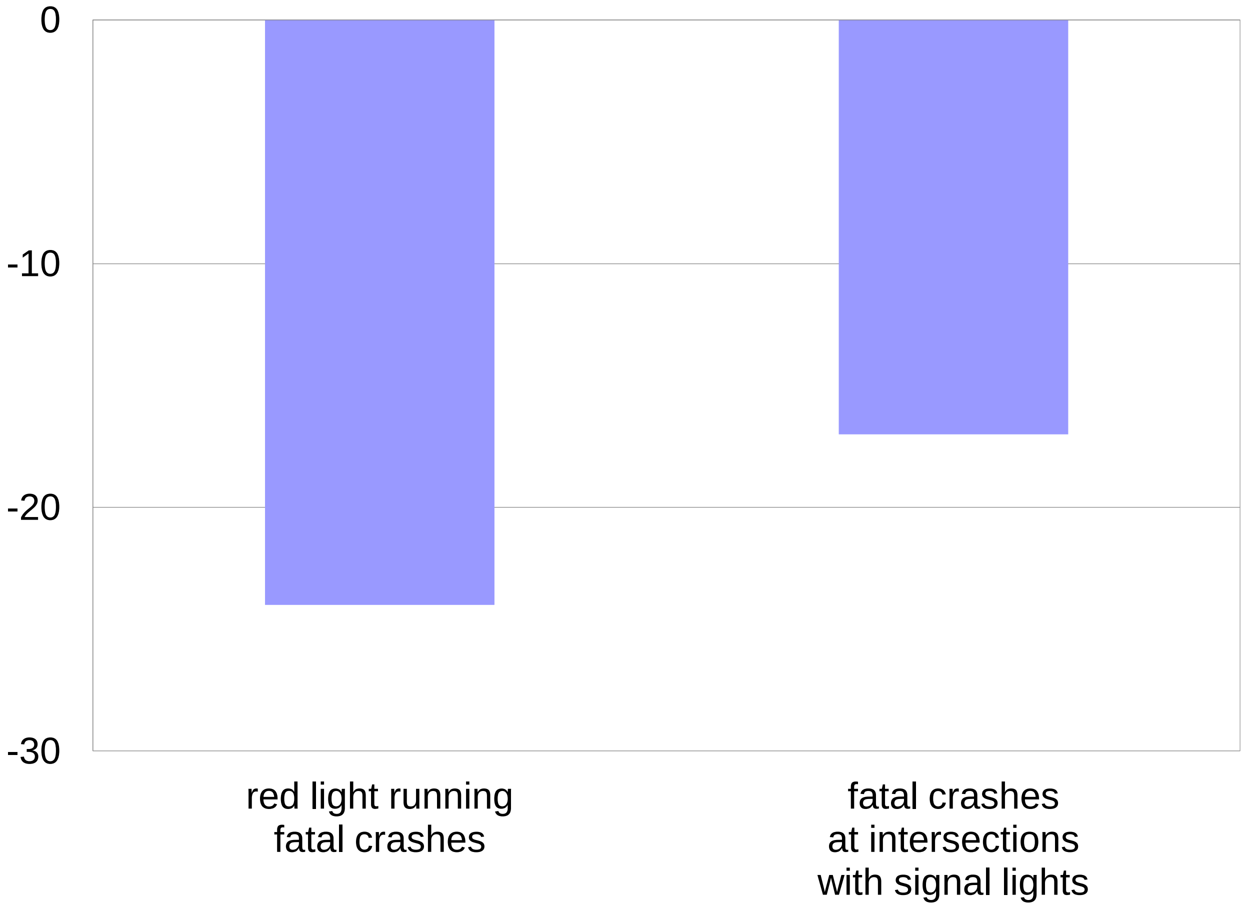
Improvements in driver attention and performance may not require new technology

Red light cameras already are making drivers pay more attention at intersections

In 2011 on US roads, about 150,000 red-light-running crashes caused about 118,000 injuries and about 700 deaths.



Percent difference in actual fatal crash rates during 2004-08 in 14 large cities with red light cameras vs. expected rates without cameras



Red light cameras are sometimes criticized for enforcing right-turn-on red rules. However, stop-before-turning rules are meant to protect pedestrians from drivers who might otherwise be looking left for oncoming traffic when pedestrians enter the road from the right.


CG PEWE 01

Roundabouts also reduce crashes

Is that partly because they make drivers pay attention (as well as slow down)?

Roundabouts are safer and more efficient

Roundabouts require drivers to:

slow down,
look for traffic in the circle,
negotiate the circle,
watch for other traffic entering the circle.

Estimated crash reductions if 10 percent of signalized intersections in US converted to roundabouts

- Approximately 43,000 crashes prevented in 2011 including:
  - 170 fatal crashes
  - 28,000 injury crashes

Estimated annual economic savings if 10 percent of signalized intersections in US converted to roundabouts

- Vehicle delays reduced by more than 900 million hours
- Fuel consumption reduced by more than 600 million gallons

Conclusion

- Infotainment and crash avoidance features promise to proliferate in the near term
- Our intuitive model of driver behavior – that the default driver state is cognitive attention to the task – probably misleads us
  - Effective integration of these features into the driving environment requires recognition that
    - Much of our daily lives involves mind wandering
    - Much of driving behavior is habitual, with limited cognitive control
- Key question for all of us: How do we get drivers the information they need and want without distracting them from the driving task as they perform it?

Postscript

Research planned at the Insurance Institute for Highway Safety

vehicle to pedestrian

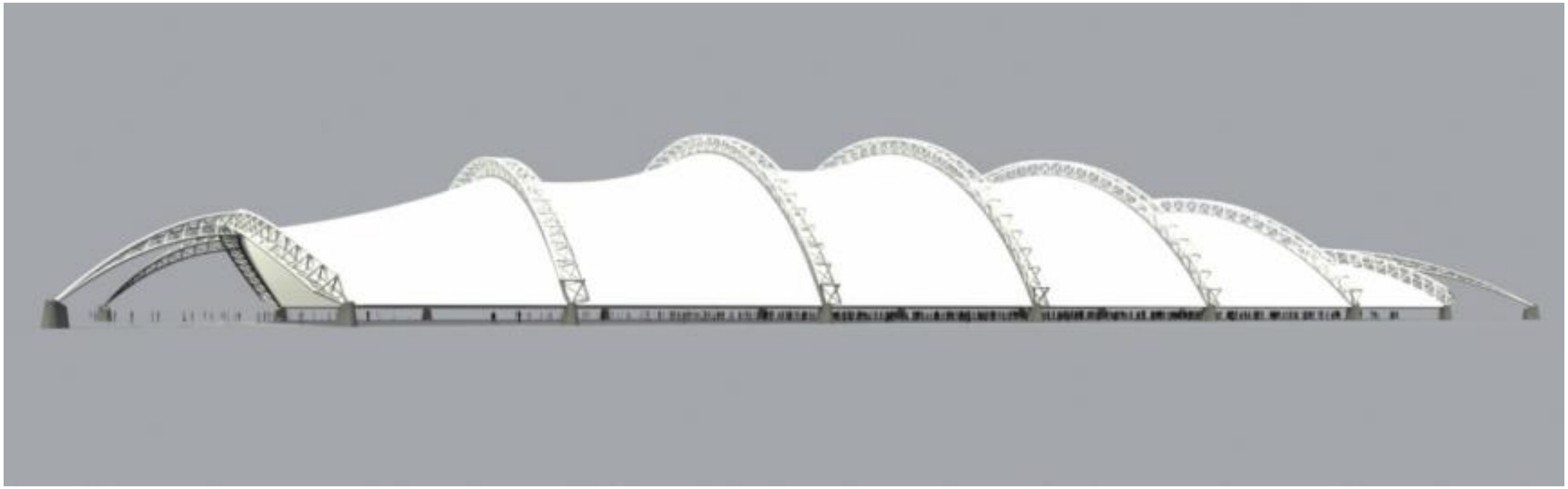
vehicle to stationary vehicle

vehicle to moving vehicle

Planned expansion of test track capability

Covered test track

Steel and tensile fabric structure



Form to finish first of 18 support piers

http://press.iihs.org/VRC_expansion/updates.html

www.iihs.org

Dedicated to reducing deaths, injuries, and property damage on the highway

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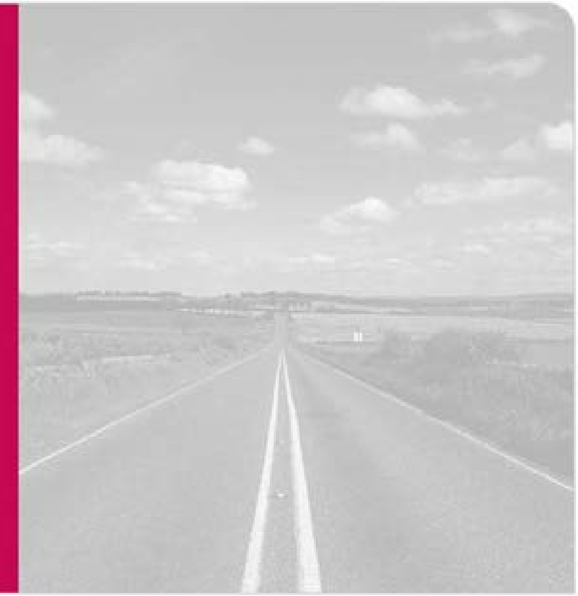


Highway Safety: What Does the Future Hold?

North Carolina Highway Safety Symposium
Winston-Salem, NC ● February 6, 2012

Anne T. McCartt, Ph.D.

www.iihs.org

The Insurance Institute for Highway Safety,

founded in 1959, is an independent, nonprofit, scientific and educational organization dedicated to reducing the losses — deaths, injuries, and property damage — from crashes on the nation's highways.

The Highway Loss Data Institute,

founded in 1972, shares and supports this mission through scientific studies of insurance data representing the human and economic losses resulting from the ownership and operation of different types of vehicles and by publishing insurance loss results by vehicle make and model.

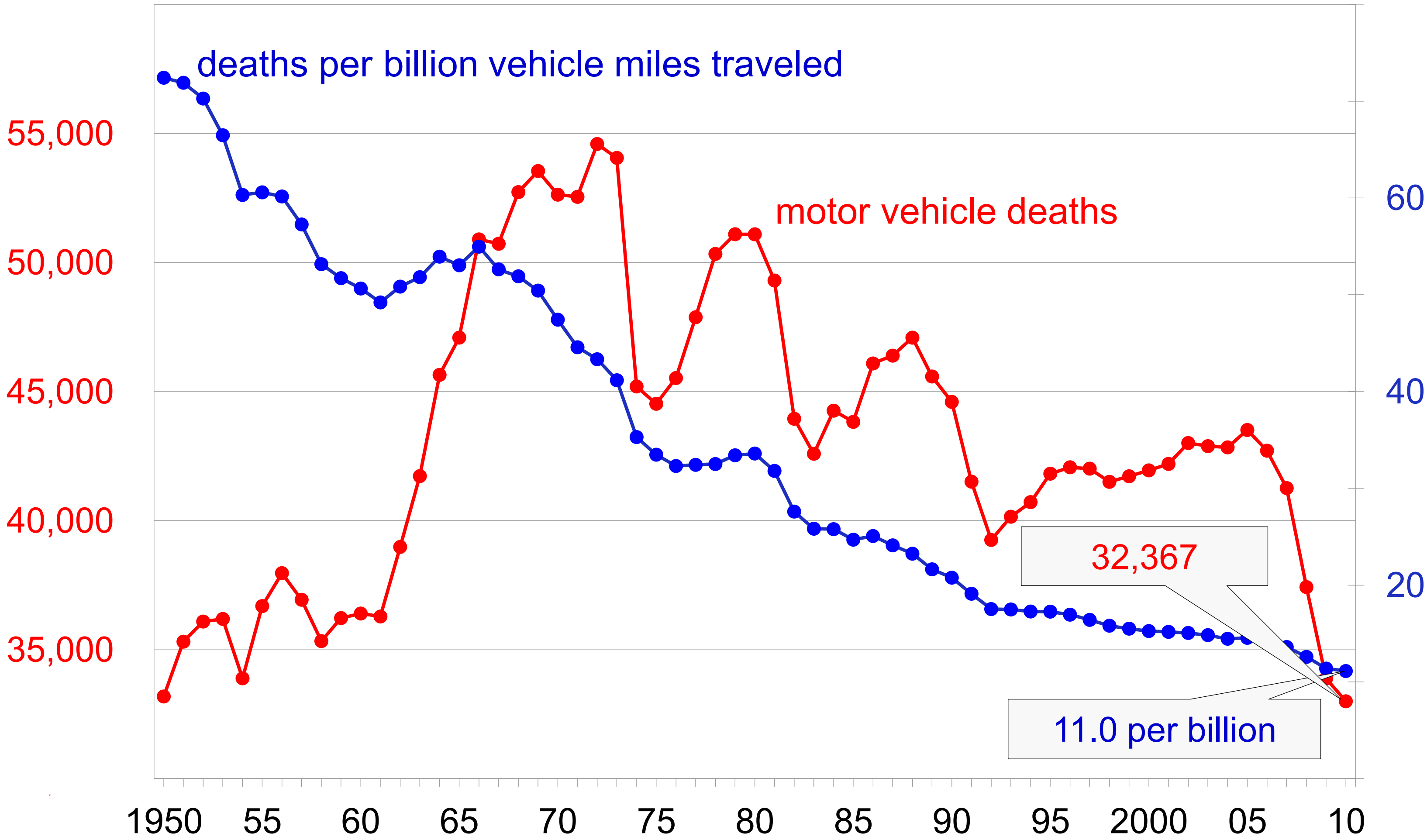
Both organizations are wholly supported by auto insurers.

Where are we?

Location of IIHS/HLDI and Vehicle Research Center

Motor vehicle crash deaths and deaths per billion vehicle miles traveled

1950-2011



Making safer vehicles

40 mph frontal offset crash test

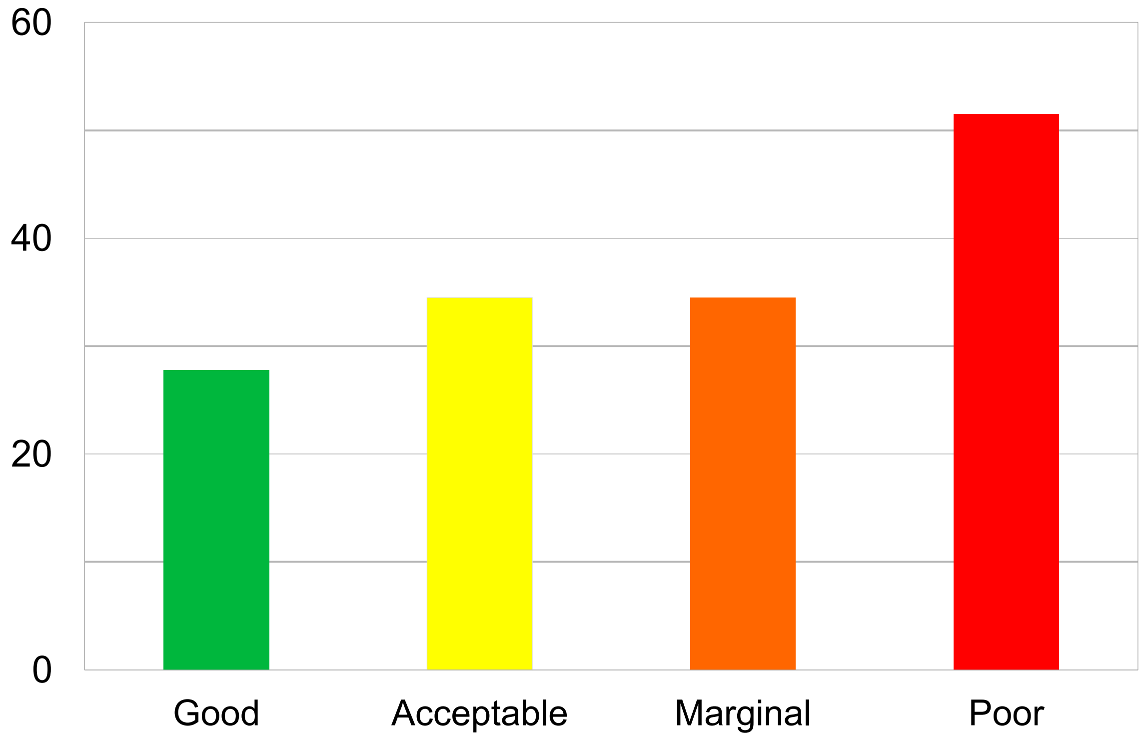
1959 Chevrolet Bel Air and 2009 Chevrolet Malibu

Front crashworthiness ratings

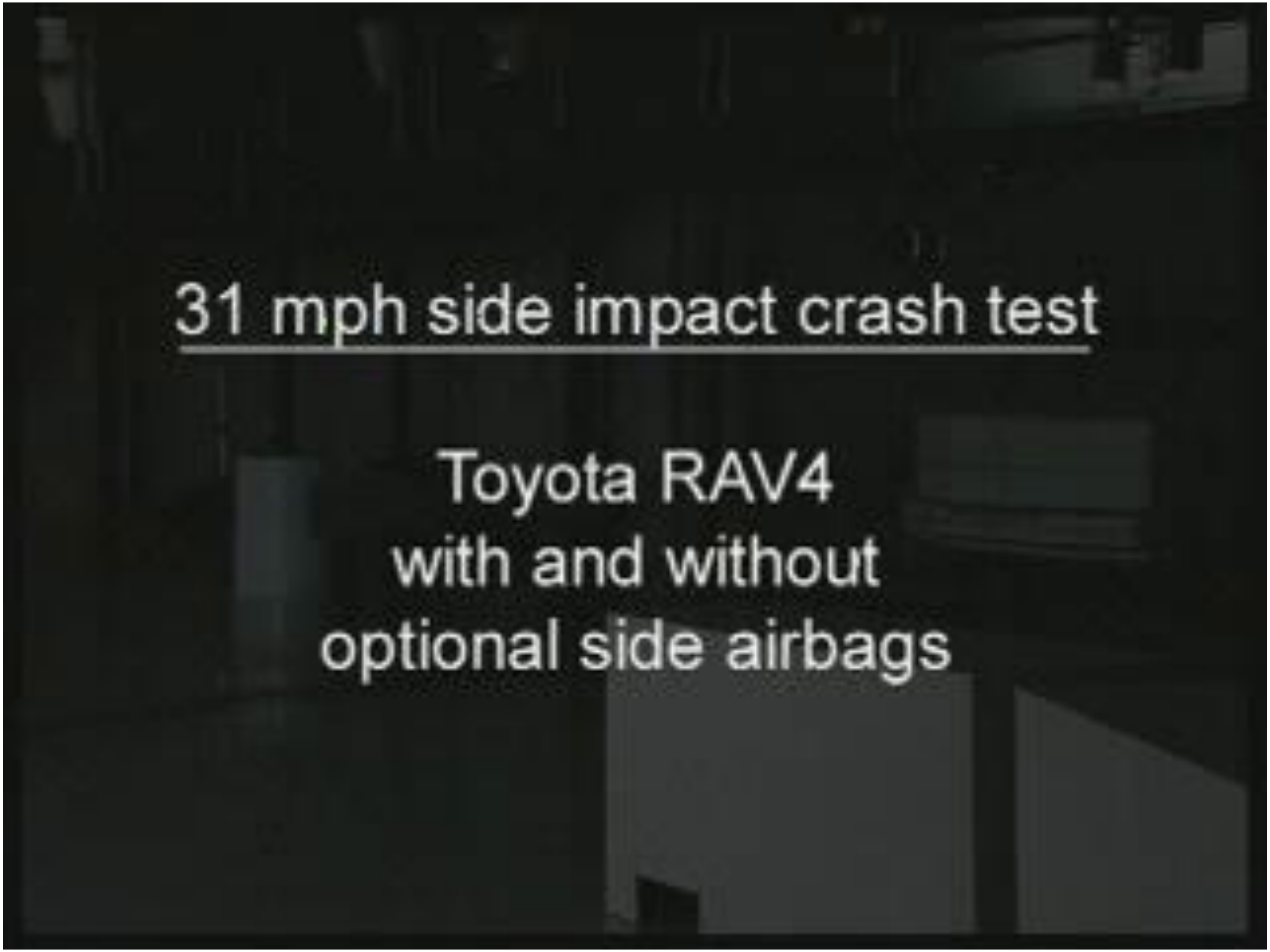
Promote stronger occupant compartment (safety cage)

Frontal offset ratings and fatality risk

Driver deaths in frontal crashes per million vehicle registrations, 1993-2004, by crashworthiness rating

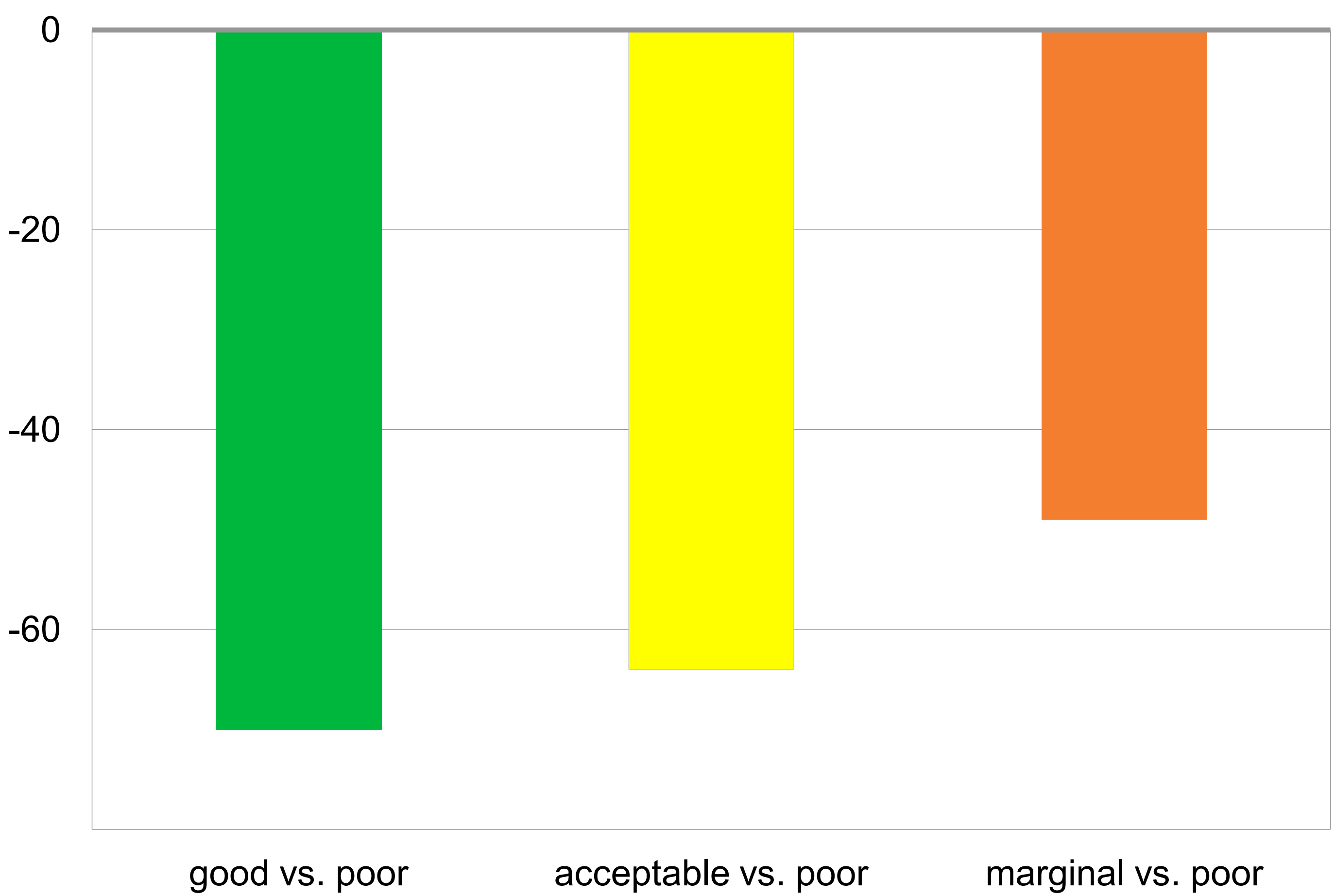


- Good designs have 46 percent lower fatality risk than Poor designs
- Acceptable or Marginal designs have 33 percent lower fatality risk than Poor designs


31 mph side impact crash test
Toyota RAV4
with and without
optional side airbags

Percent reduction in risk of driver death in left side impacts by driver-only rating

Vehicles equipped with side airbags



Requirements for *TOP SAFETY PICK* award

G evaluation in frontal crashworthiness test

G evaluation in side crashworthiness test

G evaluation in rear crashworthiness test

G evaluation in roof strength test

Availability of electronic stability control (federal requirement on 2012 and newer vehicles)

2012 *TOP SAFETY PICK* winners, as of December 2012

Large cars
Audi A6
Buick LaCrosse
Buick Regal
BMW 5 series
Cadillac CTS sedan
Chrysler 300
Dodge Charger
Ford Taurus
Hyundai Azera
Hyundai Equus
Hyundai Genesis
Infiniti M37/M56
Lexus GS
Lincoln MKS
Mercedes E class
Saab 9-5
Toyota Avalon
Volvo S80

Midsize cars
Acura TL
Acura TSX
Audi A3
Audi A4 sedan
BMW 3 series sedan
Buick Verano
Chevrolet Malibu
Chevrolet Malibu Eco
Chrysler 200
Dodge Avenger
Ford Fusion
Hyundai Sonata
Kia Optima
Lexus ES
Lincoln MKZ
Mercedes C class
Subaru Legacy
Subaru Outback
Toyota Camry
Toyota Prius V
Volkswagen CC
Volkswagen Jetta sedan
Volkswagen Jetta SportWagen
Volkswagen Passat
Volvo C30
Volvo S60

Small cars
Acura ILX
Chevrolet Cruze
Chevrolet Sonic
Chevrolet Volt
Dodge Dart
Ford Focus 4-door
Honda Civic 4-door
Honda CR-Z
Honda Insight
Hyundai Elantra
Kia Forte
Kia Soul
Lexus CT 200h
Mazda 3 sedan/hatchback
Mini Cooper Countryman
Mitsubishi Lancer
Nissan Cube
Nissan Juke
Nissan Leaf
Scion FR-S
Scion tC
Scion xB
Scion xD
Subaru BRZ
Subaru Impreza
Subaru XV Crosstek
Toyota Corolla
Toyota Prius
Toyota Prius c
Volkswagen Golf
Volkswagen GTI

Minicar
Fiat 500
Ford Fiesta
Honda Fit
Nissan Versa Sedan
Toyota Yaris Hatchback

Minivans
Chrysler Town & Country
Dodge Grand Caravan
Honda Odyssey
Toyota Sienna
Volkswagen Routan

Large pickups
Ford F-150
Honda Ridgeline
Toyota Tundra

Large SUVs
Buick Enclave
Chevrolet Traverse
GMC Acadia
Volkswagen Touareg

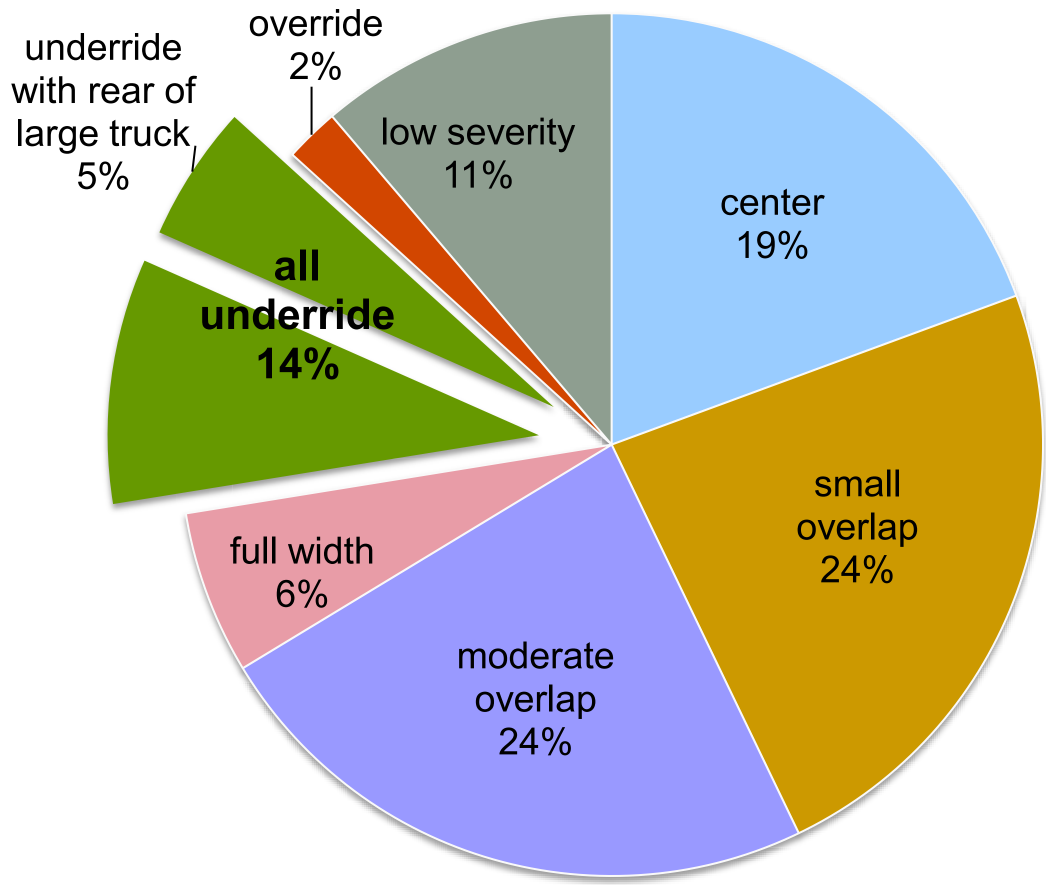
Midsize SUVs
Acura MDZ
Acura RDX
Audi Q5
BMW X3
Cadillac SRX
Chevrolet Equinox
Dodge Durango
Dodge Journey
Ford Edge
Ford Explorer
Ford Flex
GMC Terrain
Honda Pilot

Hyundai Santa Fe
Infiniti EX35
Jeep Grand Cherokee
Kia Sorento
Lexus RX
Lincoln MKT
Lincoln MKX
Mercedes GLK
Mercedes M class
Saab 9-4X
Subaru Tribeca
Toyota Highlander
Toyota Venza
Volvo XC60
Volvo XC90

Small SUVs
Ford Escape
Honda CR-V
Hyundai Tucson
Jeep Patriot
Kia Sportage
Mazda CX-5
Mitsubishi Outlander Sport
Subaru Forester
Volkswagen Tiguan

Crashworthiness challenges continue

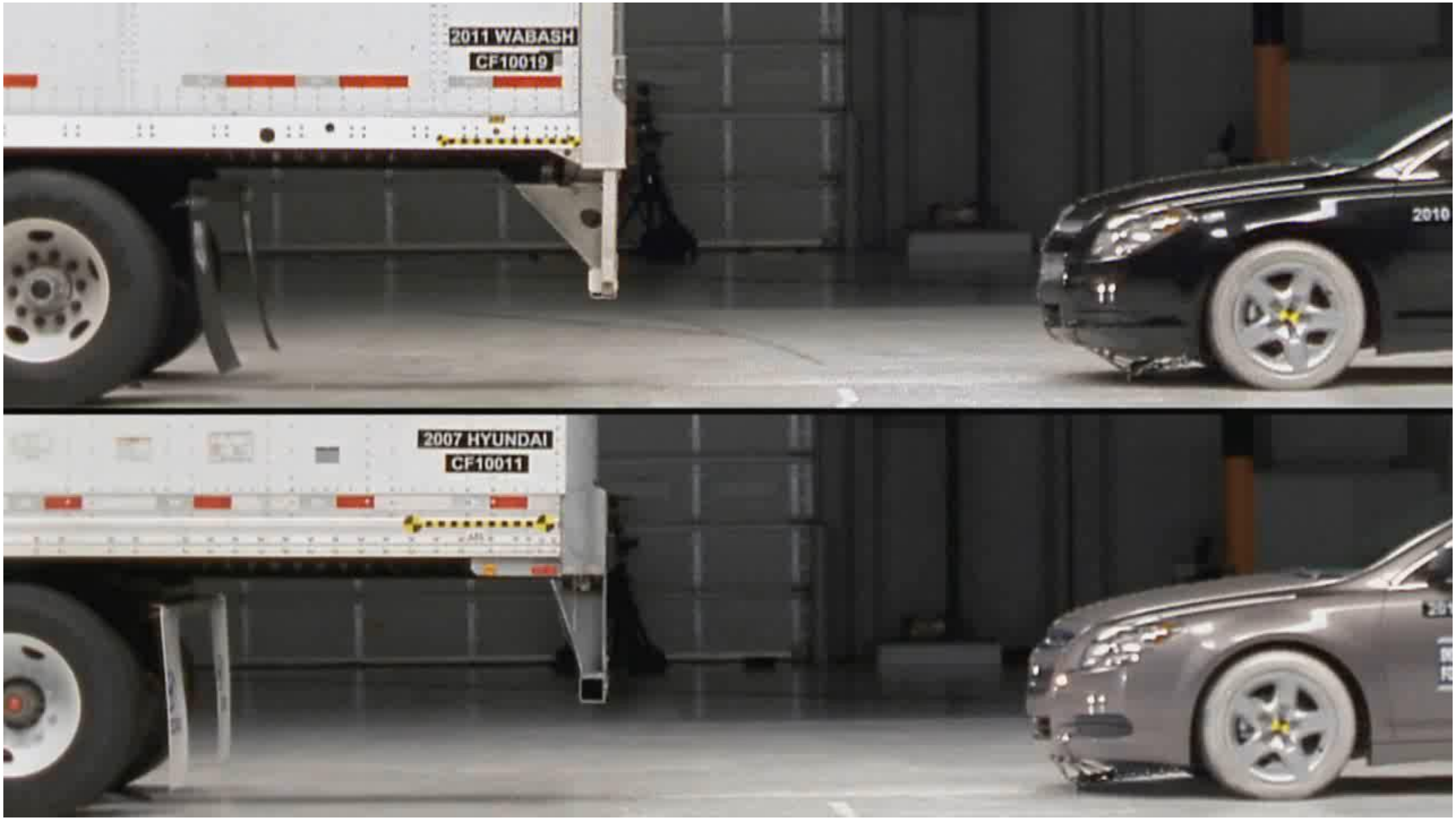
116 real-world frontal crashes with fatal or serious injuries of belted occupants in IIHS good-rated vehicles



Examples of real-world underride guard failures

Crash testing shows guard performance differences

35 mi/h center impact with 2010 Chevrolet Malibu

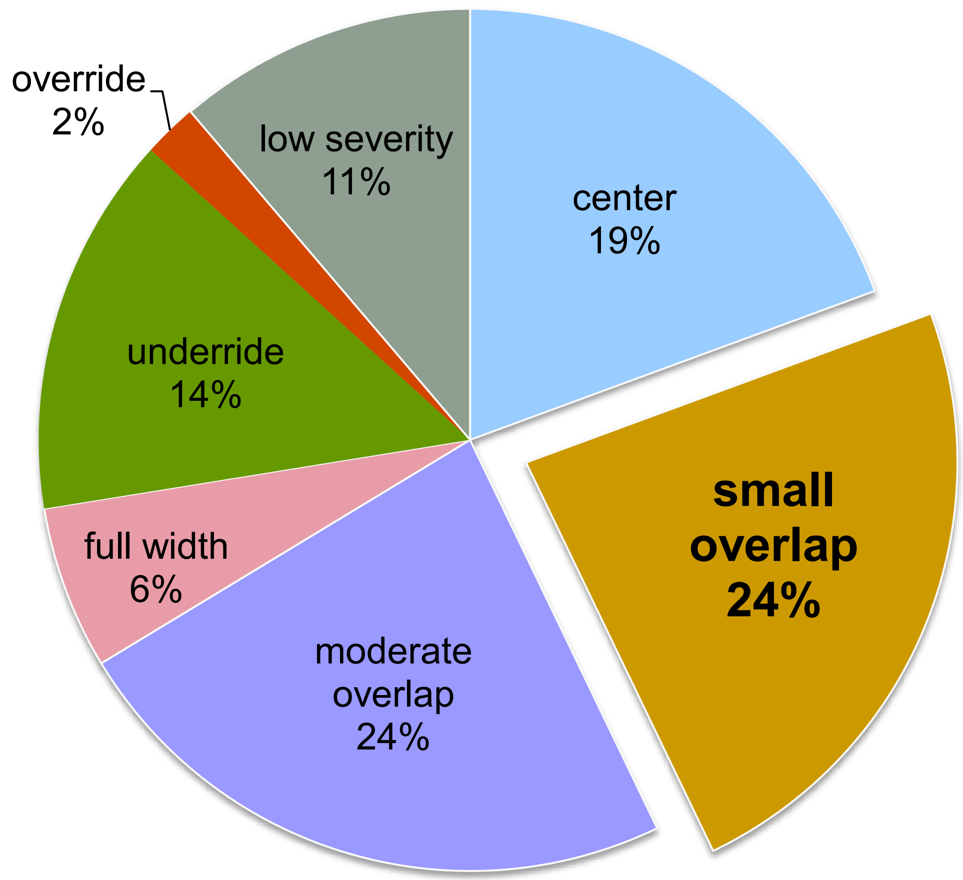


In 2011, IIHS petitioned for upgrades to federal rear underride guard standard

- Increase force requirements
- Attachments should remain intact during quasi-static testing
- Extend guard protection to full width of trailer
- Test guards while attached to trailers
- Re-evaluate practicality of lower ground clearance requirement
- Determine which current exemptions can be dropped, e.g., single unit trucks – many already have some type of guard

Small overlap crashes

116 real-world frontal crashes with fatal or serious injuries of belted occupants in IIHS good-rated vehicles



IIHS announces new small-overlap crash test program

August 14, 2012

Luxury/near luxury cars – 11 models

Midsize luxury/near luxury small overlap ratings

	Overall	Structure	Restraints & Kinematics	Dummy Injury Measures: Head & neck	Chest	Hip & thigh	Lower leg & foot
Acura TL	G	A	G	G	G	G	G
Volvo S60	G	G	A	G	G	G	G
Infiniti G	A	M	G	G	G	G	G
Acura TSX sedan/Sport Wagon	M	M	M	G	G	G	P
BMW 3 series	M	M	M	G	G	G	P
Lincoln MKZ	M	P	M	G	G	G	A
Volkswagen CC	M	M	P	G	G	A	G
Mercedes C-Class	P	P	M	G	G	G	P
Lexus IS 250/350	P	P	P	G	G	G	P
Audi A4	P	P	P	G	G	P	G
Lexus ES 350	P	P	P	G	G	M	P

good G acceptable A marginal M poor P

Midsize moderately priced cars – 16 models

Television coverage:

Small overlap crash tests midsize family cars

Midsize moderately priced cars small overlap ratings

	Overall	Structure	Restraints & kinematics	Dummy injury measures: Head & neck	Chest	Hip & thigh	Lower leg & foot
Honda Accord 4-door	G	A	G	G	G	G	G
Suzuki Kizashi	G	G	A	G	G	G	G
Ford Fusion	A	A	A	G	G	G	G
Honda Accord 2-door	A	A	A	G	G	G	G
Kia Optima	A	M	G	G	G	G	G
Nissan Altima 4-door	A	A	G	G	G	G	P
Nissan Maxima	A	M	G	G	G	G	G
Subaru Legacy	A	M	G	G	G	G	G
Subaru Outback	A	M	G	G	G	G	G
Dodge Avenger	A	A	M	G	G	G	G
Chrysler 200 4-door	A	A	M	G	G	G	G
Mazda 6	A	A	M	G	G	G	G
Volkswagen Passat	A	A	M	G	G	G	G
Hyundai Sonata	M	M	A	G	G	G	M
Chevrolet Malibu	M	M	M	G	G	G	M
Volkswagen Jetta sedan	M	M	M	G	G	G	P
Toyota Camry	P	P	P	G	G	G	A
Toyota Prius v	P	P	P	G	G	P	P

Good G Acceptable A Marginal M Poor P

Vehicle damage in small overlap crashes

Primary structural member completely missed

Good structural rating

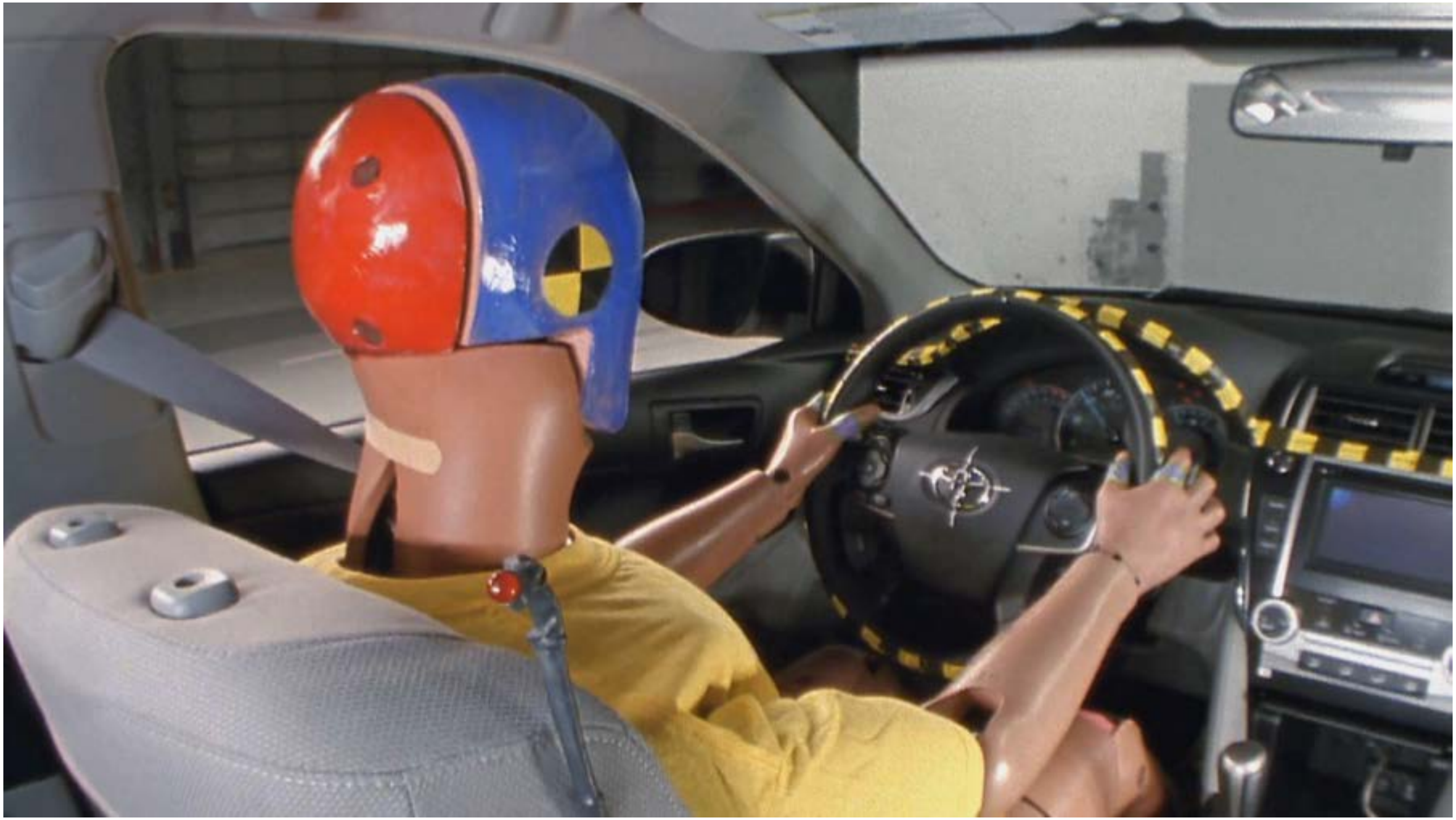
Suzuki Kizashi

Poor structural rating

Toyota Prius v

Stable airbag interaction – Honda Accord 4-door

Minimal airbag protection – Toyota Camry



2013 *TOP SAFETY PICK* Plus winners, January 2013

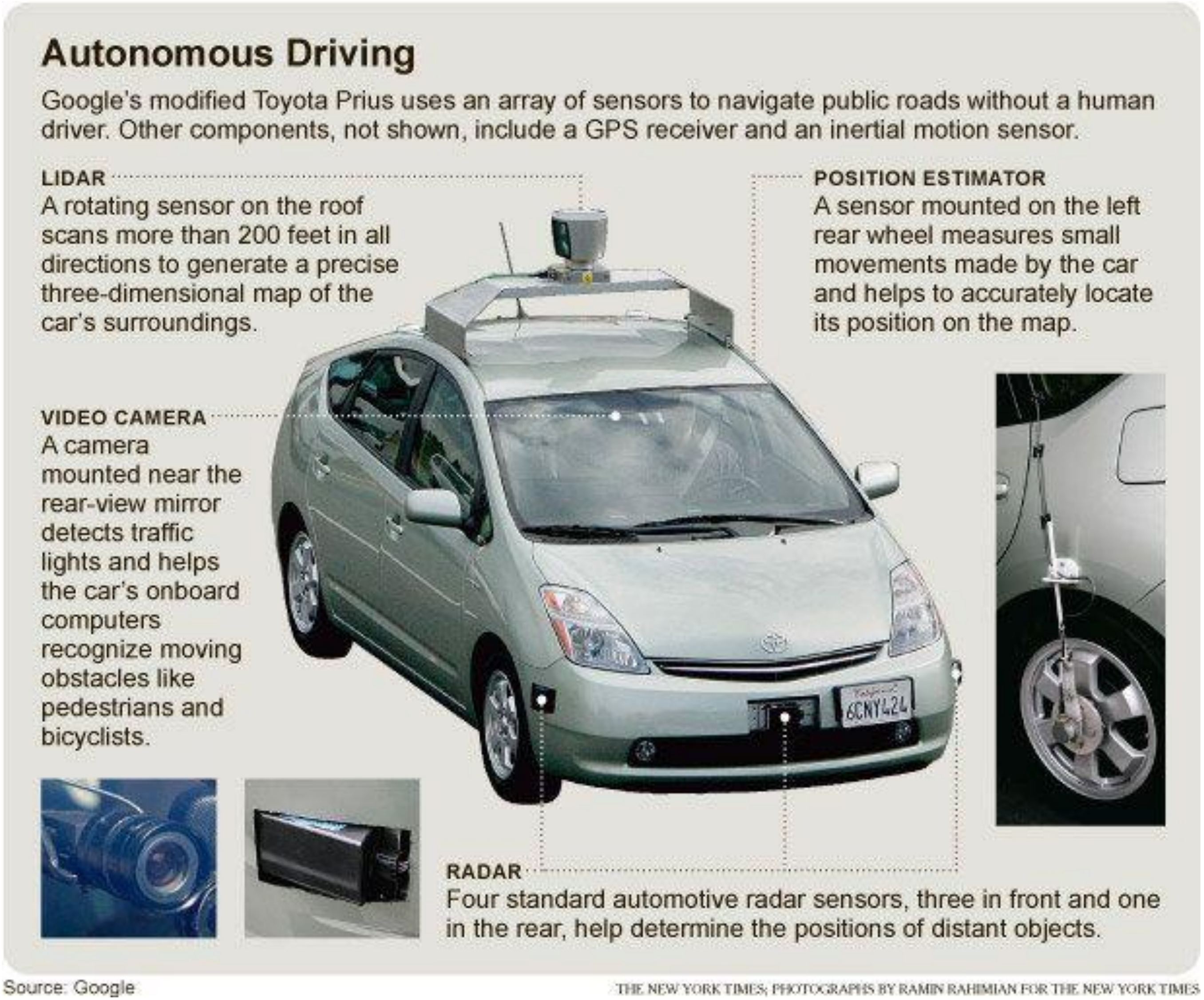
Good or Acceptable performance in small overlap test

- Acura TL
- Chrysler 200 4-door
- Dodge Avenger
- Ford Fusion
- Honda Accord 2-door
- Honda Accord 4-door
- Kia Optima
- Nissan Altima 4-door
- Subaru Legacy
- Subaru Outback
- Suzuki Kizashi
- Volkswagen Passat
- Volvo S60


VOLVO
SWEDEN 1
GERMANY 0
TOP SAFETY PICK 2012
The 2012 Volvo S60- the highest rated vehicle in the Insurance Institute for Highway Safety's new small overlap frontal crash test. The German guys? Well, let's just say that they didn't even come close.
5 YEAR WARRANTY - 5 YEAR SCHEDULED MAINTENANCE
5 YEAR WEAR & TEAR - 5 YEAR ROADSIDE ASSISTANCE
SAFE + SECURE COVERAGE PLAN

Crash avoidance is the new frontier

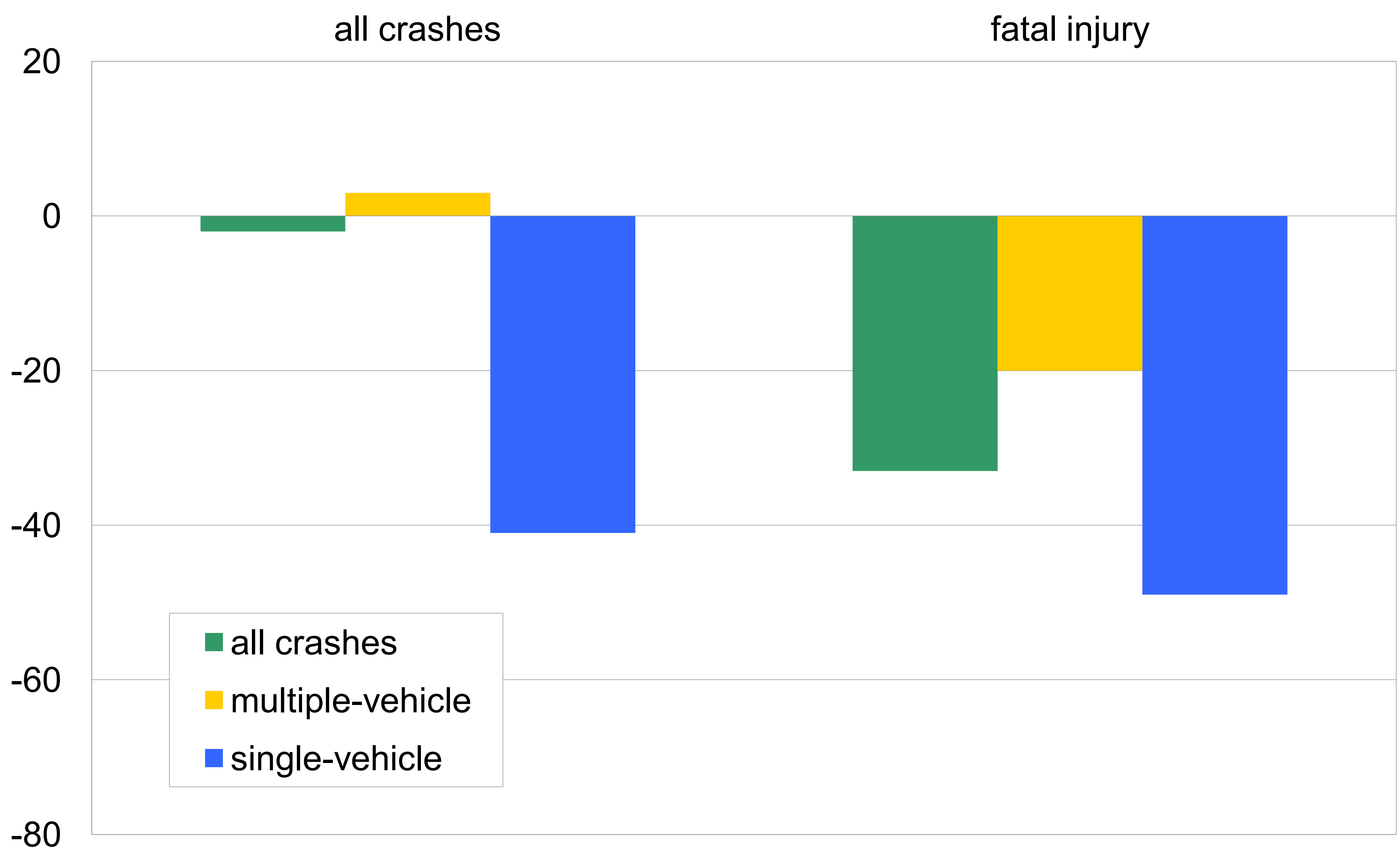
Google autonomous car




Split-screen:
Vehicle with ESC
compared with
vehicle with ESC deactivated

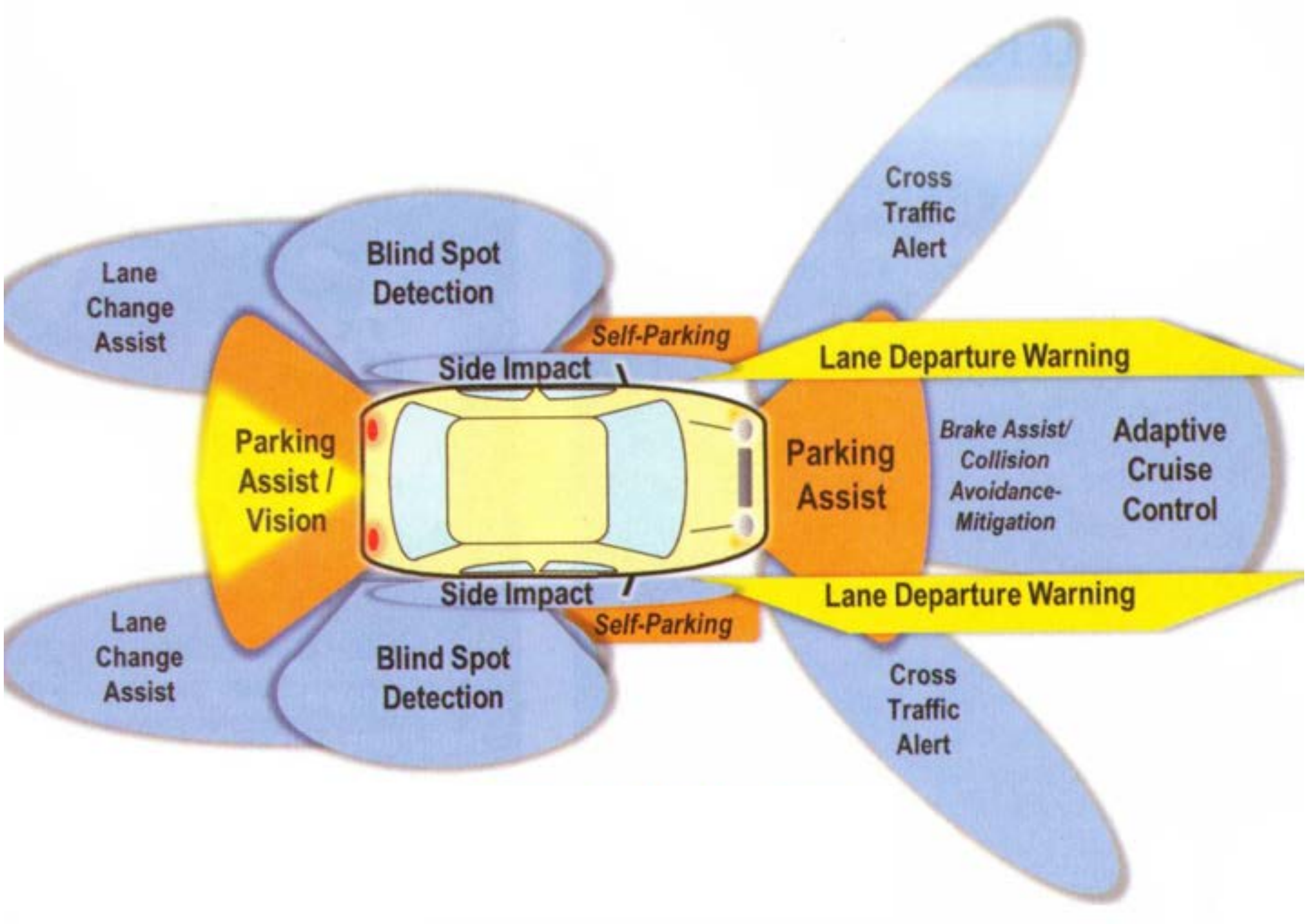
Effects on crash risk

Percent change in crash rates for vehicles with standard ESC vs. optional or no ESC, updated May 2010



Wave of new technologies

Radar, LIDAR, ultrasonic, infrared, cameras, GPS



Systems available on vehicles sold in United States

	number of makes	
	2008	2013
forward collision warning	8	27
lane departure warning	6	20
side view assist	6	29
adaptive headlights	16	23

Success of crash avoidance technology depends on answers to 5 questions

- Relevance
  - What is size and nature of crash problem being addressed?
  - Is present technology capable of addressing the problem?
- Acceptability
  - Will drivers use and accept technology?
- Intuitiveness
  - What kinds of information will elicit right responses from drivers?
- Adaptation
  - How will driver behavior change in response to technology?

Annual crashes potentially prevented or mitigated

Based on 2004-08 crash totals

	all	injury	fatal
forward collision warning	1,165,000	66,000	879
lane departure warning	179,000	37,000	7,529
side view assist	395,000	20,000	393
adaptive headlights	142,000	29,000	2,484
total unique crashes	1,866,000	149,000	10,238
percent of crashes	32%	21%	31%

Effectiveness of forward collision avoidance systems

Television coverage:

Volvo's City Safety

HLDI analyses involving optional features

Published July, 2012

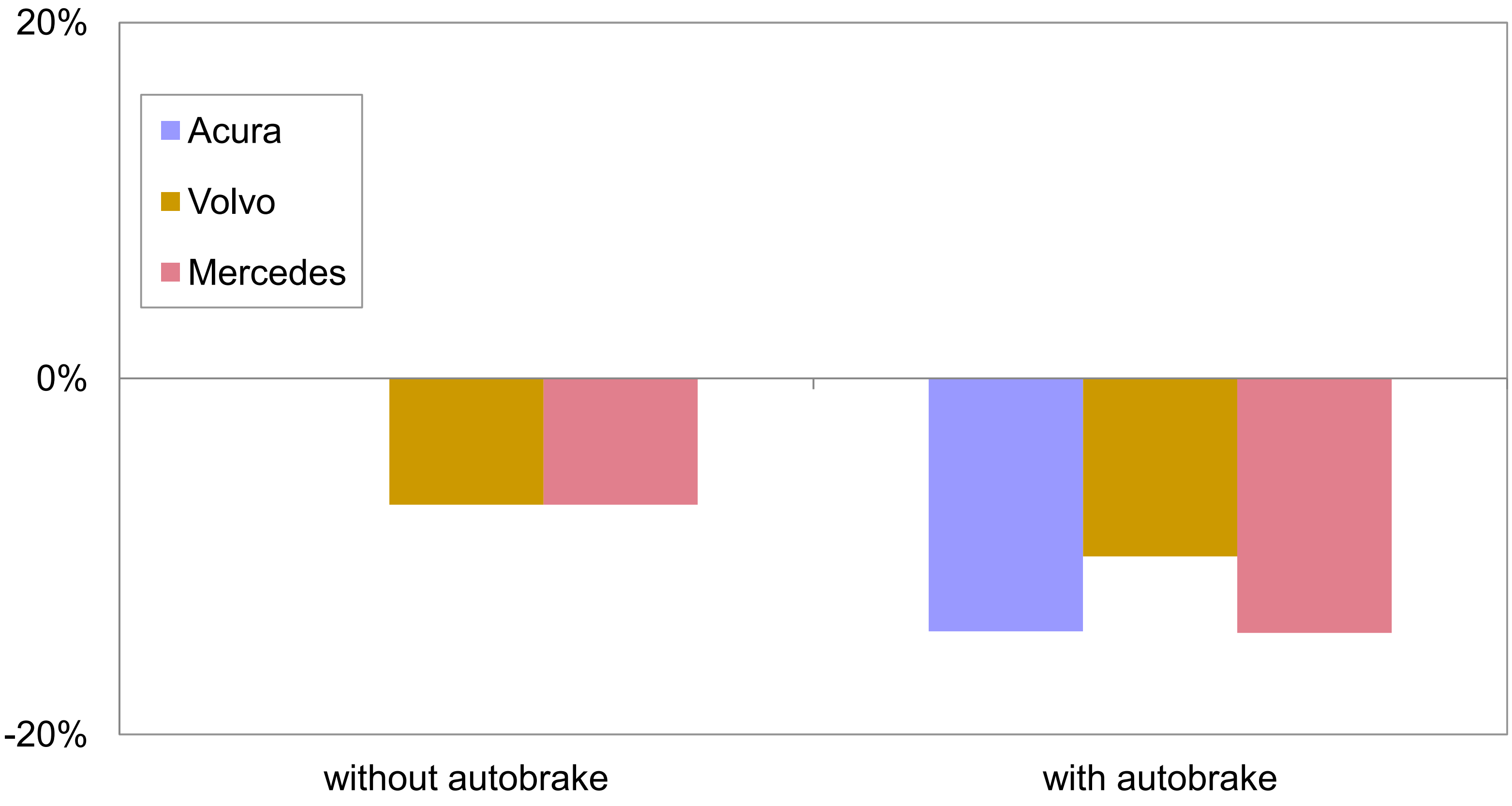
Forward collision avoidance

INSURANCE INSTITUTE FOR HIGHWAY SAFETY

HIGHWAY LOSS DATA INSTITUTE

Percent differences in property damage liability claim frequency with and without forward collision warning

By manufacturer



Lane departure warning and prevention

INSURANCE INSTITUTE FOR HIGHWAY SAFETY

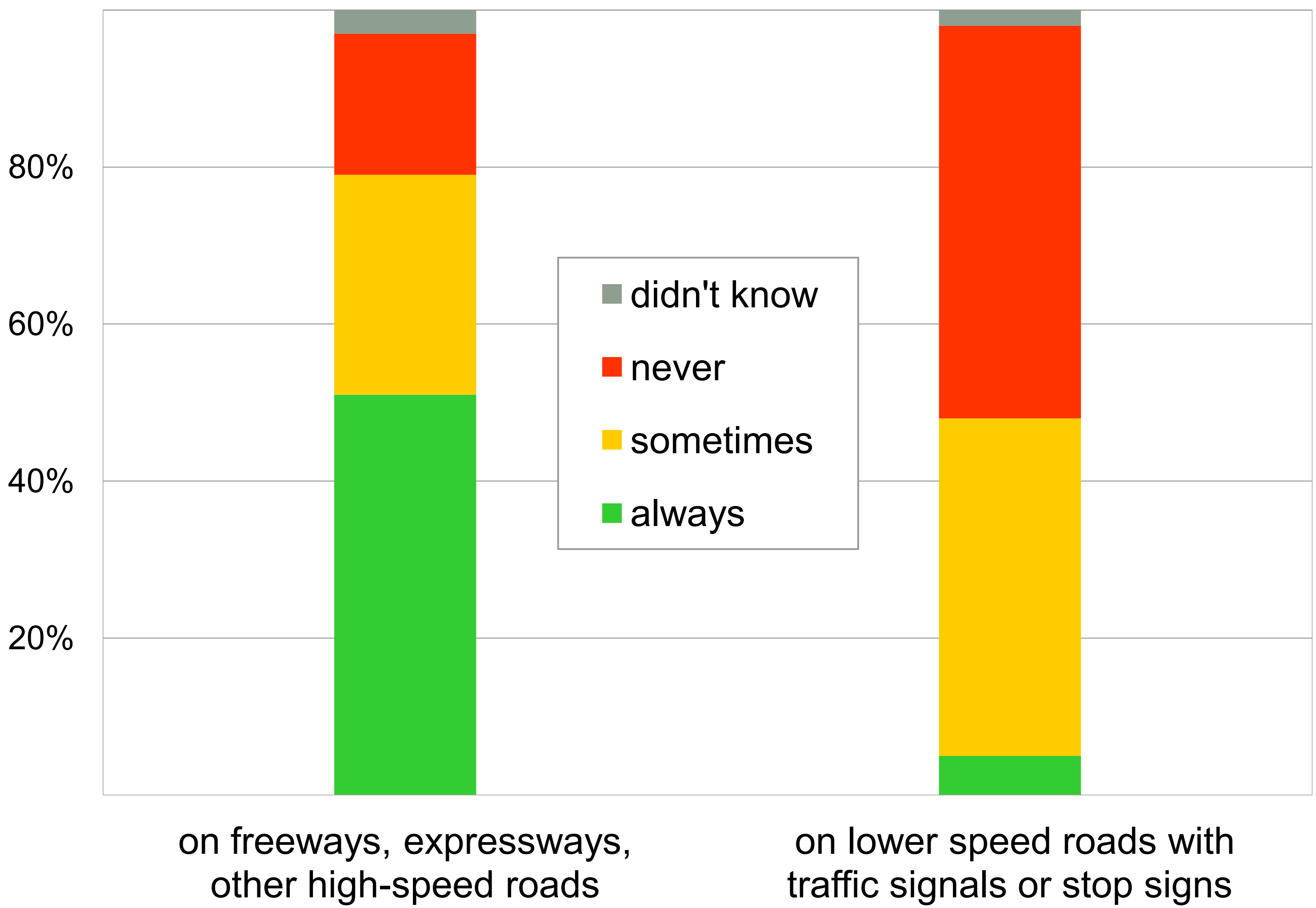
HIGHWAY LOSS DATA INSTITUTE

Analyses of insurance claims data involving other crash avoidance technologies

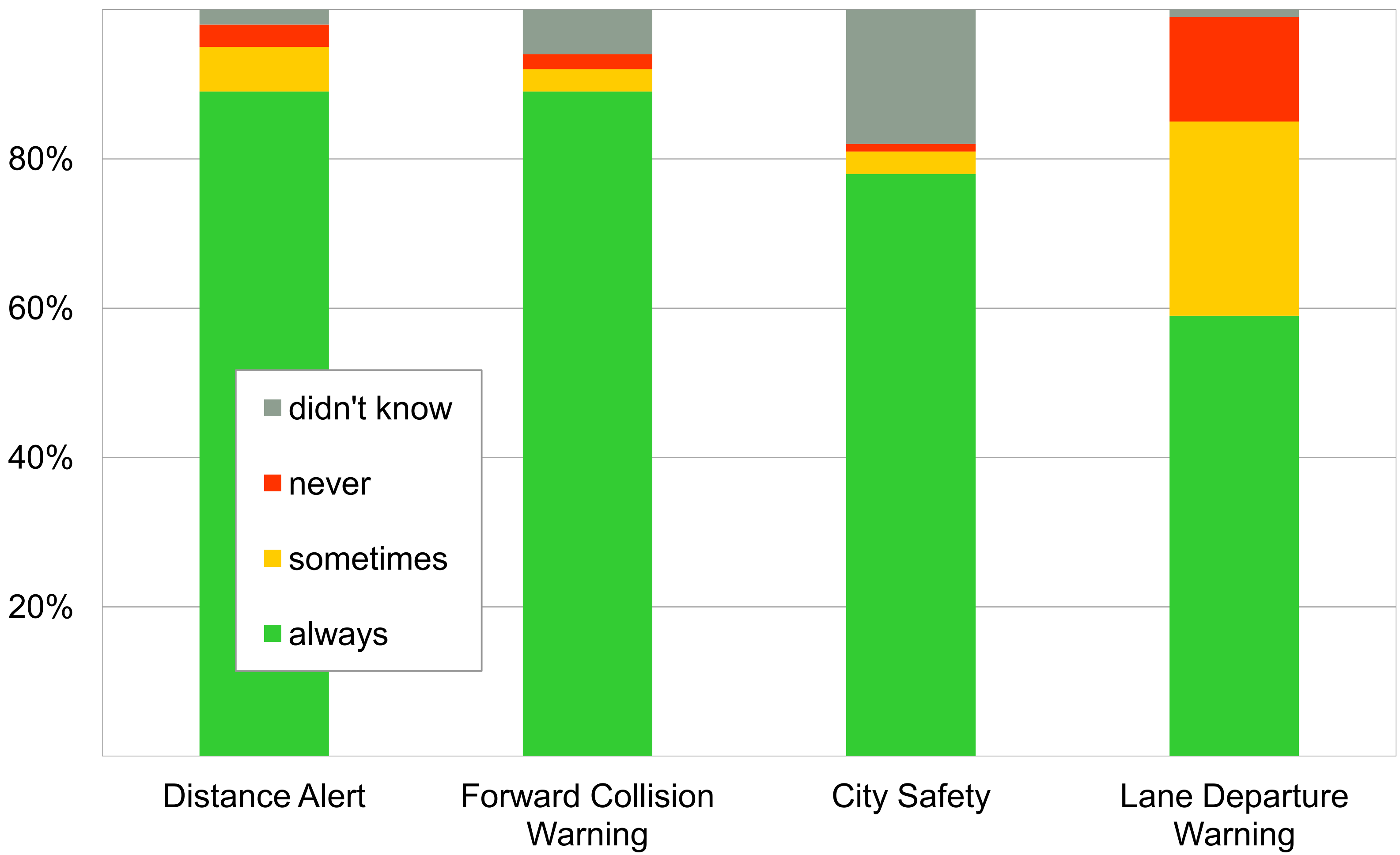
- Adaptive headlamps (pivot beam in the direction of travel) appear to be reducing crashes with other vehicles
- Lane departure warning does not appear to be reducing crashes

Do Volvo owners use and accept crash avoidance technologies?

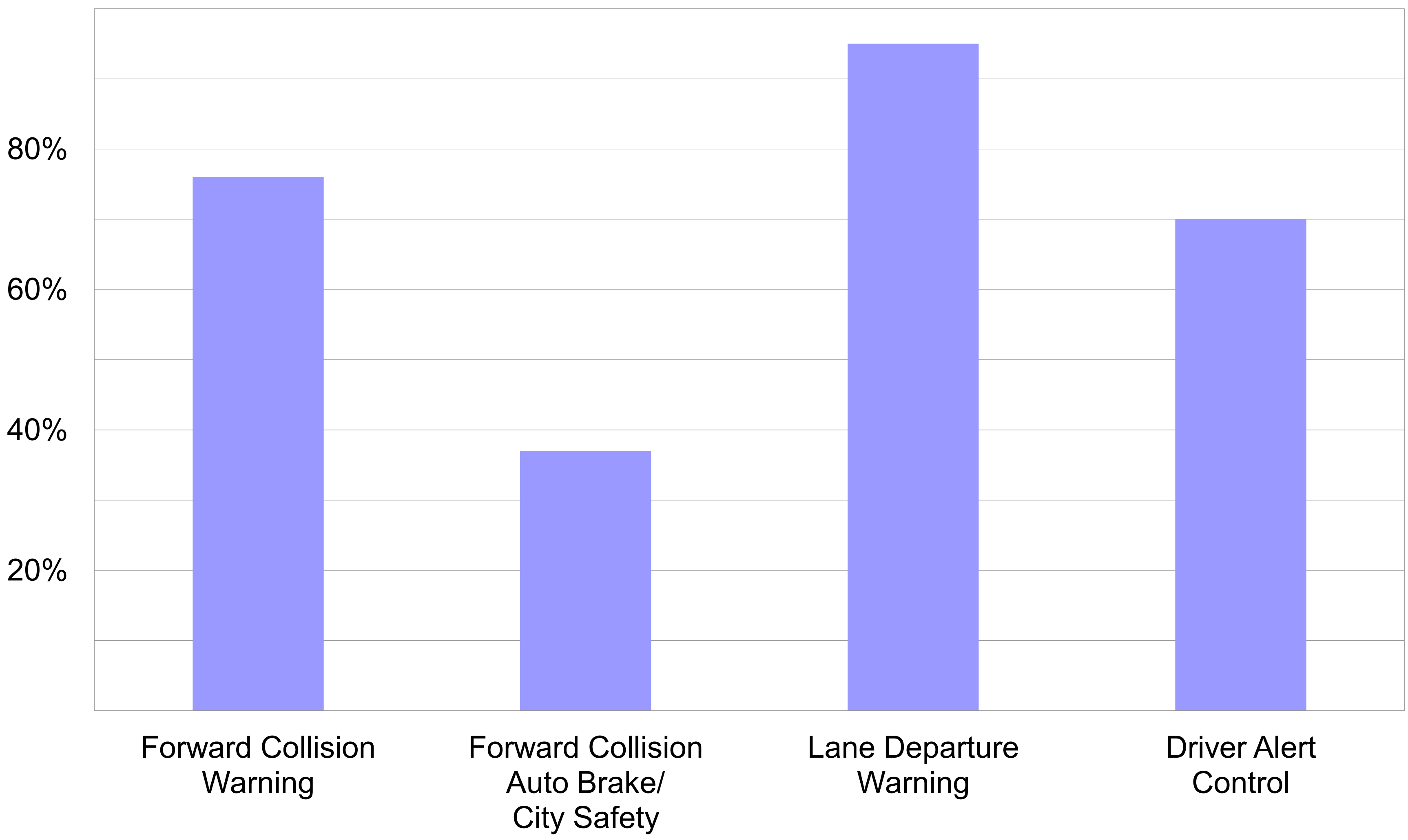
Percent of owners who use Adaptive Cruise Control



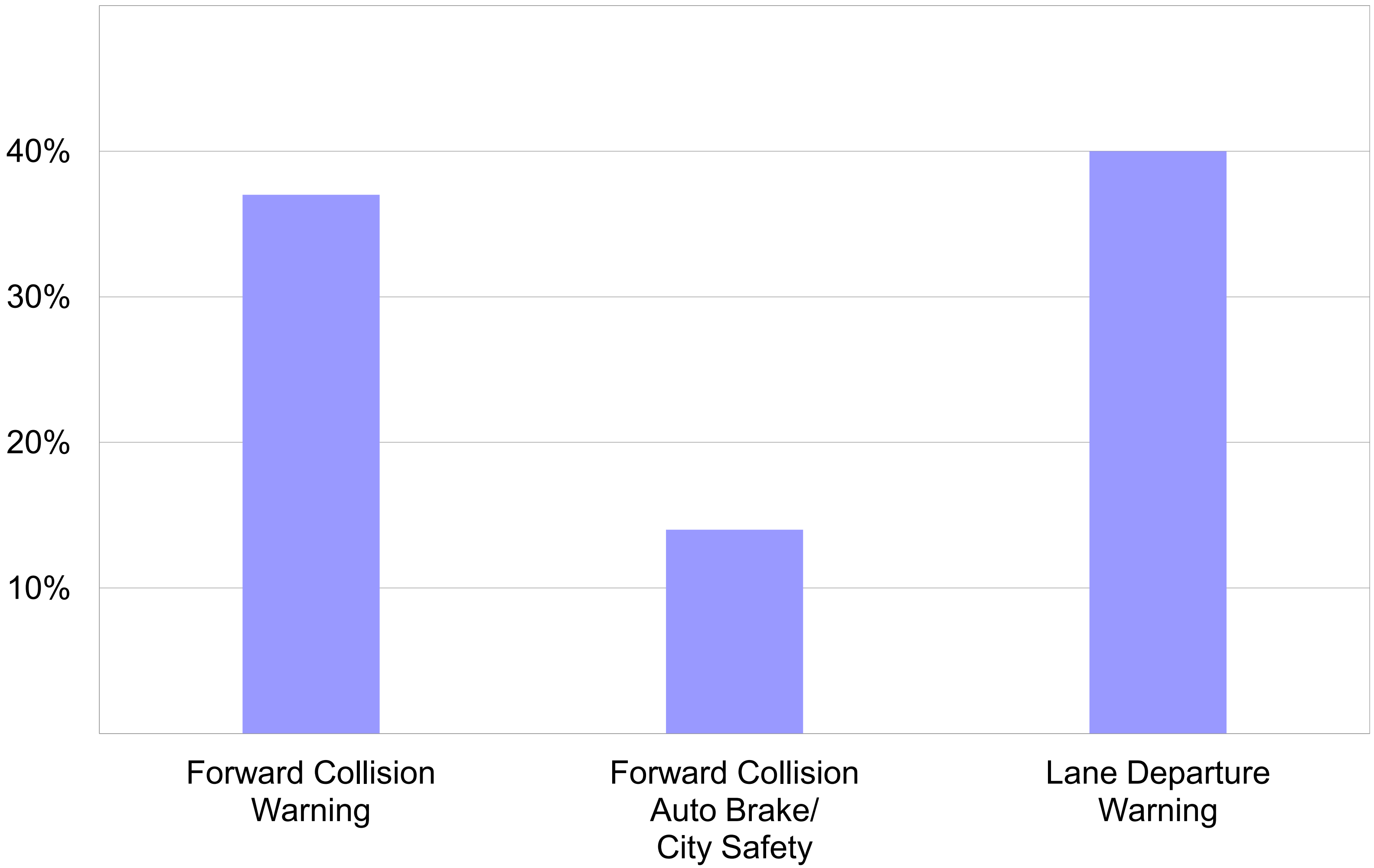
Percent of owners who drive with crash avoidance systems on



Percent of owners who report system activations



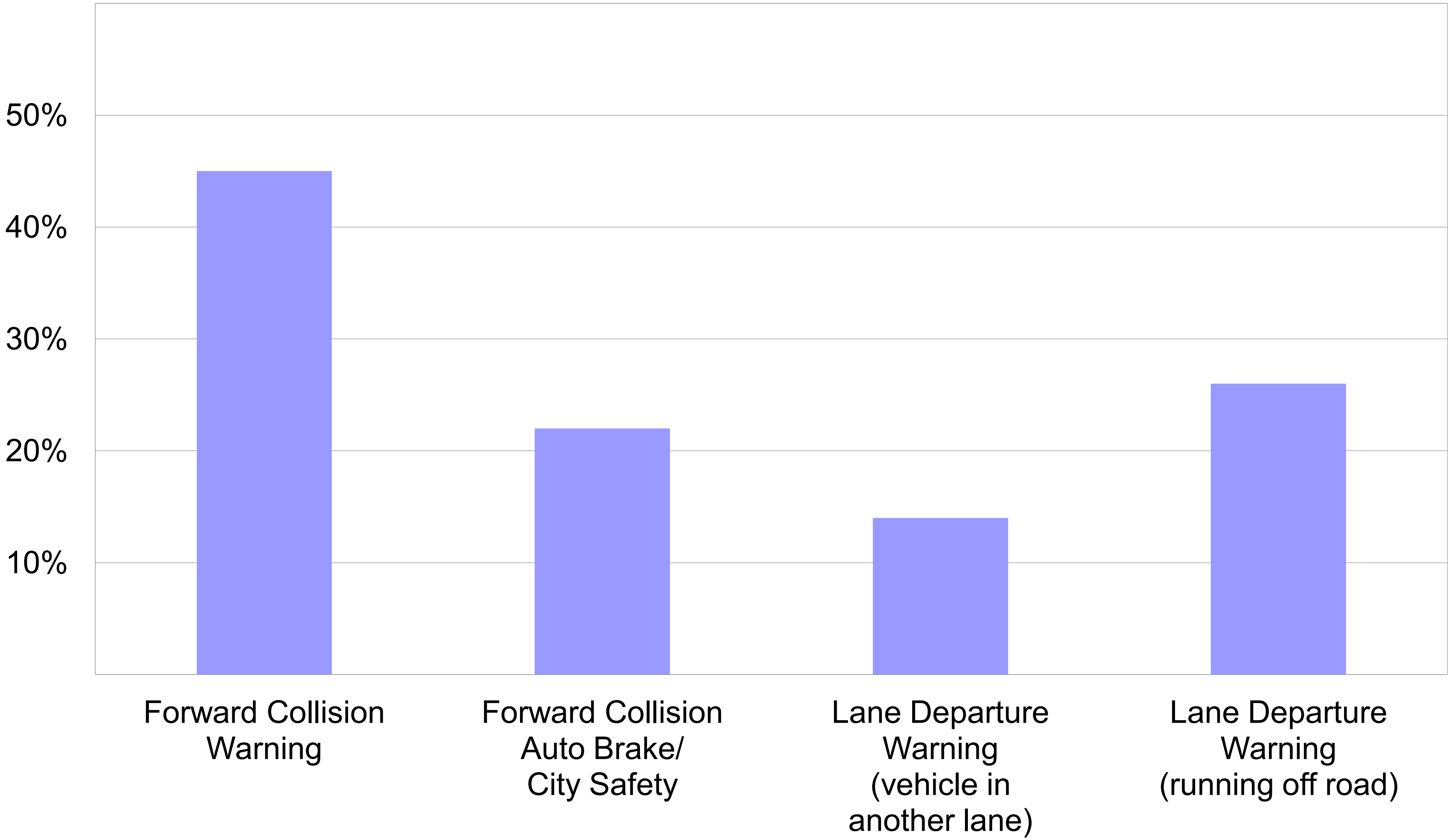
Percent of owners who report activations perceived as false or unnecessary



Experiences with warnings

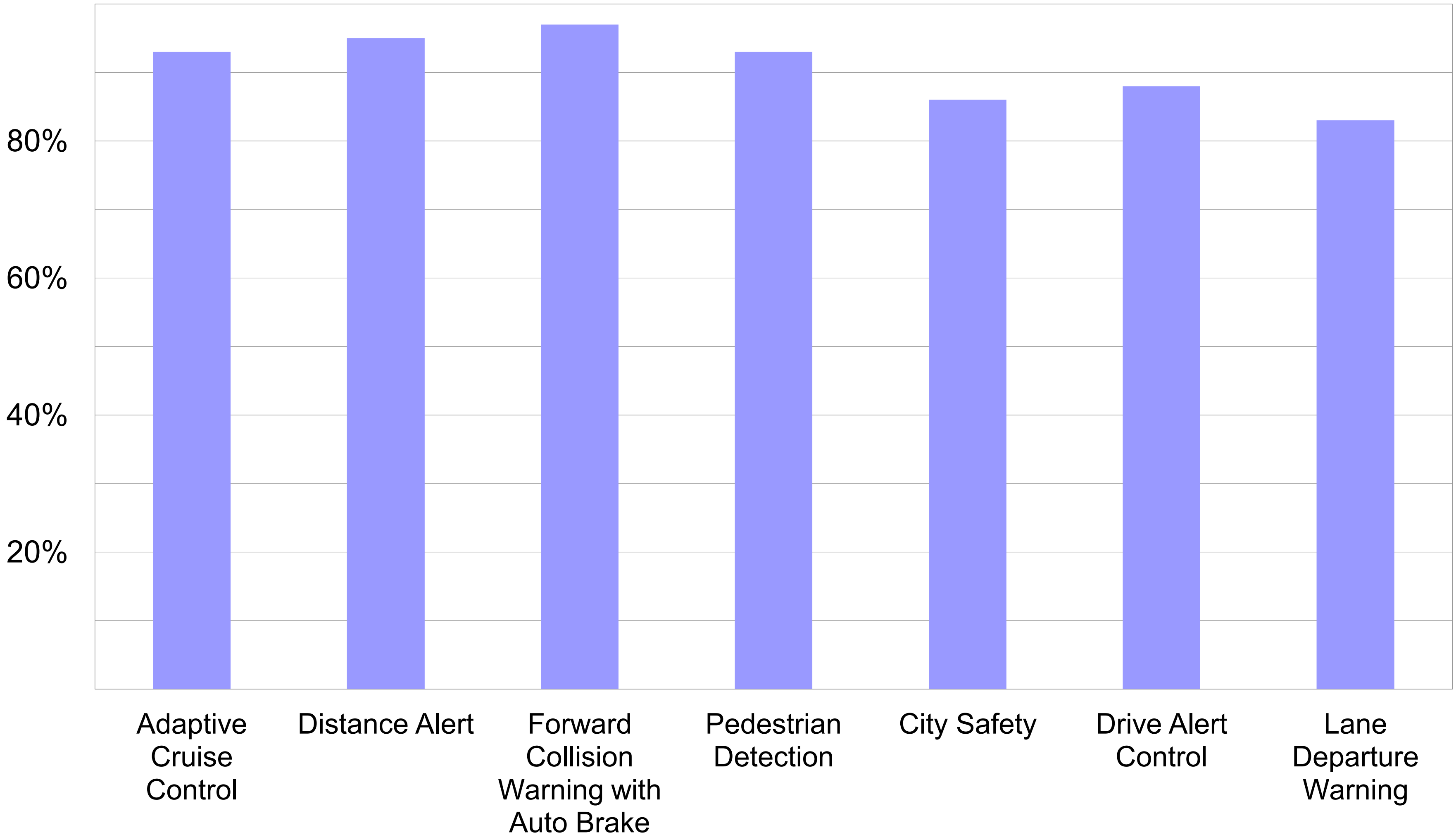
Percent of owners who find warning….	Forward Collision Warning buzzer	Forward Collision Warning flashing light	Lane Departure Warning chime
useful	97	98	96
annoying	24	10	33

Percent of owners who believe systems helped prevent a crash



Percent of owners who want system on next vehicle

Among all owners with the system



Conclusions

- Despite some annoyance, most owners leave systems on, although fewer do for lane departure warning
- Most owners want systems on next car
- Some owners report systems have prevented crashes
- Some owners report safer driving habits with systems, and a few report less safe driving habits
- Researchers should continue to study driver experience with the systems as they become available on more vehicles

Testing forward collision warning and autonomous emergency braking systems

Sample test measurements to characterize forward collision avoidance system performance

- Impact - yes/no
- Velocity change due to auto braking
- Warning timing
  - Audible and visual
- Ambient temperature and lighting

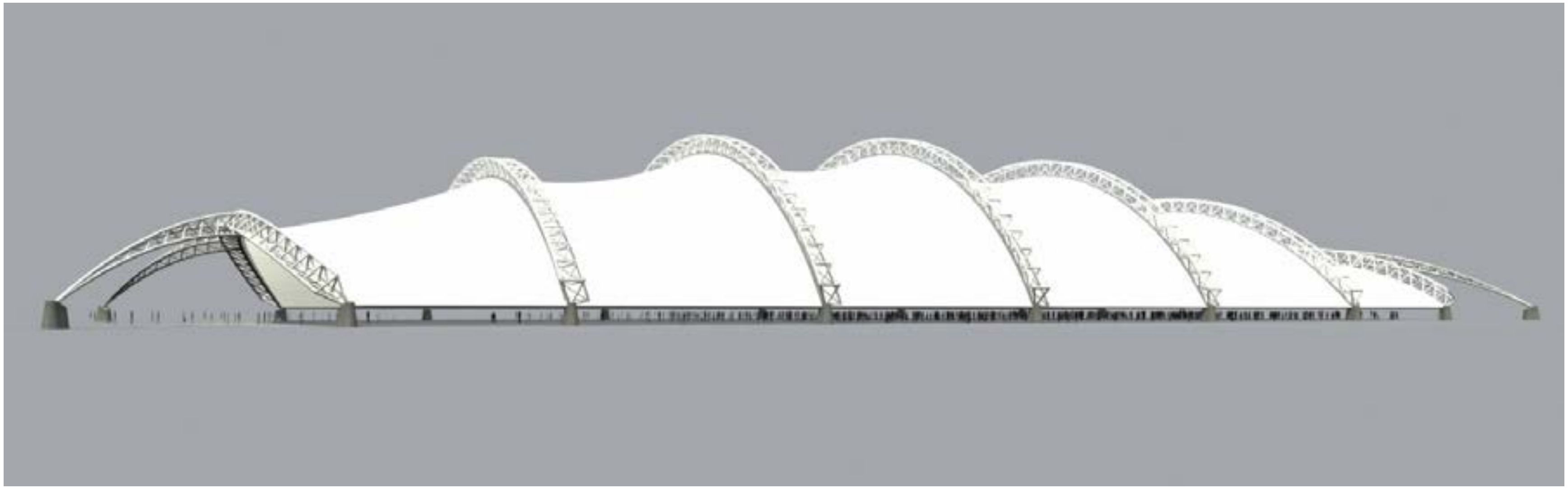
Vehicle to slower moving target testing

Vehicle to decelerating moving target testing

Vehicle to pedestrian testing

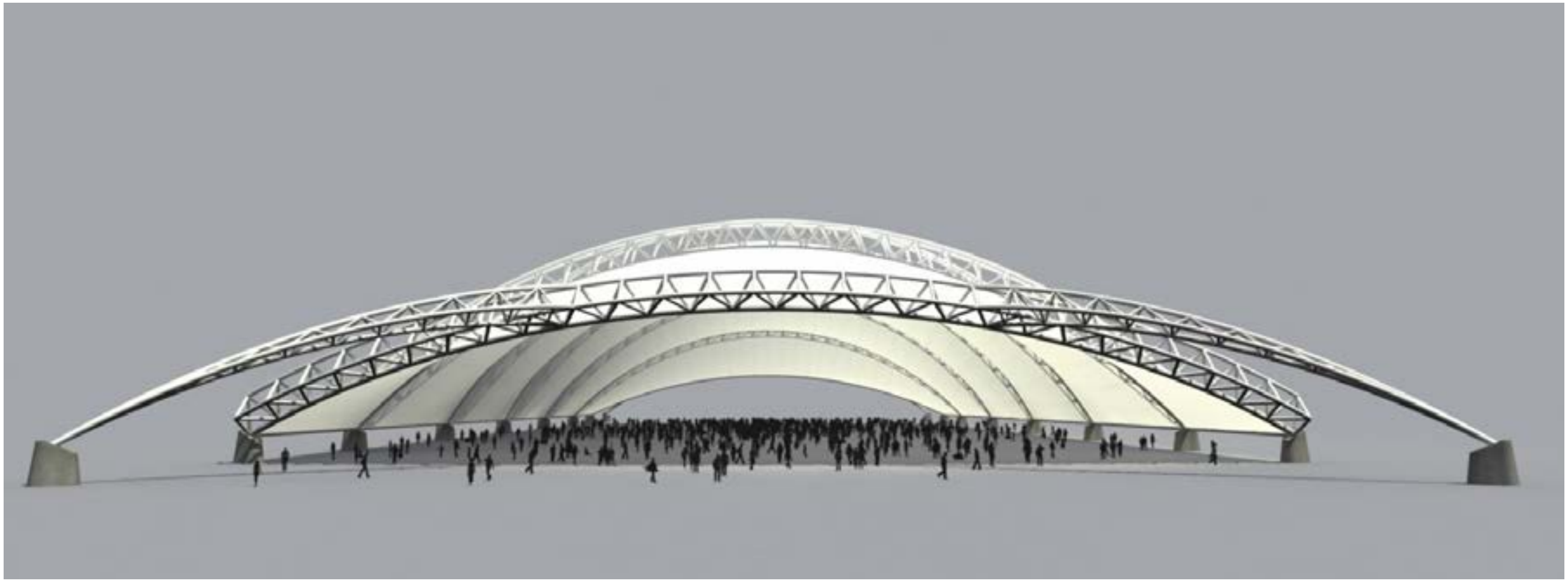
Covered test track rendering

Covered test track area: 300’ x 700’ steel and tensile fabric structure



Covered test track rendering

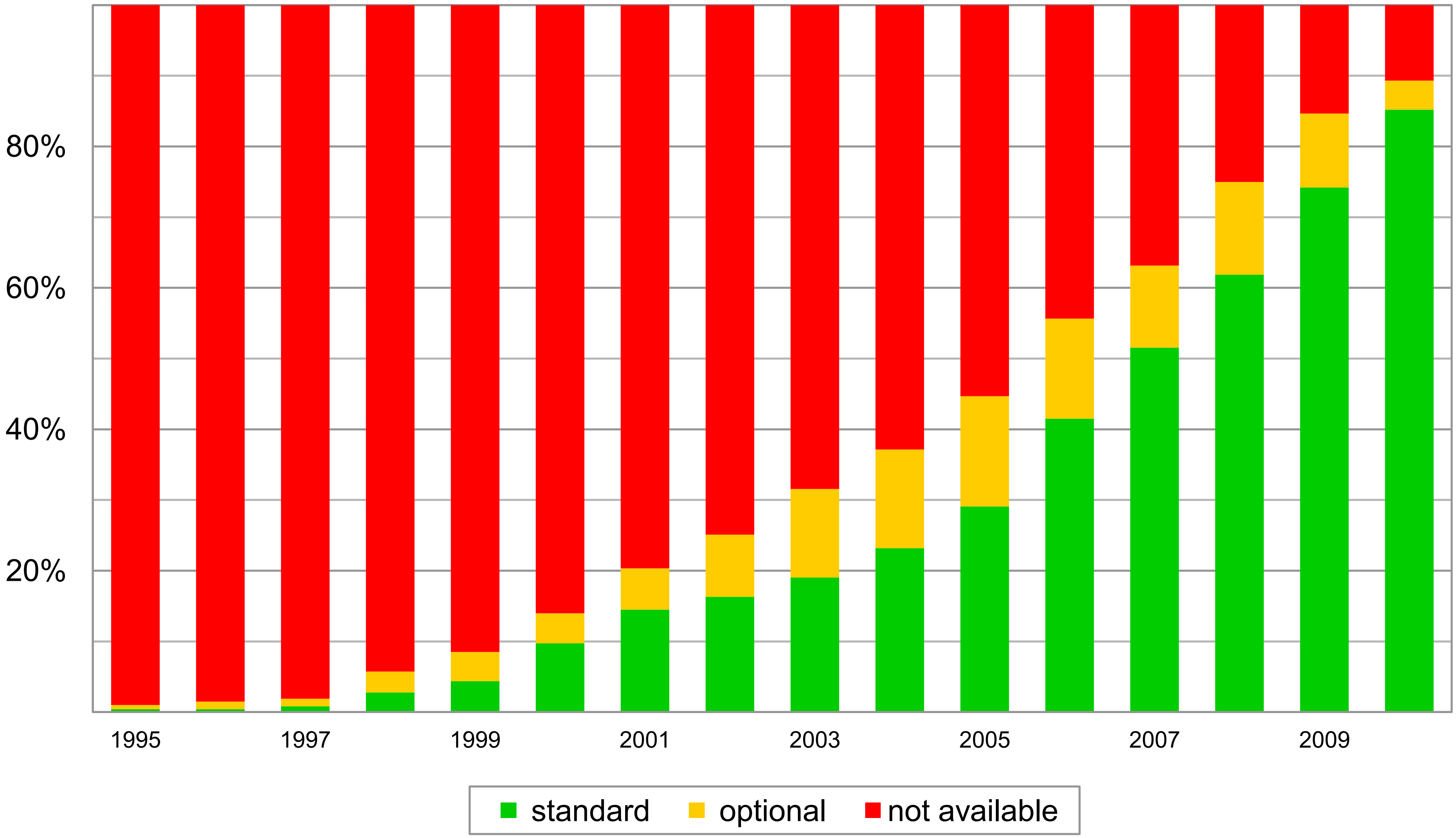
Covered test track area: 300’ x 700’ steel and tensile fabric structure



Benefits of crash avoidance technology will occur gradually

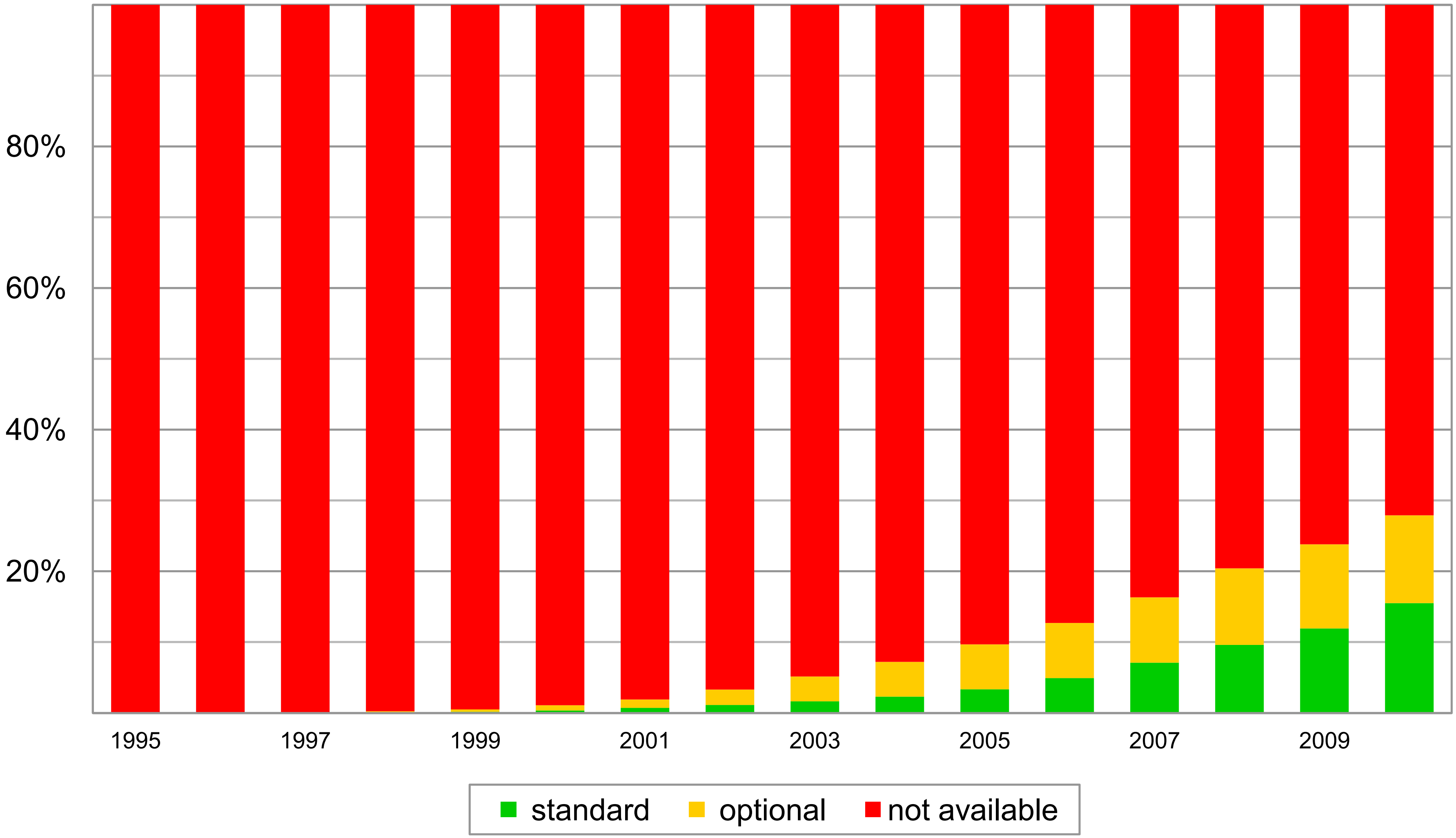
New vehicle series with electronic stability control

U.S., by model year



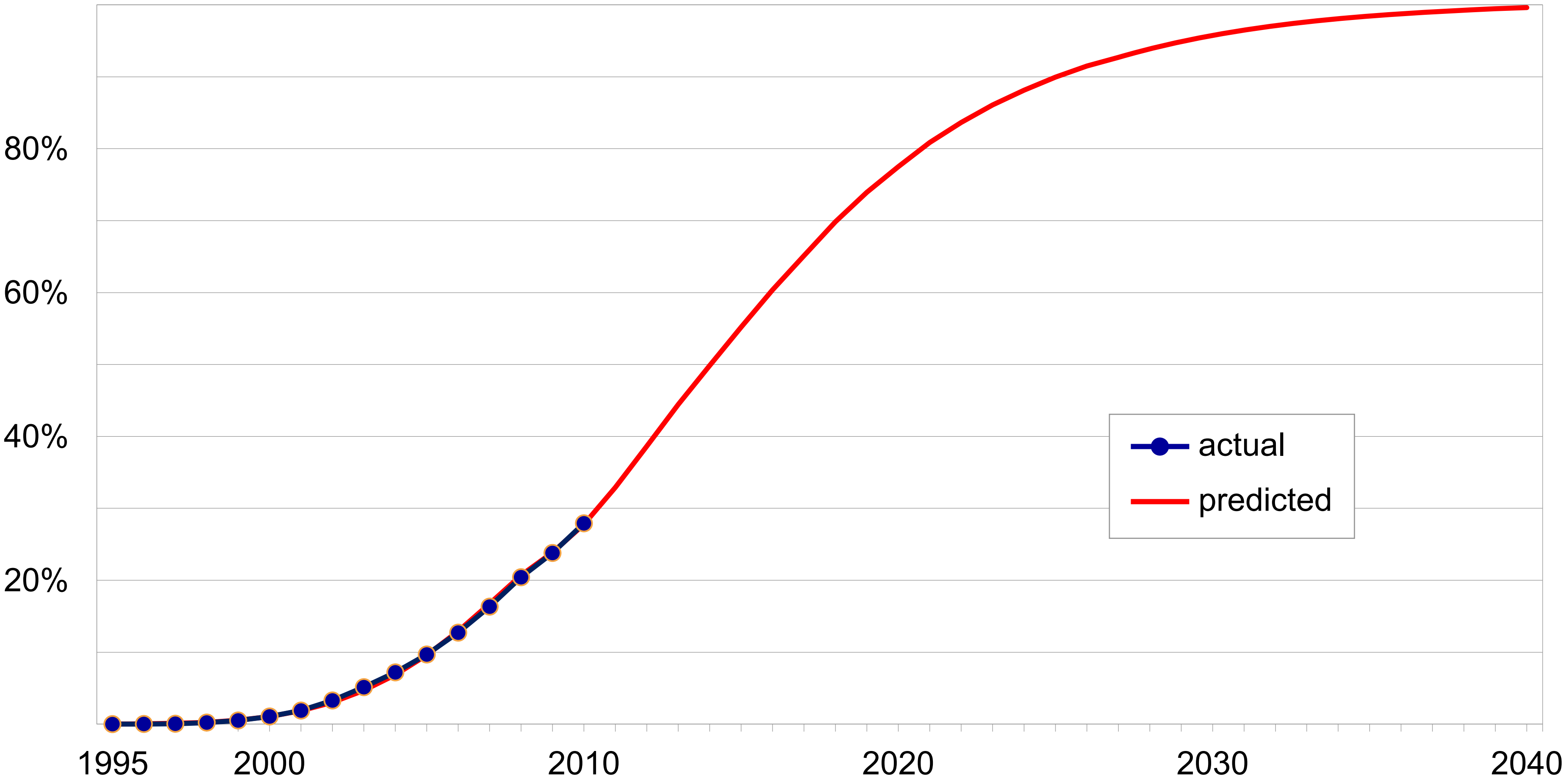
Registered vehicles with electronic stability control

U.S., by calendar year



Registered vehicles with electronic stability control, actual and predicted

U.S., by calendar year



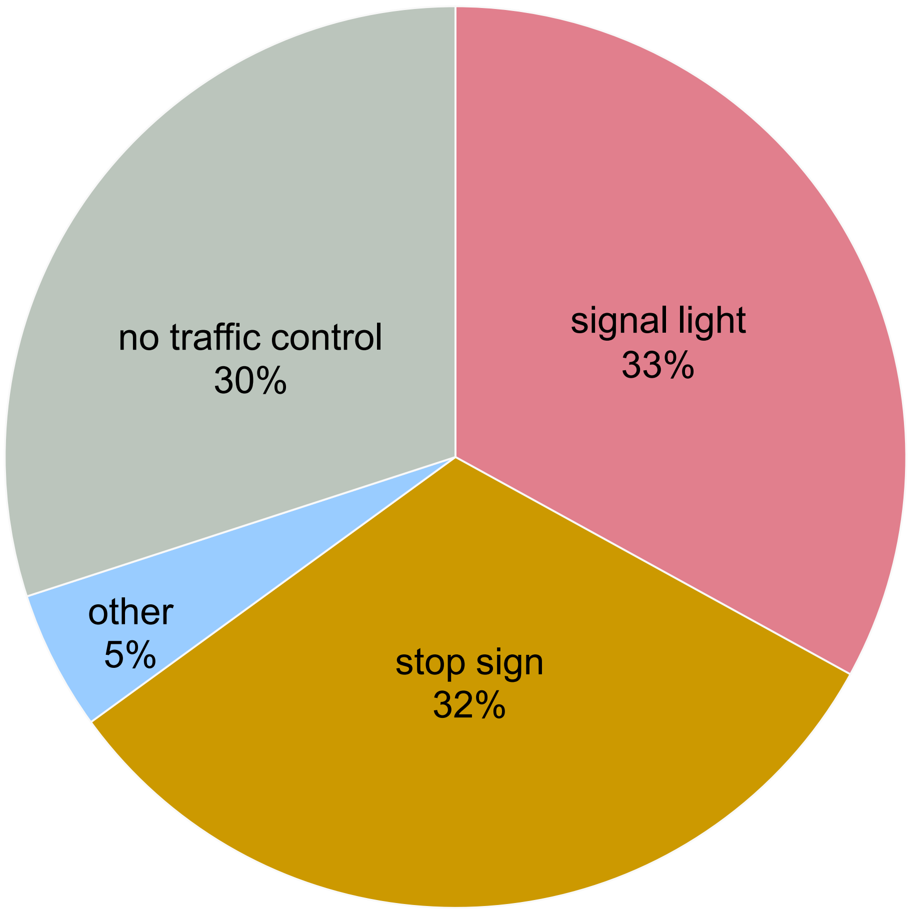
Summary and next steps

- Potential applicability of crash avoidance systems is huge
- Owner survey data indicate some annoyance with the technology, but most owners are leaving it active
- Vehicles with City Safety show significant reductions in collision claims compared with similar non-equipped vehicles
- Forward collision warning systems, especially with auto-brake, are reducing claims
- Will drivers adapt behavior in ways to offset benefits of the technology?
  - Some indication in surveys, but effectiveness studies are needed
  - Some adaptation may be slow to appear

Intersection crashes

7,296 deaths at U.S. intersections in 2011

Distribution by type of traffic control



Conversion of stop sign and traffic signal intersections to roundabouts:

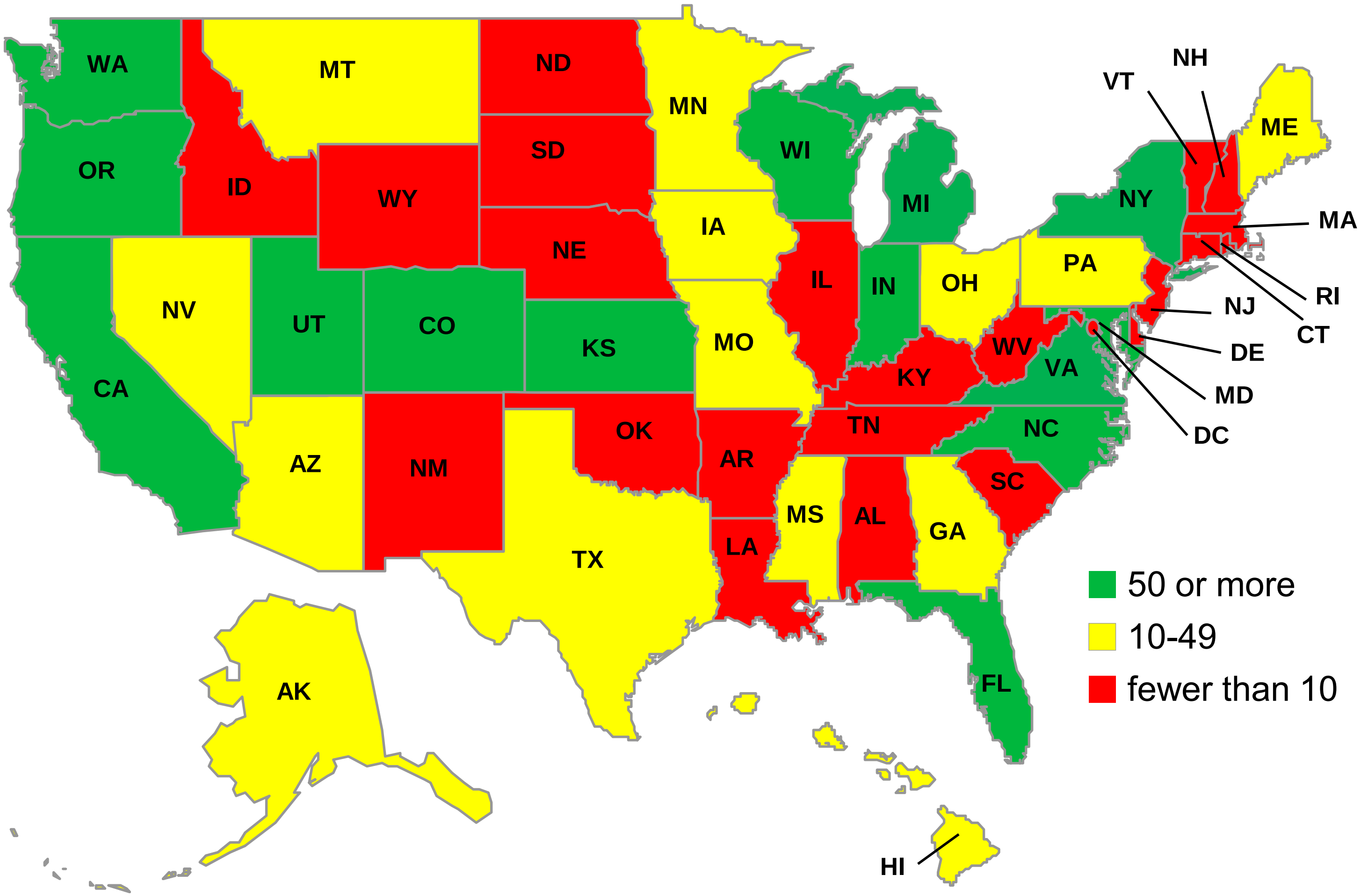
- 40% reduction in all crashes
- 80% reduction in injury crashes
- 90% reduction in fatal & incapacitating injury crashes

If 10 percent of signalized intersections in the United States were converted to roundabouts

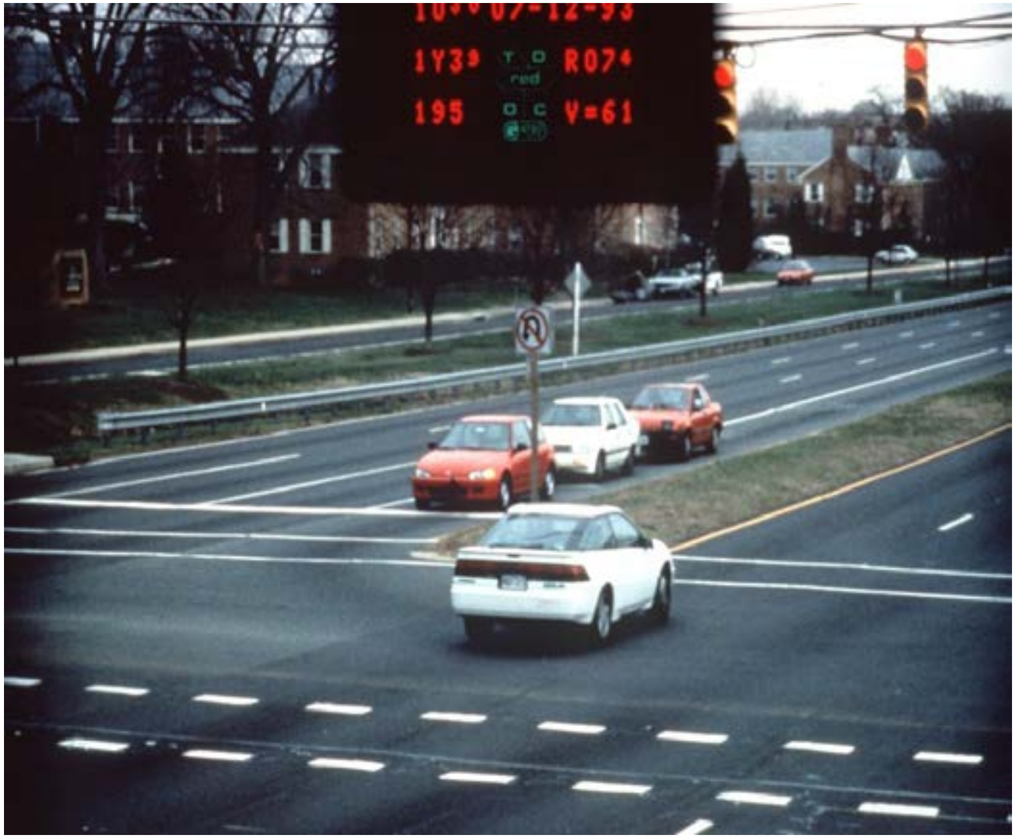
- Approximately 43,000 crashes prevented in 2011 including:
  - 170 fatal crashes
  - 28,000 injury crashes
- Vehicle delays reduced by more than 900 million hours
- Fuel consumption reduced by more than 600 million gallons

Progress in building roundabouts

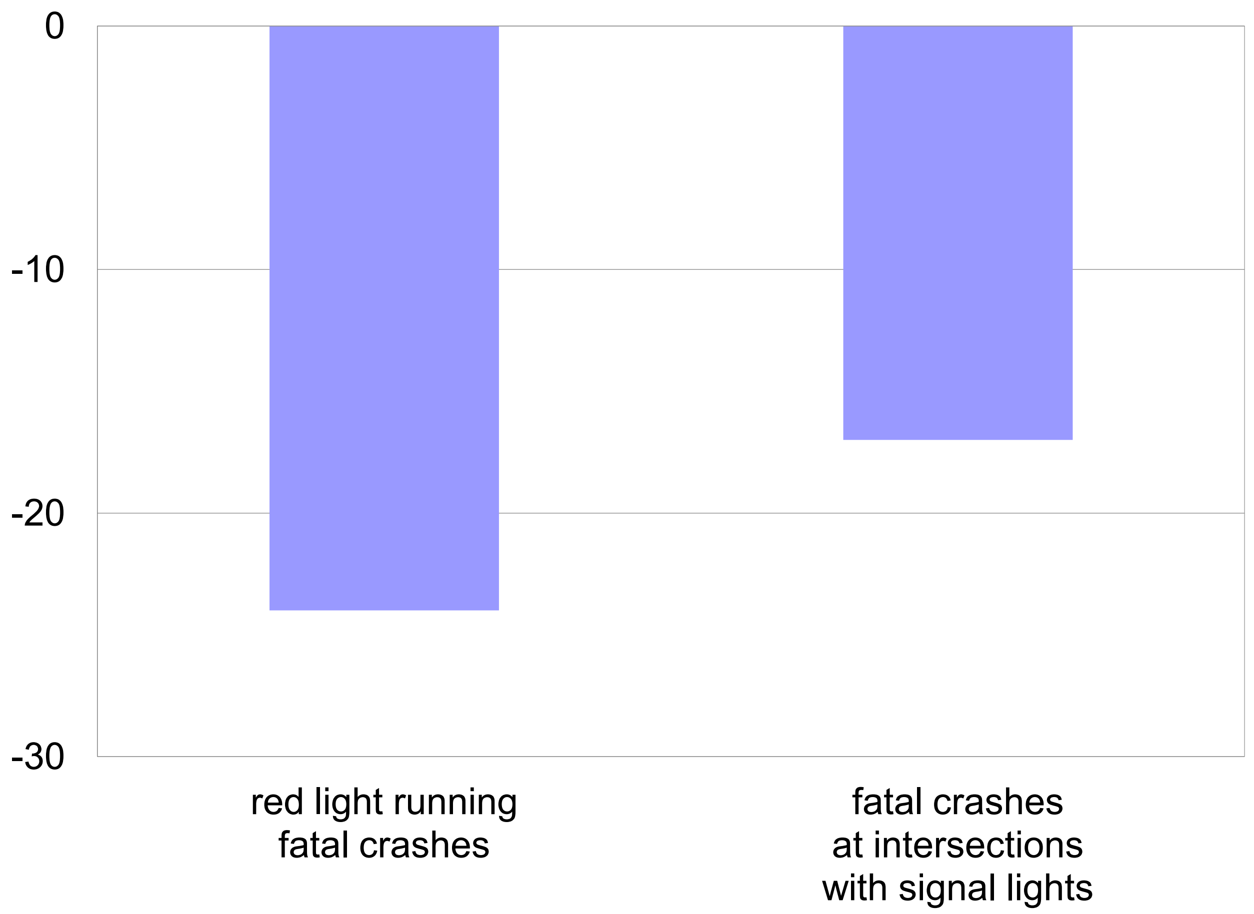
January 2013



In 2011 on US roads, about 150,000 red-light-running crashes caused about 118,000 injuries and about 700 deaths. Over half of the deaths were pedestrians, bicyclists and people in other vehicles hit by red light runners



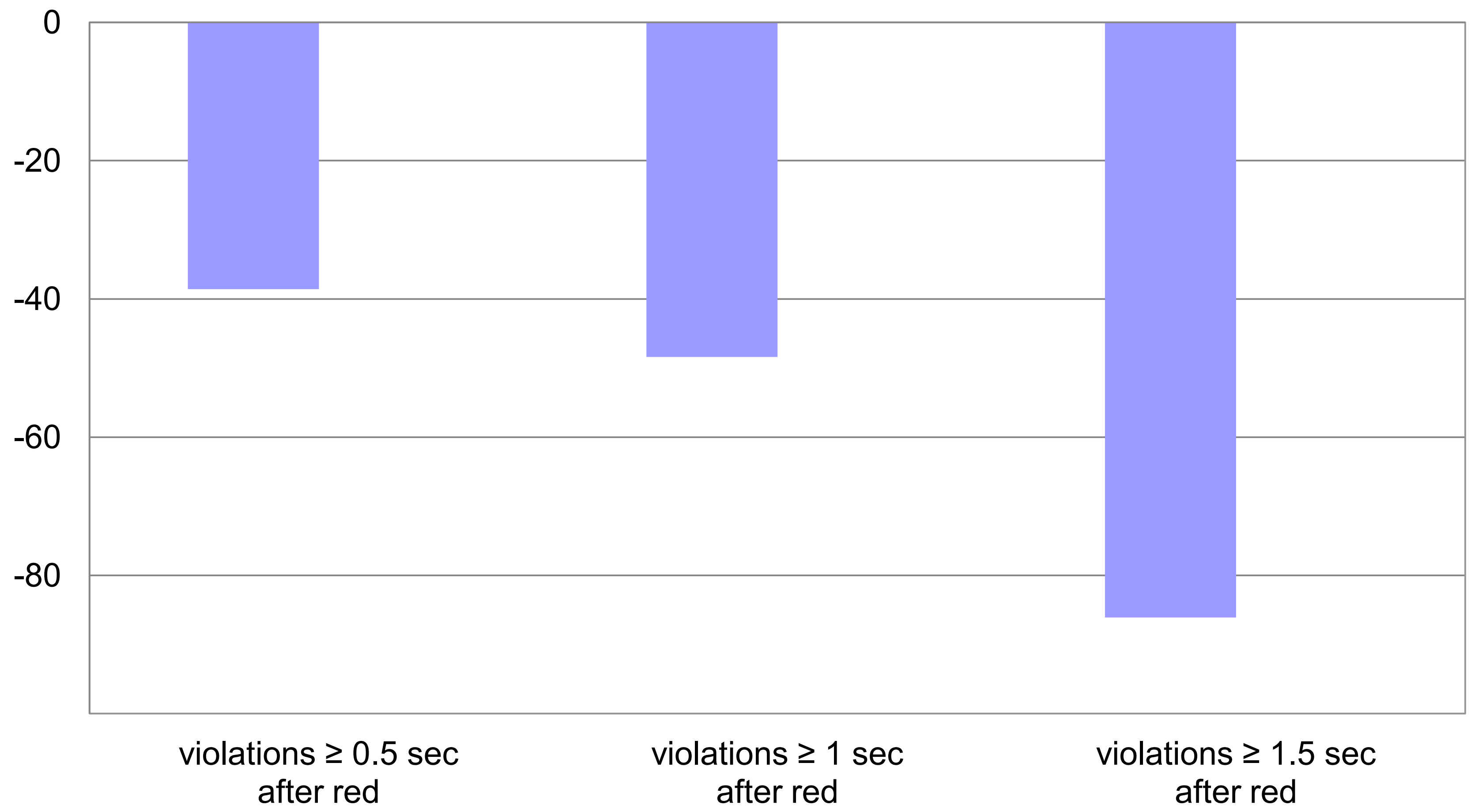
Percent difference in actual fatal crash rates during 2004-08 in 14 large cities with red light cameras vs. expected rates without cameras



Television coverage:

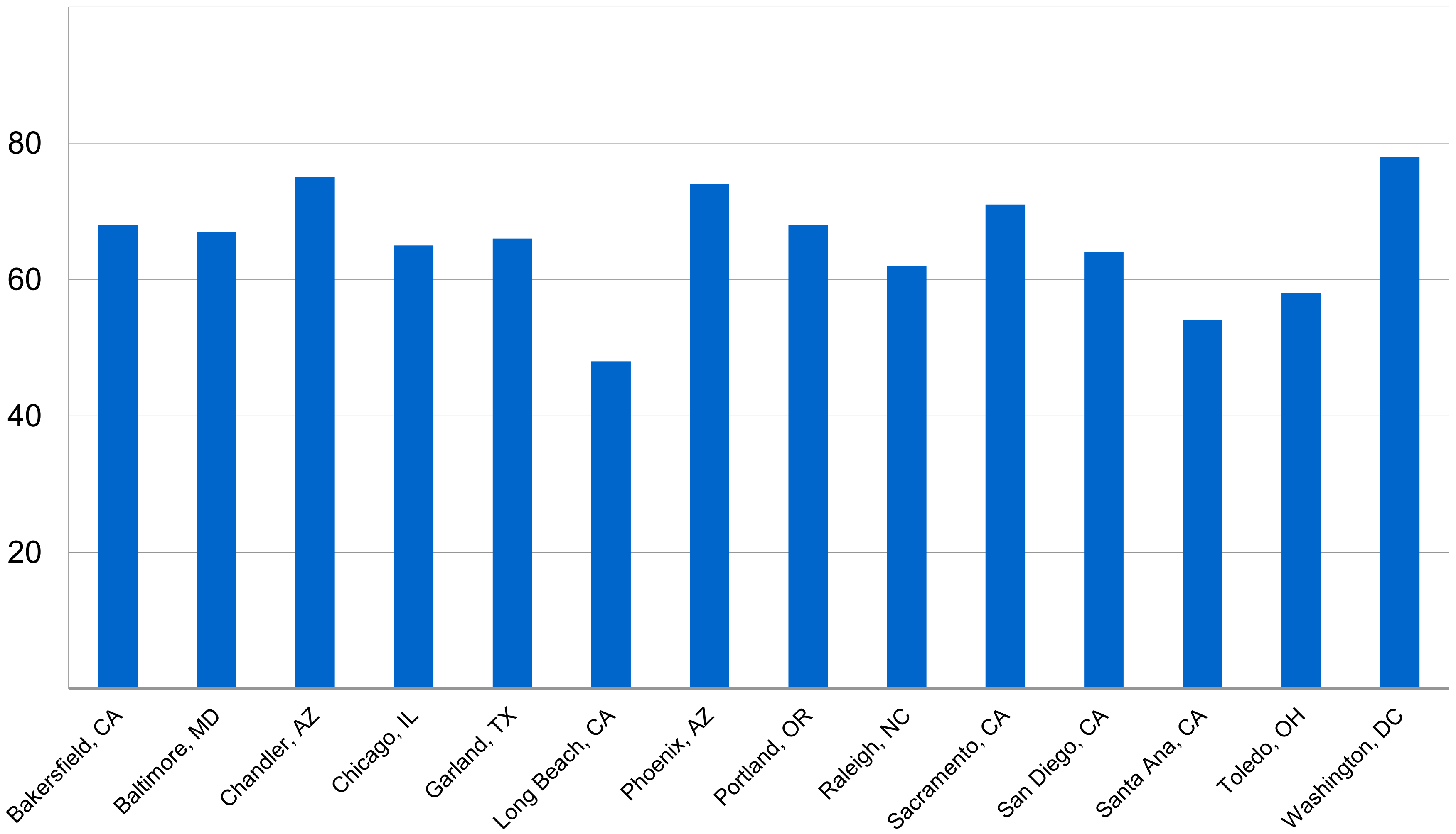
Red light cameras

Percent difference in odds of red light violations at intersections in Arlington, Virginia, with cameras vs. expected odds without cameras



Percent who favor using red light cameras

Telephone survey in 14 cities with red light cameras, 2011



Wheeling police defend red -light cameras

photo enforcement is fraud

Voters targeting red light cameras at po

More questions arise concerning red-light cameras

ban red light cameras not a ative agenda

Stop whining over red-light camera

Red Light Camera Blues? There's an App for That

pproved

Safety, not money, should be p light ca

Houston voters to decide on ght cameras

Despite questio Petersburg moves forw

d-Light Came

issue ser

usive

t Cameras

red light ca

Opposition weighs for some red light offences

More red-light camera questions

Royal P

Revenu

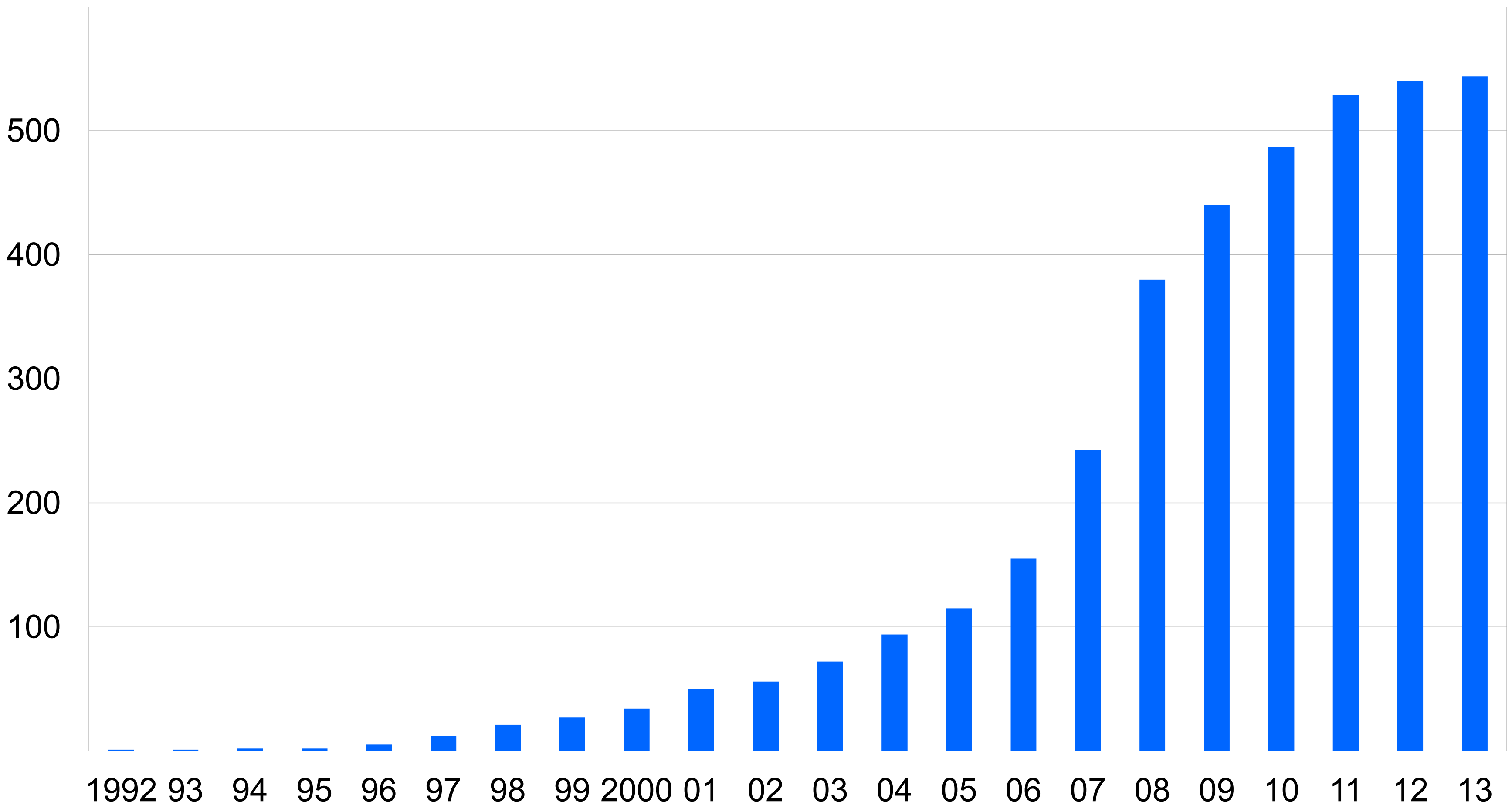
It's Official: Red Light Cameras Don't Work

Aventura cites safety in defending camera program

light camera program

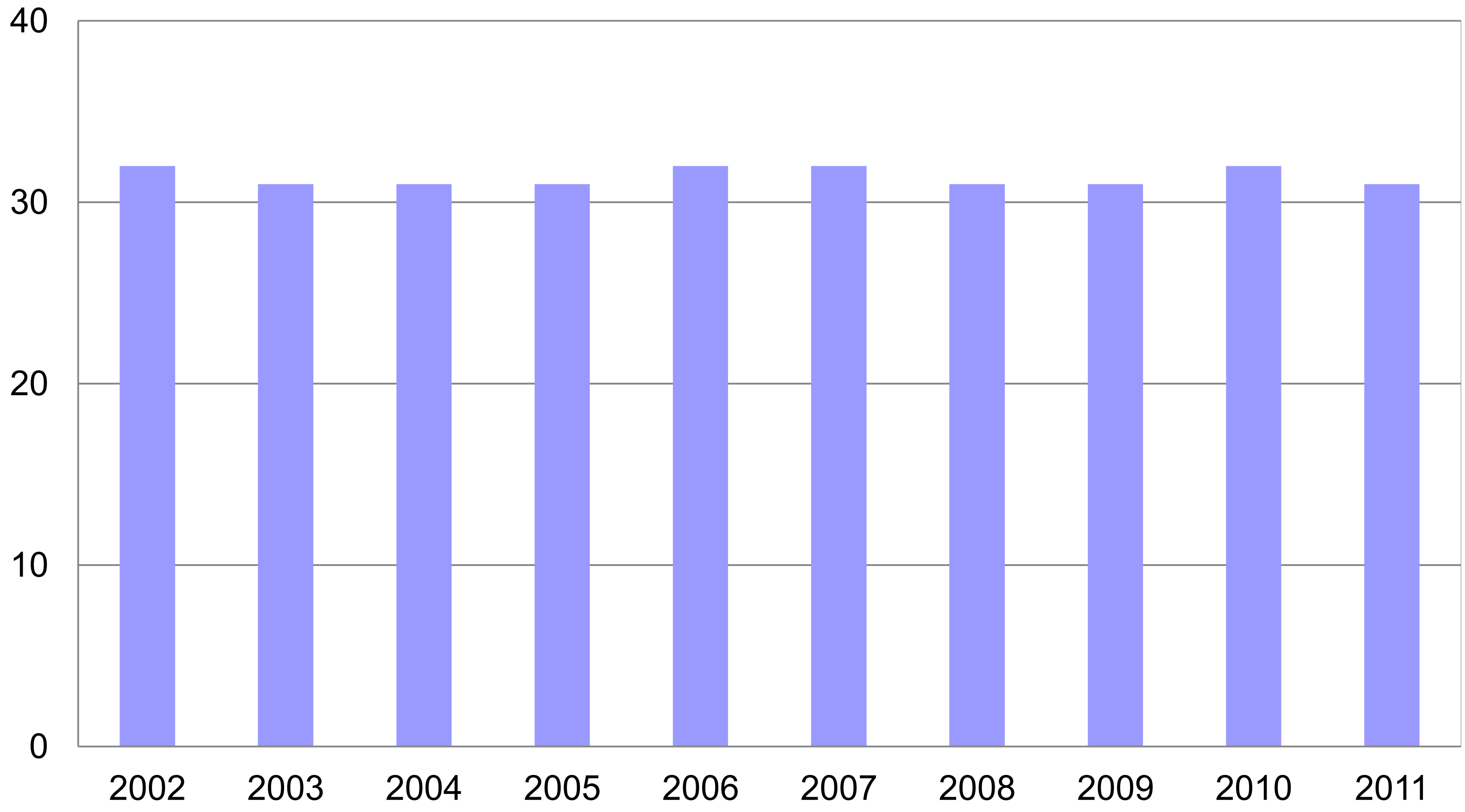
US communities with red light cameras

1992-2013



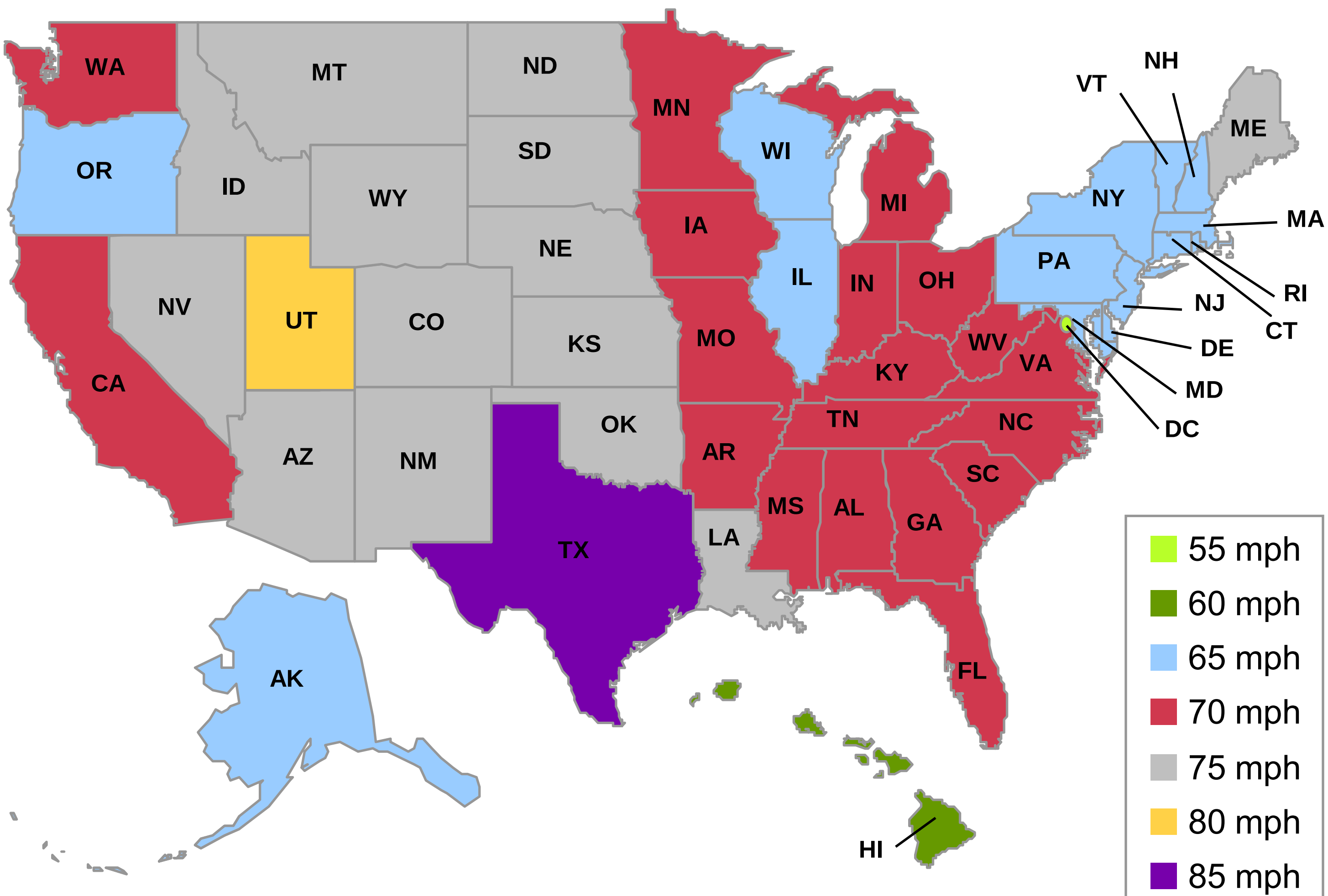
Vehicle speed

Percent of U.S. motor vehicle crash deaths involving speeding as a contributing factor, 2002-12



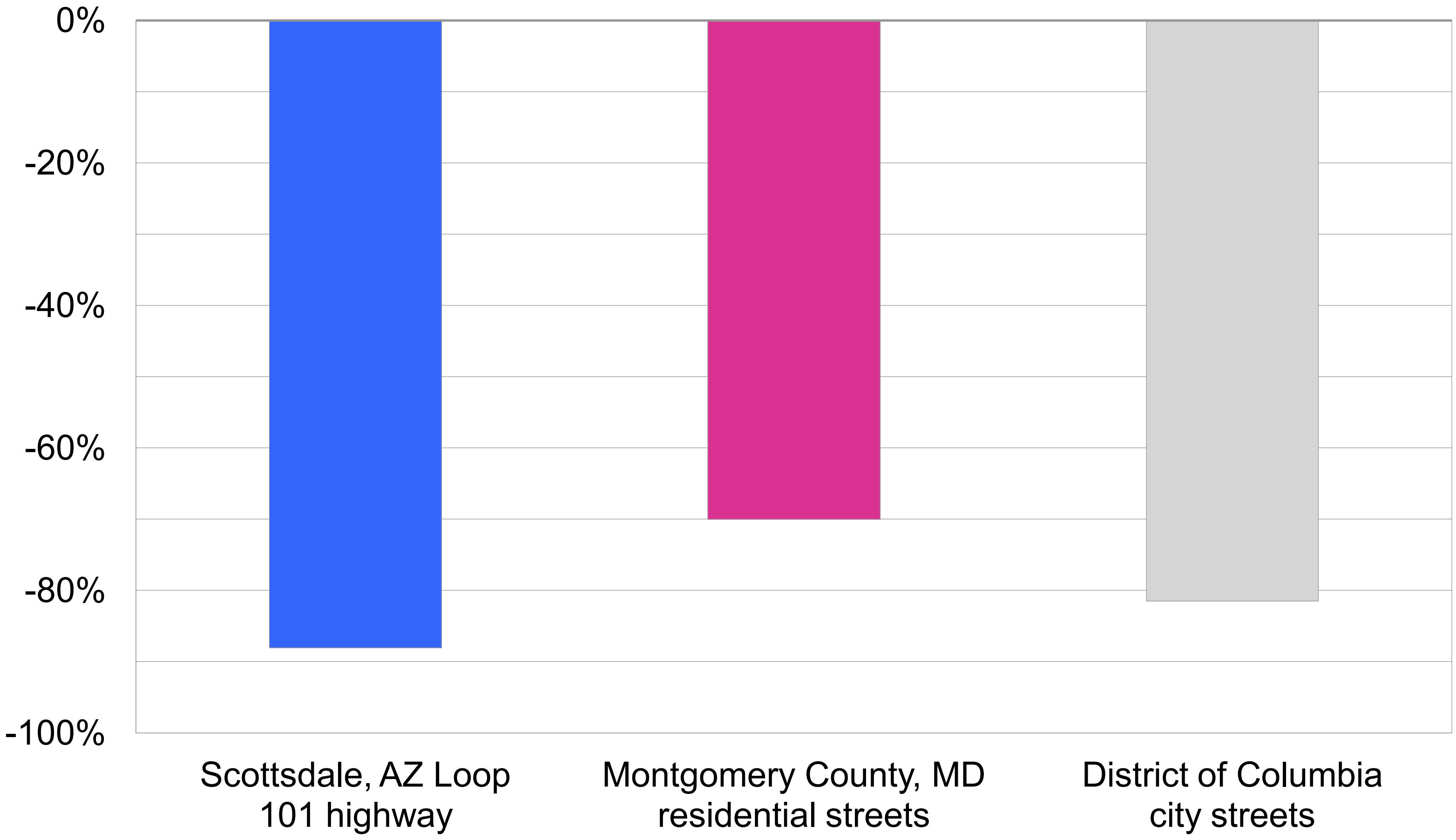
Maximum authorized speed limits

January 2013



Reductions in proportion of vehicles exceeding speed limit by more than 10 mph after camera enforcement

Relative to comparison sites (IIHS, 2003, 2008a, 2008b)



Opinions of residents during speed camera enforcement programs

IIHS, 2008a, 2008b

	Montgomery County, Maryland	Scottsdale, Arizona
think speeding is a problem on targeted roads	74%	79%
aware of speed cameras	60%	90%
favor speed camera use on targeted roads	62%	77%

Reviews of international research show that speed camera enforcement reduces injury and fatal crashes

Cochrane Review

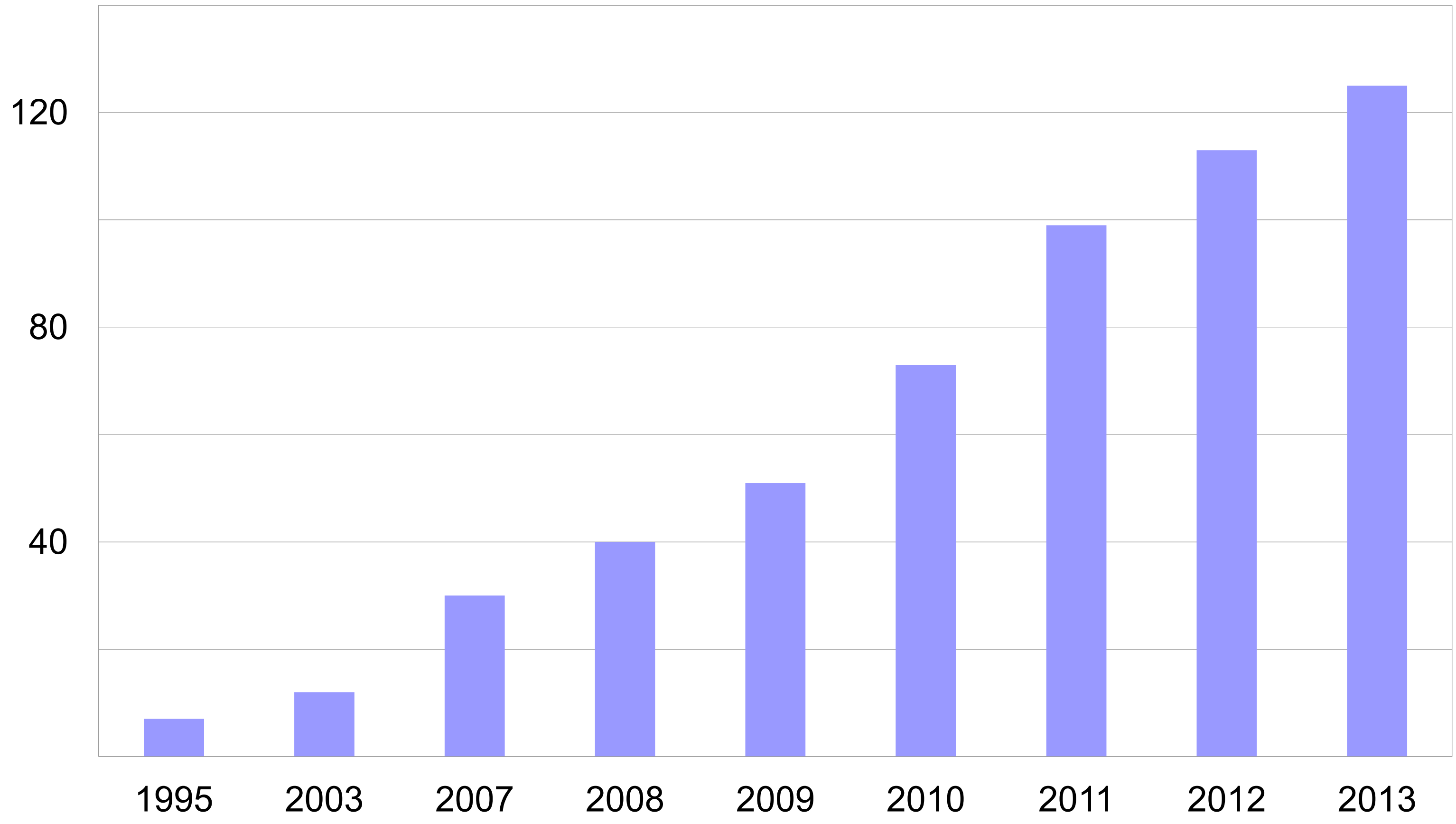
(Wilson et al., 2010)

28 studies

- 8-50% reduction in injury crashes in the vicinity of camera sites
- 11-44% reduction in fatal or serious injury crashes in the vicinity of camera sites
- 17-58% reduction in fatal or serious injury crashes over wider areas

U.S. communities with speed cameras

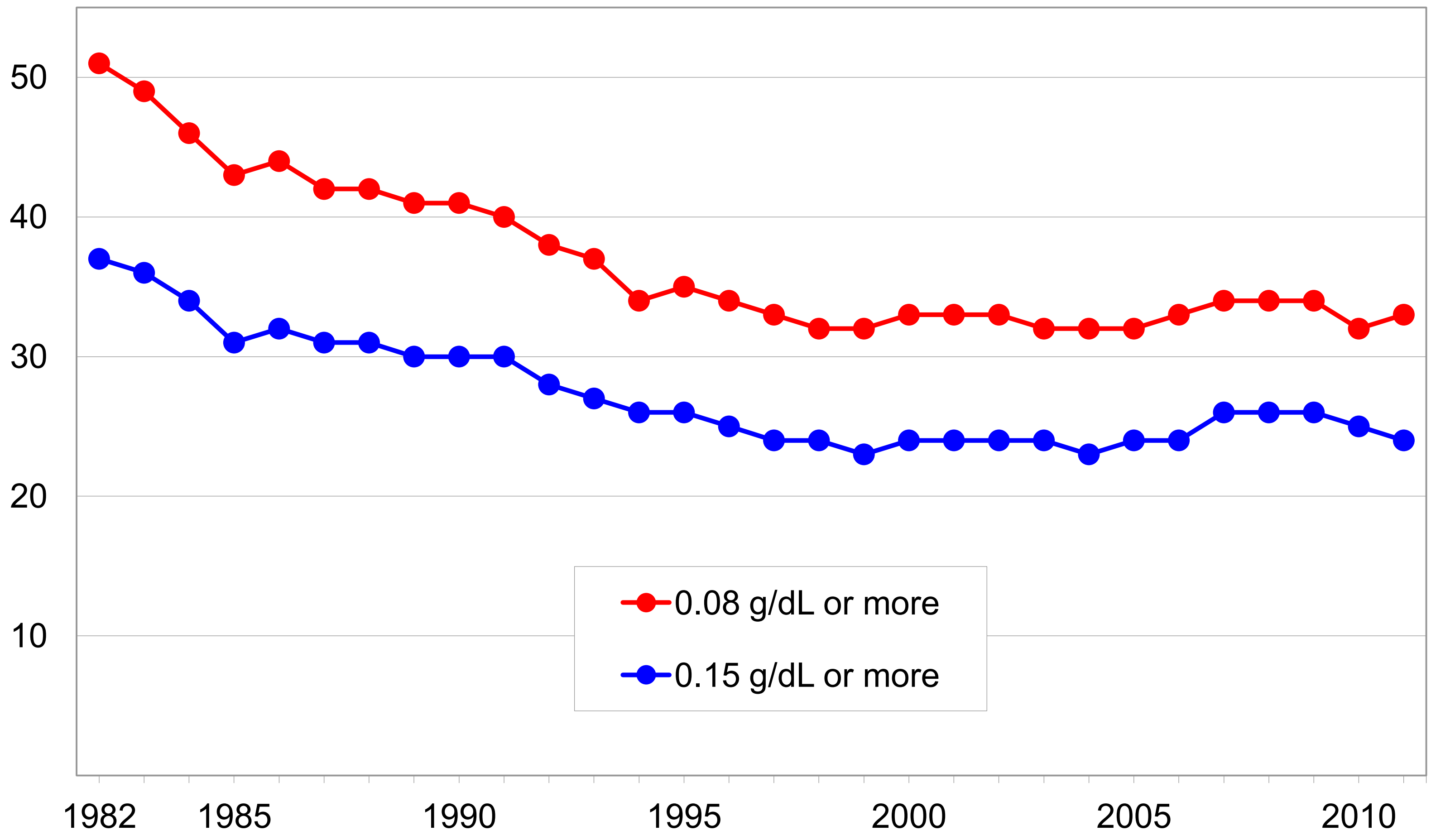
1995-2013



Alcohol-impaired driving

Percent of fatally injured passenger vehicle drivers with BACs at or above specified levels

1982-2011



Despite effectiveness of sobriety checkpoints, many U.S. communities don't conduct them regularly

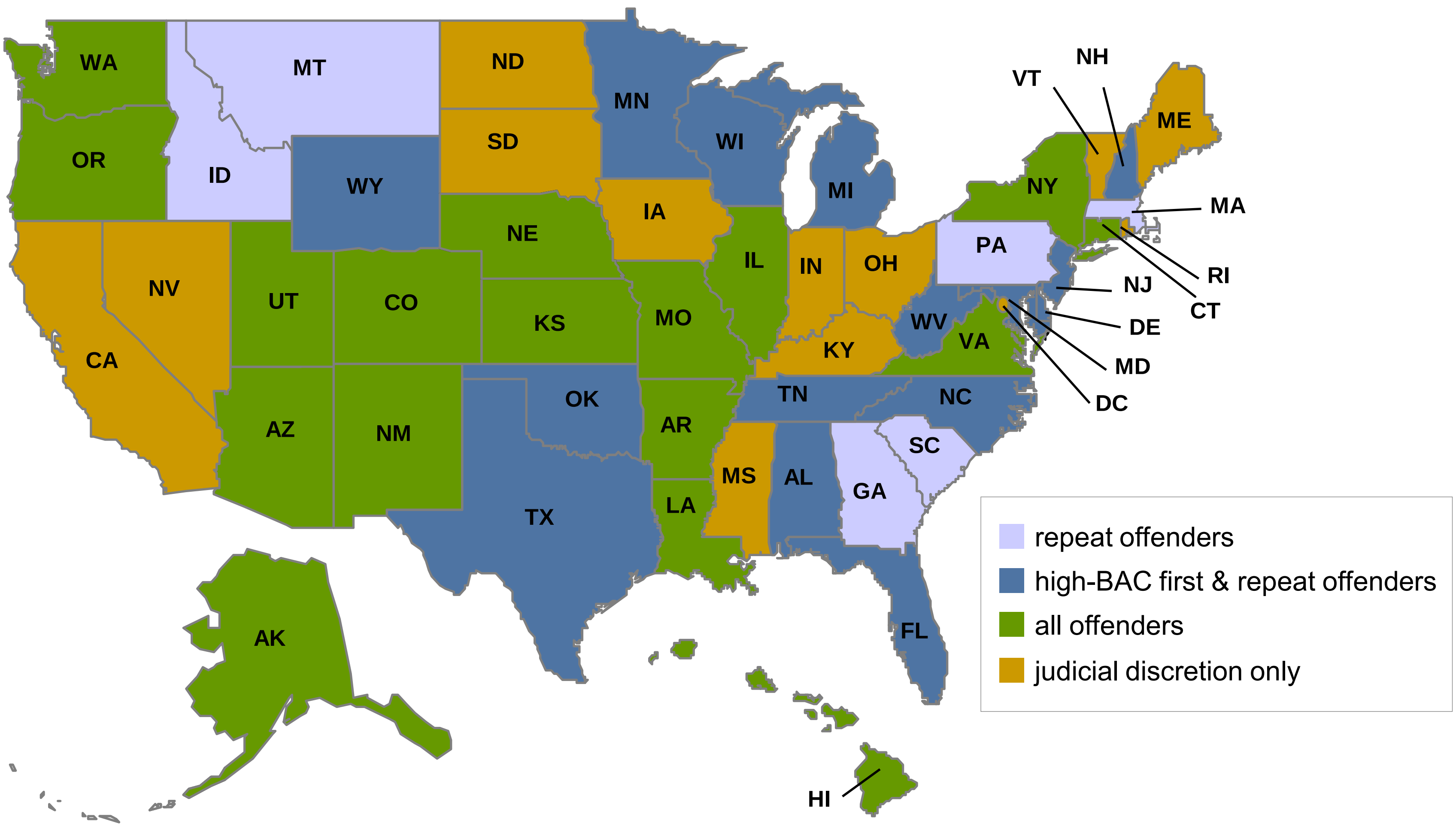
- Median reduction of 20 percent in alcohol-related crashes associated with publicized sobriety checkpoints (Elder et al., 2002)
- 10 U.S. states prohibit sobriety checkpoints by state constitution or law
- Some enforcement agencies believe a large number of officers are required, but small-scale checkpoints can be conducted successfully and safely

Traditional sobriety checkpoints

Low manpower checkpoints reduced percent of drivers with BACs of 0.05 percent or higher

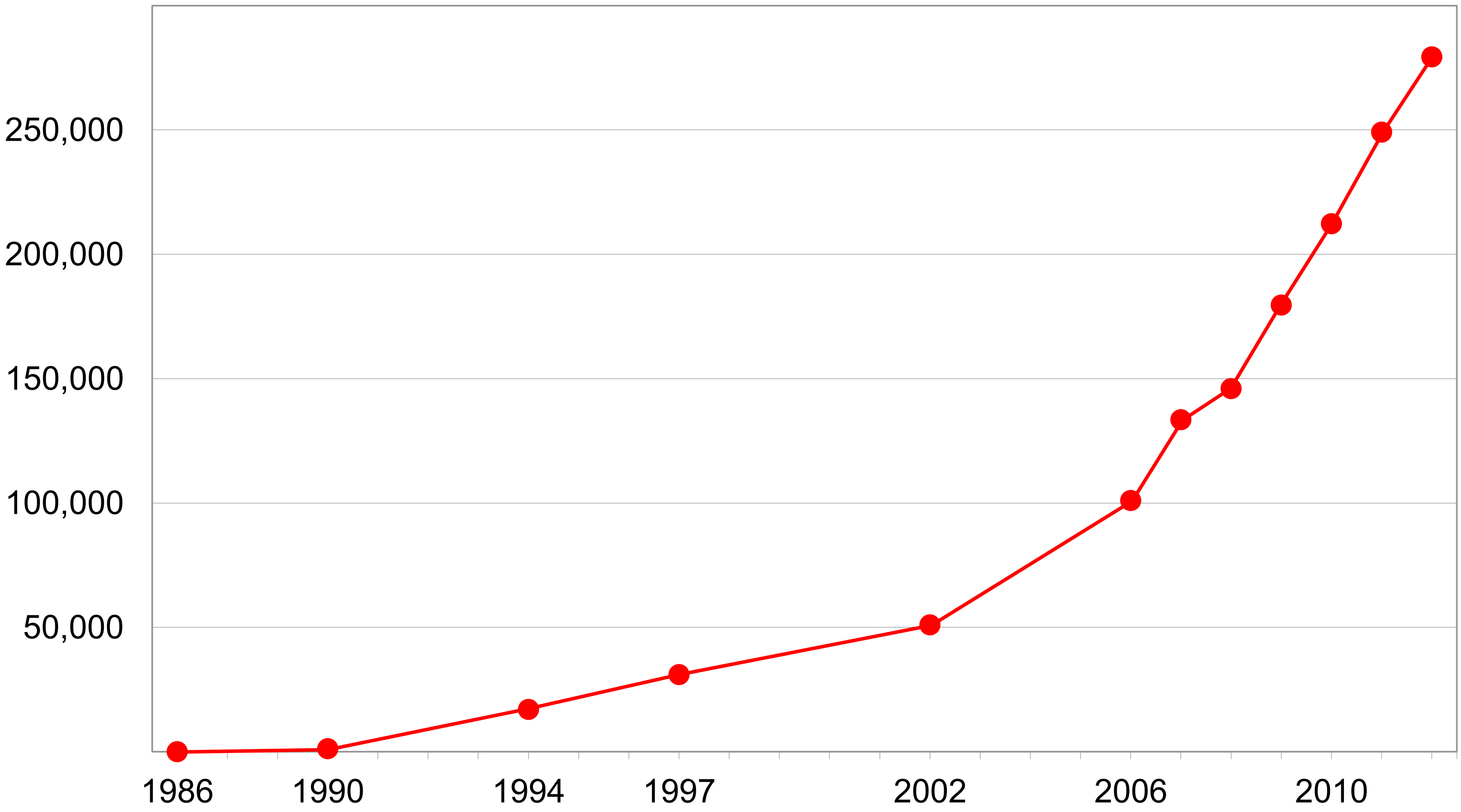
Laws mandating alcohol ignition interlock orders

January 2013



Installed interlocks in United States

1986-2012



Evaluation of Washington state law extending interlock requirement to all offenders

- Recidivism reduced by 12 percent among affected offenders, even though only about one-third of offenders used them
- If installation rates had been 100 vs. 34 percent at the end of the study period, recidivism could have been reduced by nearly half
- Law change associated with 8.3 percent reduction in single-vehicle late-night crash risk
  - Publicity about interlock requirements could increase general deterrent effect

Potential lives saved in 2010 if BACs of drivers limited to specific maximums

	BAC < 0.08 g/dl	zero BAC
drivers with multiple DUI convictions within 3 years	104	143
drivers with at least one prior DUI conviction within 3 years	552	785
all drivers	7,082	10,600

Broader installation of alcohol detection technology

- Current ignition interlocks are not suitable for use in all vehicles
  - Inconvenient, expensive, require calibration
  - People who obey alcohol-impaired driving laws
  - People who don’t drink alcohol
- Need technology that is virtually invisible to driver without sacrificing precision
  - Accurately detects alcohol impairment (without false positives or false negatives)
  - Must differentiate between driver and passenger
  - Technologies in research and development

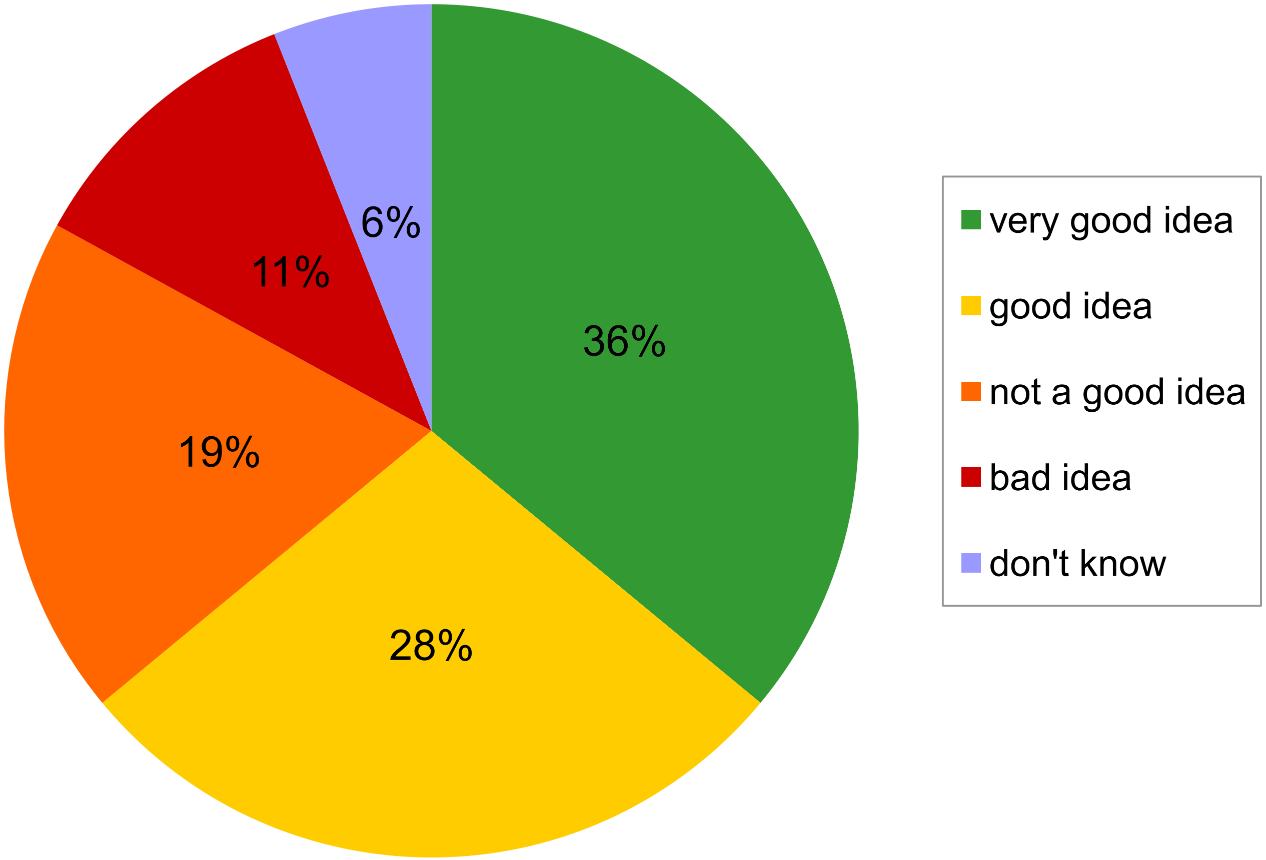
Driver Alcohol Detection System for Safety

- Partnership between federal government and automakers
- Phase two
  - Two technology developers selected to develop system to reliably determine driver's BAC in 1/3 second
  - System must be reliable and durable enough to install in test vehicle by end of two years
  - Gauging public response to specific technologies

dadss
Driver Alcohol Detection
System for Safety

Attitudes toward advanced alcohol test technology in all vehicles, if technology shown to be reliable

U.S. national telephone survey, 2009



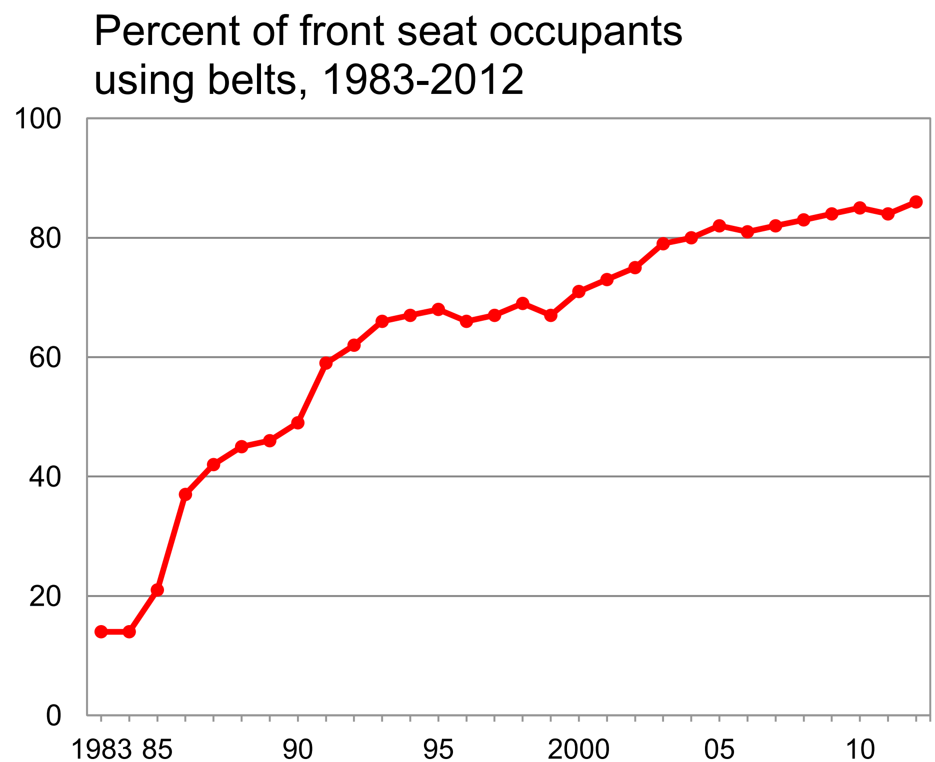
Safety belt use

Safety belt use in the U.S. has increased in large part due to publicized enforcement and passage of primary belt laws

STATUS REPORT
INSURANCE INSTITUTE FOR HIGHWAY SAFETY
Vol. 44, No. 7, July 11, 2009

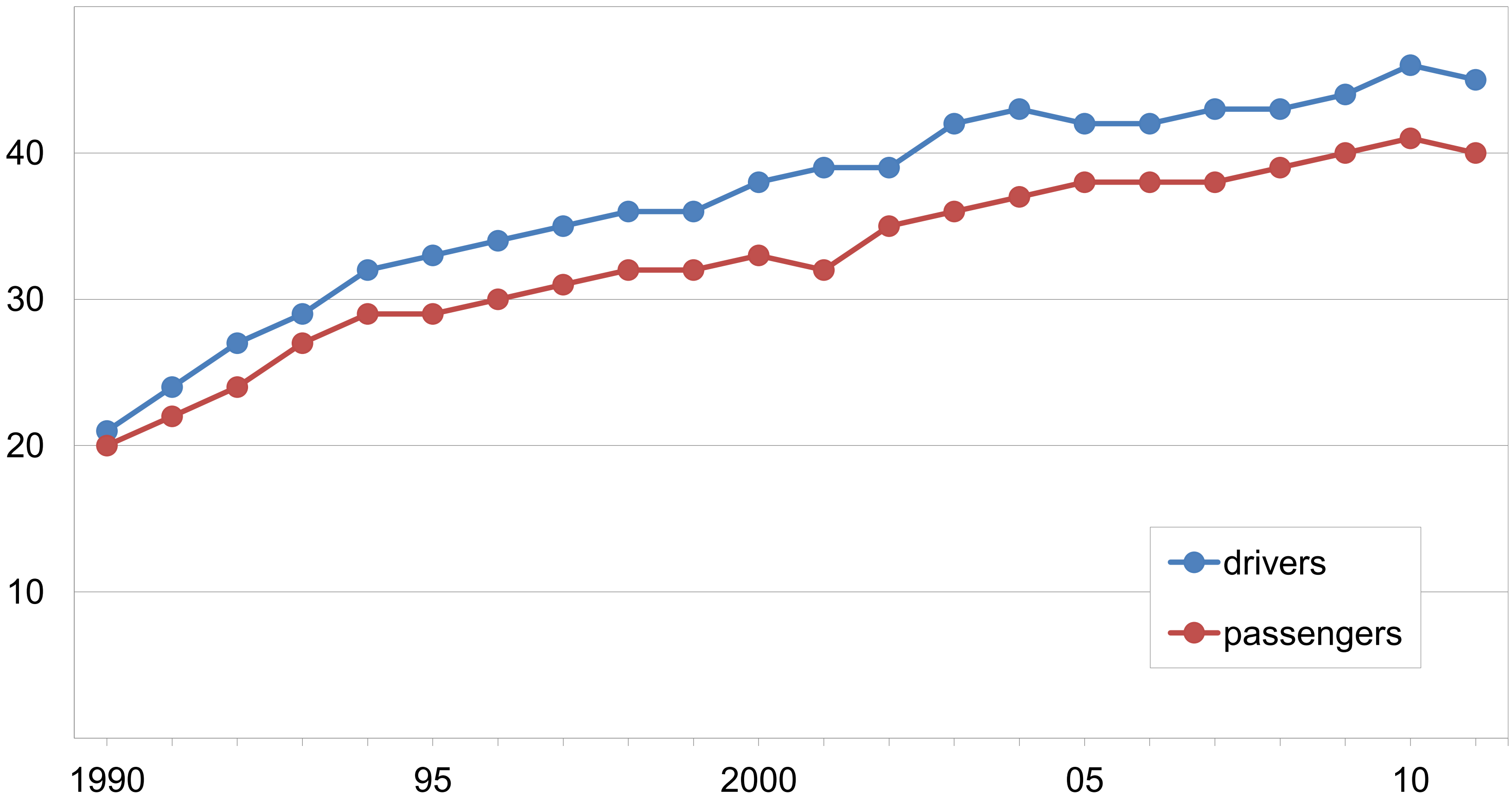
IT'S SIMPLE
CLICK IT OR TICKET

Sixteen years into this US belt enforcement program and its blunt message still resonates. A record 83 percent of front seat occupants buckled up in 2008, thanks largely to Click It or Ticket. Considering only 73 percent used belts just 7 years earlier, the gain is impressive. More than 91,000 people have survived crashes since 2002 in the United States because of belts, federal data show. Primary laws help, too. Arkansas, Florida, Minnesota, and Wisconsin are the latest states to allow police officers to stop and ticket motorists solely for



Percent belt use among fatally injured passenger vehicle occupants 13 and older in U.S., 1990-2011

By calendar year

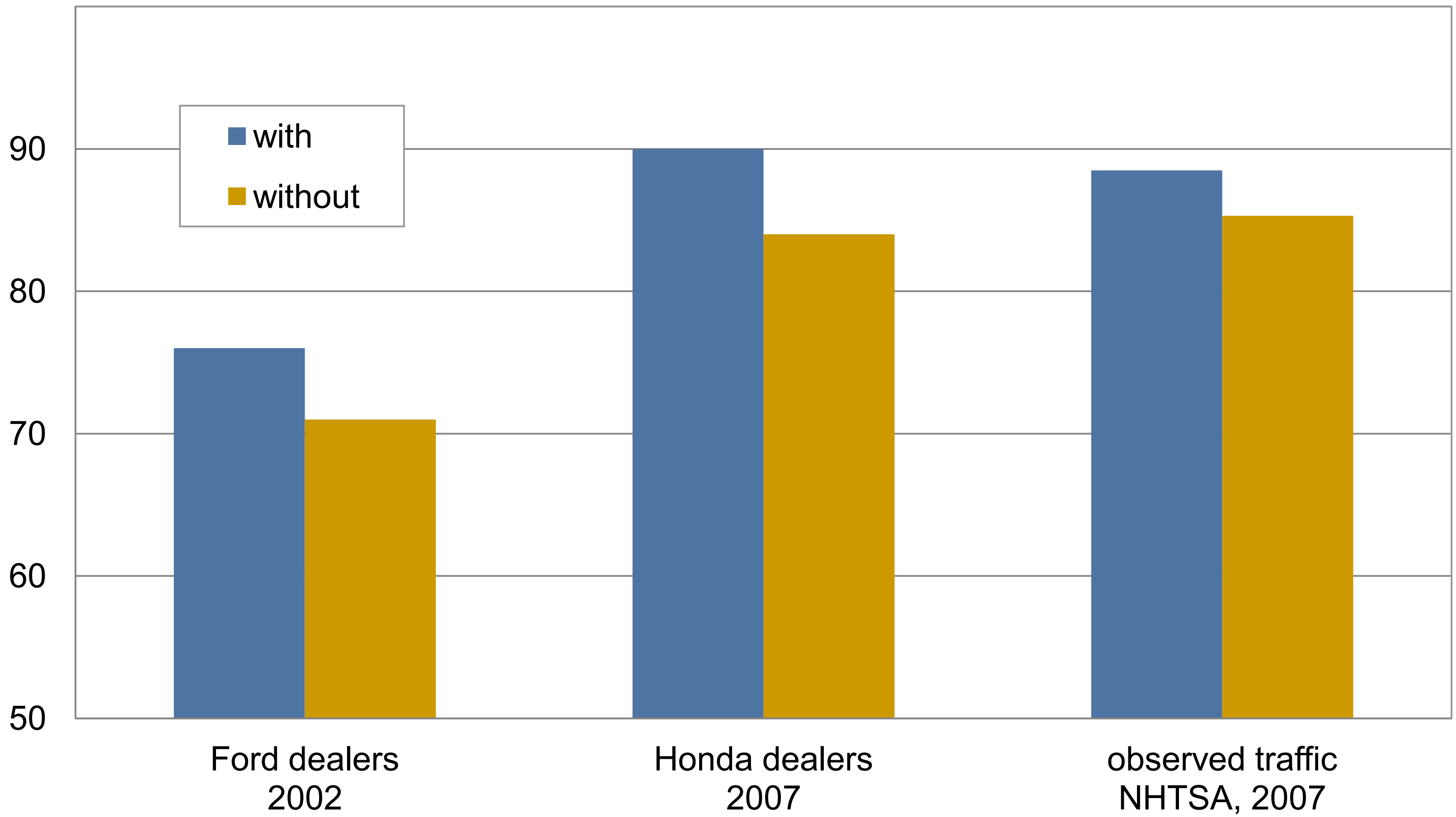


Effects of increasing belt use among front seat passengers 13+ years old in 2011

Estimated 85 percent belt use in 2011

target percent belt use	lives saved	percent of all deaths
90%	1,666	5
95%	3,057	9
100%	4,447	14

Percent driver belt use in vehicles with and without enhanced reminders



Can enhanced reminders be used more effectively to boost safety belt use in the U.S.?

- Many part-time users forget to buckle up; enhanced reminders can help
- Enhanced reminders in 2012 models: 91 percent driver, 77 percent front passenger, 3 percent rear passenger
- 2012 highway bill (MAP-21) removes some limits on National Highway Traffic Safety Administration requirements for technology to encourage belt use
  - Can require chime for more than 8 seconds
  - Cannot require ignition interlock but can allow automakers to use an interlocks to meet a safety regulation
  - Must begin rulemaking to require rear seat reminders

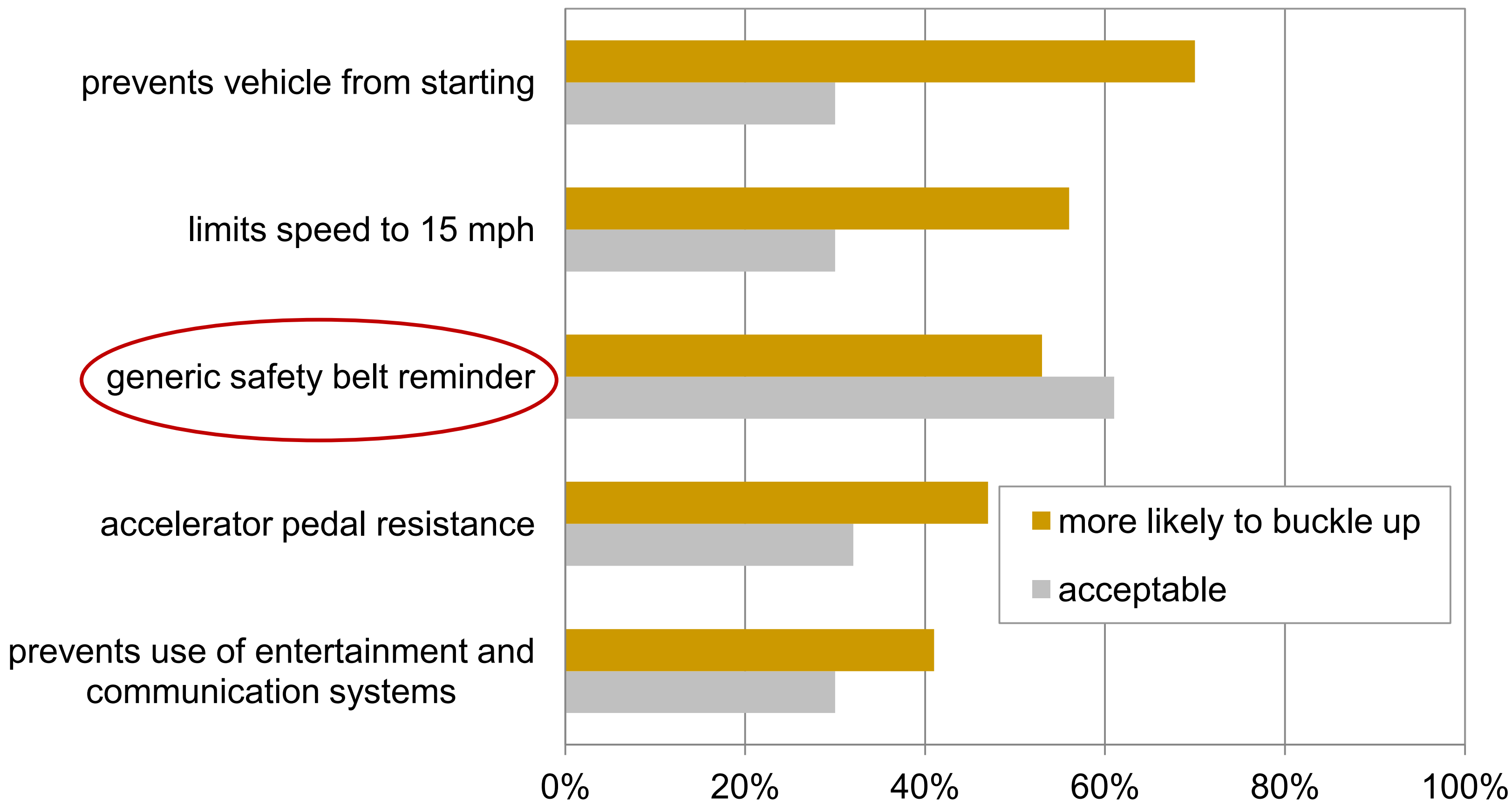
Top 3 reasons for not using seat belt

IIHS survey of 1,218 drivers and passengers, 2012

part-time users	nonusers
short trip (67%)	comfort (77%)
forget (60%)	don’t need belt (54%)
comfort (47%)	don’t like being told what to do (50%)

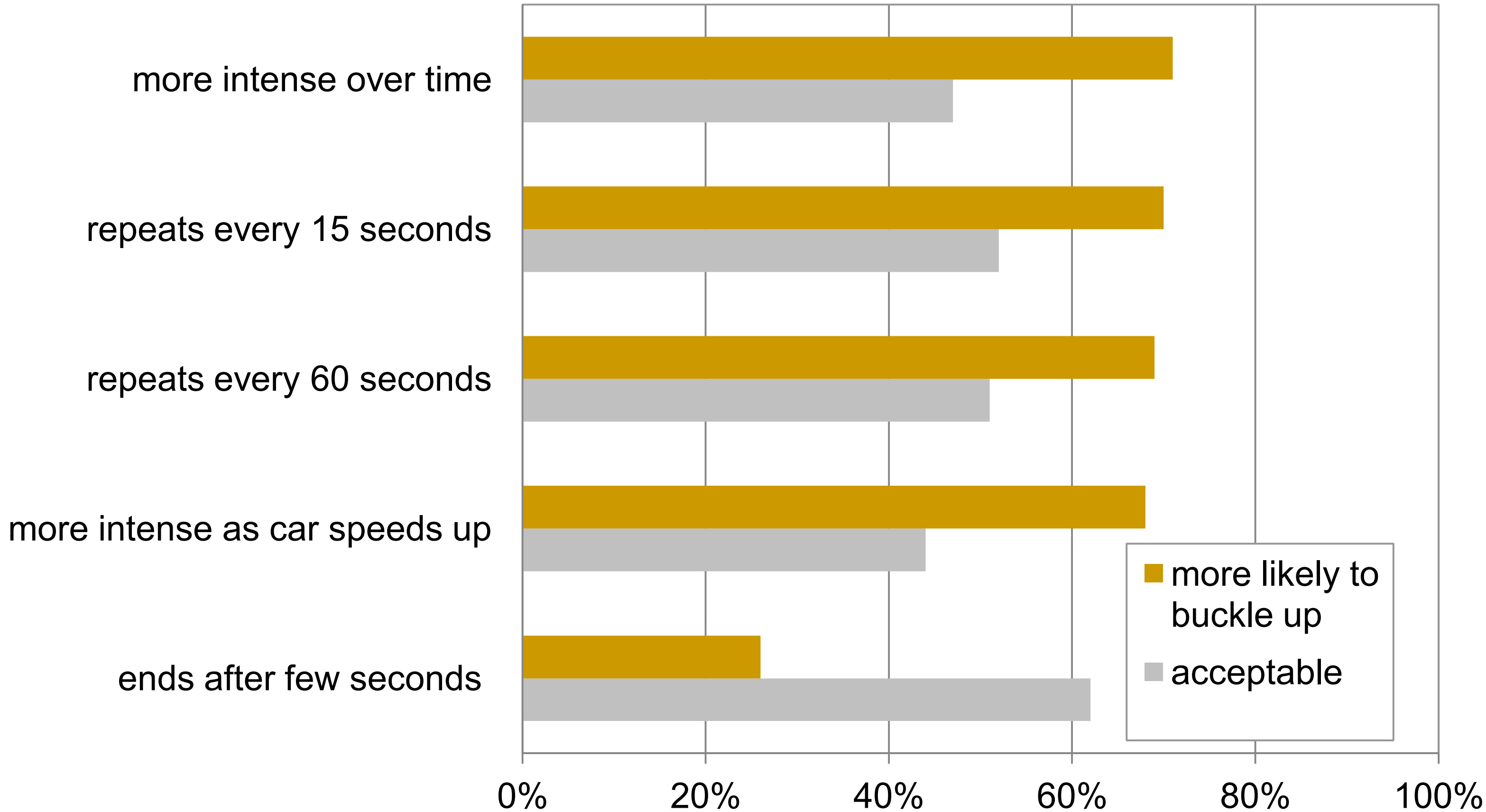
Part-time users' opinions about belt use interlocks and reminders

Percent that agree



Part-time users' opinions about effectiveness and acceptability of different intensities of reminders

Percent who agree



Increasing benefit of front passenger belt reminders

- Euro NCAP gives credit to driver and front passenger reminders that meet certain criteria
  - "Loud and clear" audiovisual signal lasting at least 90 seconds
  - Signal can be intermittent or continuous
- In Europe, belt use rate in cars with Euro NCAP reminders about 12 percentage points higher than in cars without reminders
- Systems meeting Euro NCAP criteria vary widely
  - Proportion of time chime sounds
  - Overall duration of chime
- Estimate one-third of enhanced seat belt reminders in the U.S. meet Euro NCAP criteria

Reminder features parents want

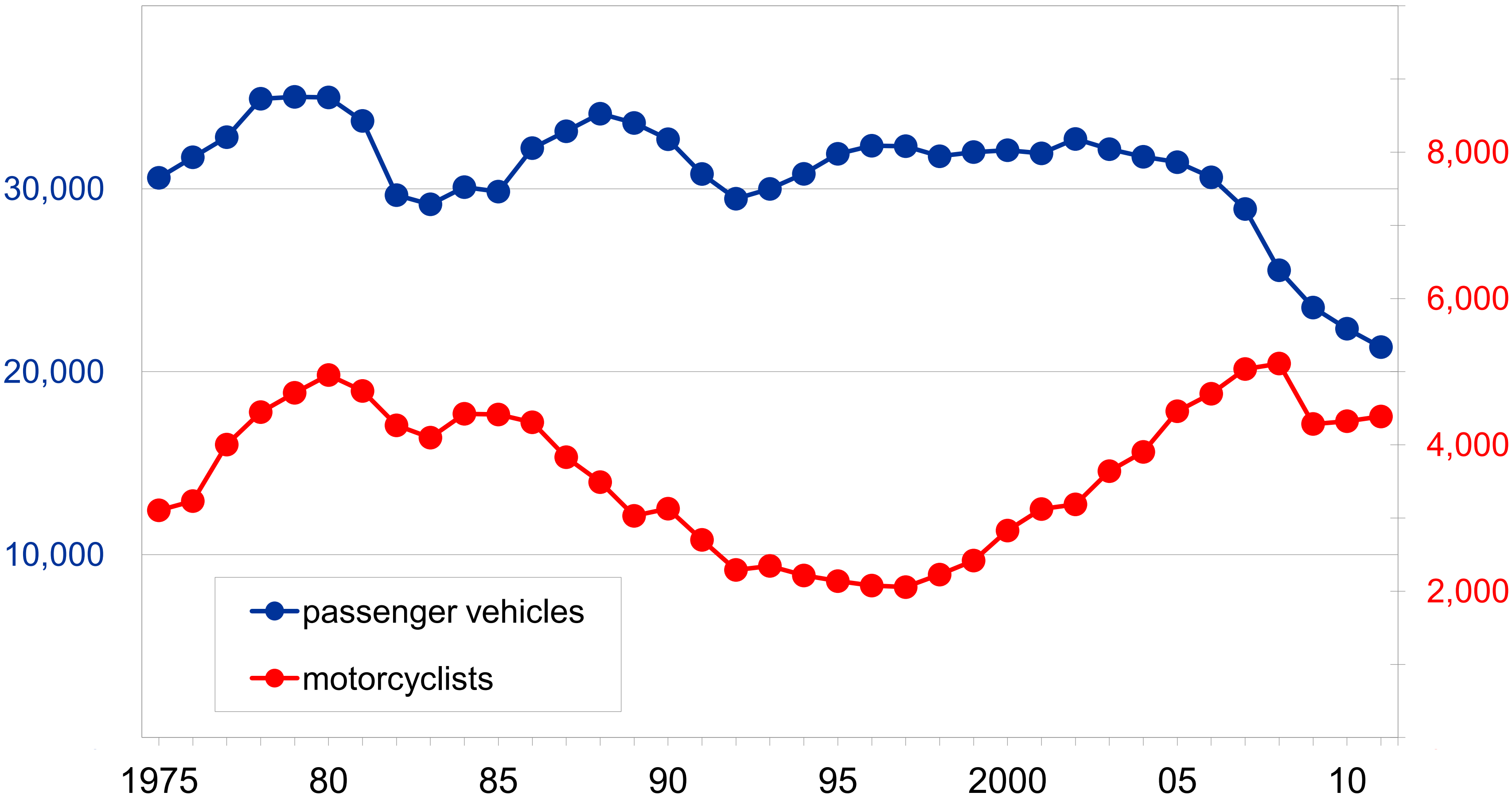
IIHS survey of 254 drivers with 8-15 year-olds in back seat, 2012

- 82 percent of all parents want to know when child is unbuckled
- Desired reminder information
  - Diagram of seating positions and belt use (87%)
  - Flashing or illuminated light or text display (85%)
  - Chime or buzzer (79%)
- Desired reminder duration
  - Until children buckle up (63%)
  - Several miles into trip (17%)
  - Brief, ending shortly after vehicle starts (19%)

Motorcycles

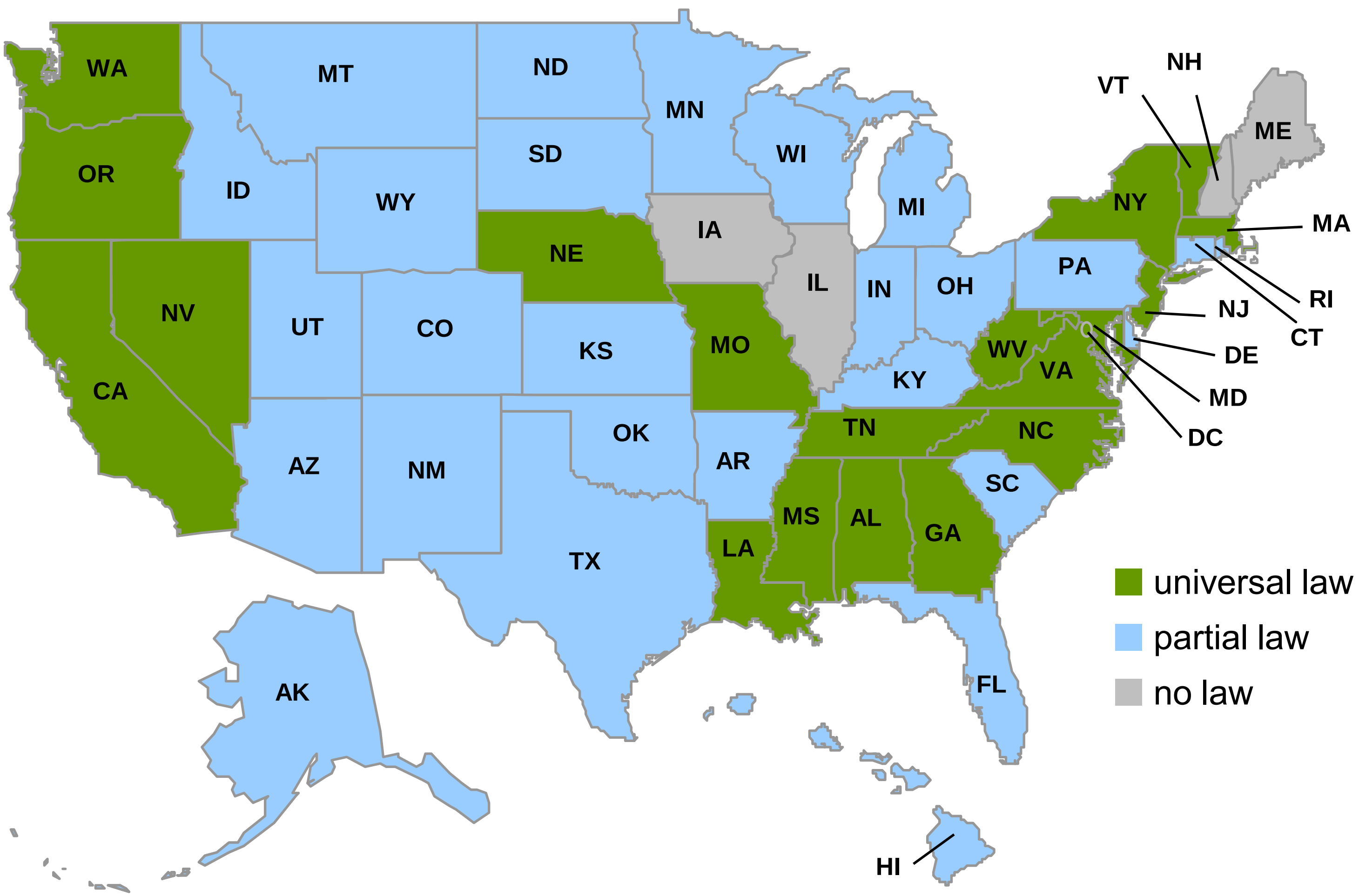
Deaths of motorcyclists and passenger vehicle occupants in the United States

1975-2011



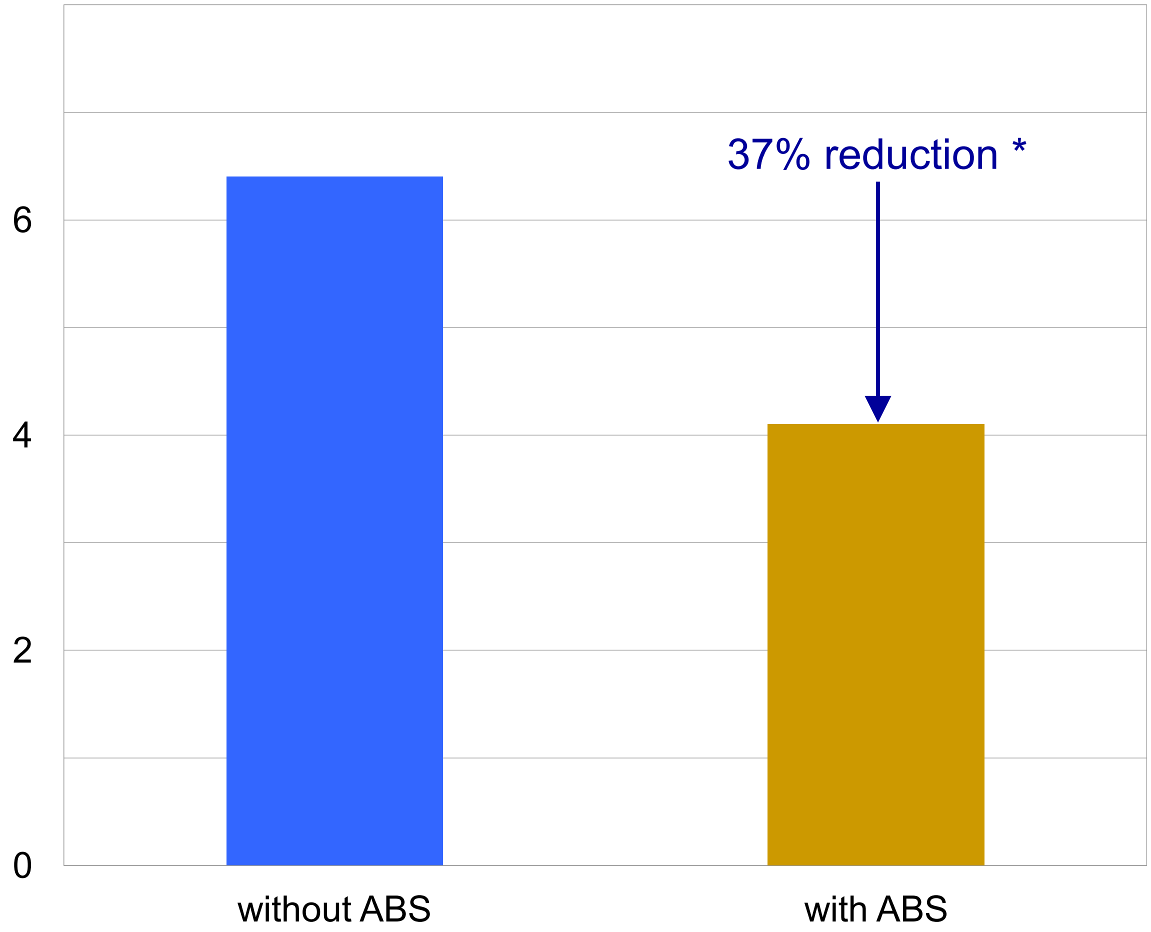
Map of motorcycle helmet laws

January 2013



Fatal crash rates for motorcycles with/without ABS

Fatal crashes per 10,000 registrations, U.S., 2003-08

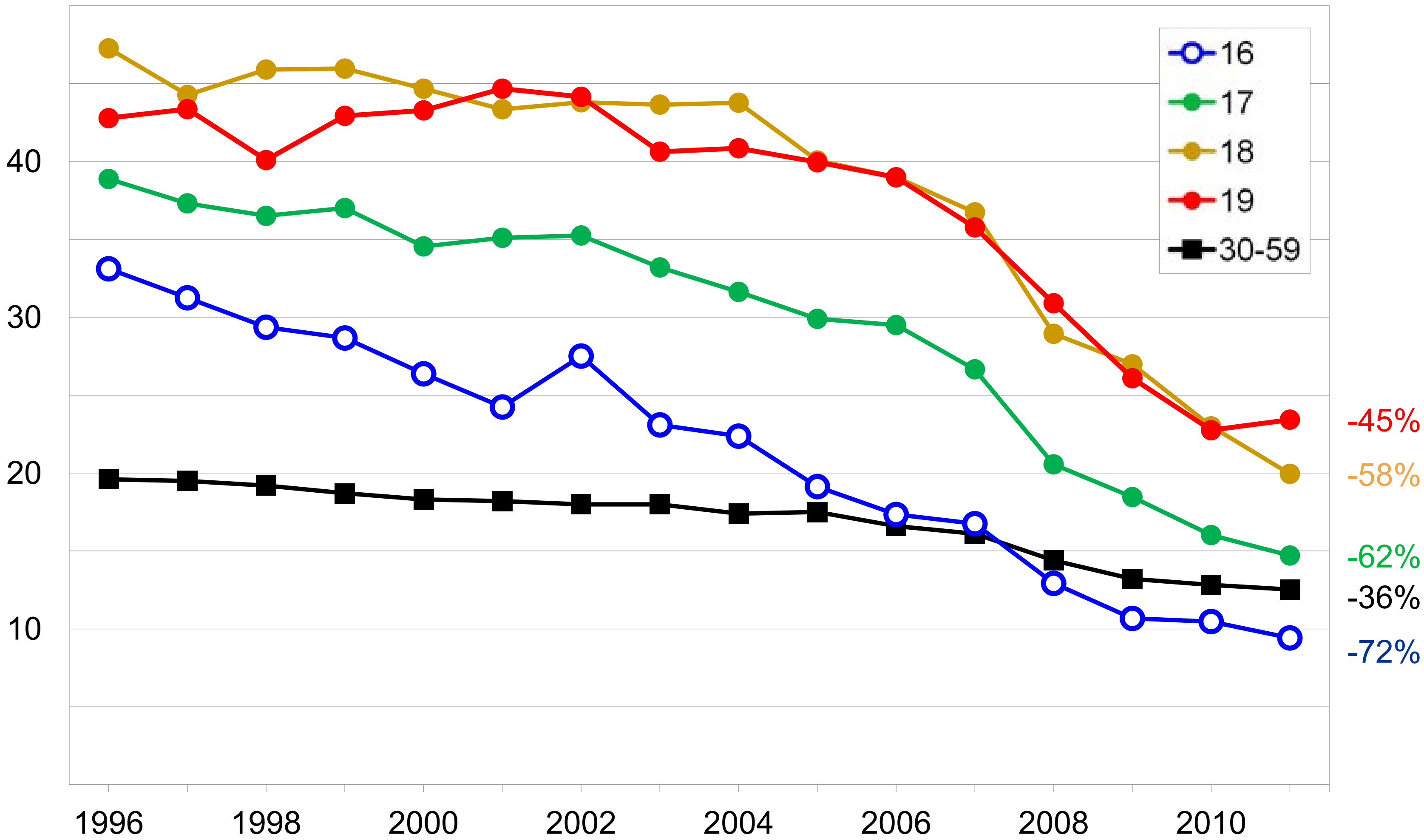


* statistically significant at 0.05 level

Teenage drivers

Fatal crashes per 100,000 people in the U.S.

Passenger vehicle drivers, by driver age, 1996-2011



IIHS ratings of teenage licensing laws, 2000-11

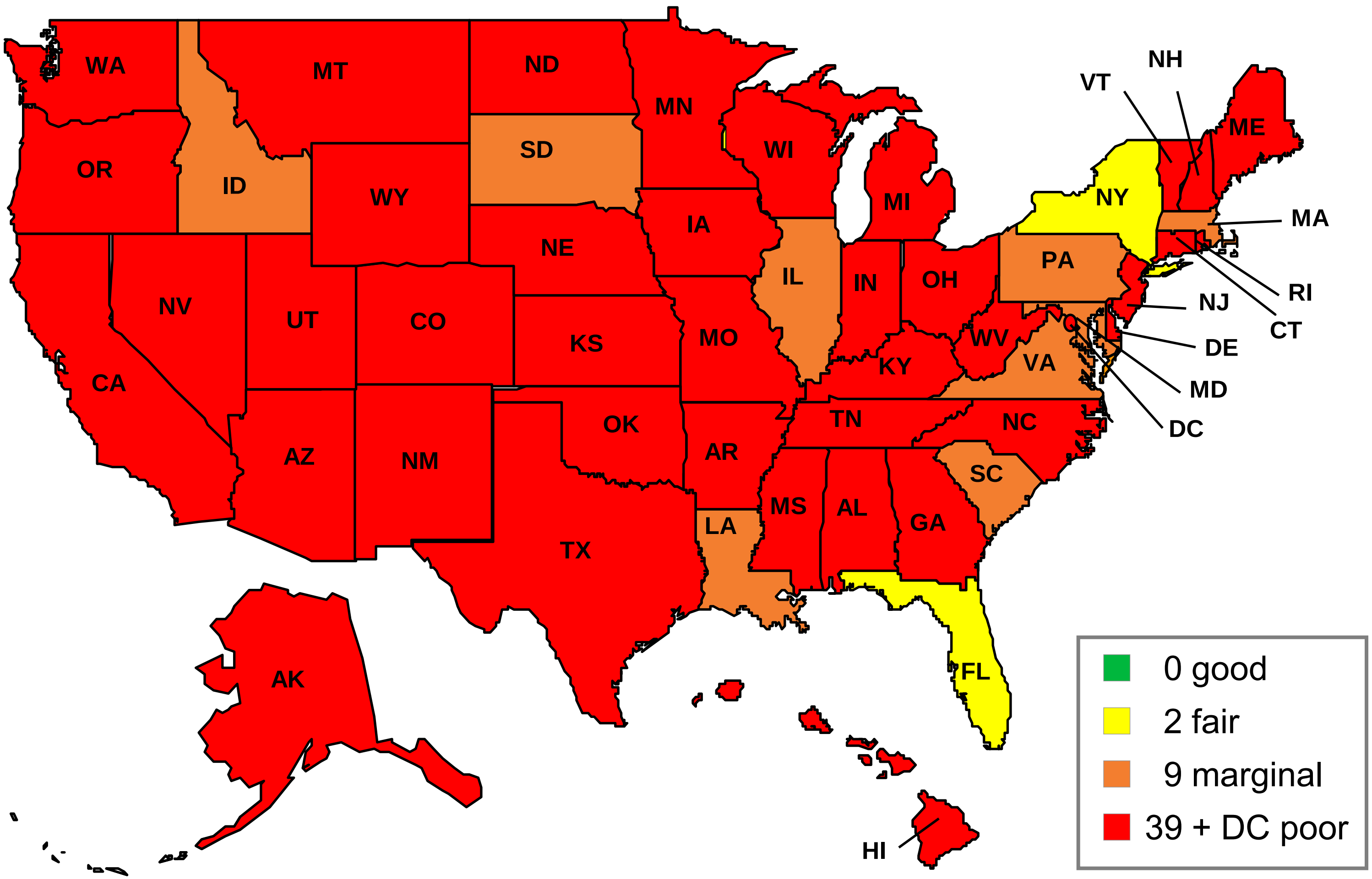
G F M P

learner's phase
entry age
holding period
supervised driving certification

intermediate phase
entry age
night driving restriction
passenger restriction
duration of restrictions

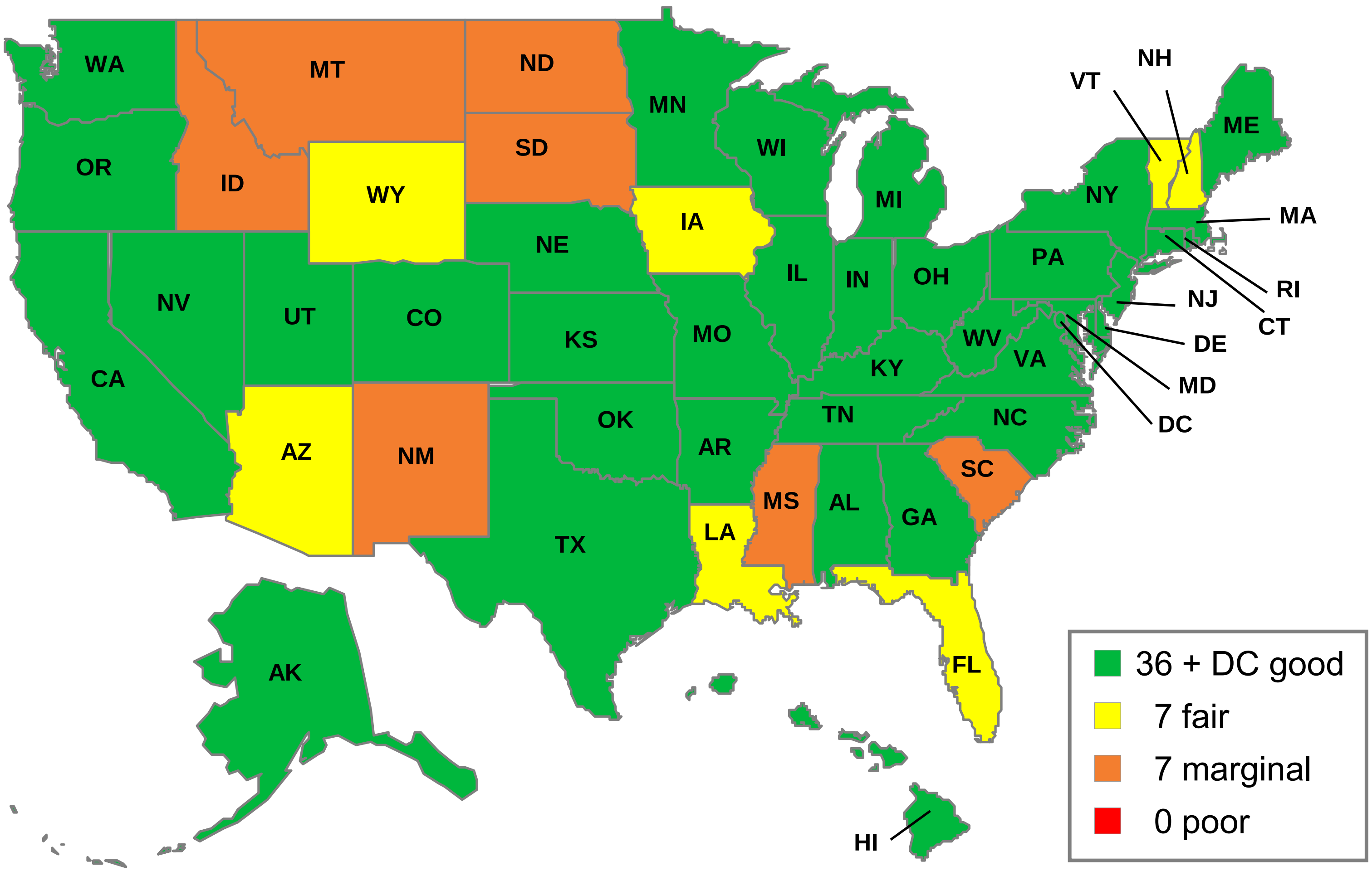
IIHS ratings of graduated licensing laws

July 1996, using 2005-2011 rating system



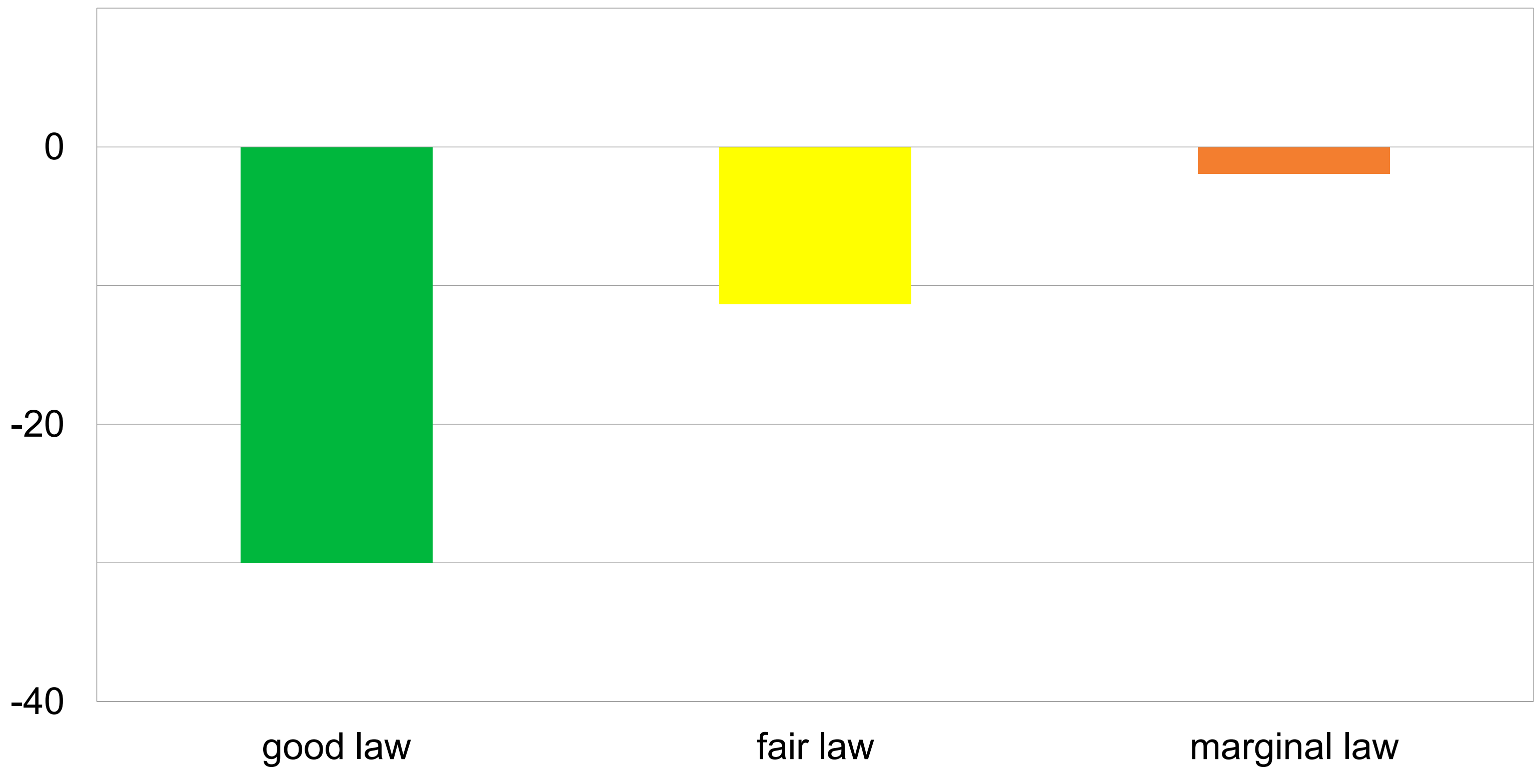
IIHS ratings of graduated licensing laws

August 2011, using 2005-11 rating system



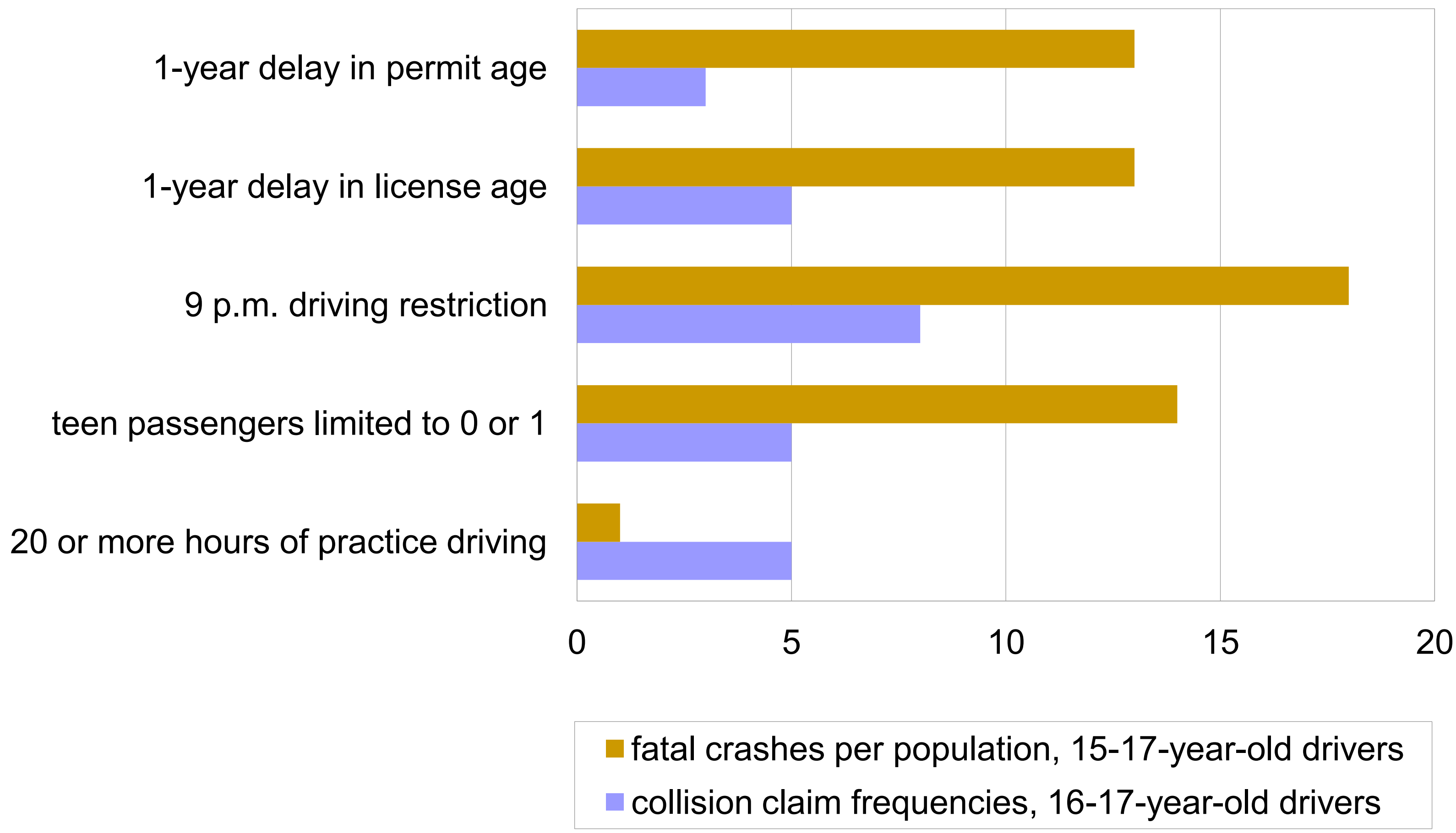
Percent reduction in per capita fatal crash rates of 15-17 year-olds by graduated licensing law rating

1996-2007, compared with states that had laws rated poor



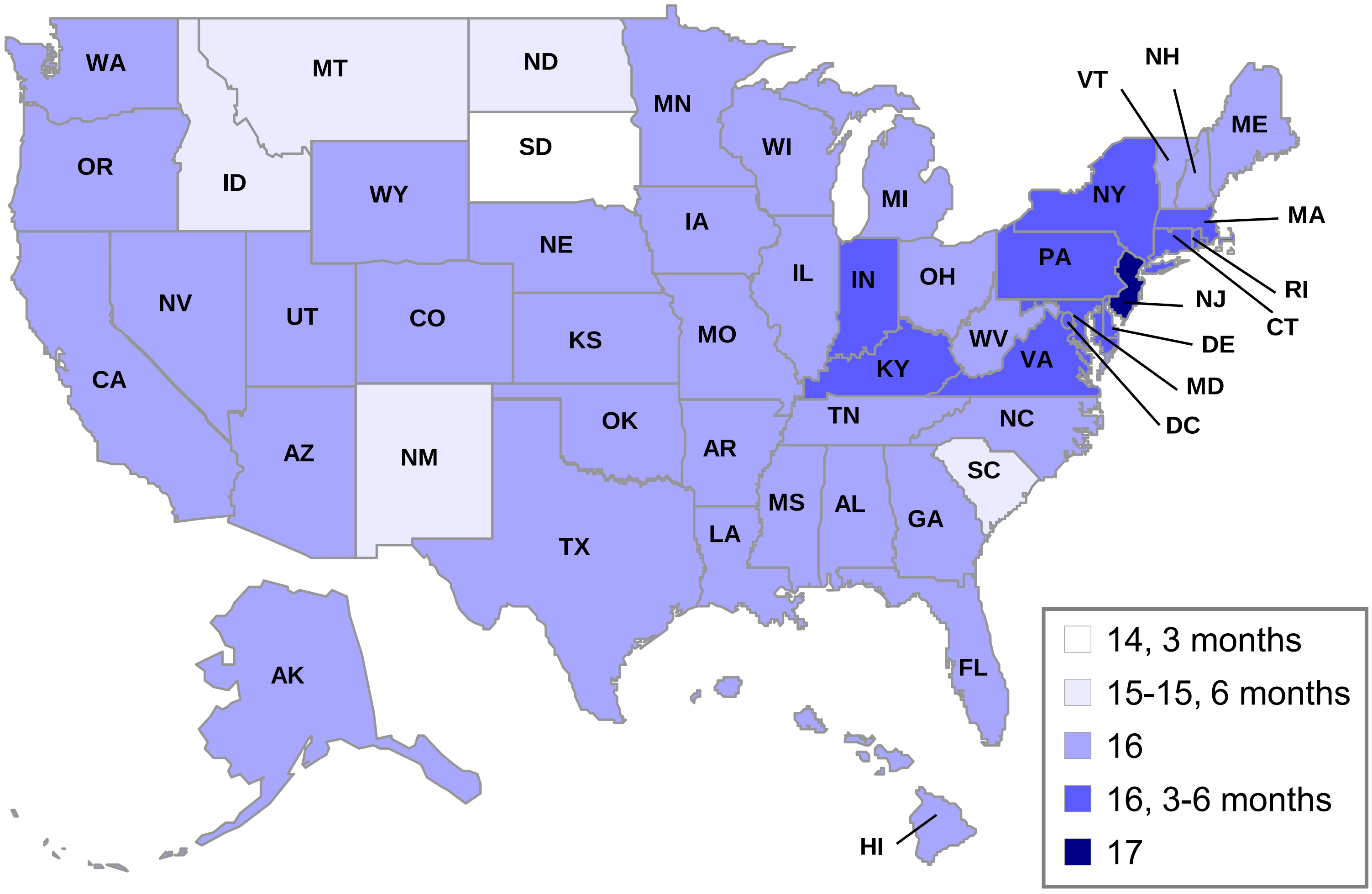
Percent reduction in teenagers' crash rates

By graduated licensing component



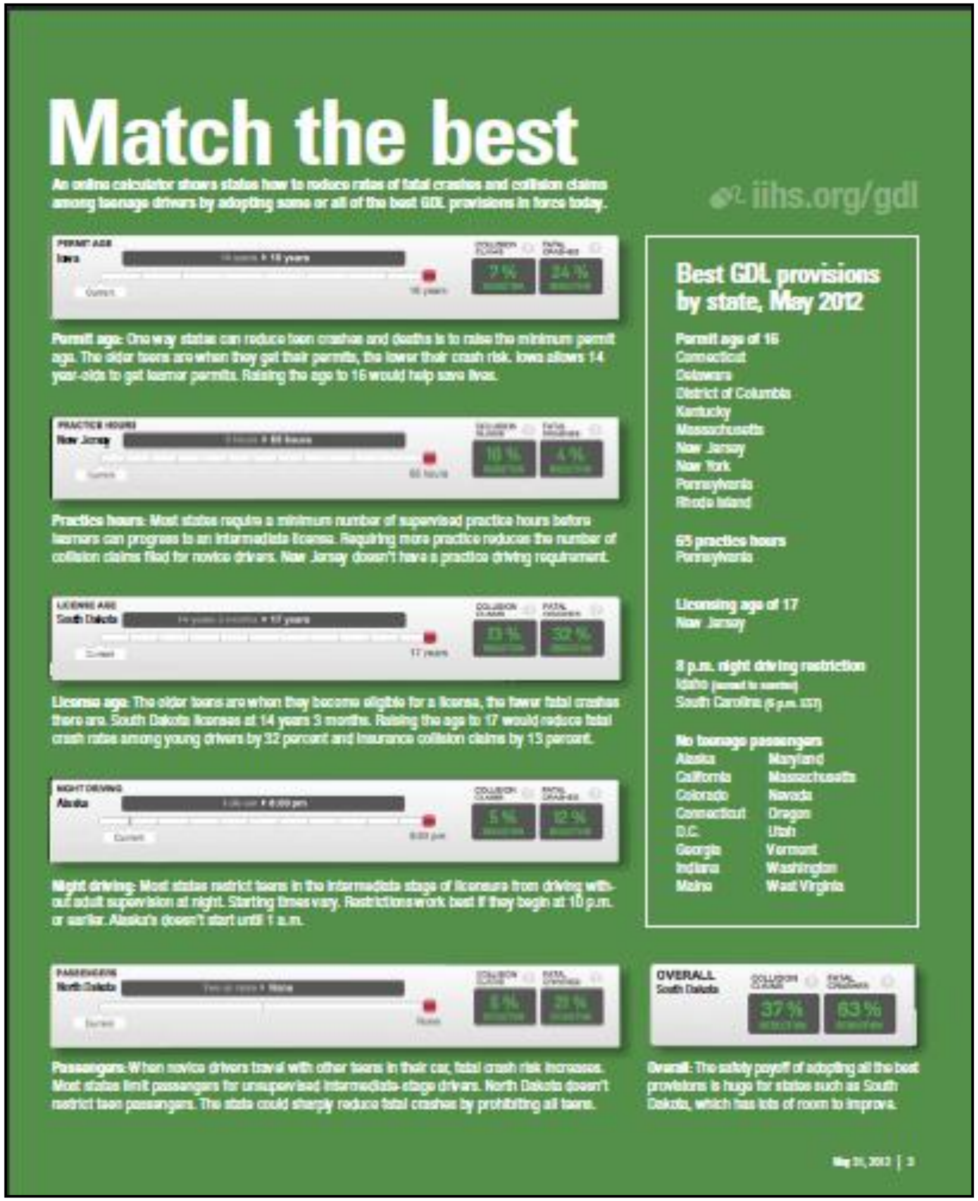
Minimum age for intermediate license

January 2013



GDL calculator

- Estimates effects of given improvements
- Overall crash reductions based on improving all five components
- “Match the best” feature permits state to see benefits of matching the strongest provisions for all five components



Match the best

An online calculator shows states how to reduce rates of fatal crashes and collision claims among teenage drivers by adopting some or all of the best GDL provisions in force today.

iihs.org/gdl

PERMIT AGE
Iowa
7 %
24 %

Permit age: One way states can reduce teen crashes and deaths is to raise the minimum permit age. The older teens are when they get their permits, the lower their crash risk. Iowa allows 14 year-olds to get learner permits. Raising the age to 16 would help save lives.

PRACTICE HOURS
New Jersey
10 %
4 %

Practice hours: Most states require a minimum number of supervised practice hours before learners can progress to an intermediate license. Requiring more practice reduces the number of collision claims filed for novice drivers. New Jersey doesn't have a practice driving requirement.

LICENSE AGE
South Dakota
17 years
13 %
32 %

License age: The older teens are when they become eligible for a license, the fewer fatal crashes there are. South Dakota licenses at 14 years 3 months. Raising the age to 17 would reduce fatal crash rates among young drivers by 32 percent and insurance collision claims by 13 percent.

NIGHT DRIVING
Alaska
Current
5 %
12 %

Night driving: Most states restrict teens in the intermediate stage of licensure from driving without adult supervision at night. Starting times vary. Restrictions work best if they begin at 10 p.m. or earlier. Alaska's doesn't start until 1 a.m.

PASSENGERS
North Dakota
8 %
21 %

Passengers: When novice drivers travel with other teens in their car, fatal crash risk increases. Most states limit passengers for unsupervised intermediate-stage drivers. North Dakota doesn't restrict teen passengers. The state could sharply reduce fatal crashes by prohibiting all teens.

Best GDL provisions by state, May 2012

Permit age of 16
Connecticut
Delaware
District of Columbia
Kentucky
Massachusetts
New Jersey
New York
Pennsylvania
Rhode Island

65 practice hours
Pennsylvania

Licensing age of 17
New Jersey

8 p.m. night driving restriction
Idaho
South Carolina

No teenage passengers

Alaska	Maryland
California	Massachusetts
Colorado	Nevada
Connecticut	Oregon
D.C.	Utah
Georgia	Vermont
Indiana	Washington
Maine	West Virginia

OVERALL
South Dakota
37 %
63 %

Overall: The safety payoff of adopting all the best provisions is huge for states such as South Dakota, which has lots of room to improve.

Summary

- We are entering an exciting period in automotive engineering
  - Technology that can prevent crashes is becoming a reality
  - Research must sort out which new technology is helpful
- Reaping the rewards of this technology will be a gradual, slow process
- A crash-free environment is not on the immediate horizon; putting people in packages that protect them in crashes remains a top priority
- In the near term – over the next ten years – our success in reducing deaths and injuries from motor vehicle crashes will also depend on other proven countermeasures in highway safety

www.iihs.org

Dedicated to reducing deaths, injuries, and property damage on the highway

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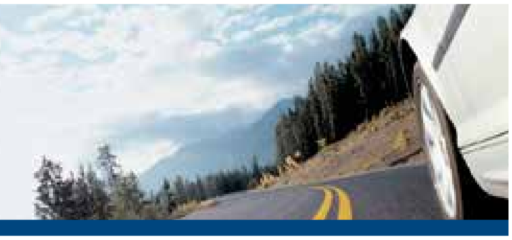
HIGHWAY LOSS
DATA INSTITUTE

Bulletin | Vol. 28, No. 26 : April 2012



Predicted availability of safety features on registered vehicles

Introduction

In 2008, the Insurance Institute for Highway Safety (IIHS) estimated the potential benefits of several collision avoidance technologies. Researchers estimated that 3,435,000 unique crashes could be addressed by the assessed technologies (Farmer, 2008). A follow-up study published by IIHS in 2011 took into account the limitations of the systems and estimated that nearly 1.9 million crashes could be prevented or mitigated each year by four collision avoidance technologies (Jermakian, 2011). In 2009, the Highway Loss Data Institute (HLDI) produced the first ever evaluation of the effect of a collision avoidance technology on insurance losses. The evaluated system, Distronic, an adaptive cruise control system bundled with forward collision warning functionality, was found to reduce property damage liability claim frequencies by 8 percent and collision claim frequencies by 5 percent (HLDI, 2009). In June of 2011 HLDI studied Volvo's City Safety technology and found that it reduced property damage liability claim frequencies by 27 percent and collision claim frequencies by 22 percent when compared with other midsize luxury SUVs (HLDI, 2011).

Given the potential and proven benefits of these systems, it is almost certain that they will reduce the number of crashes and insurance claims. While estimating the efficacy of available systems is an important part of understanding the long-term impact of these systems, it is also important to understand the prevalence of these systems in the current fleet and to estimate their growth in the fleet over time. The purpose of this bulletin is to quantify the prevalence of vehicle features in the registered vehicle fleet, trace that prevalence from introduction through the most current registration data, and then to predict the prevalence in the future.

Methods

This bulletin combines vehicle feature information from the Highway Loss Data Institute with vehicle registration data from R.L. Polk and Company. For each feature studied there are three figures:

- The **first figure** illustrates the percentage of new vehicle series with a given feature by model year. In this figure each new vehicle series (model year, make, series) is a single observation. The observations have not been weighted by insurance exposure or vehicle registration information. Using new vehicle series to illustrate how common a feature is can be deceiving because new safety features typically appear initially on luxury vehicles which tend to be sold in lower volumes than non-luxury vehicles.
- The **second figure** for each feature illustrates the percentage of registered vehicles with a feature by calendar year. In this figure each observation (model year, make, series) is weighted by the number of registered vehicles.
- The **third figure** for each feature illustrates the predicted availability for that feature. The actual availability is also displayed for comparison. This figure helps to provide insight into the time required for the presence of a feature to build in the registered vehicle fleet.

The following features are included in this bulletin: antilock brakes (ABS), electronic stability control (ESC), driver frontal airbags, side airbags, and forward collision warning (FCW) systems. These features have been selected for a variety of reasons. ABS and ESC were chosen because they are interesting when contrasted with each other. Early safety research on ABS did not demonstrate a benefit for this feature and it was never required by the National Highway Traffic Safety Administration (NHTSA). By contrast ESC, which is an extension of ABS, did show early promise in safety research and was eventually required by NHTSA. Front and side airbags were included for similar reasons as they both showed promise in reducing serious occupant injury and death. Federal requirements for driver frontal airbags were phased in over a period of several years. They were first required on some vehicles beginning on September 1, 1996. Side airbags, however, are not required by federal mandate to be installed in vehicles. Forward collision warning systems were included in the analysis because of the promising results found in the evaluation of the Mercedes Distronic system.

Vehicle feature information was obtained by HLDI. The feature information is structured by model year, make, and series. The same three variables were mapped to the registration data from R.L. Polk. For each model year-make-series combination, one of three possible feature values are provided: “standard,” “optional,” and “not available.” Registration counts belonging to either of the first two groups are hereafter referred to as “available.” For example, in calendar year 2007, 7.1 percent of registered vehicles had standard ESC and another 9.2 percent had it as an option, so it is said that ESC was available in 16.3 percent of the 2007 registered vehicles.

The most recent R.L. Polk data available to HLDI contains calendar years 1976 to 2010. For each calendar year, a number of recent model years is available, ranging from 9 model years for calendar year 1976 to 37 model years for calendar year 2010. The number of model years included in each calendar year has increased over time. For calendar years 2003 and later, 37 most recent model years were available. For calendar years 1996 to 2002 at least 30 most recent model years were in the dataset. This covered at least 95 percent of the overall fleet in calendar years where safety features started to gain popularity. There are model years that are present in earlier calendar years, age out of the dataset, and then re-enter when the dataset was expanded. To increase the amount of usable data, missing values were extrapolated based on existing values.

In order to predict the availability of features in future calendar years, the registration data was extrapolated to reflect the hypothetical fleet for each calendar year from 2011 to 2050. The extrapolation was made on the following two assumptions:

1. The number of new vehicles will stay at the same level, calculated as the average of the five most recent years available, rounded to the next million.
2. The future attrition rate of the aging vehicles will be the same as in the past.

Approach used to estimate the number of new vehicles: There were a total of 8,045,311 registered model year 2010 vehicles in calendar year 2010, 6,886,581 model year 2009 vehicles in 2009, 10,803,133 model year 2008 in 2008, 12,014,754 model year 2007 in 2007, and 11,596,942 model year 2006 in 2006. The average of those 5 numbers equals 9,869,344 and rounding to the nearest million produces a value of 10,000,000. This is the assumed value for new vehicles.

Approach used to estimate attrition rates: Attrition rates were calculated for each calendar/model year combination using the average of all available attrition rates for that age of vehicle (vehicle age = calendar year – model year). For example, the number of registrations for model year 2008 in calendar year 2011 had to be extrapolated. The vehicle age of this cell is 3. The average attrition rate from cells with a vehicle age of 3 (i.e. model year 2007 in calendar year 2010, model year 2006 in calendar year 2009, etc.) were averaged (1.46 percent). This average was applied to the last known value for model year 2008 in calendar year 2010 (13,572,642) to produce the number of model year 2008 vehicles in calendar year 2011 (13,374,396).

The estimation procedure was conducted separately for each feature in the study. The procedure involved running a logistic regression model (assuming a binomial distribution with a probit link) on the past year data where feature prevalence is known and then applying the model estimates to predict the feature prevalence for future years. For ESC and driver frontal airbags, the percentage for these features after the required model year is set to 100 percent. The dependent variable in the model was the ratio of the registration count where the feature was available to the total registration count. The only two independent variables were calendar year and model year.

Figure 1: Percentage of new vehicle series with ABS

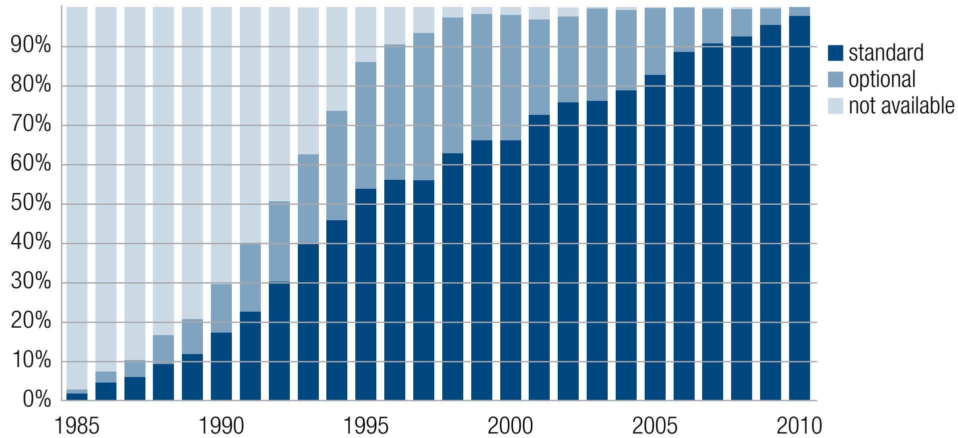


Figure 1 shows the percentage of vehicle series by model year with either standard or optional ABS. ABS first appeared on the 1971 Chrysler Imperial. However, modern ABS has been continuously available since model year 1985. By the 1990 model year had become standard on 17% and optional on 12% of vehicle series. For the 2010 model year, ABS was standard on 99% and optional on 1% of vehicle series.

Figure 2: Percentage of registered vehicles with ABS

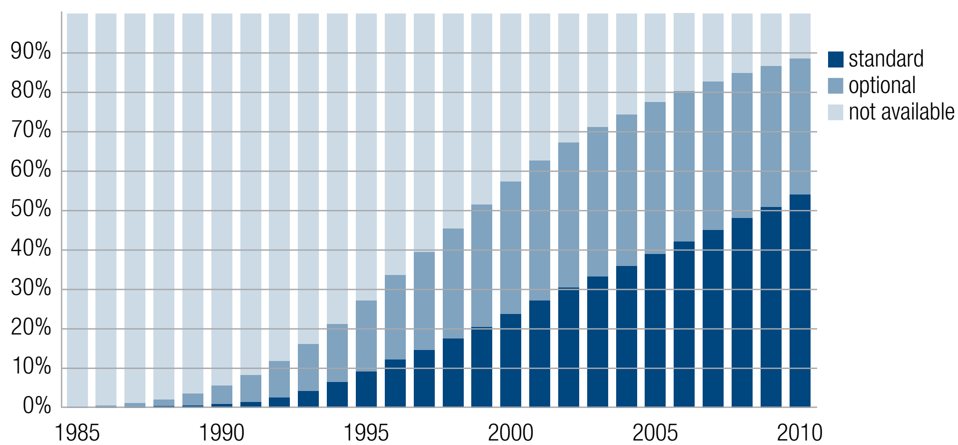


Figure 2 shows the percentage of registered vehicles by calendar year with either standard or optional ABS. By 1990, ABS had become standard on only 1% and optional on 5% of registered vehicles. By 2010, ABS was standard or optional on 88% of registered vehicles.

Figure 3: Predicted percentage of registered vehicles with ABS

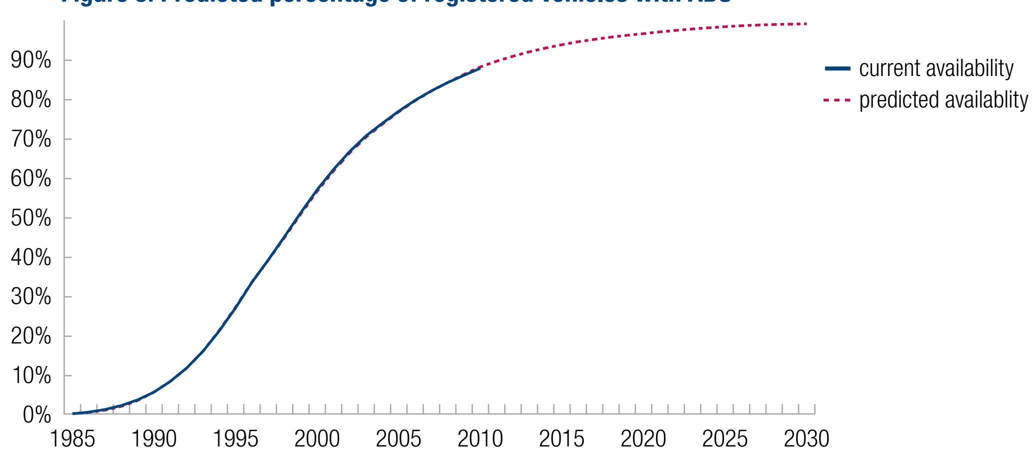


Figure 3 shows the percentage of predicted registered vehicles by calendar year with ABS. It is predicted that ABS will be standard or optional on 95% of registered vehicles in 2015 and 100% by 2030.

Figure 4: Percentage of new vehicle series with ESC

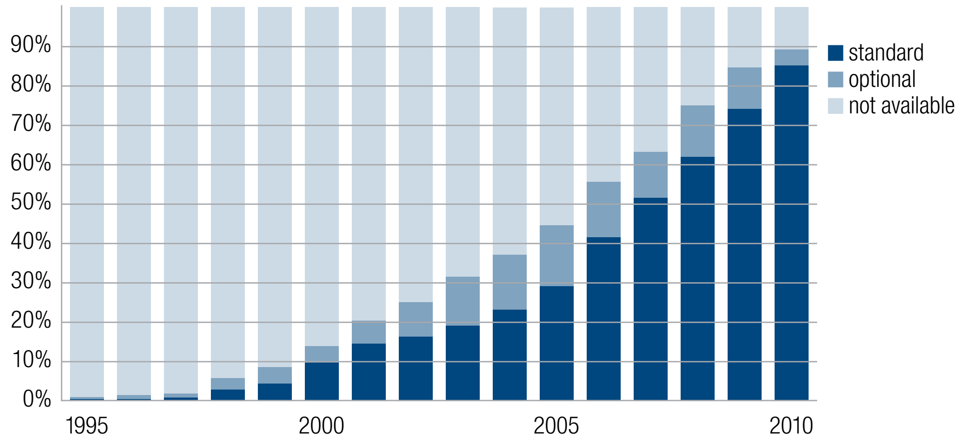


Figure 4 shows the percentage of vehicle series by model year with either standard or optional ESC. ESC was introduced in model year 1995 and by the 2000 model year had become standard on 10% and optional on 4% of vehicle series. For the 2010 model year, ESC was standard on 91% and optional on 4% of vehicle series.

Figure 5: Percentage of registered vehicles with ESC

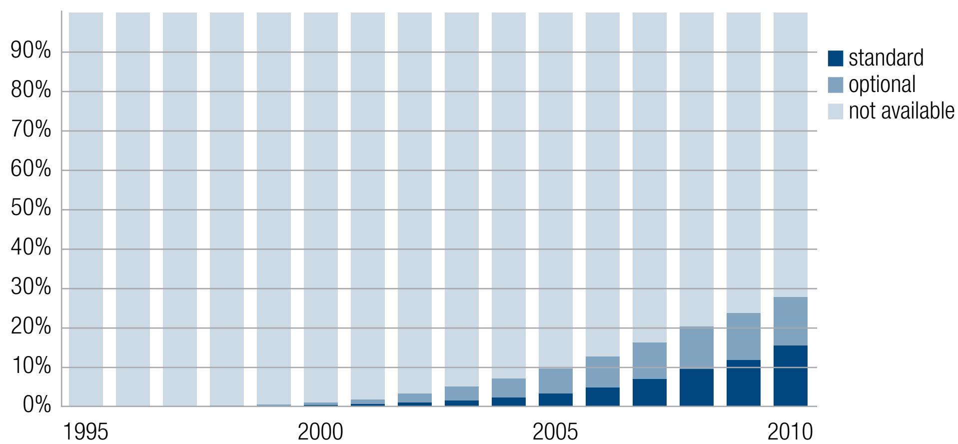


Figure 5 shows the percentage of registered vehicles by calendar year with either standard or optional ESC. By 2000, ESC had become standard on less than 1% and optional on 1% of registered vehicles. By 2010, ESC was standard or optional on 27% of registered vehicles.

Figure 6: Predicted percentage of registered vehicles with ESC

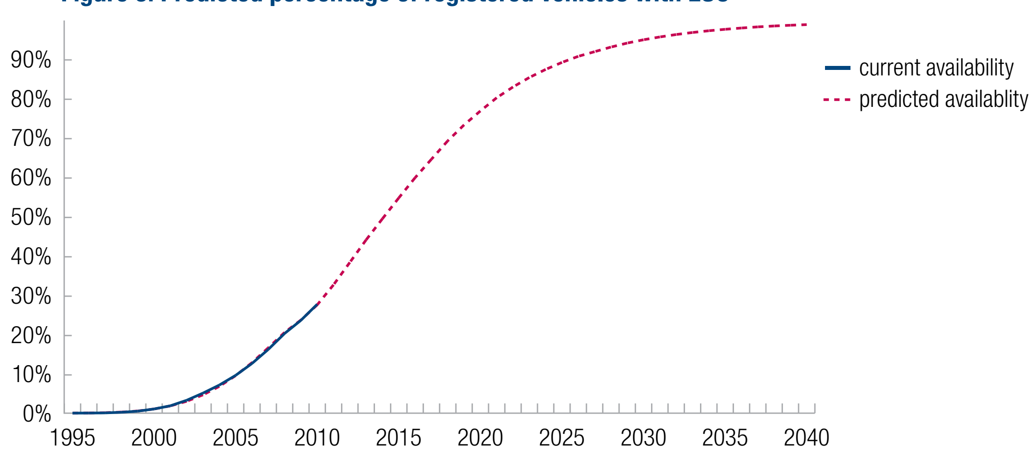


Figure 6 shows the percentage of predicted registered vehicles by calendar year with ESC. It is predicted that ESC will be standard or optional on 95% of registered vehicles in 2029 and 100% by 2040.

Figure 7: Percentage of new vehicle series with driver front airbags

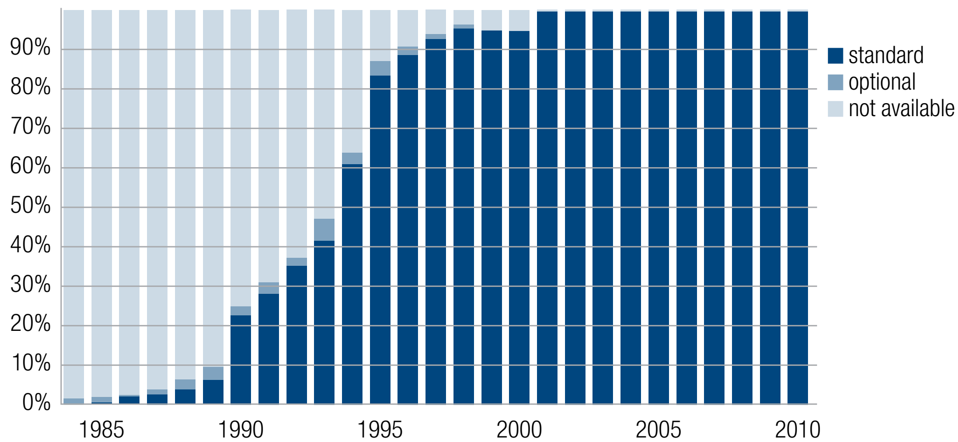


Figure 7 shows the percentage of vehicle series by model year with either a standard or optional driver front airbag.The driver front airbag has been continuously available since model year 1984. However, front airbags were installed on a limited number of General Motors vehicles in the mid-1970s. Federal law began requiring driver frontal airbags on some vehicles starting in 1996. By the 1990 model year driver front airbags had become standard on 23% and optional on 2% of HLDI series. By the 2001 model year, driver front airbags were standard on virtually all HLDI series.

Figure 8: Percentage of registered vehicles with driver front airbags

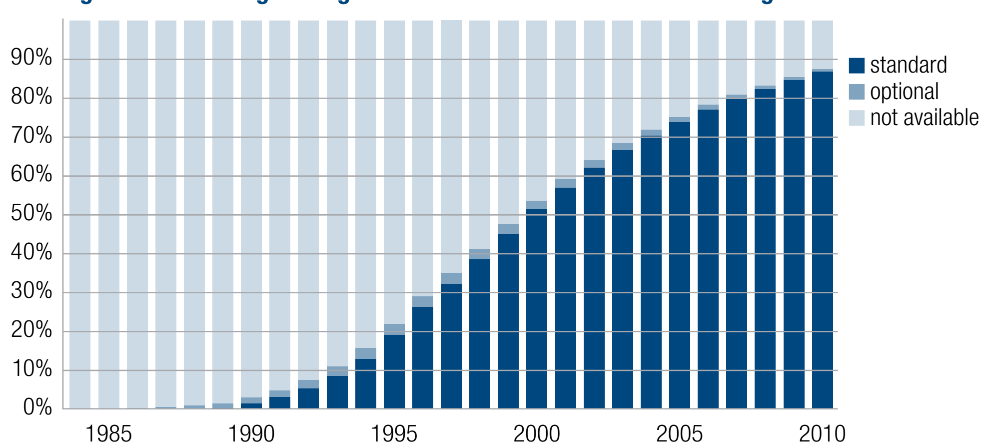


Figure 8 shows the percentage of registered vehicles by calendar year with either a standard or optional driver front airbag. By 1990, a driver front airbag had become standard on only 1% and optional on 2% of registered vehicles. By 2010, driver front airbags were standard or optional on 88% of registered vehicles.

Figure 9: Predicted percentage of registered vehicles with driver front airbags

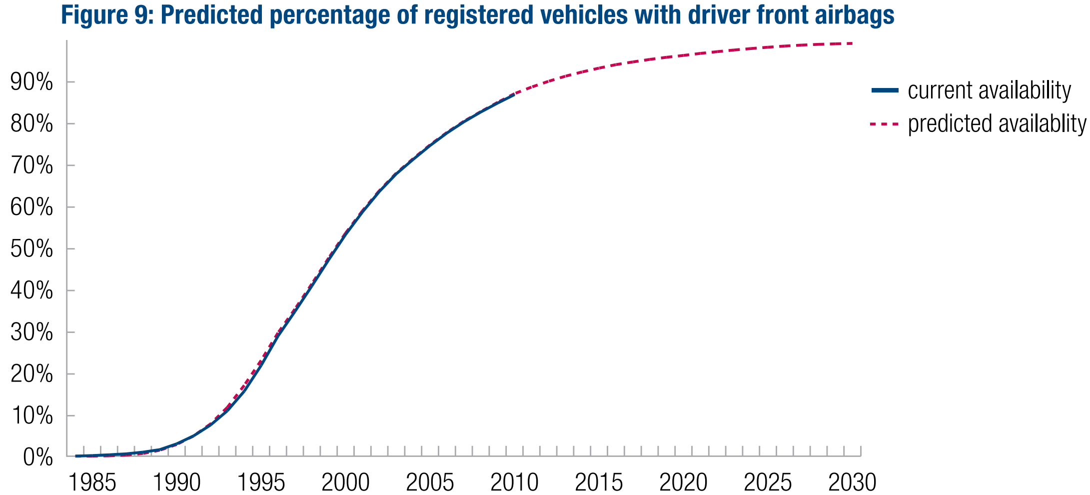


Figure 9 shows the percentage of predicted registered vehicles by calendar year with either a standard or optional driver front airbag. It is predicted that a driver front airbag will be standard or optional on 95% of registered vehicles in 2016 and 100% by 2030.

Figure 10: Percentage of new vehicle series with driver side airbags

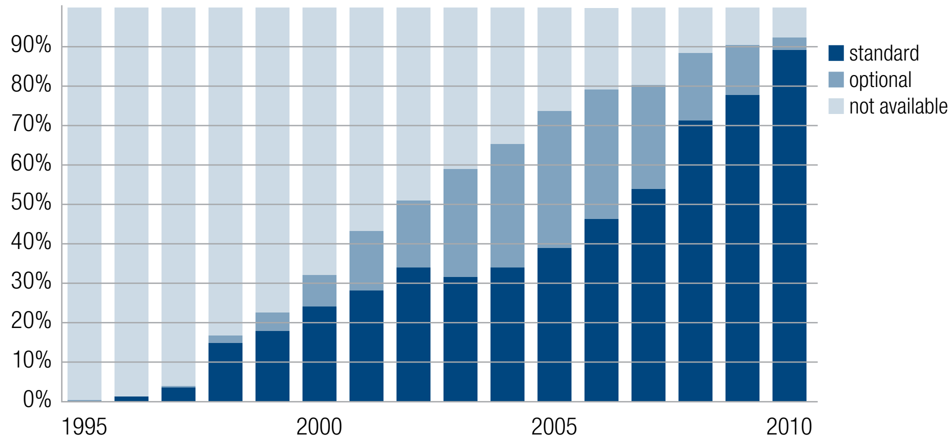


Figure 10 shows the percentage of vehicle series by model year with either a standard or optional driver side airbag. The driver side airbag was introduced in model year 1995 and by the 2000 model year had become standard on 24% and optional on 8% of vehicle series. For the 2010 model year, driver side airbags were standard on 92% and optional on 4% of vehicle series.

Figure 11: Percentage of registered vehicles with driver side airbags

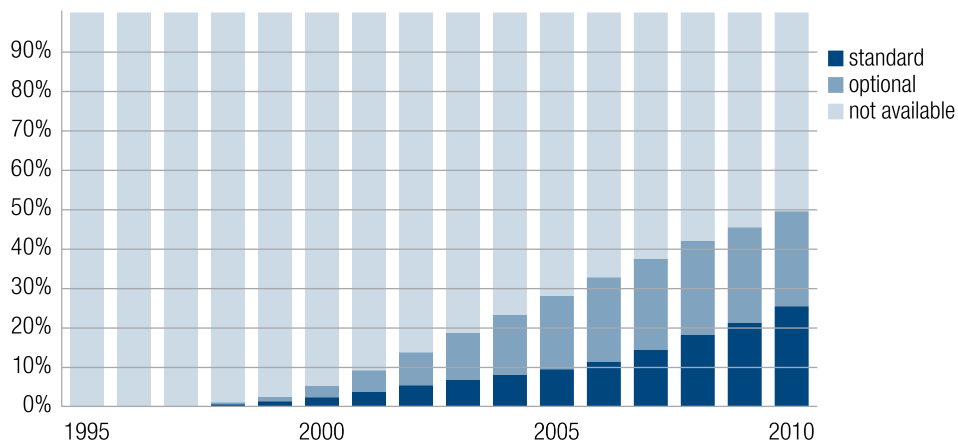


Figure 11 shows the percentage of registered vehicles by calendar year with either a standard or optional driver side airbag. By 2000, driver side airbags had become standard on less than 2% and optional on 3% of registered vehicles. By 2010, a driver side airbag was standard or optional on 49% of registered vehicles.

Figure 12: Predicted percentage of registered vehicles with driver side airbags

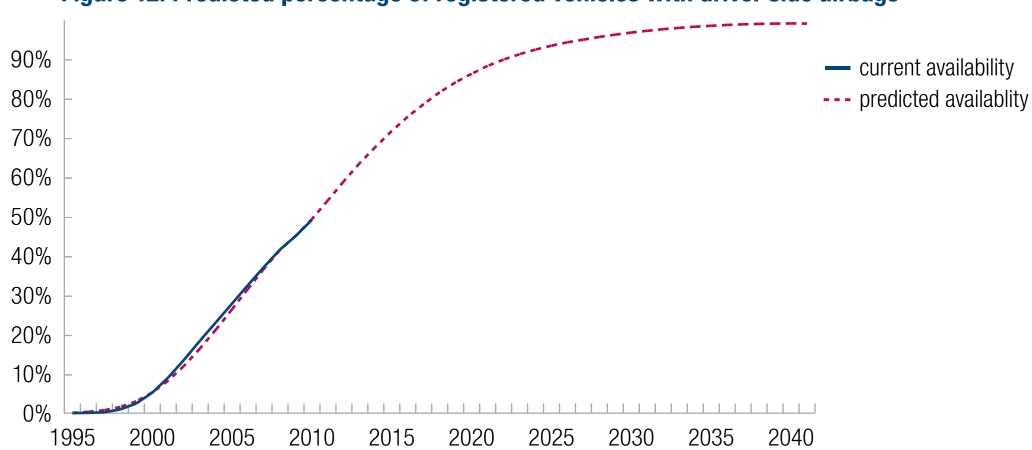


Figure 12 shows the percentage of predicted registered vehicles by calendar year with either a standard or optional driver side airbag. It is predicted that a driver side airbag will be standard or optional on 95% of registered vehicles in 2026 and 100% by 2040.

Figure 13: Percentage of new vehicle series with driver side head-protecting airbags

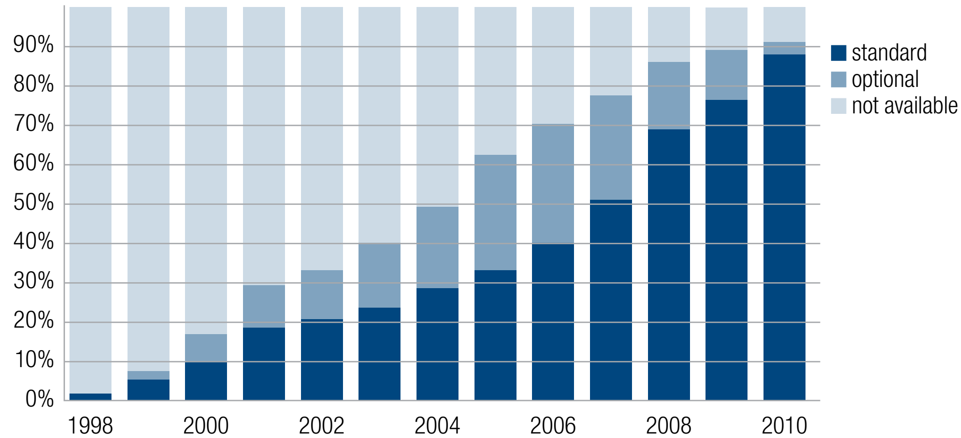


Figure 13 shows the percentage of vehicle series by model year with either a standard or optional head-protecting driver side airbag. The head-protecting driver side airbag was introduced in model year 1998 and by the 2005 model year had become standard on 33% and optional on 29% of vehicle series. For the 2010 model year, head-protecting driver side airbags were standard on 88% and optional on 3% of vehicle series.

Figure 14: Percentage of registered vehicles with driver side head-protecting airbags

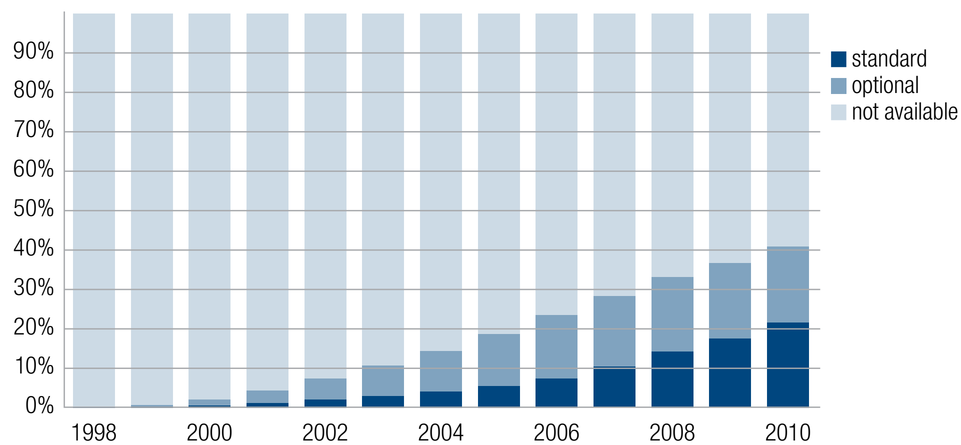


Figure 14 shows the percentage of registered vehicles by calendar year with either a standard or optional head-protecting driver side airbag. By 2005, head-protecting driver side airbags had become standard on less than 5% and optional on 13% of registered vehicles. By 2010, a head-protecting driver side airbag was standard or optional on 41% of registered vehicles.

Figure 15: Predicted percentage of registered vehicles with driver side head-protecting airbags

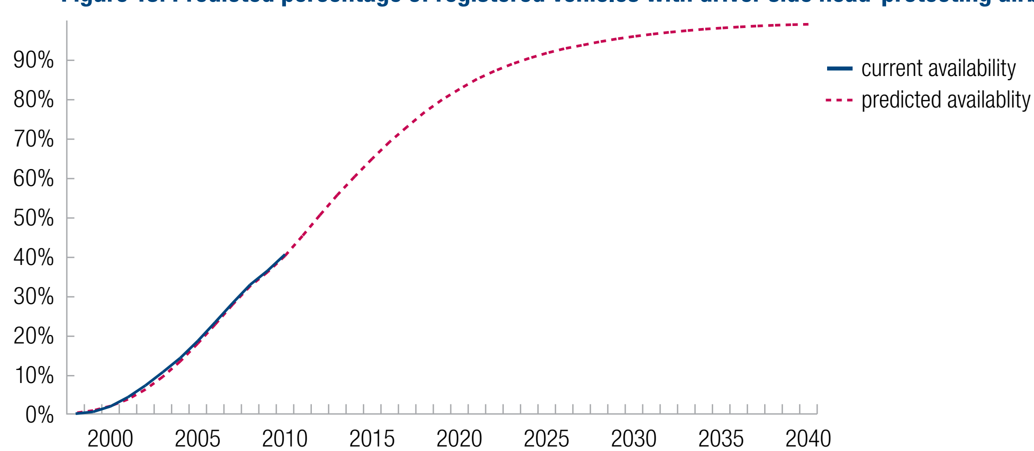


Figure 15 shows the percentage of predicted registered vehicles by calendar year with either a standard or optional head-protecting driver side airbag. It is predicted that a head-protecting driver side airbag will be standard or optional on 95% of registered vehicles in 2028 and 100% by 2040.

Figure 16: Percentage of new vehicle series with forward collision warning

Figure 16 shows the percentage of vehicle series by model year with either standard or optional forward collision warning. Forward collision warning was introduced in model year 2000 and by the 2005 model year had become standard on 1% and optional on 2% of vehicle series. For the 2010 model year, forward collision warning was standard on 1% and optional on 11% of vehicle series.

Figure 17: Percentage of registered vehicles with forward collision warning

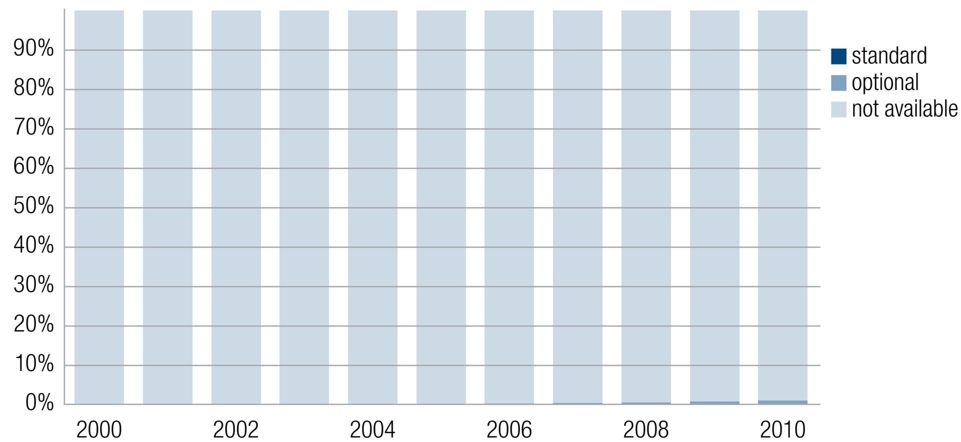


Figure 17 shows the percentage of registered vehicles by calendar year with either standard or optional forward collision warning. By 2005, forward collision warning had become standard on less than 1% and optional on less than 1% of registered vehicles. By 2010, forward collision warning was standard or optional on 1% of registered vehicles.

Figure 18: Predicted percentage of registered vehicles with forward collision warning

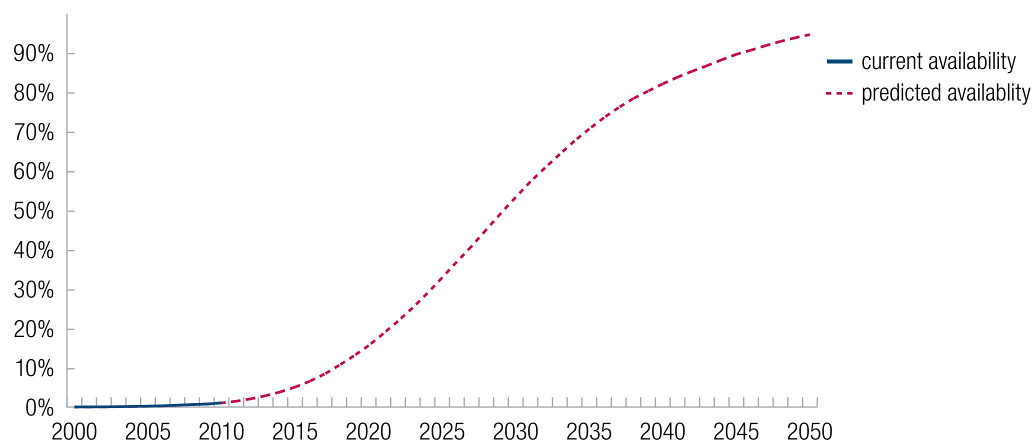


Figure 18 shows the percentage of predicted registered vehicles by calendar year with either standard or optional forward collision warning. It is predicted that forward collision warning will be standard or optional on 95% of registered vehicles in 2049.

Discussion

It takes a long time for new vehicle features to spread through the registered vehicle fleet. Even when features are required by NHTSA, it takes many years for features to be available on all vehicles. Frontal airbags for example, were first available to consumers in 1984 and by calendar year 2000 most vehicles used by private passengers were required to have frontal airbags to protect the driver. However, in calendar year 2010 (ten years later) there were still an estimated 13 percent of vehicles registered without this feature available. Forward collision warning systems were first introduced in the U.S. market in 1999 and by calendar year 2010 the feature was still only available on 1.1 percent of registered vehicles. If the prevalence of FCW continues to grow on the same path, it will take until 2050 for the feature to be available on 95 percent of vehicles. If all new vehicles were to be equipped with FCW starting in model year 2013, it would still take until 2034 for the feature to be available on 95 percent of vehicles.

Limitations

One limitation of the logistic model with a probit link is that it assumes a distribution with an asymptote of 100 percent, which it approaches slowly towards the end of the distribution. When a given feature's prevalence reaches 95 percent, its growth substanstially slows and it takes a number of years to capture the remaining 5 percent. It is not known how this remaining small percentage will be captured since no feature has reached 100 percent prevalence yet. The model was carefully chosen to fit the existing (past year) data well, and there is reason to believe that it does not adequately describe the future data. It may be the case that the full 100 percent prevalence is never reached, as some people tend to keep old cars as collectable vehicles. Finally, the goal of the study was to estimate when each feature will be available for the vast majority of the fleet, not 100 percent of the fleet.

Another limitation is that the prediction was based on the coarse calendar/model year registration counts rather than stratified by make and series. However, the stratified approach would be difficult if not impossible to accomplish. The future is uncertain, and so is the future new-model fleet. Even with the present approach, a bold assumption of stalled vehicle sales had to be made. Making further assumptions on which makes and series will be popular in the future or which manufacturers will introduce safety features more aggressively is beyond the scope of this analysis. However, as mentioned previously and reflected in the graphs, the model fits the existing data well, and consequently it is reasonable to believe that the predictions for the future fleet are the best possible.

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Highway Loss Data Institute Bulletin

Volvo City Safety Loss Experience – Initial Results

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INTRODUCTION

This Highway Loss Data Institute (HLDI) bulletin provides an initial look at the effects of Volvo's City Safety technology on insurance losses. The loss experience for Volvo XC60s equipped with City Safety was compared with losses for comparable vehicles without the system. Losses under property damage liability, bodily injury liability, and collision coverage were examined.

City Safety, a low-speed collision avoidance system, was released as standard equipment on the 2010 Volvo XC60, a midsize luxury SUV. The system was developed by Volvo to reduce low-speed front-to-rear crashes, which commonly occur in urban traffic, by assisting the driver in braking. According to a Volvo news release, 75 percent of all crashes occur at speeds up to 19 mph, and half of these occur in city traffic. The City Safety system has an infrared laser sensor built into the windshield that detects other vehicles traveling in the same direction up to 18 feet in front of the XC60. The system initially reacts to slowing or stopped vehicles by pre-charging the brakes. The vehicle will brake automatically if forward collision risk is detected and the driver does not react in time, but only at travel speeds up to 19 mph. If the relative speed difference is less than 9 mph, a collision can be avoided entirely. If the speed difference is between 9 and 19 mph, the XC60 speed will be reduced to lessen the collision severity. City Safety is automatically activated when the vehicle ignition is turned on but can be manually deactivated by the driver.

When examining the magnitude of City Safety on insurance losses, it is important to consider that the system is not designed to mitigate all types of crashes and that many factors can limit the system's ability to perform its intended function. City Safety works equally well during the day and night, but fog, heavy rain, or snow may limit the ability of the system's infrared laser to detect vehicles. If the sensor becomes blocked by dirt, ice, or snow, the driver is advised.

METHODS

Insurance Data – Automobile insurance covers damages to vehicles and property as well as injuries to people involved in crashes. Different insurance coverages pay for vehicle damage versus injuries, and different coverages may apply depending on who is at fault. The current study is based on property damage liability, bodily injury liability, and collision coverages. Data are supplied to HLDI by its member companies.

Property damage liability coverage insures against physical damage that at-fault drivers cause to other people's vehicles and property in crashes. Bodily injury liability coverage insures against medical, hospital, and other expenses for injuries that at-fault drivers inflict on occupants of other vehicles or others on the road. In the current study, bodily injury liability losses were restricted to data from traditional tort states. Collision coverage insures against physical damage to an at-fault driver's vehicle sustained in a crash with an object or other vehicle.

Analysis Methods – Loss data for the 2010 Volvo XC60 were compared with two control groups: other midsize luxury SUVs and other Volvo vehicles. Vehicle models with two- and four-wheel drive versions were combined to provide sufficient data for analysis.

Regression analysis was used to quantify the effect of City Safety while controlling for other covariates. The covariates included calendar year, model year, garaging state, vehicle density (number of registered vehicles per square mile), rated driver age, rated driver gender, marital status, deductible, and risk. Claim frequency was modeled using a Poisson distribution, whereas claim severity (average loss payment per claim) was modeled using a Gamma distribution. Both models used a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models.

Vehicle series was included as a variable in the regression models, with the Volvo XC60 assigned as the reference group. The model produced estimates for each series' losses relative to the XC60. When predicted losses were calculated, the XC60's value was postulated to be equal to the actual losses, whereas for any other series the losses were calculated by multiplying the XC60's value by the relative estimate obtained from the regression. For example, the actual property damage liability claim frequency for the Volvo XC60 equaled 2.2 claims per 100 insured vehicle years. The model estimated that the claim frequency for the Volvo XC70 would be 9.6 percent higher than that for the Volvo XC60 if these vehicles had the same distribution of drivers and garaging locations. Therefore, the comparable estimate for the Volvo XC70 property damage liability claim frequency was calculated as 2.2 x 1.096 = 2.4 claims per 100 insured vehicle years.

Additionally, the estimated losses for all control vehicles (i.e., all vehicle series in the analysis except for the Volvo XC60) were calculated as the weighted average of the estimates for the individual vehicle series included. The weights in the average were proportional to the inverse variance of the respective estimates, meaning that the estimates with high variance (those with large confidence intervals, typically due to little exposure and/or claims) contributed less than estimates with low variance (those with small confidence intervals).

Subject Vehicles – The XC60 was one of the first model year 2010 vehicles offered for sale in the United States. Sales of the vehicle began in February 2009. Consequently, the control population included Volvo vehicles and midsize luxury SUVs from both model years 2009 and 2010. However, only calendar years 2009 and 2010 were included. The loss experience of the model year 2009 vehicles in calendar year 2008 were excluded because no XC60s were on the road during this time period.

Results

Summary results of the regression analysis for property damage liability claim frequencies using a Poisson distribution are listed in Table 1. Results for all independent variables in the model had p-values less than 0.05, indicating their effects on claim frequency were statistically significant. Detailed results of the regression analysis using property damage liability claim frequency as the dependent variable are listed in Table 2. The table shows estimates and significance levels for the individual values of the categorical variables. The intercept outlines losses for the reference (baseline) categories: the estimate corresponds to the claim frequency for a 2010 Volvo XC60, garaged in a high vehicle density area in Texas, and driven by a married female age 40-49 with standard risk. The remaining estimates are in the form of multiples, or ratios relative to the reference categories. In an effort to condense the regression results, Table 2 also includes an abbreviated list of results by state. Only states with the five highest and five lowest effects are listed, along with the comparison state of Texas. Detailed results for all states are listed in the Appendix.

Table 1 Summary Results of Linear Regression Analysis of Property Damage Liability Claim Frequencies

	Degrees of Freedom	Chi-square	p-value
Calendar Year	1	7.16	0.0075
Vehicle Make and Series	22	151.2	<0.0001
State	50	270.42	<0.0001
Registered Vehicle Density	6	209.49	<0.0001
Rated Driver Age	10	172.87	<0.0001
Rated Driver Gender	2	29.42	<0.0001
Rated Driver Marital Status	2	74.74	<0.0001
Risk	1	58.62	<0.0001

Table 2 Detailed Results of Linear Regression Analysis of Property Damage Liability Claim Frequencies

Parameter	Degrees of Freedom	Estimate	Effect	Standard Error	Wald 95% Confidence Limits		Chi-square	p-value
Intercept	1	-9.4684		0.0700	-9.6056	-9.3312	18296.3	<0.0001
Calendar Year								
2009	1	0.0480	4.9%	0.0179	0.0128	0.0831	7.16	0.0075
2010	0	0	0	0	0	0		
Vehicle Make and Series								
Acura MDX 4D	1	0.3084	36.1%	0.0671	0.1769	0.4400	21.11	<0.0001
Acura RDX 4D	1	0.1853	20.4%	0.0763	0.0357	0.3349	5.9	0.0152
Acura ZDX 4D	1	0.3993	49.1%	0.2176	-0.0273	0.8259	3.37	0.0666
Audi Q5 QUATTRO 4D	1	0.1347	14.4%	0.0773	-0.0168	0.2862	3.04	0.0813
BMW X3 4D	1	0.1388	14.9%	0.0949	-0.0473	0.3249	2.14	0.1437
BMW X5 4D	1	0.4846	62.4%	0.0680	0.3514	0.6177	50.85	<0.0001
BMW X6 4D	1	0.4209	52.3%	0.0977	0.2295	0.6124	18.57	<0.0001
BMW X6 HYBRID 4D	1	0.0082	0.8%	1.0020	-1.9556	1.9719	0	0.9935
Cadillac SRX 4D	1	0.2943	34.2%	0.0721	0.1531	0.4355	16.68	<0.0001
Infiniti EX35 4D	1	0.0055	0.6%	0.1062	-0.2026	0.2136	0	0.9587
Infiniti FX35 4D	1	0.3742	45.4%	0.0755	0.2263	0.5221	24.59	<0.0001

Table 2 Detailed Results of Linear Regression Analysis of Property Damage Liability Claim Frequencies (cont'd)

Parameter	Degrees of Freedom	Estimate	Effect	Standard Error	Wald 95% Confidence Limits		Chi-square	p-value
Infiniti FX50 4D	1	0.2224	24.9%	0.1632	-0.0974	0.5423	1.86	0.1729
Land Rover LR2 4D	1	0.6382	89.3%	0.0965	0.4491	0.8274	43.73	<0.0001
Lexus RX 350 4D	1	0.2971	34.6%	0.0638	0.1721	0.4221	21.7	<0.0001
Lexus RX 450H HYBRID 4D	1	0.3507	42.0%	0.0826	0.1889	0.5125	18.04	<0.0001
Lincoln MKT 4D	1	0.1549	16.8%	0.1342	-0.1082	0.4180	1.33	0.2485
Lincoln MKX 4D	1	0.3677	44.4%	0.0756	0.2196	0.5158	23.68	<0.0001
Mercedes Benz GLK CLASS 4D	1	0.2340	26.4%	0.0720	0.0928	0.3752	10.55	0.0012
Mercedes Benz M CLASS 4D	1	0.2707	31.1%	0.0682	0.1370	0.4044	15.75	<0.0001
Mercedes Benz M CLASS HYBRID 4D	1	-0.2721	-23.8%	0.4130	-1.0815	0.5374	0.43	0.510
Saab 9-7X 4D	1	0.4560	57.8%	0.1434	0.1750	0.7370	10.12	0.0015
Volvo XC90 4D	1	0.4243	52.9%	0.0763	0.2748	0.5738	30.94	<0.0001
Volvo XC60 4D	0	0	0	0	0	0		
State								
Wyoming	1	-2.0656	-87.3%	0.9922	-4.0102	-0.1209	4.33	0.0374
Michigan	1	-1.4984	-77.7%	0.1153	-1.7245	-1.2723	168.75	<0.0001
Idaho	1	-0.7537	-52.9%	0.3553	-1.4501	-0.0573	4.5	0.0339
Delaware	1	-0.4888	-38.7%	0.1882	-0.8577	-0.1200	6.75	0.0094
Maine	1	-0.4282	-34.8%	0.3181	-1.0517	0.1952	1.81	0.1782
Rhode Island	1	0.0696	7.2%	0.1297	-0.1845	0.3237	0.29	0.5913
South Dakota	1	0.1029	10.8%	0.3568	-0.5963	0.8022	0.08	0.7729
DC	1	0.1467	15.8%	0.1332	-0.1143	0.4077	1.21	0.2706
West Virginia	1	0.1926	21.2%	0.1525	-0.1063	0.4915	1.59	0.2066
North Dakota	1	0.6982	101.0%	0.3196	0.0718	1.3246	4.77	0.0289
Texas	0	0	0	0	0	0		
Registered Vehicle Density								
Unknown	1	-0.1622	-15.0%	0.708	-1.5499	1.2254	0.05	0.8188
<50	1	-0.5654	-43.2%	0.0589	-0.6807	-0.4500	92.29	<0.0001
50-99	1	-0.4151	-34.0%	0.0451	-0.5036	-0.3266	84.55	<0.0001
100-249	1	-0.3188	-27.3%	0.0332	-0.3839	-0.2538	92.21	<0.0001
250-499	1	-0.2282	-20.4%	0.0271	-0.2813	-0.1752	71.07	<0.0001
500-999	1	-0.1665	-15.3%	0.0274	-0.2202	-0.1128	36.96	<0.0001
1,000+	0	0	0	0	0	0		
Rated Driver Age								
Unknown	1	-0.0364	-3.6%	0.0469	-0.1284	0.0556	0.6	0.4381
15-19	1	0.3871	47.3%	0.0705	0.2489	0.5254	30.13	<0.0001
20-24	1	0.1264	13.5%	0.0595	0.0098	0.2429	4.51	0.0336
25-29	1	0.0762	7.9%	0.0445	-0.0110	0.1633	2.94	0.0867
30-39	1	0.0270	2.7%	0.0255	-0.0230	0.0771	1.12	0.2900
50-59	1	-0.1400	-13.1%	0.0255	-0.1900	-0.0899	30.02	<0.0001
60-64	1	-0.0860	-8.2%	0.0324	-0.1496	-0.0225	7.04	0.0080
65-69	1	0.0123	1.2%	0.0361	-0.0586	0.0831	0.12	0.7339
70-74	1	0.1526	16.5%	0.0431	0.0683	0.2370	12.57	0.0004
75+	1	0.2911	33.8%	0.0441	0.2048	0.3774	43.66	<0.0001
40-49	0	0	0	0	0	0		
Rated Driver Gender								
Male	1	-0.0894	-8.6%	0.0204	-0.1294	-0.0495	19.27	<0.0001
Unknown	1	-0.1861	-17.0%	0.0484	-0.2810	-0.0912	14.78	0.0001
Female	0	0	0	0	0	0		
Rated Driver Marital Status								
Single	1	0.1890	20.8%	0.0241	0.1417	0.2363	61.44	<0.0001
Unknown	1	0.2208	24.7%	0.0471	0.1284	0.3132	21.95	<0.0001
Married	0	0	0	0	0	0		
Risk								
Nonstandard	1	0.2035	22.6%	0.0266	0.1514	0.2555	58.62	<0.0001
Standard	0	0	0	0	0	0		

Property damage liability claim frequencies (measured in claims per 100 insured vehicle years) were calculated for the 2010 Volvo XC60 equipped with City Safety and compared with claim frequencies for other 2009-10 midsize luxury SUVs and for other Volvo vehicles without the system. Results for the XC60 were based on 260 claims and 11,641 insured vehicle years. Figure 1 shows the property damage liability claim frequency for the 2010 Volvo XC60 compared with those for other midsize luxury SUVs. The estimated claim frequency for the Volvo XC60 was 27 percent lower than that for all other midsize luxury SUVs combined. At the 95 percent confidence level, the range for this estimate was 24 to 29 percent. Compared with individual vehicle series in the control group, only the Mercedes M class hybrid had a lower estimated claim frequency. However, the difference between the estimates for the Mercedes M class hybrid and Volvo XC60 did not reach statistical significance. Note that the vertical I-bars for each comparison group are the 95 percent confidence limits for the comparison of that group with the XC60, not the 95 percent confidence interval for that group's frequency estimate.

FIGURE 1 PROPERTY DAMAGE LIABILITY CLAIM FREQUENCIES FOR 2010 VOLVO XC60 WITH CITY SAFETY VS. OTHER 2009-10 MIDSIZE LUXURY SUVS

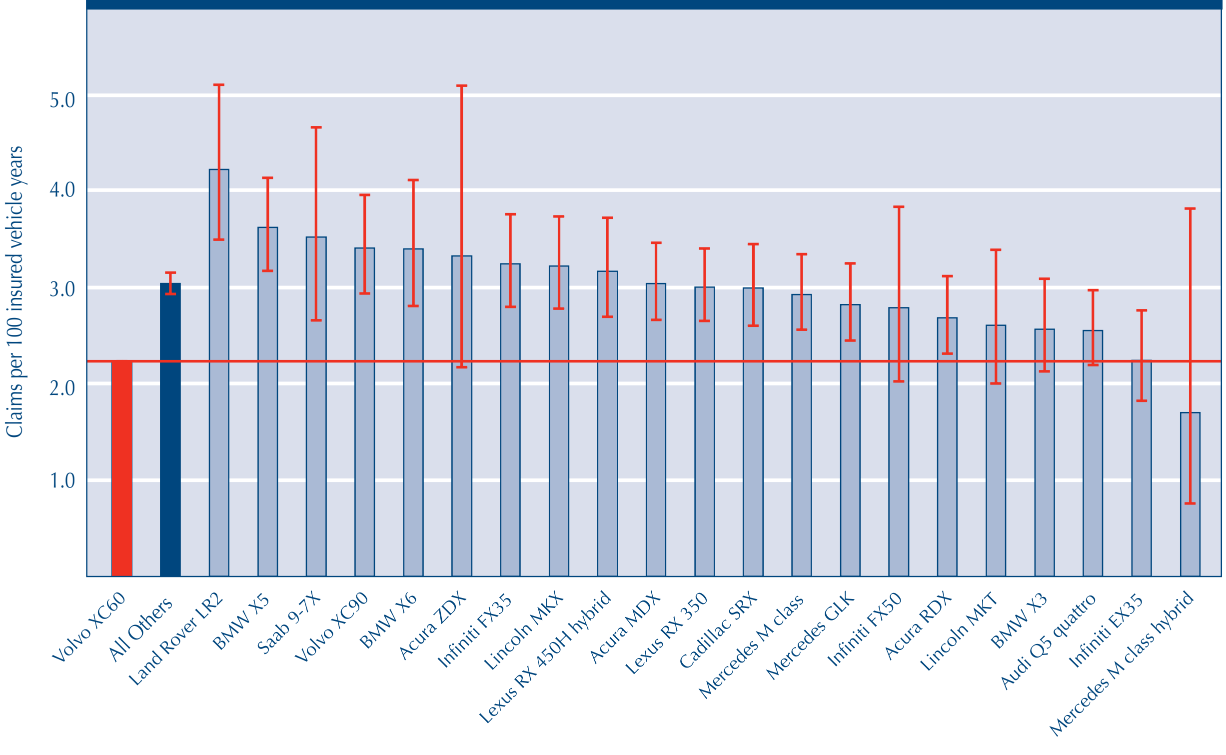
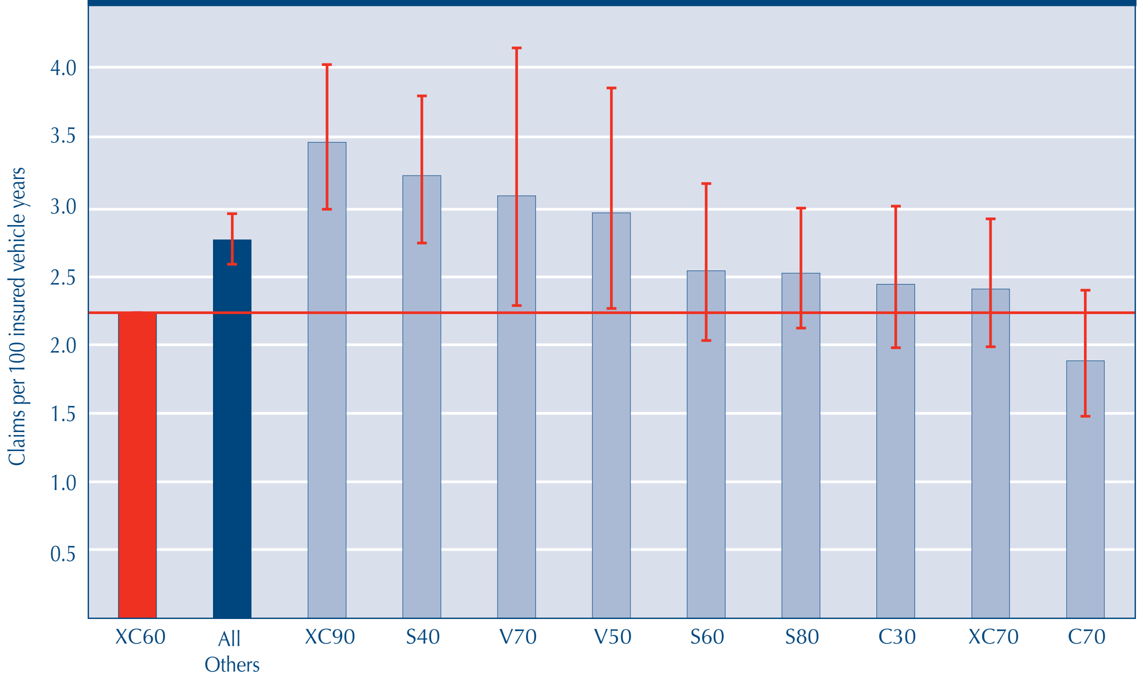


Figure 2 shows the property damage liability claim frequency for the 2010 Volvo XC60 compared with those for other Volvo vehicles. The estimated claim frequency for the Volvo XC60 (2.2 claims per 100 insured vehicle years) was 19 percent lower than that for all other Volvos combined (2.8 claims per 100 insured vehicle years). At the 95 percent confidence level, the range for this estimate was 14 to 24 percent. Compared with individual vehicle series, only the C70, a convertible, had a lower estimated claim frequency. The difference between the estimates for the XC60 and C70 did not reach statistical significance. Furthermore, it is likely that because the C70 is a convertible, it has fewer annual miles driven, which leads to lower claim frequencies. It also is interesting to note that the XC60 did significantly better than the only other SUV from Volvo, the XC90, which had the highest estimated claim frequency (3.5 claims per 100 insured vehicle years).

Figure 2 Property Damage Liability Claim Frequencies for 2010 Volvo XC60 with City Safety vs. Other 2009-10 Volvo Vehicles



Summary results of the regression analysis for property damage liability claim severities using a Gamma distribution are listed in Table 3. Estimates for most independent variables in the model had p-values less than 0.05, indicating their effects on claim severity were statistically significant. Estimates for vehicle density and risk had p-values slightly above 0.05. Detailed results of the regression analysis using property damage liability claim severity as the dependent variable are listed in Table 4. The table shows estimates and significance levels for the individual values of the categorical variables. The intercept outlines losses for the reference (baseline) categories: the estimate corresponds to the claim severity for a 2010 Volvo XC60, garaged in a high vehicle density area in Texas, and driven by a married female age 40-49 with standard risk. The remaining estimates are in the form of multiples, or ratios relative to the reference categories. In an effort to condense the regression results, Table 4 also includes an abbreviated list of results by state. Only states with the five highest and five lowest effects are listed, along with the comparison state of Texas. Detailed results for all states are listed in the Appendix.

Table 3 Summary Results of Linear Regression Analysis of Property Damage Liability Claim Severities

	Degrees of Freedom	Chi-square	p-value
Calendar Year	1	28.04	<0.0001
Vehicle Make and Series	22	64.01	<0.0001
State	50	292.76	<0.0001
Registered Vehicle Density	6	12.28	0.0560
Rated Driver Age	10	25.39	0.0047
Rated Driver Gender	2	23.37	<0.0001
Rated Driver Marital Status	2	7.66	0.0217
Risk	1	3.79	0.0514

Table 4 Detailed Results of Linear Regression Analysis of Property Damage Liability Claim Severities

Parameter	Degrees of Freedom	Estimate	Effect	Standard Error	Wald 95% Confidence Limits		Chi-square	p-value
Intercept	1	7.9923		0.0645	7.8658	8.1187	15347.6	<0.0001
Calendar Year								
2009	1	0.0873	9.1%	0.0165	0.0550	0.1196	28.04	<0.0001
2010	0	0	0	0	0	0		
Vehicle Make and Series								
Acura MDX 4D	1	-0.2018	-18.3%	0.0617	-0.3228	-0.0808	10.69	0.0011
Acura RDX 4D	1	-0.1877	-17.1%	0.0700	-0.3248	-0.0506	7.2	0.0073
Acura ZDX 4D	1	0.1543	16.7%	0.2031	-0.2437	0.5523	0.58	0.4473
Audi Q5 QUATTRO 4D	1	-0.0392	-3.8%	0.0709	-0.1781	0.0997	0.31	0.5800
BMW X3 4D	1	-0.0109	-1.1%	0.0874	-0.1822	0.1603	0.02	0.9005
BMW X5 4D	1	-0.0786	-7.6%	0.0624	-0.2009	0.0437	1.59	0.2077
BMW X6 4D	1	-0.0645	-6.2%	0.0896	-0.2401	0.1111	0.52	0.4716
BMW X6 HYBRID 4D	1	-0.0196	-1.9%	0.9136	-1.8102	1.7711	0	0.9829
Cadillac SRX 4D	1	-0.1304	-12.2%	0.0661	-0.2599	-0.0008	3.89	0.0486
Infiniti EX35 4D	1	-0.1318	-12.3%	0.0973	-0.3225	0.0589	1.83	0.1756
Infiniti FX35 4D	1	-0.1155	-10.9%	0.0692	-0.2511	0.0200	2.79	0.0949
Infiniti FX50 4D	1	0.2699	31.0%	0.1497	-0.0234	0.5633	3.25	0.0713
Land Rover LR2 4D	1	0.0971	10.2%	0.0882	-0.0759	0.2700	1.21	0.2713
Lexus RX 350 4D	1	-0.0978	-9.3%	0.0584	-0.2123	0.0168	2.8	0.0944
Lexus RX 450H HYBRID 4D	1	-0.1255	-11.8%	0.0756	-0.2737	0.0228	2.75	0.0972
Lincoln MKT 4D	1	-0.2495	-22.1%	0.1231	-0.4908	-0.0083	4.11	0.0426
Lincoln MKX 4D	1	-0.0391	-3.8%	0.0692	-0.1748	0.0965	0.32	0.5717
Mercedes Benz GLK CLASS 4D	1	-0.0286	-2.8%	0.0663	-0.1585	0.1013	0.19	0.6659
Mercedes Benz M CLASS 4D	1	-0.1088	-10.3%	0.0625	-0.2314	0.0137	3.03	0.0818
Mercedes Benz M CLASS HYBRID 4D	1	-0.0456	-4.5%	0.3773	-0.7851	0.6939	0.01	0.9038
Saab 9-7X 4D	1	0.0220	2.2%	0.1312	-0.2352	0.2791	0.03	0.8670
Volvo XC90 4D	1	-0.1871	-17.1%	0.0701	-0.3245	-0.0497	7.12	0.0076
Volvo XC60 4D	0	0	0	0	0	0		
State								
Montana	1	-0.7821	-54.3%	0.3274	-1.4238	-0.1404	5.71	0.0169
Michigan	1	-0.7671	-53.6%	0.1046	-0.9722	-0.5621	53.78	<.0001
North Dakota	1	-0.5712	-43.5%	0.2914	-1.1422	-0.0001	3.84	0.0500
Hawaii	1	-0.5323	-41.3%	0.1335	-0.7940	-0.2705	15.88	<0.0001
New Hampshire	1	-0.4185	-34.2%	0.1371	-0.6872	-0.1498	9.32	0.0023
Connecticut	1	0.1299	13.9%	0.0580	0.0162	0.2436	5.02	0.0251
Iowa	1	0.1344	14.4%	0.1525	-0.1645	0.4332	0.78	0.3782
Oklahoma	1	0.2904	33.7%	0.0976	0.0991	0.4817	8.85	0.0029
Arkansas	1	0.3024	35.3%	0.1320	0.0437	0.5611	5.25	0.0220
Delaware	1	0.5303	69.9%	0.1718	0.1936	0.8670	9.53	0.0020
Texas	0	0	0	0	0	0		
Registered Vehicle Density								
Unknown	1	-1.0077	-63.5%	0.6467	-2.2751	0.2598	2.43	0.1192
<50	1	-0.0622	-6.0%	0.0542	-0.1684	0.044	1.32	0.2508
50-99	1	-0.1053	-10.0%	0.0416	-0.1870	-0.0237	6.4	0.0114
100-249	1	-0.0257	-2.5%	0.0308	-0.0860	0.0346	0.7	0.4043
250-499	1	-0.0145	-1.4%	0.0255	-0.0644	0.0354	0.32	0.5696
500-999	1	0.0218	2.2%	0.0257	-0.0285	0.0721	0.72	0.3954
1,000+	0	0	0	0	0	0		
Rated Driver Age								
Unknown	1	0.0395	4.0%	0.0428	-0.0444	0.1233	0.85	0.3566
15-19	1	0.1705	18.6%	0.0646	0.0439	0.2972	6.97	0.0083
20-24	1	0.1043	11.0%	0.0548	-0.0031	0.2116	3.63	0.0569
25-29	1	0.1148	12.2%	0.0409	0.0347	0.1949	7.89	0.0050

Table 4 Detailed Results of Linear Regression Analysis of Property Damage Liability Claim Severities (cont'd)

Parameter	Degrees of Freedom	Estimate	Effect	Standard Error	Wald 95% Confidence Limits		Chi-square	p-value
30-39	1	-0.0174	-1.7%	0.0234	-0.0632	0.0284	0.56	0.4559
50-59	1	0.0075	0.8%	0.0234	-0.0384	0.0534	0.1	0.7487
60-64	1	-0.0463	-4.5%	0.0297	-0.1045	0.0119	2.43	0.1191
65-69	1	-0.0233	-2.3%	0.0331	-0.0881	0.0414	0.5	0.4801
70-74	1	0.0120	1.2%	0.0394	-0.0651	0.0891	0.09	0.7604
75+	1	0.0204	2.1%	0.0406	-0.0592	0.1000	0.25	0.6156
40-49	0	0	0	0	0	0		
Rated Driver Gender								
Male	1	0.0695	7.2%	0.0186	0.0331	0.1060	13.97	0.0002
Unknown	1	-0.1077	-10.2%	0.0439	-0.1938	-0.0217	6.02	0.0142
Female	0	0	0	0	0	0		
Rated Driver Marital Status								
Single	1	0.0413	4.2%	0.0220	-0.0019	0.0845	3.51	0.0609
Unknown	1	0.0980	10.3%	0.0428	0.0140	0.1819	5.23	0.0222
Married	0	0	0	0	0	0		
Risk								
Nonstandard	1	-0.0469	-4.6%	0.0241	-0.0940	0.0003	3.79	0.0514
Standard	0	0	0	0	0	0		

Property damage liability claim severities (measured in average loss payments per claim) were calculated for the 2010 Volvo XC60 equipped with City Safety and compared with claim severities for other 2009-10 midsize luxury SUVs and for other Volvo vehicles without the system. Figure 3 shows the property damage liability claim severity for the 2010 Volvo XC60 compared with those for other midsize luxury SUVs. The estimated claim severity for the Volvo XC60 was 10 percent higher than that for all other midsize luxury SUVs combined ($2,789 per claim). At the 95 percent confidence level, this estimated increase fell between 13 and 6 percent. Compared with individual vehicle series, the XC60 outperformed only four vehicles.

Figure 3 Property Damage Liability Claim Severities for 2010 Volvo XC60 with City Safety vs. Other 2009-10 Midsize Luxury SUVs

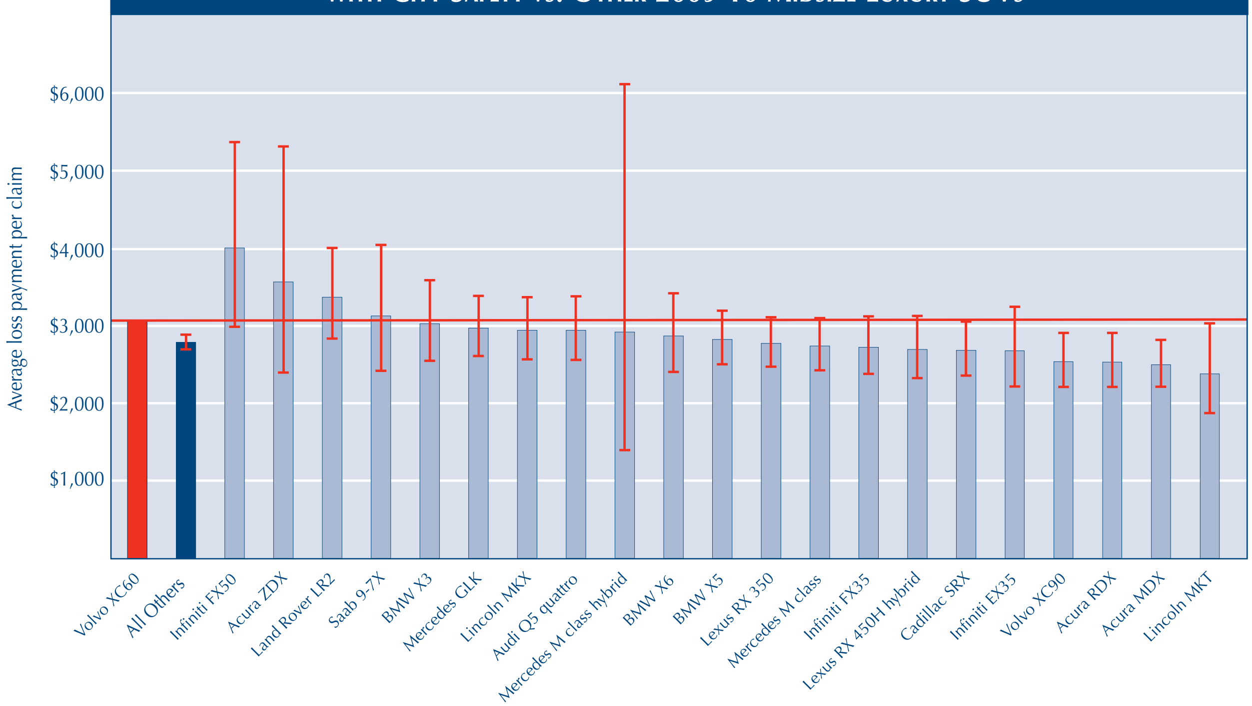
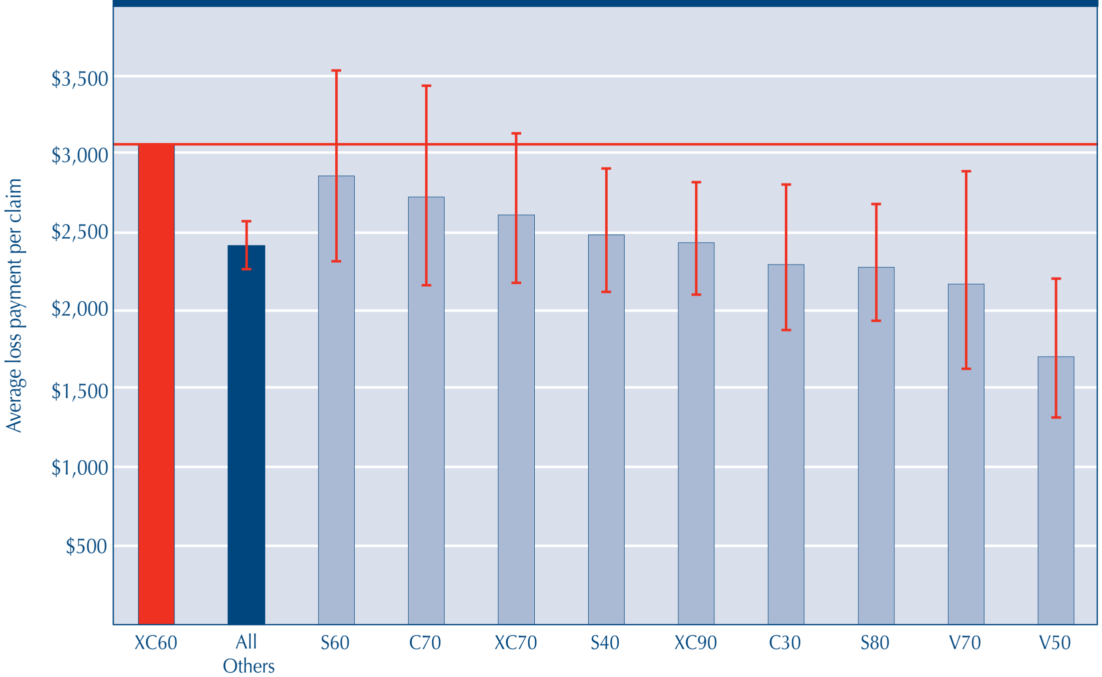


Figure 4 shows the property damage liability claim severity for the 2010 Volvo XC60 compared with those for other Volvo vehicles. The estimated claim severity for the Volvo XC60 was 27 percent higher than that for all other Volvos combined. At the 95 percent confidence level, this estimated increase fell between 35 and 19 percent. Additionally, the claim severity for the XC60 was higher than that for each individual Volvo vehicle.

FIGURE 4 PROPERTY DAMAGE LIABILITY CLAIM SEVERITIES FOR 2010 VOLVO XC60 WITH CITY SAFETY VS. OTHER 2009-10 VOLVO VEHICLES



An examination of claim frequency by claim size explains this result. Table 5 summarizes results of several regression analyses conducted for property damage liability coverage. The table includes an analysis of claim frequencies for the XC60 by claim size compared with those for other midsize luxury SUVs and other Volvo vehicles. Detailed results are listed in the Appendix. The estimated effects indicate that the frequency of low-severity claims was much higher for other midsize SUVs and other Volvos, compared with the XC60, whereas the frequency of high-severity claims was about the same.

TABLE 5 ESTIMATED PROPERTY DAMAGE LIABILITY CLAIM FREQUENCIES BY CLAIM SEVERITY RANGE FOR COMPARISON GROUPS RELATIVE TO VOLVO XC60

Control Group	Claim Size	Estimate	Standard error	Effect	Lower Bound	Upper Bound
Midsize Luxury SUVs	<$1,500	0.3015	0.0277	35%	28%	43%
Midsize Luxury SUVs	$1,500-$6,999	0.3528	0.0276	42%	35%	50%
Midsize Luxury SUVs	$7,000+	0.1277	0.0629	14%	0%	29%
Volvos	<$1,500	0.3318	0.0488	39%	27%	53%
Volvos	$1,500-$6,999	0.1671	0.0516	18%	7%	31%
Volvos	$7,000+	-0.1844	0.1270	-17%	-35%	7%

Figure 5 shows these results for the XC60 compared with those for other midsize luxury SUVs. The property damage liability claim frequency for the XC60 was lower than those for other midsize luxury SUVs at all claim amounts. The difference in claim frequencies was much greater at the two lowest claim severity ranges. The difference at the highest claim severity range was the smallest but was statistically significant. This finding is consistent with expectations based on what is known about the City Safety system. It is designed to eliminate, or at least mitigate, low-speed and low-severity front-to-rear crashes. By removing many of the lowest cost claims, City Safety shifted the distribution of claim severity to a higher mean.

FIGURE 5 PROPERTY DAMAGE LIABILITY CLAIM FREQUENCIES BY CLAIM SEVERITY RANGE, VOLVO XC60 VS. OTHER MIDSIZE LUXURY SUVS

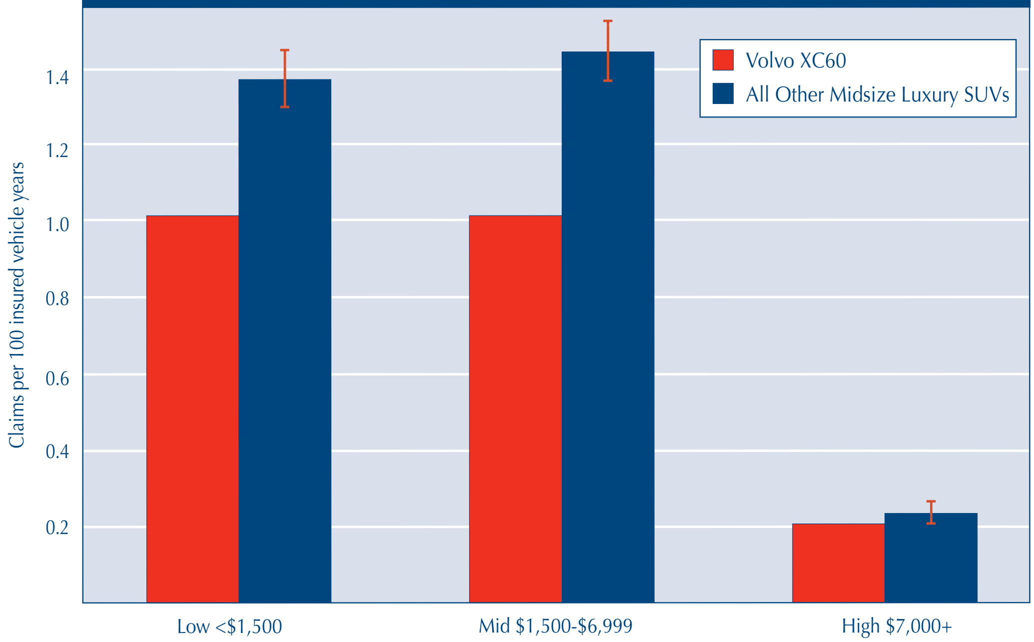
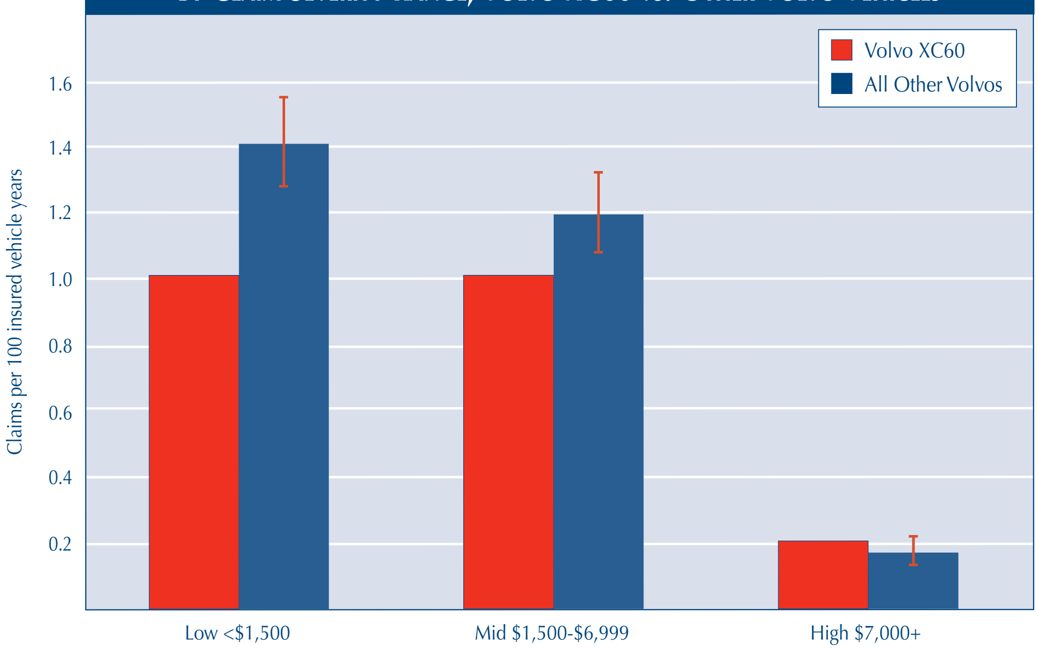


Figure 6 shows property damage liability claim frequencies for the 2010 Volvo XC60 by claim severity range compared with those for other Volvo vehicles. Claim frequencies exhibited a similar pattern to those in Figure 5. As the dollar value of claims increased, the difference in claim frequencies between the XC60 and other Volvos narrowed until the highest claim severity range, where there was no measurable difference.

FIGURE 6 PROPERTY DAMAGE LIABILITY CLAIM FREQUENCIES BY CLAIM SEVERITY RANGE, VOLVO XC60 VS. OTHER VOLVO VEHICLES



Detailed results of the regression analysis using property damage liability overall loss as the dependent variable are listed in Table 6. The table shows estimates and significance levels for the individual values of the categorical variables. The intercept outlines losses for the reference (baseline) categories: the estimate corresponds to the claim frequency for a 2010 Volvo XC60, garaged in a high vehicle density area in Texas, and driven by a married female age 40-49 with standard risk. The remaining estimates are in the form of multiples, or ratios relative to the reference categories. In an effort to condense the regression results, Table 6 also includes an abbreviated list of results by state. Only states with the five highest and five lowest effects are listed, along with the comparison state of Texas. Detailed results for all states are listed in the Appendix.

Table 6 Results for Property Damage Liability Overall Losses Derived from Claim Frequency and Claim Severity Models

Parameter	Estimate	Effect	Standard Error	Wald 95% Confidence Limits		p-value
Intercept	-1.4761	-77.1%	0.095185	-1.6627	-1.2895	<0.0001
Calendar Year						
2009	0.1353	14.5%	0.024345	0.0876	0.1830	<0.0001
2010	0	0	0	0	0	
Vehicle Make and Series						
Acura MDX 4D	0.1066	11.2%	0.091155	-0.0721	0.2853	0.2422
Acura RDX 4D	-0.0024	-0.2%	0.103546	-0.2053	0.2005	0.9815
Acura ZDX 4D	0.5536	74.0%	0.297656	-0.0298	1.1370	0.0629
Audi Q5 QUATTRO 4D	0.0955	10.0%	0.104891	-0.1101	0.3011	0.3626
BMW X3 4D	0.1279	13.6%	0.129015	-0.1250	0.3808	0.3215
BMW X5 4D	0.4060	50.1%	0.092292	0.2251	0.5869	<0.0001
BMW X6 4D	0.3564	42.8%	0.132565	0.0966	0.6162	0.0072
BMW X6 HYBRID 4D	-0.0114	-1.1%	1.355975	-2.6691	2.6463	0.9933
Cadillac SRX 4D	0.1639	17.8%	0.097814	-0.0278	0.3556	0.0938
Infiniti EX35 4D	-0.1263	-11.9%	0.144034	-0.4086	0.1560	0.3806
Infiniti FX35 4D	0.2587	29.5%	0.102415	0.0580	0.4594	0.0115
Infiniti FX50 4D	0.4923	63.6%	0.22146	0.0582	0.9264	0.0262
Land Rover LR2 4D	0.7353	108.6%	0.130734	0.4791	0.9915	<0.0001
Lexus RX 350 4D	0.1993	22.1%	0.086493	0.0298	0.3688	0.0212
Lexus RX 450H HYBRID 4D	0.2252	25.3%	0.111974	0.0057	0.4447	0.0443
Lincoln MKT 4D	-0.0946	-9.0%	0.182108	-0.4515	0.2623	0.6034
Lincoln MKX 4D	0.3286	38.9%	0.102489	0.1277	0.5295	0.0013
Mercedes Benz GLK CLASS 4D	0.2054	22.8%	0.097876	0.0136	0.3972	0.0359
Mercedes Benz M CLASS 4D	0.1619	17.6%	0.092507	-0.0194	0.3432	0.0801
Mercedes Benz M CLASS HYBRID 4D	-0.3177	-27.2%	0.559396	-1.4141	0.7787	0.5701
Saab 9-7X 4D	0.4780	61.3%	0.194363	0.0971	0.8589	0.0139
Volvo XC90 4D	0.2372	26.8%	0.103613	0.0341	0.4403	0.0221
Volvo XC60 4D	0	0	0	0	0	
State						
Wyoming	-2.4675	-91.5%	1.349698	-5.1129	0.1779	0.0675
Michigan	-2.2655	-89.6%	0.155677	-2.5706	-1.9604	<0.0001
Hawaii	-0.8290	-56.4%	0.198129	-1.2173	-0.4407	<0.0001
Montana	-0.7900	-54.6%	0.485651	-1.7419	0.1619	0.1038
Idaho	-0.7730	-53.8%	0.481117	-1.7160	0.1700	0.1081
California	0.0901	9.4%	0.046637	-0.0013	0.1815	0.0534
Oklahoma	0.1079	11.4%	0.144753	-0.1758	0.3916	0.4560
North Dakota	0.1270	13.5%	0.432502	-0.7207	0.9747	0.7690
Louisiana	0.1344	14.4%	0.106451	-0.0742	0.3430	0.2068
Arkansas	0.2866	33.2%	0.195641	-0.0968	0.6700	0.1429
Texas	0	0	0	0	0	
Registered Vehicle Density						
Unknown	-1.1699	-69.0%	0.958898	-3.0493	0.7095	0.2224
<50	-0.6276	-46.6%	0.080043	-0.7845	-0.4707	<0.0001
50-99	-0.5204	-40.6%	0.061356	-0.6407	-0.4001	<0.0001

Table 6 Results for Property Damage Liability Overall Losses Derived from Claim Frequency and Claim Severity Models (cont'd)						
Parameter	Estimate	Effect	Standard Error	Wald 95% Confidence Limits		p-value
100-249	-0.3445	-29.1%	0.045287	-0.4333	-0.2557	<0.0001
250-499	-0.2427	-21.5%	0.037211	-0.3156	-0.1698	<0.0001
500-999	-0.1447	-13.5%	0.037567	-0.2183	-0.0711	0.0001
1,000+	0	0	0	0	0	
Rated Driver Age						
Unknown	0.0031	0.3%	0.063494	-0.1213	0.1275	0.9611
15-19	0.5576	74.6%	0.095621	0.3702	0.7450	<0.0001
20-24	0.2307	25.9%	0.080891	0.0722	0.3892	0.0043
25-29	0.1910	21.0%	0.060441	0.0725	0.3095	0.0016
30-39	0.0096	1.0%	0.034609	-0.0582	0.0774	0.7815
50-59	-0.1325	-12.4%	0.034609	-0.2003	-0.0647	0.0001
60-64	-0.1323	-12.4%	0.043953	-0.2184	-0.0462	0.0026
65-69	-0.0110	-1.1%	0.048978	-0.1070	0.0850	0.8223
70-74	0.1646	17.9%	0.058395	0.0501	0.2791	0.0048
75+	0.3115	36.5%	0.059943	0.1940	0.4290	<0.0001
40-49	0	0	0	0	0	
Rated Driver Gender						
Male	-0.0199	-2.0%	0.027607	-0.0740	0.0342	0.4710
Unknown	-0.2938	-25.5%	0.065343	-0.4219	-0.1657	<0.0001
Female	0	0	0	0	0	
Rated Driver Marital Status						
Single	0.2303	25.9%	0.032631	0.16634	0.29426	<0.0001
Unknown	0.3188	37.5%	0.063642	0.19406	0.44354	<0.0001
Married	0	0	0	0	0	
Risk						
Nonstandard	0.1566	17.0%	0.035894	0.08625	0.22695	<0.0001
Standard	0	0	0	0	0	

Table 7 summarizes results of the regression analysis conducted for property damage liability coverage. It includes estimates of claim frequency, claim severity, and overall loss for other midsize luxury SUVs and other Volvo vehicles relative to the XC60.

Table 7 Estimated Property Damage Liability Loss Results for Comparison Groups Relative to Volvo XC60					
Control Group	Estimate	Standard error	Effect	Lower Bound	Upper Bound
Claim Frequency					
Midsize Luxury SUVs	0.3095	0.0187	36%	31%	41%
Volvos	0.2138	0.0340	24%	16%	32%
Claim Severity					
Midsize Luxury SUVs	-0.0923	0.0171	-9%	-12%	-6%
Volvos	-0.2373	0.0324	-21%	-26%	-16%
Overall Loss					
Midsize Luxury SUVs	0.2173	0.0253	24%	18%	31%
Volvos	-0.0235	0.0470	-2%	-11%	7%

Property damage liability overall losses (measured in average loss payments per insured vehicle year) were calculated for the 2010 Volvo XC60 equipped with City Safety and compared with overall losses for other 2009-10 midsize luxury SUVs and for other Volvo vehicles without the system. Figure 7 shows the property damage liability overall loss for the 2010

Volvo XC60 compared with those for other midsize luxury SUVs. The estimated overall loss for the Volvo XC60 was 20 percent lower than that for all other midsize luxury SUVs combined ($85 per insured vehicle year). At the 95 percent confidence level, the range for this estimate was 15 to 23 percent. Compared with individual vehicle series, the XC60 had a lower overall loss than most other midsize luxury SUVs.

FIGURE 7 PROPERTY DAMAGE LIABILITY OVERALL LOSSES FOR 2010 VOLVO XC60 WITH CITY SAFETY VS. OTHER 2009-10 MIDSIZE LUXURY SUVS

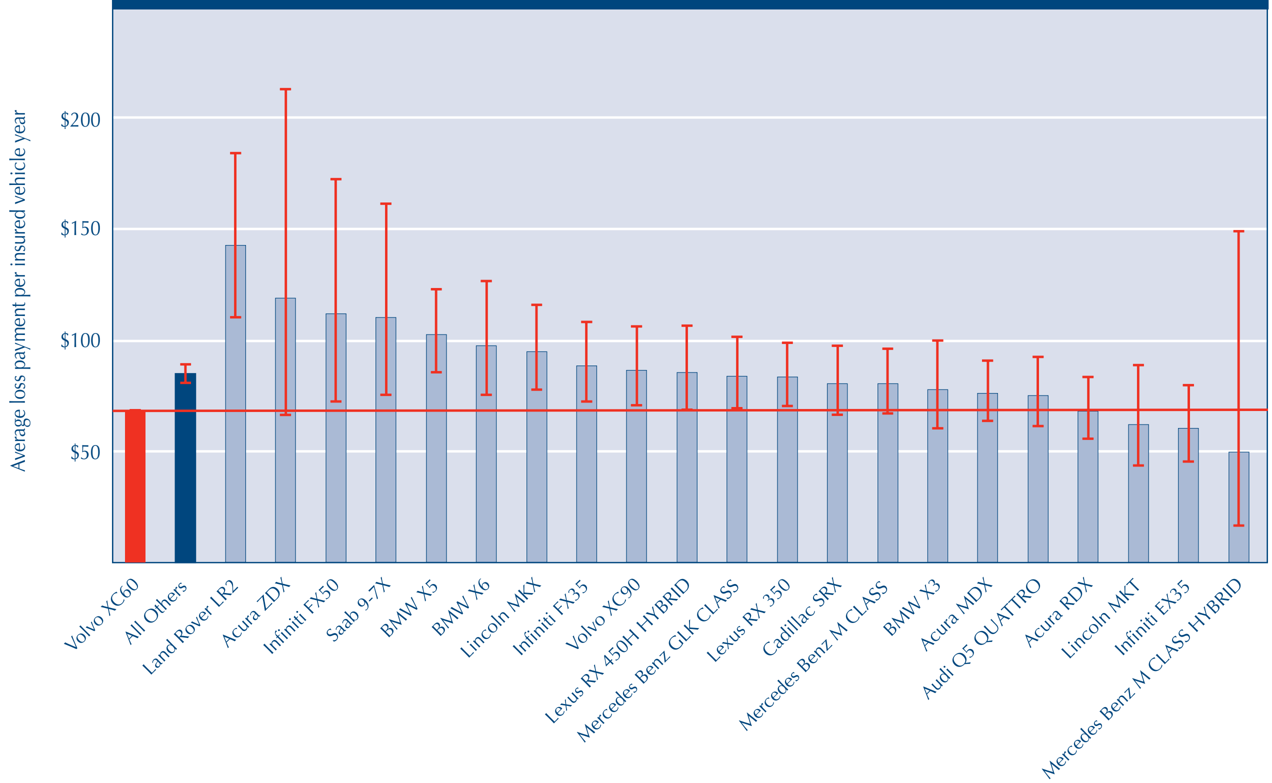


Figure 8 shows the property damage liability overall loss for the 2010 Volvo XC60 compared with those for other Volvo vehicles. The estimated overall loss for the Volvo XC60 was only 2 percent higher than that for all other Volvos combined. At the 95 percent confidence level, this estimate fell between a 12 percent increase and a 7 percent decease. Additionally, the overall loss for XC60 was higher than those for most other Volvo vehicles.

FIGURE 8 PROPERTY DAMAGE LIABILITY OVERALL LOSSES FOR 2010 VOLVO XC60 WITH CITY SAFETY VS. OTHER 2009-10 VOLVO VEHICLES

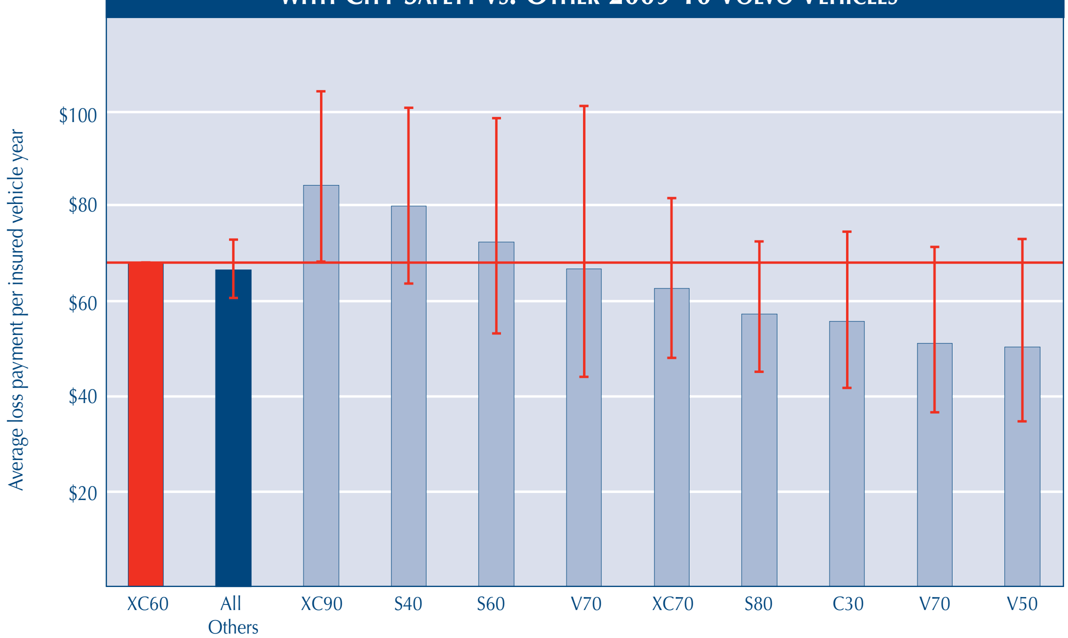


Table 8 summarizes results of the regression analysis conducted for bodily injury liability coverage. It includes estimates of claim frequency for other midsize luxury SUVs and other Volvo vehicles relative to the XC60. Detailed results of the regression analysis are listed in the Appendix.

Table 8 Estimated Bodily Injury Liability Claim Frequencies for Comparison Groups Relative to Volvo XC60

Control Group	Estimate	Standard error	Effect	Lower Bound	Upper Bound
Midsize Luxury SUVs	0.7154	0.0892	104%	72%	144%
Volvos	0.6766	0.1530	97%	46%	166%

Figures 9 and 10 show bodily injury liability claim frequencies (measured in claims per 1,000 insured vehicle years) for the 2010 Volvo XC60 equipped with City Safety compared with claim frequencies for other 2009-10 midsize luxury SUVs and for other Volvo vehicles without the system. Results for the XC60 were based on only 10 claims and 2,683 insured vehicle years. Consequently, the confidence intervals for comparisons of bodily injury liability were large. The Volvo XC60 had the lowest claim frequency of all midsize luxury SUVs as well as other Volvos. Although based on limited data, these differences were statistically significant overall and for many of the individual vehicle series comparisons. Especially when viewed in the context of other findings in the current study, the Volvo XC60's lowest claim frequency provides evidence that City Safety is reducing injury claims in vehicles struck by the XC60.

Figure 9 Bodily Injury Liability Claim Frequencies for 2010 Volvo XC60 with City Safety vs. Other 2009-10 Midsize Luxury SUVs

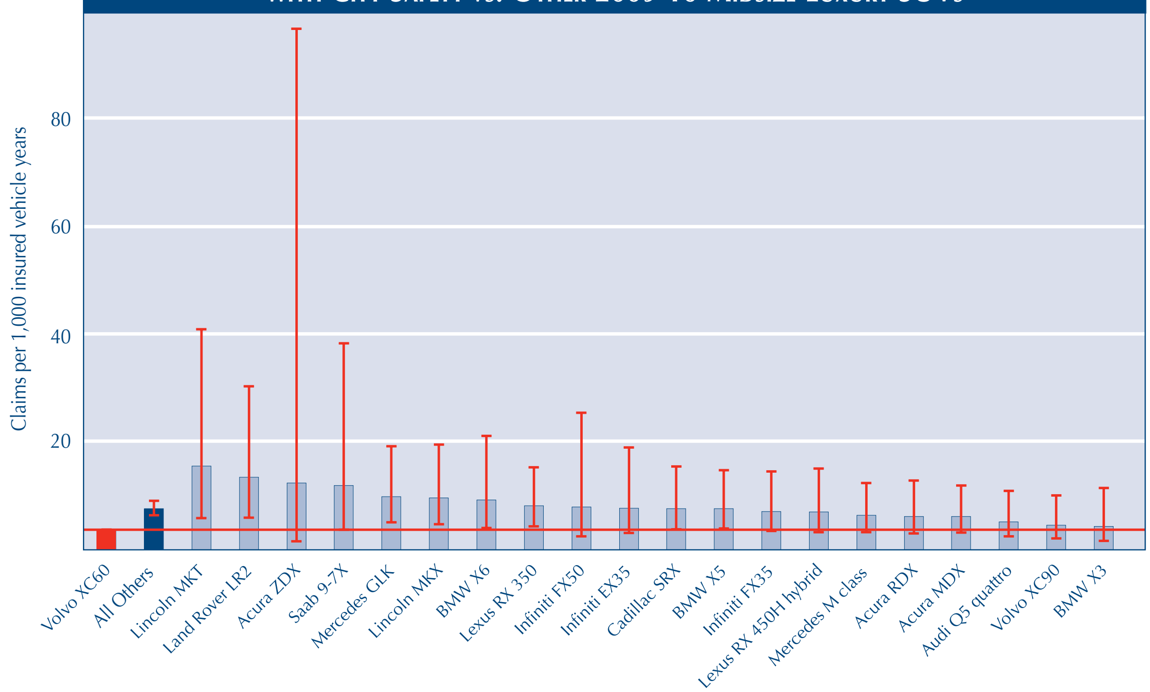


Figure 10 Bodily Injury Liability Claim Frequencies for 2010 Volvo XC60 with City Safety vs. Other 2009-10 Volvo Vehicles

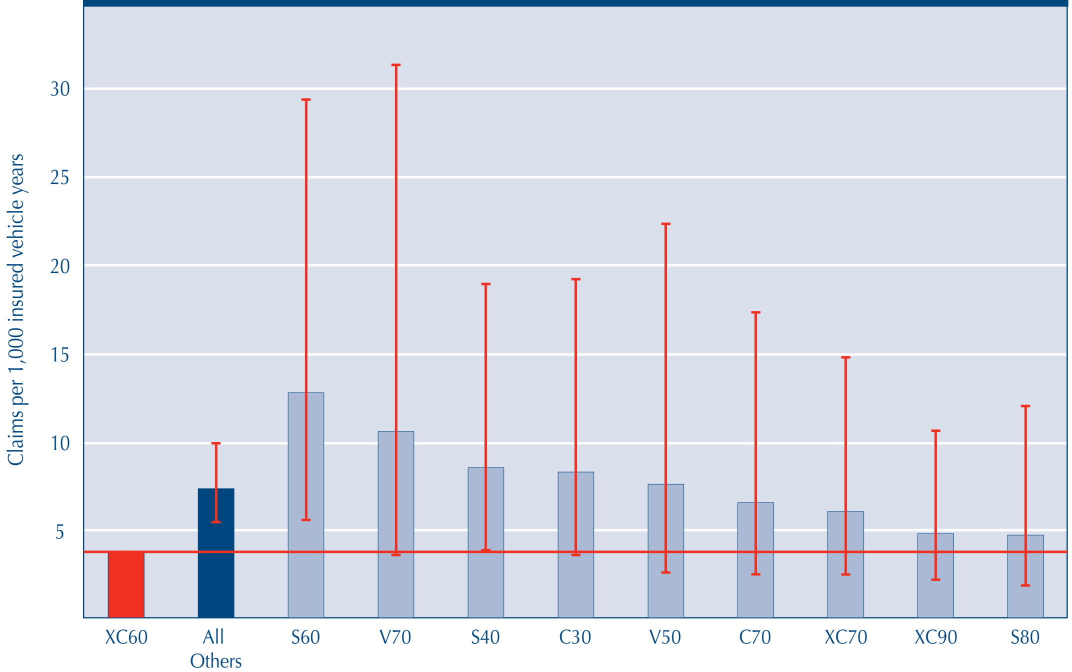


Table 9 summarizes results of the regression analysis conducted for collision coverage. It includes estimates of claim frequency, claim severity, and overall loss for other midsize luxury SUVs and other Volvo vehicles relative to the XC60. Detailed results of the regression analysis are listed in the Appendix.

Table 9 Estimated Collision Loss Results for Comparison Groups Relative to Volvo XC60

Control Group	Estimate	Standard error	Effect	Lower Bound	Upper Bound
Claim Frequency					
Midsize Luxury SUVs	0.2482	0.0121	28%	25%	31%
Volvos	0.1824	0.0220	20%	15%	25%
Claim Severity					
Midsize Luxury SUVs	0.1196	0.0140	13%	10%	16%
Volvos	0.0355	0.0254	4%	-1%	9%
Overall Loss					
Midsize Luxury SUVs	0.3678	0.0186	44%	39%	50%
Volvos	0.2179	0.0336	24%	16%	33%

Collision claim frequencies (measured in claims per 100 insured vehicle years) were calculated for the 2010 Volvo XC60 equipped with City Safety and compared with claim frequencies for other 2009-10 midsize luxury SUVs and for other Volvo vehicles without the system. Results for the XC60 were based on 628 claims and 11,641 insured vehicle years. Figure 11 shows the collision claim frequency for the 2010 Volvo XC60 compared with those for other midsize luxury

SUVs. The estimated claim frequency for the Volvo XC60 was 22 percent lower than that for all other midsize luxury SUVs combined. At the 95 percent confidence level, the range for this estimate was 20 to 24 percent. At the individual vehicle series level, the XC60 had the lowest claim frequency.

FIGURE 11 COLLISION CLAIM FREQUENCIES FOR 2010 VOLVO XC60 WITH CITY SAFETY VS. OTHER 2009-10 MIDSIZE LUXURY SUVS

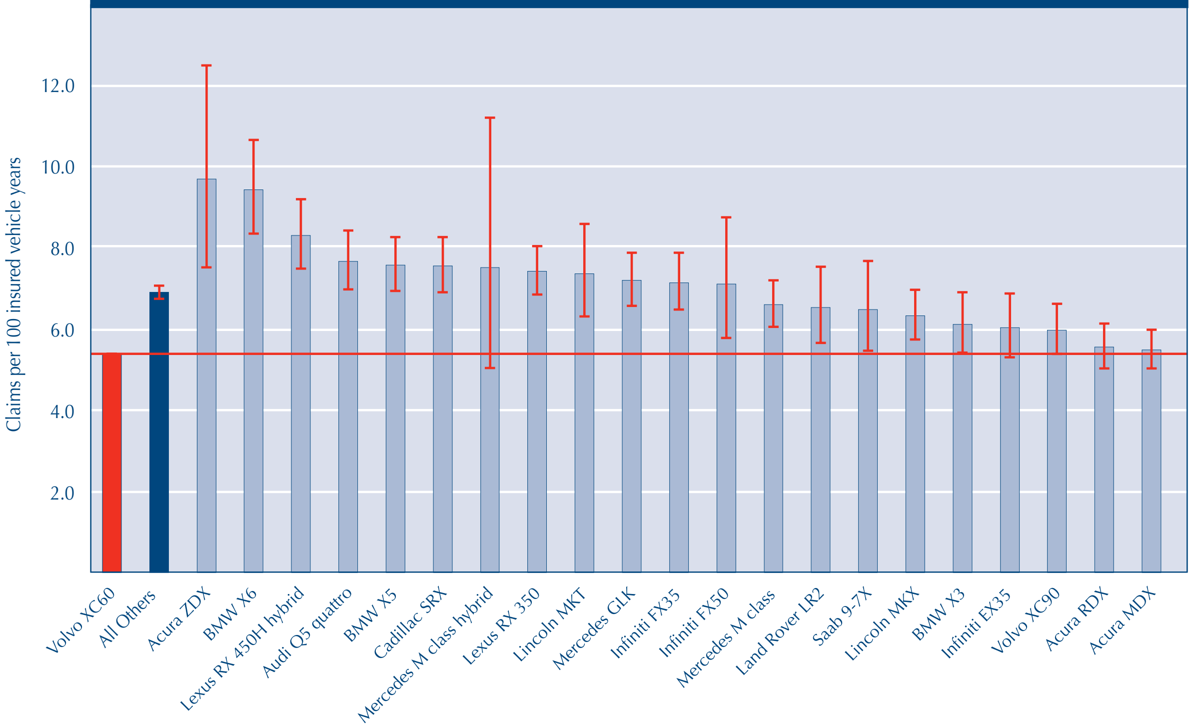
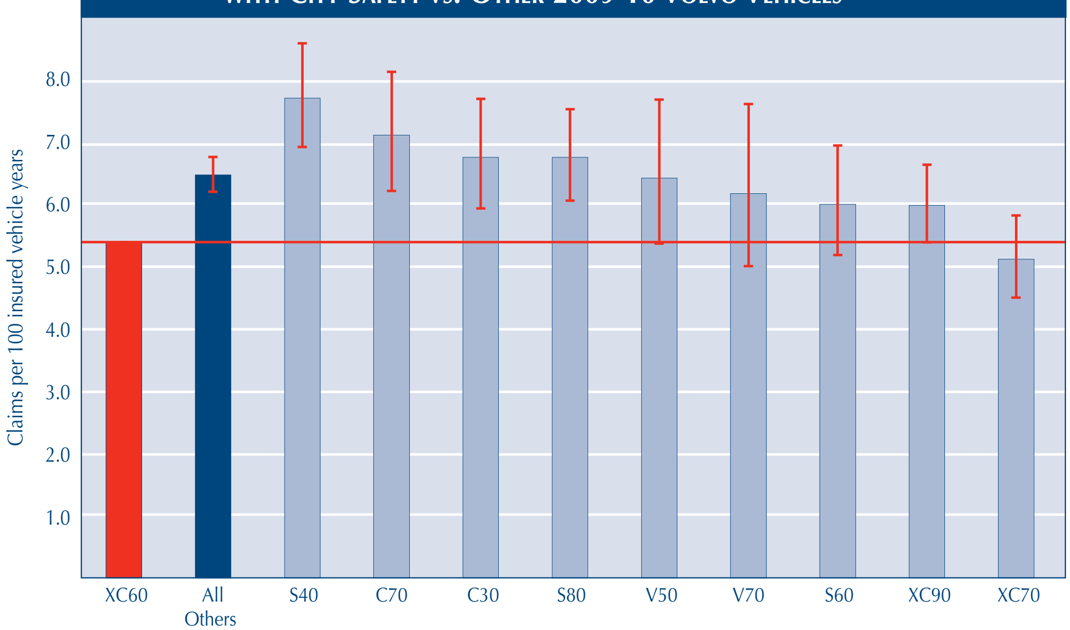


Figure 12 shows the collision claim frequency for the 2010 Volvo XC60 compared with those for other Volvo vehicles. The estimated claim frequency for the Volvo XC60 was 17 percent lower than that for all other Volvos combined. At the 95 percent confidence level, the range for this estimate was 13 to 20 percent. At the individual vehicle series level, the XC60 had an estimated claim frequency lower than those for all Volvos but one, the XC70. However, the difference between the estimates for the XC70 and XC60 did not reach statistical significance.

FIGURE 12 COLLISION CLAIM FREQUENCIES FOR 2010 VOLVO XC60 WITH CITY SAFETY VS. OTHER 2009-10 VOLVO VEHICLES



Figures 13 and 14 show the collision claim severity for the 2010 Volvo XC60 compared with those for other midsize luxury SUVs and other Volvo vehicles. The estimated claim severity for the Volvo XC60 was 11 percent lower than that for all other midsize luxury SUVs combined. At the 95 percent confidence level, the range for this estimate was 9 to 14 percent. The estimated claim severity for the Volvo XC60 was only 3 percent lower than that for all other Volvos combined. At the 95 percent confidence level, this estimate fell between a 1 percent increase and an 8 percent decease. Results were mixed at the individual vehicle series level.

FIGURE 13 COLLISION CLAIM SEVERITIES FOR 2010 VOLVO XC60 WITH CITY SAFETY VS. OTHER 2009-10 MIDSIZE LUXURY SUVs

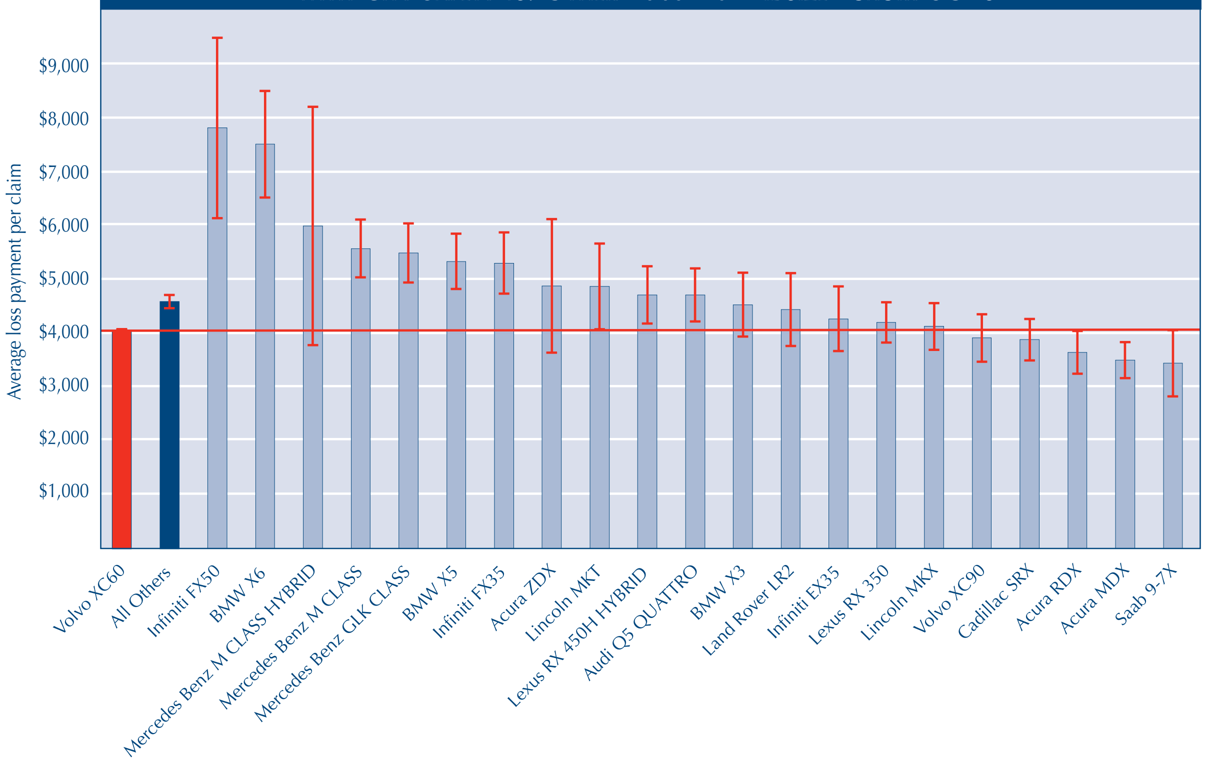
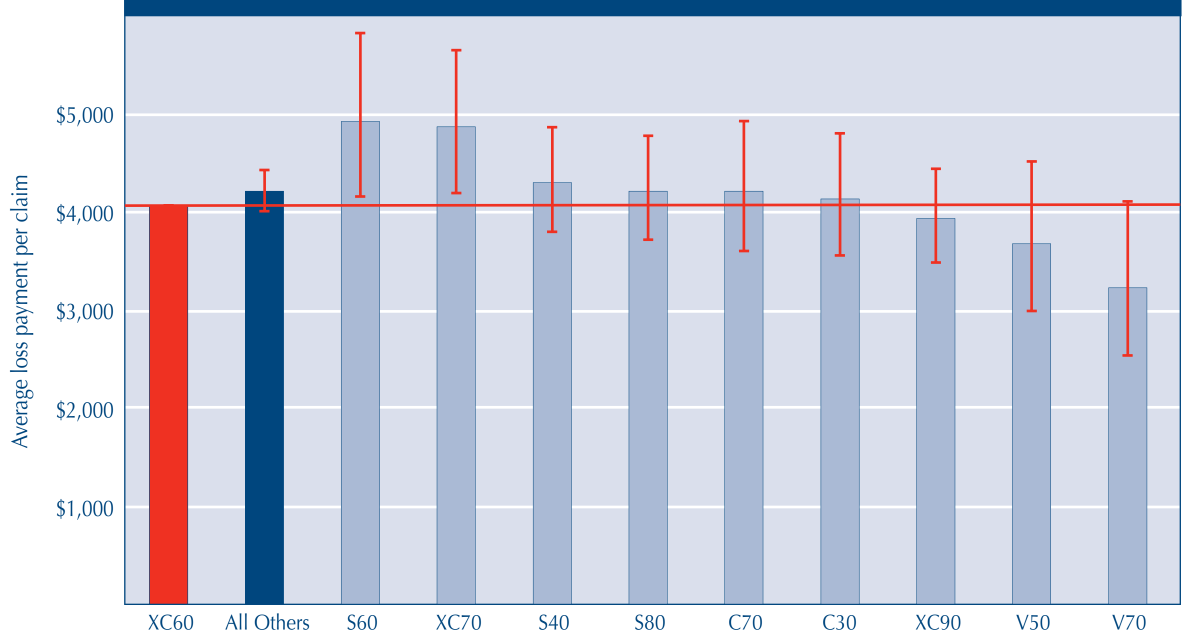


FIGURE 14 COLLISION CLAIM SEVERITIES FOR 2010 VOLVO XC60 WITH CITY SAFETY VS. OTHER 2009-10 VOLVO VEHICLES



As with the analysis of property damage liability claim frequencies reported in Table 5, Table 10 summarizes results of regression analysis conducted for collision coverage. Detailed results are listed in the Appendix. The XC60 had lower collision claim frequencies compared with other Volvos or other midsize luxury SUVs for all claim severity ranges. However, the effect was greatest for the $5,000-$11,999 range.

Table 10 Estimated Collision Claim Frequencies by Severity Range for Comparison Groups Relative to Volvo XC60

Control Group	Claim Size	Estimate	Standard error	Effect	Lower Bound	Upper Bound
Midsize Luxury SUVs	<$2,000	0.1373	0.0166	14.7%	11.0%	18.5%
Midsize Luxury SUVs	$2,000-$4,999	0.3177	0.0256	37.4%	30.7%	44.4%
Midsize Luxury SUVs	$5,000-$11,999	0.4138	0.0327	51.3%	41.9%	61.3%
Midsize Luxury SUVs	$12,000+	0.3985	0.0394	49.0%	37.9%	60.9%
Volvos	<$2,000	0.1255	0.0298	13.4%	6.9%	20.2%
Volvos	$2,000-$4,999	0.1442	0.0475	15.5%	5.2%	26.8%
Volvos	$5,000-$11,999	0.3920	0.0583	48.0%	32.0%	65.9%
Volvos	$12,000+	0.3032	0.0719	35.4%	17.6%	55.9%

Figures 15 and 16 illustrate these results for the XC60 compared with those for other midsize luxury SUVs and other Volvo vehicles, respectively. In both comparisons, the smallest reduction was for the lowest severity range, claims less than $2,000.

Figure 15 Collision Claim Frequencies by Claim Severity Range, Volvo XC60 vs. Other Midsize Luxury SUVs

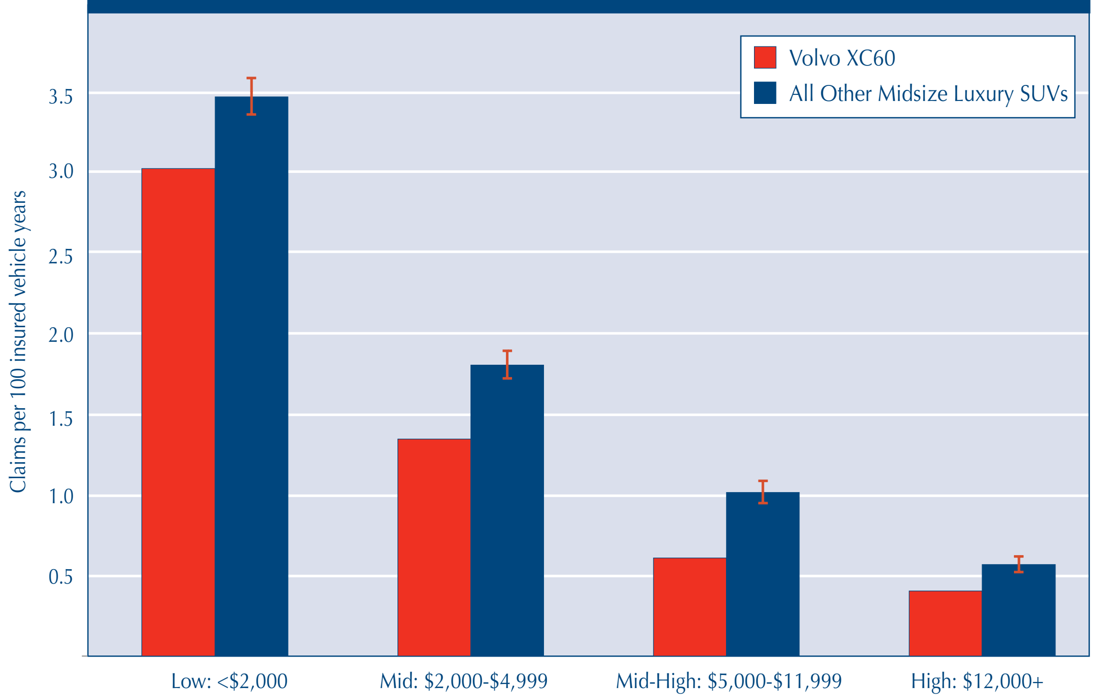
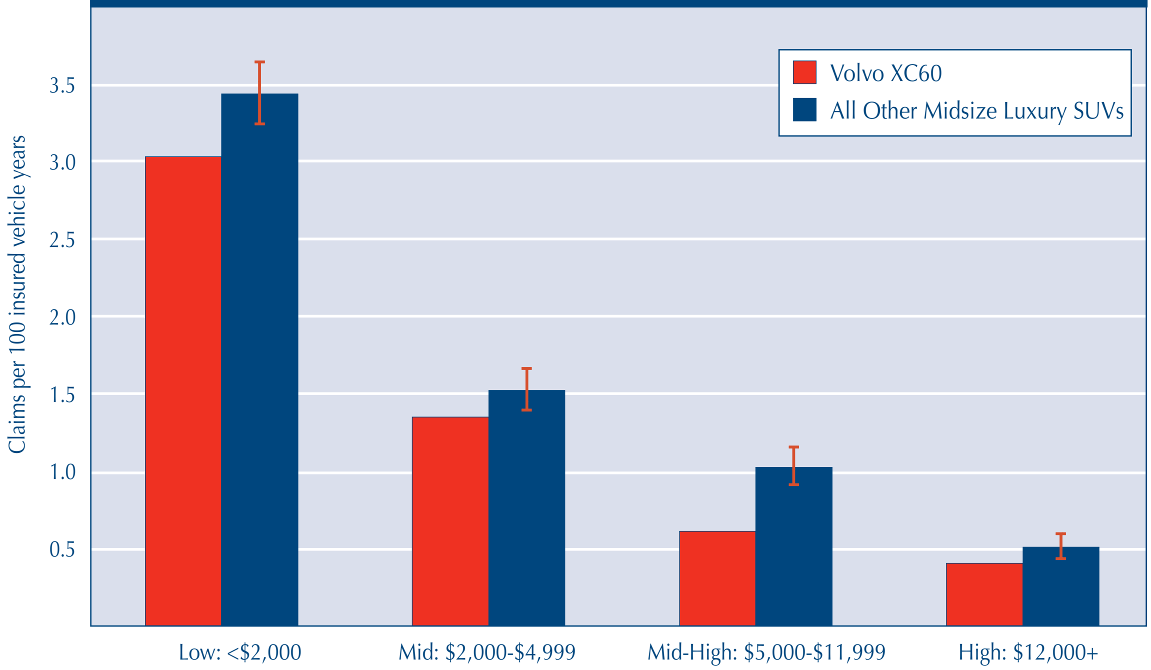


Figure 16 Collision Claim Frequencies by Claim Severity Range, Volvo XC60 vs. Other Volvo Vehicles



Collision overall losses (measured in average loss payments per insured vehicle year) were calculated for the 2010 Volvo XC60 equipped with City Safety and compared with overall losses for other 2009-10 midsize luxury SUVs and for other Volvo vehicles without the system. Figure 17 shows the collision overall loss for the 2010 Volvo XC60 compared with those for other midsize luxury SUVs. The estimated overall loss for the Volvo XC60 was 31 percent lower than that for all other midsize luxury SUVs combined. At the 95 percent confidence level, the range for this estimate was 28 to 33 percent. Compared with individual vehicle series, the XC60 had a lower overall loss than all but two Acura vehicles.

Figure 17 Collision Overall Losses for 2010 Volvo XC60 with City Safety vs. Other 2009-10 Midsize Luxury SUVs

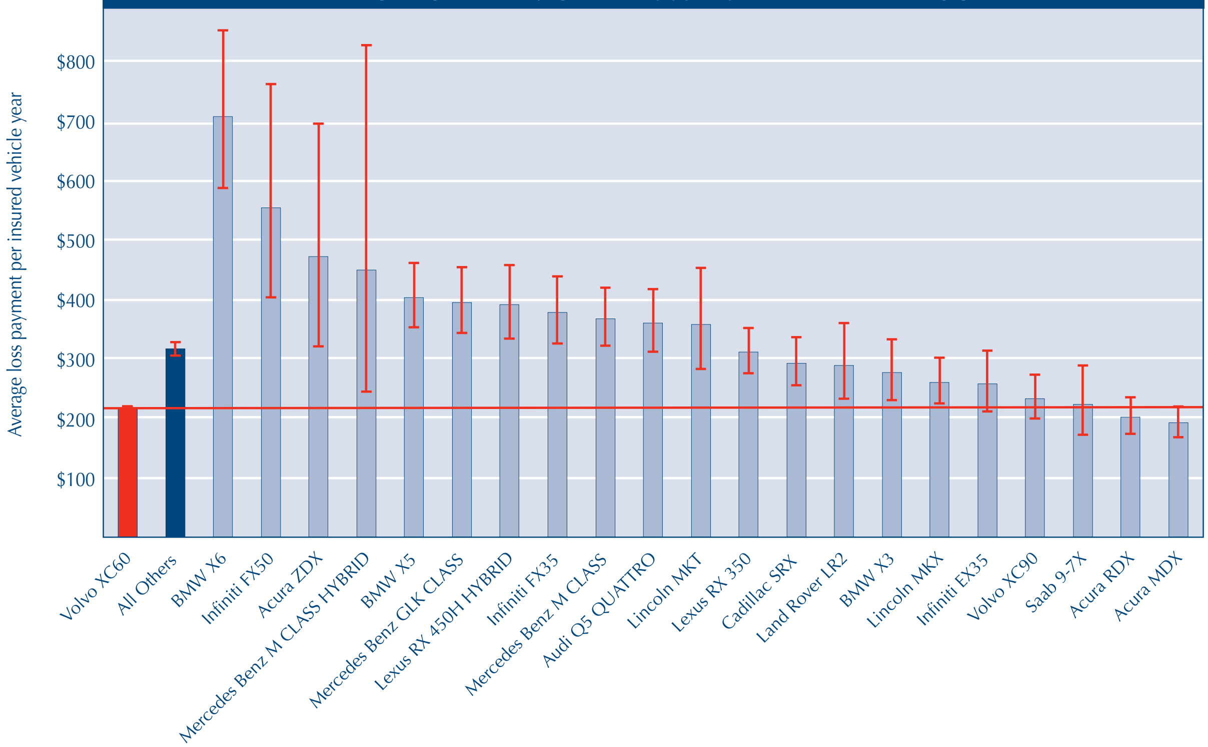
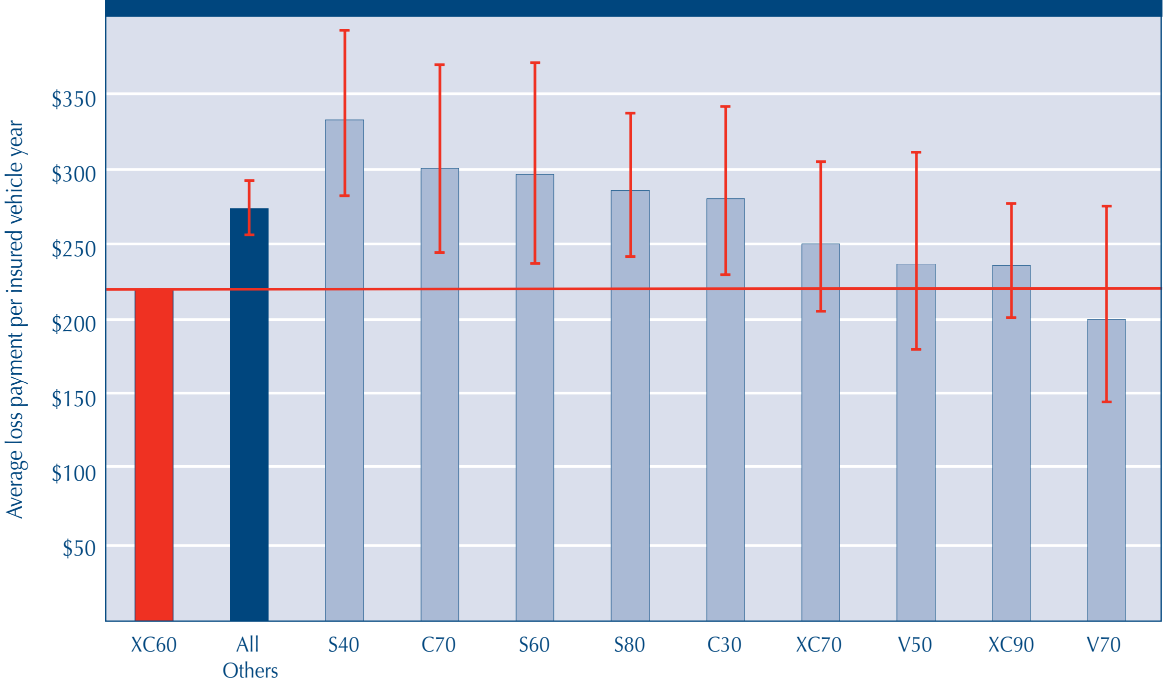


Figure 18 shows collision overall losses for the 2010 Volvo XC60 compared with those for other Volvo vehicles. The estimated overall loss for the Volvo XC60 was 20 percent lower than that for all other Volvos combined. At the 95 percent confidence level, the range for this estimate was 14 to 25 percent. Additionally, the overall loss for the XC60 was lower than those for all other Volvos except the V70.

Figure 18 Collision Overall Losses for 2010 Volvo XC60 with City Safety vs. Other 2009-10 Volvo Vehicles



Discussion

Volvo's City Safety system appears to be preventing crashes, at least in comparison with other midsize luxury SUVs and other Volvo models. Estimated claim frequency rates for the Volvo XC60, the only Volvo model equipped with City Safety in the current study, were considerably lower for property damage liability and collision coverages relative to losses for both control groups. All four of these estimates were substantial and statistically significant — 27 percent for property damage liability and 22 percent for collision relative to midsize luxury SUVs. Relative to other Volvos, claim frequency benefits were significant but not as large as the benefit relative to other midsize luxury SUVs.

It was expected that property damage liability losses would be a more sensitive measure of City Safety effectiveness because it involves a larger proportion of vehicle-to-vehicle crashes than collision coverage. Past HLDI (2007) research has shown that 57 percent of vehicles repaired under property damage liability coverage were struck in the rear, likely by the front of the covered vehicle. In contrast, only 48 percent of collision claims were for front impacts, some of which would not have involved another vehicle. Still, the effect on collision claim frequency observed in the current study was substantial and suggests that City Safety also may be preventing collisions with some nonvehicle objects. This may not be so surprising considering that, despite City Safety being designed especially for the vehicle-to-vehicle situation, the system sometimes is demonstrated with nonvehicle crash targets.

City Safety not only is preventing crashes but also appears to be preventing injuries through a combination of preventing some crashes and reducing the severity of other crashes. Claim frequencies under bodily injury liability coverage for the XC60 were only half (51 percent) of those for other midsize luxury SUVs and slightly less than half (49 percent) of those for other Volvo vehicles. Both estimates were statistically significant, although based on limited data. Because the crashes being prevented are minor, it is expected that the injuries being prevented also are minor, but the data cannot address this.

Claim severities under property damage liability coverage were higher, on average, for the XC60 than for vehicles in either control group — 10 percent higher than for other midsize luxury SUVs and 27 percent higher than for other Volvo vehicles. Analysis of claim size distribution suggested this largely was a result of shifting the mean due to elimination of many low-cost claims from the low-speed crashes that City Safety is intended to prevent. Another factor in the difference between the XC60 and the rest of the Volvo fleet is that the XC60 is an SUV and all other Volvos, except the XC90, are cars. The bottom of the XC60's front bumper is higher off the ground than the front bumpers of Volvo cars and even slightly higher than the front bumper of the Volvo XC90. Prior research from HLDI (2006) and the Insurance Institute for Highway Safety (2008) has illustrated the effect on struck vehicle damage when a striking vehicle's front bumper overrides the struck vehicle's rear bumper.

Unlike for property damage liability, average claim severity for collision claims did not increase for the Volvo XC60. An analysis of the differences between collision claim frequencies for the XC60 and the control groups for different claim severities showed that, although City Safety reduced low-severity collision claims, as was true for property damage liability claims, the technology had even larger effects on higher severity collision claims. Thus, average claim severity did not change. These different results may seem contradictory, but it is likely they result from the difference in typical costs of property damage liability claims and collision claims.

In 2007, HLDI published an evaluation of collision and property damage liability claim severities by point of vehicle impact. Information on point of impact was supplied by CCC Information Services, Inc. The study showed that the most expensive damage repair claims were collision claims for the 12 o'clock position (front of the striking vehicle), with a claim severity of $4,658. At the same time, the least expensive damage repair claims were property damage liability claims for the 6 o'clock position (rear of the struck vehicle), with a claim severity of $1,714. In other words, the average cost of a front-strike collision claim was well more than double the cost of a rear-strike property damage liability claim. The implication of this pattern is that, even though City Safety reduces the frequency of low-severity front-to-rear collisions, the cost of these low-speed collisions that are prevented is higher than for property damage liability claims. At the same time, City Safety is not expected to affect many of the crashes leading to the lowest severity collision claims.

Despite a higher claim severity under property damage liability coverage, the overall loss ($68 per insured vehicle year) for the XC60 was lower than that for other midsize luxury SUVs combined by 20 percent, a statistically significant result. The property damage liability overall loss for the XC60 was about the same as the average for all other Volvo models. Thus, City Safety appears able to prevent crashes and reduce insurance costs. There also is the indication that the system reduces injury rates, though the confidence bounds of the estimates still are quite large.

Limitations

All of the XC60s included in the current study were equipped with the City Safety technology, but there was no way to know how many, if any, of the drivers in these crash-involved vehicles had manually turned off the system prior to the crash. Also, most of the vehicles in this study, including the XC60, can be equipped with a variety of collision avoidance features that might also affect claim frequencies; however, based on data available to HLDI at the time of the study, it was not possible to control for the presence of these other features. Finally, 2010 was the first available model year for the XC60, and drivers of prior model year XC60s may differ in ways that were not adjusted for in analysis. To fully understand the benefits of City Safety, subsequent analysis will be required as additional loss data become available. Therefore, it will be important to continue monitoring the performance of City Safety as more and potentially different drivers insure the vehicle.

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Highway Loss Data Institute. 2007. Point of impact distribution. *HLDI Bulletin* 24(3). Arlington, VA.

Insurance Institute for Highway Safety. 2008. Bumper rules should extend to light trucks, Institute tells NHTSA. *Status Report* 43(5):1-3. Arlington, VA

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Initial Evaluation of Crash Avoidance Technologies Using Insurance Data

TRB Annual Meeting
Washington, DC • January 14, 2013

Matthew Moore, Vice President, HLDI

The Insurance Institute for Highway Safety,

founded in 1959, is an independent, nonprofit, scientific, and educational organization dedicated to reducing the losses — deaths, injuries, and property damage — from crashes on the nation's highways.

The Highway Loss Data Institute,

founded in 1972, shares and supports this mission through scientific studies of insurance data representing the human and economic losses resulting from the ownership and operation of different types of vehicles and by publishing insurance loss results by vehicle make and model.

Both organizations are wholly supported by auto insurers.

Highway Loss Data Institute

HLDI data providers have 80% share of U.S. auto insurance market

- AAA Northern California, Nevada and Utah
- AIG Agency
- Allstate
- American Family
- Amica
- ANPAC
- Auto Club Group
- Automobile Insurers Bureau of Mass.
- Chubb
- COUNTRY
- Erie
- Farm Bureau Financial Services (Iowa Farm Bureau)
- Farmers
- Foremost
- GEICO
- GMAC
- The Hartford
- High Point
- Kentucky Farm Bureau
- Liberty Mutual
- MetLife
- Nationwide
- PEMCO
- Progressive
- Rockingham
- Safeco
- Secura Insurance
- State Farm
- Tennessee Farm Bureau
- Travelers
- Unitrin
- USAA

Insurance coverages

- Collision
- Physical damage liability
- Bodily injury liability
- Medical payments
- Personal injury protection

Insurance measures

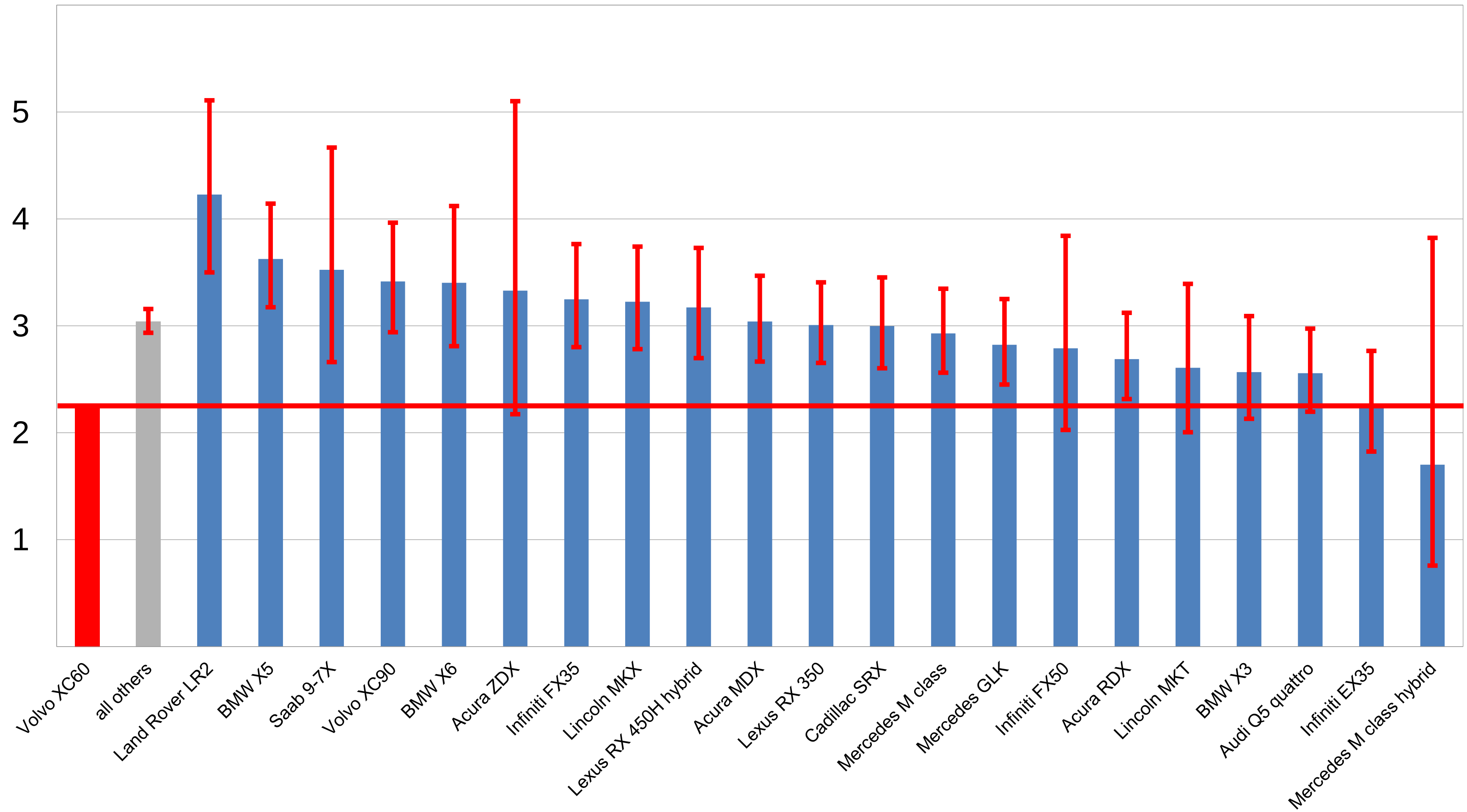
- Exposure
  - Expressed in insured vehicle years
  - One insured vehicle year represents 1 vehicle insured for 1 year or 2 vehicles insured for 6 months
- Claim frequency
  - Calculated by dividing claims by exposure
  - Expressed as the number of claims per selected number of insured vehicle years (exposure)
- Claim severity
  - Represents the average cost per claim
  - Calculated by dividing dollars paid for all claims by the claim count
- Overall losses
  - Represents the average cost per insured vehicle (year)
  - Calculated by dividing total dollars paid for claims by exposure

Evaluation of crash avoidance technologies

Volvo City Safety

Property damage liability claim frequencies for 2010 Volvo XC60

With City Safety vs. other 2009-10 midsize luxury SUVs



Early information about new technology

Example of Volvo City Safety loss reduction benefits (HLDI)

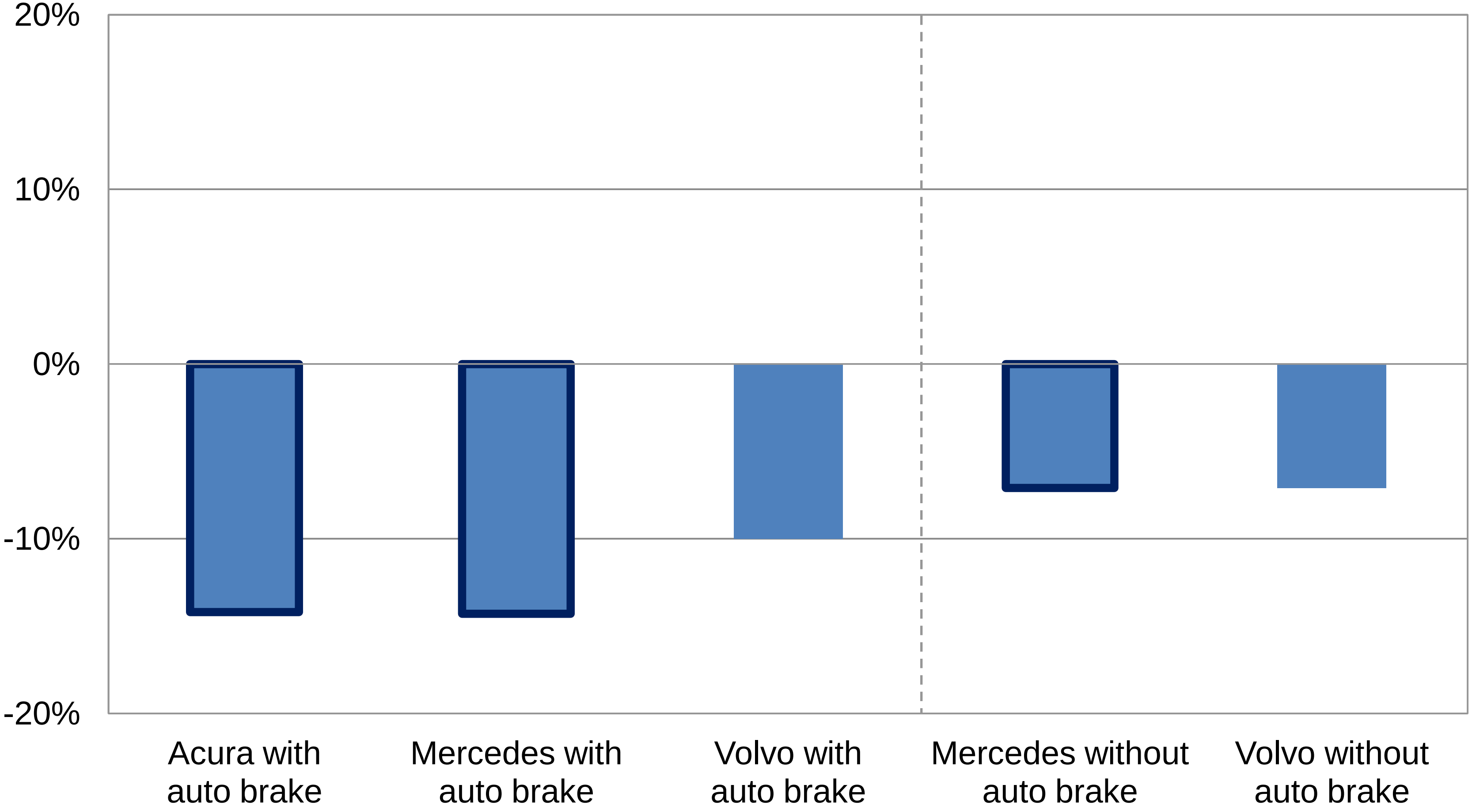
vs. other midsize luxury SUVs	claim frequency			claim severity			overall losses		
property damage liability	-29.3%	-26.6%	-23.9%	$174	$270	$362	-$21	-$166	-$125
bodily injury	-58.9%	-51.1%	-41.8%						
collision	-23.8%	-22.0%	-20.1%	-$645	-$517	-$392	-$109	-$98	-$86

vs. other Volvos	claim frequency			claim severity			overall losses		
property damage liability	-24.5%	-19.2%	-13.7%	$488	$646	$794	-$5	$2	$7
bodily injury	-62.3%	-49.2%	-31.4%						
collision	-20.2%	-16.7%	-13.0%	-$362	-$147	$58	-$72	-$53	-$36

Forward collision warning and mitigation systems

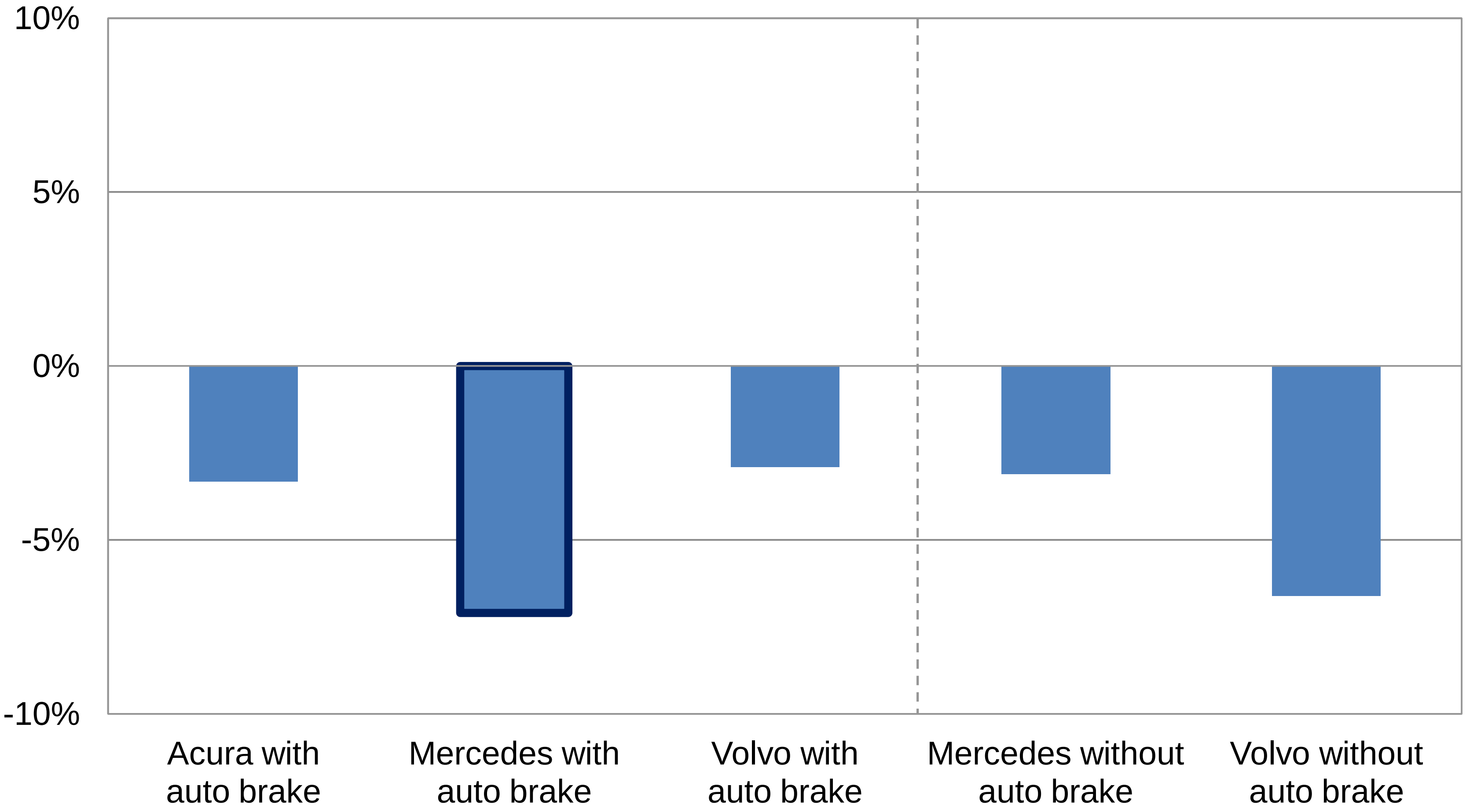
Forward collision warning with and without autonomous braking

Property damage liability claim frequency by manufacturer



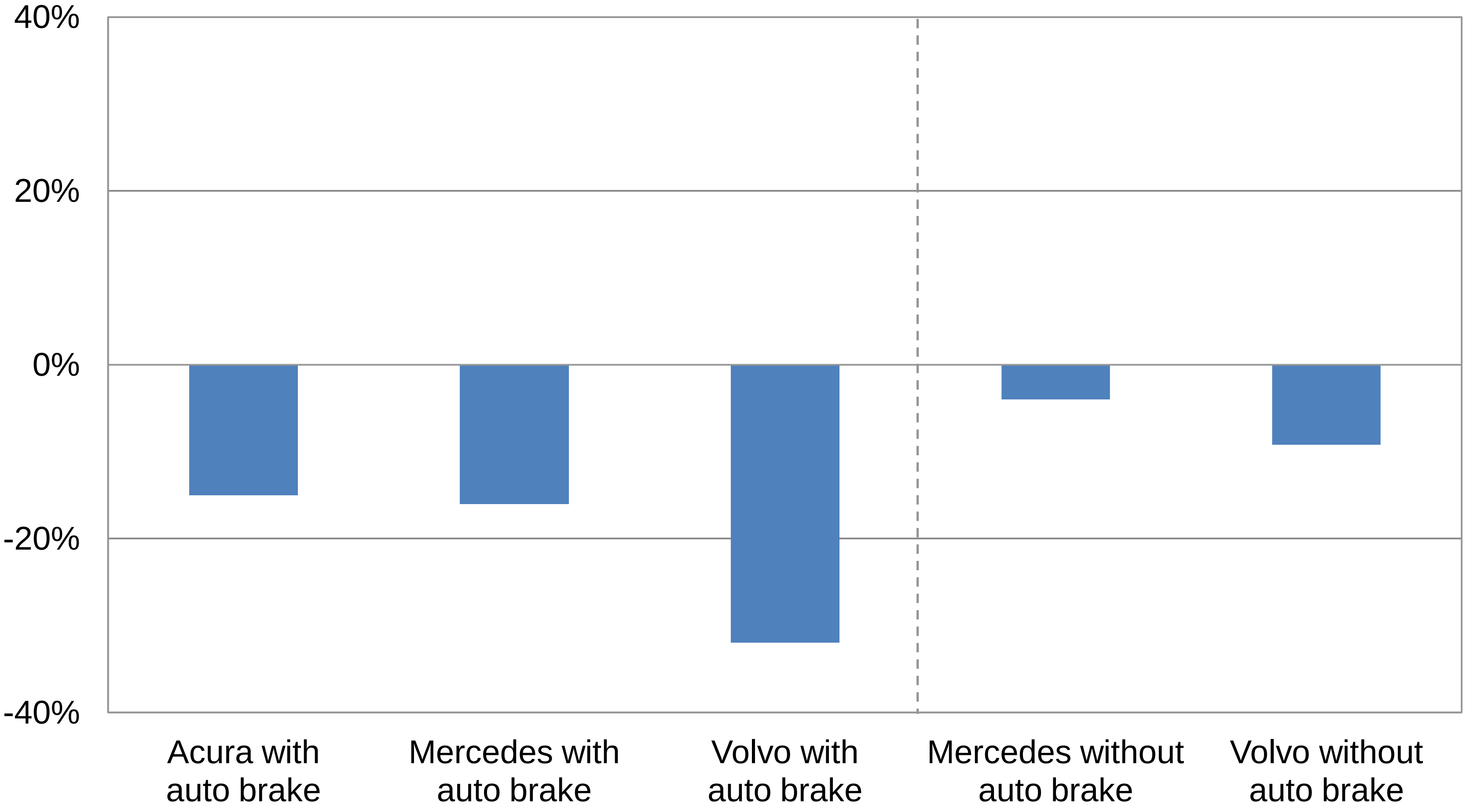
Forward collision warning with and without autonomous braking

Collision claim frequency by manufacturer



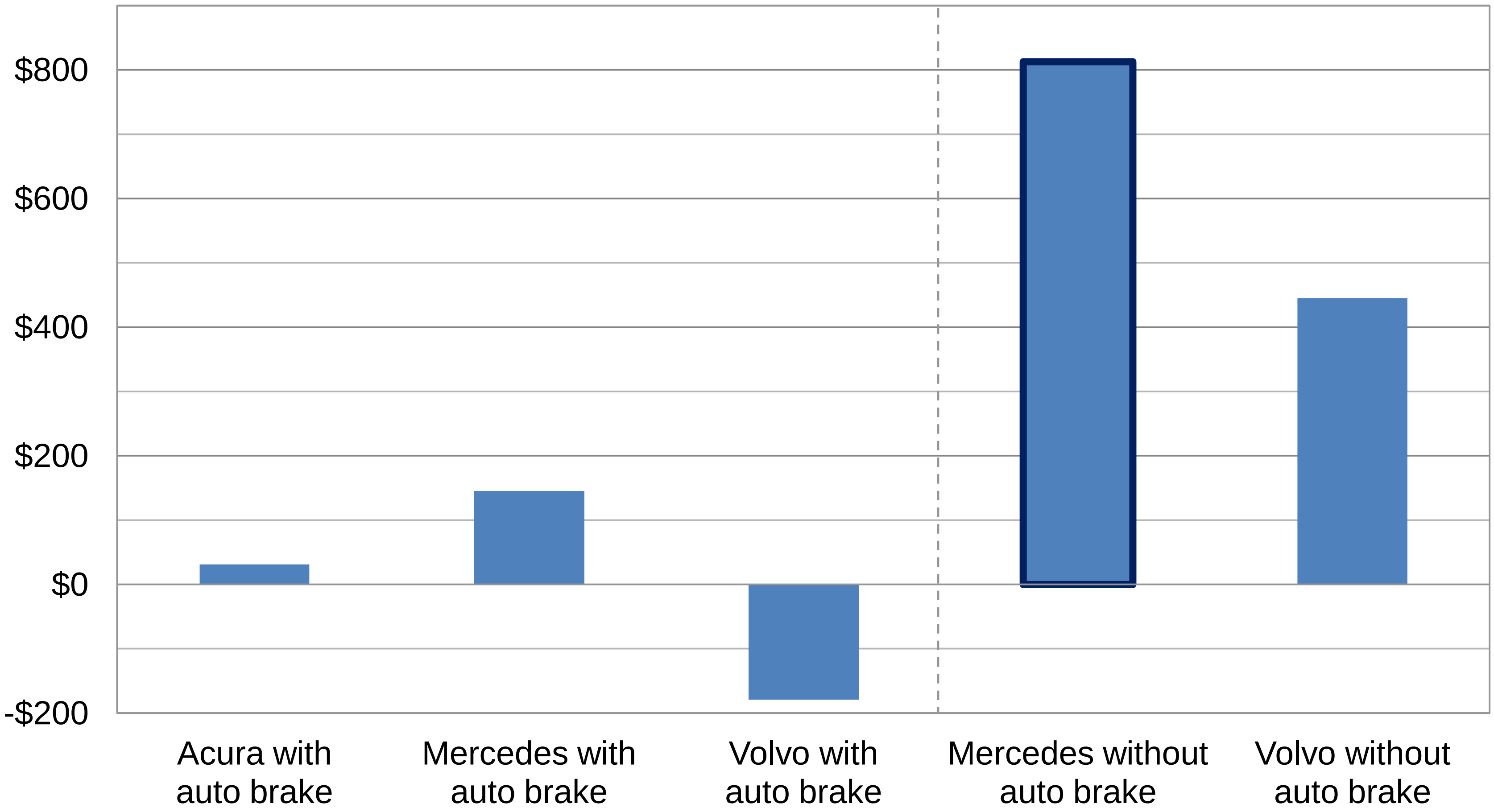
Forward collision warning with and without autonomous braking

Bodily injury claim frequency by manufacturer



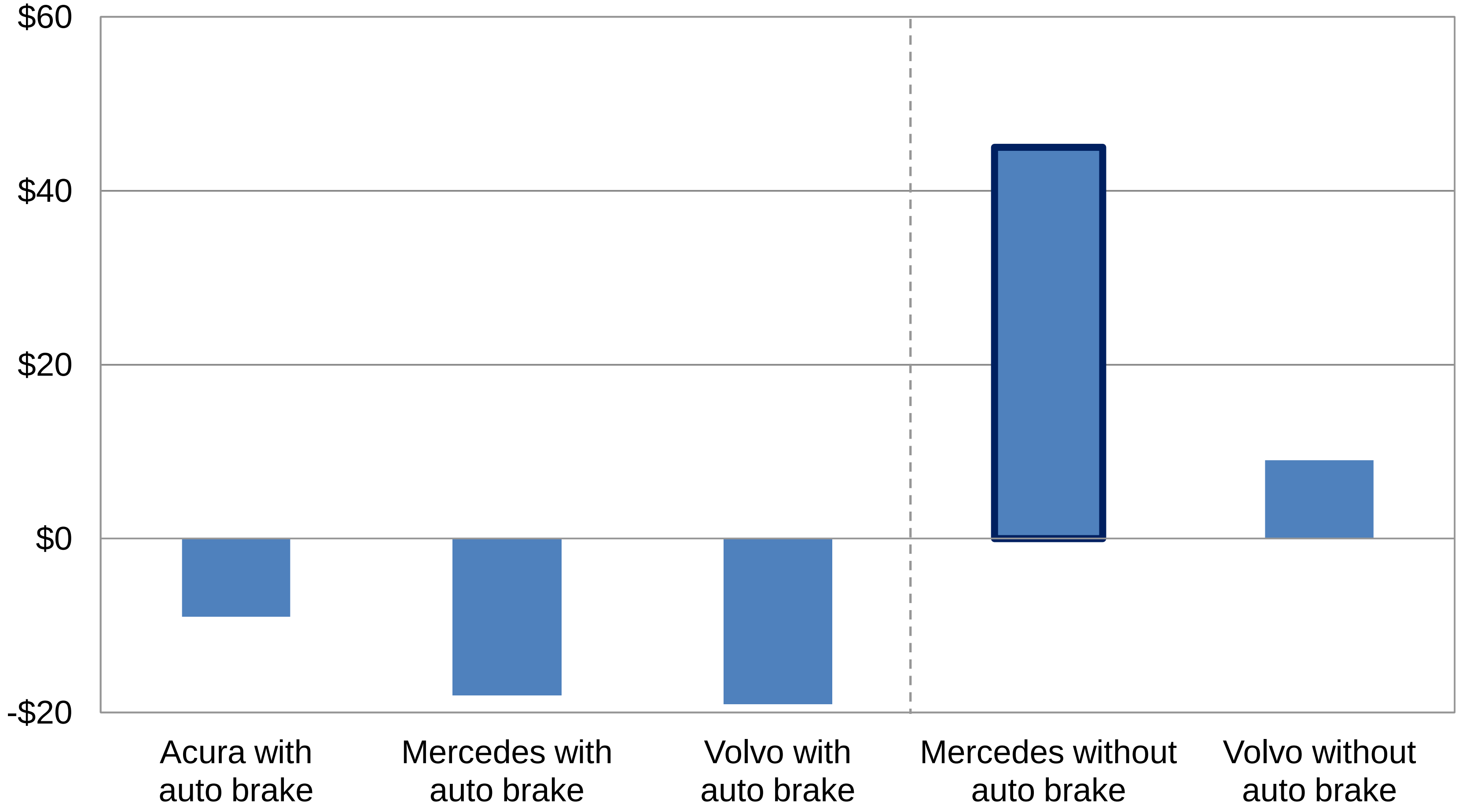
Forward collision warning with and without autonomous braking

Collision claim severity by manufacturer



Forward collision warning with and without autonomous braking

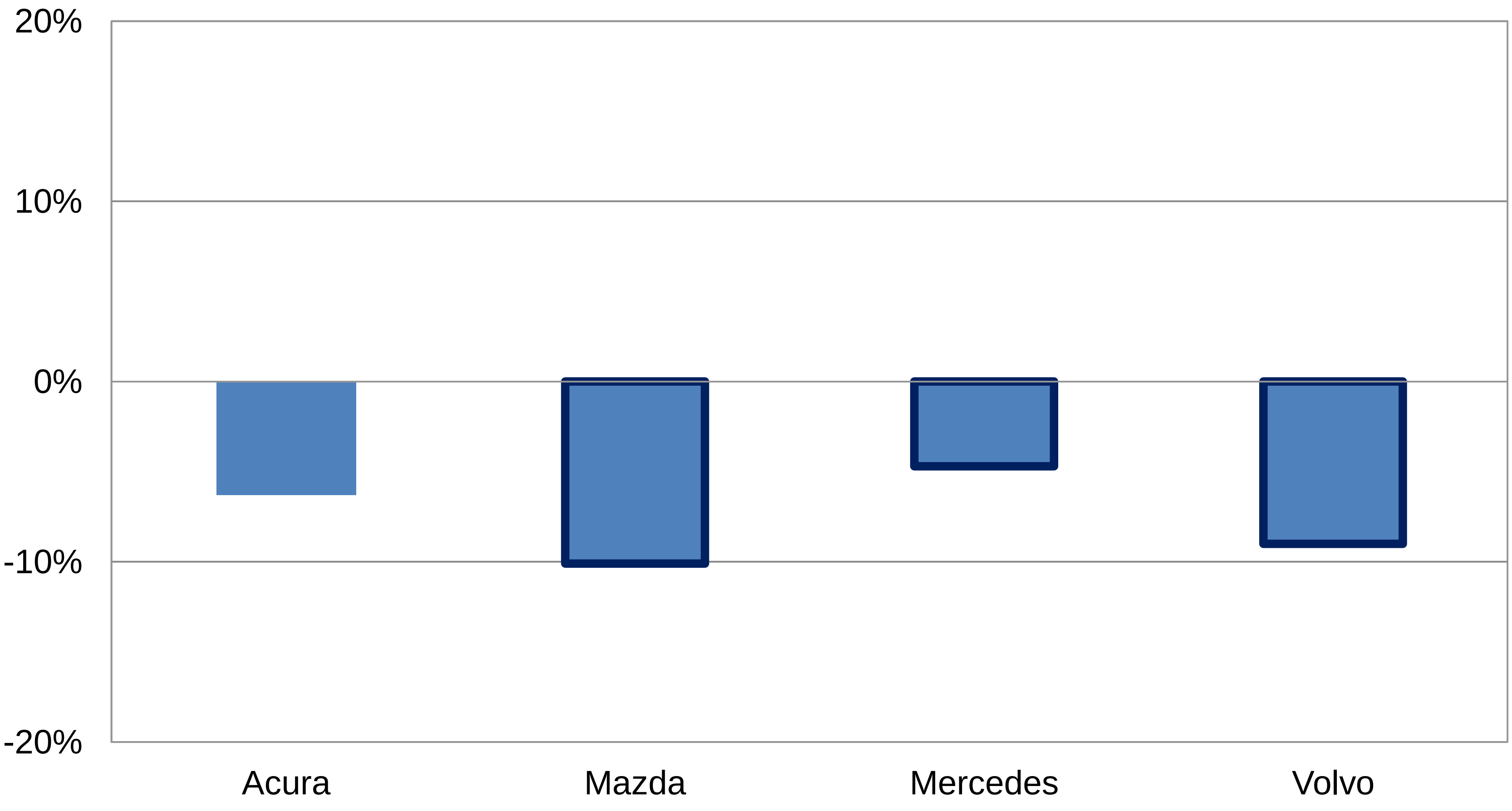
Collision claim losses per insured vehicle year by manufacturer



Adaptive headlights

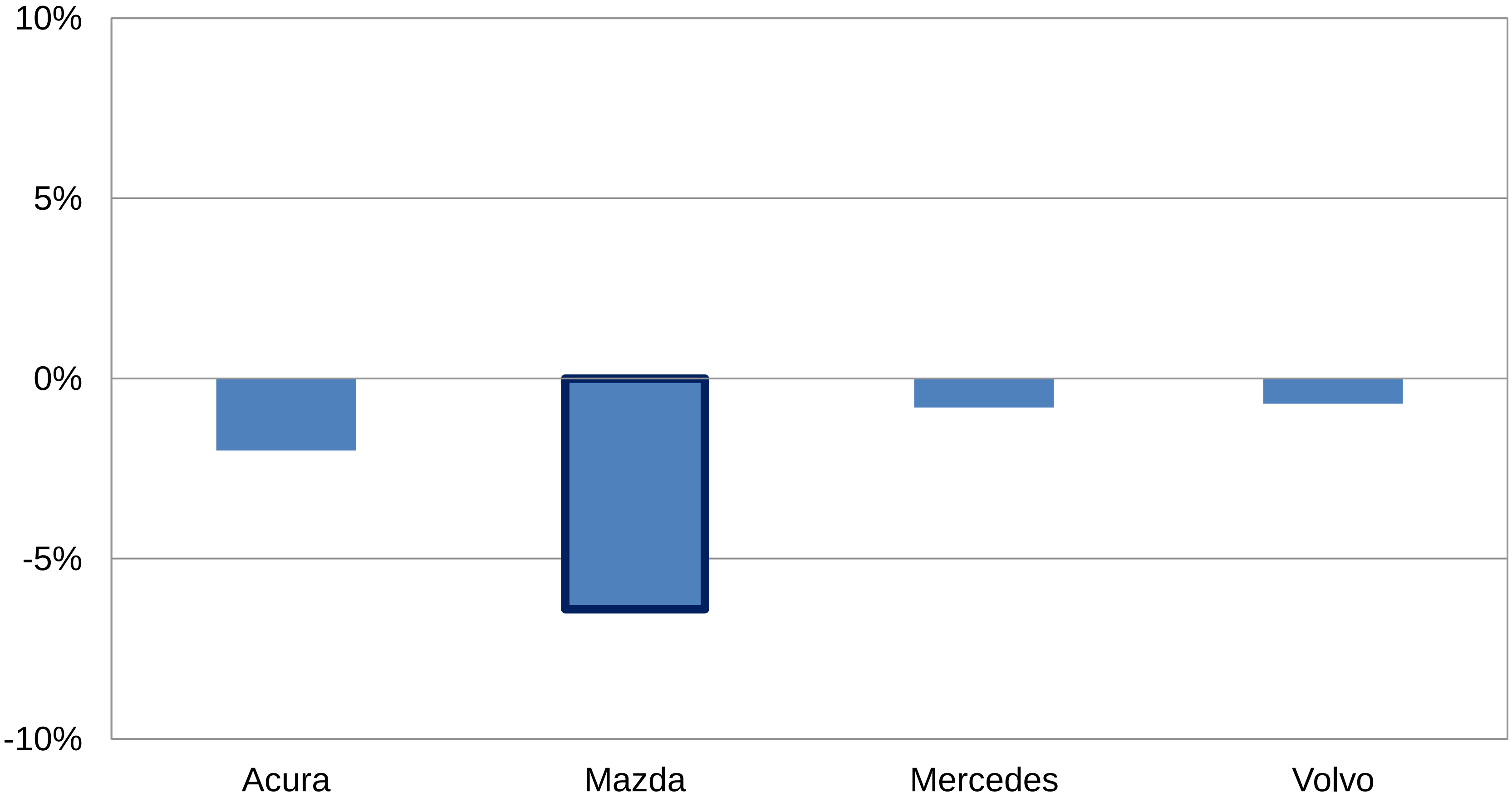
Adaptive headlights

Property damage liability claim frequency by manufacturer



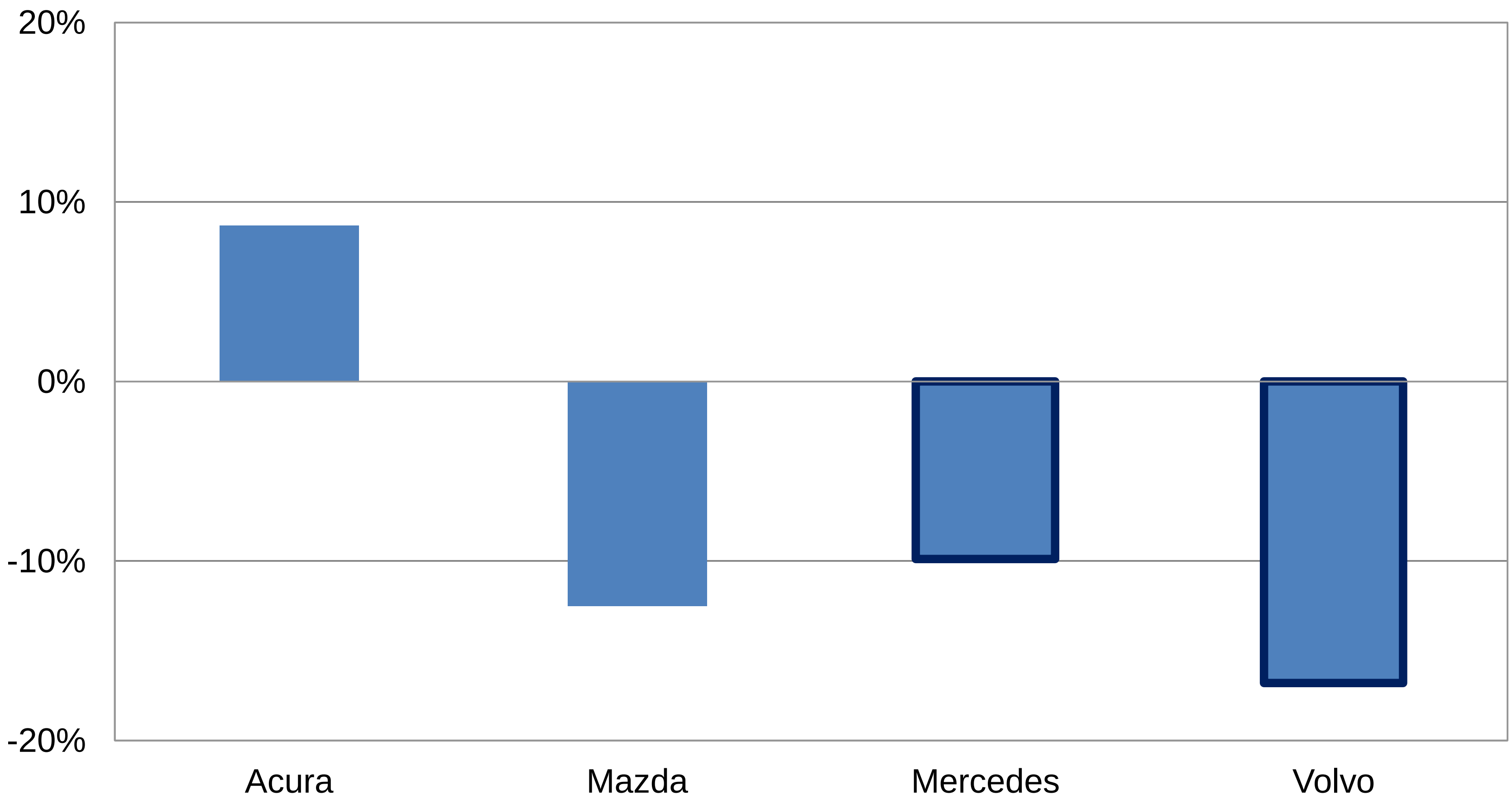
Adaptive headlights

Collision claim frequency by manufacturer



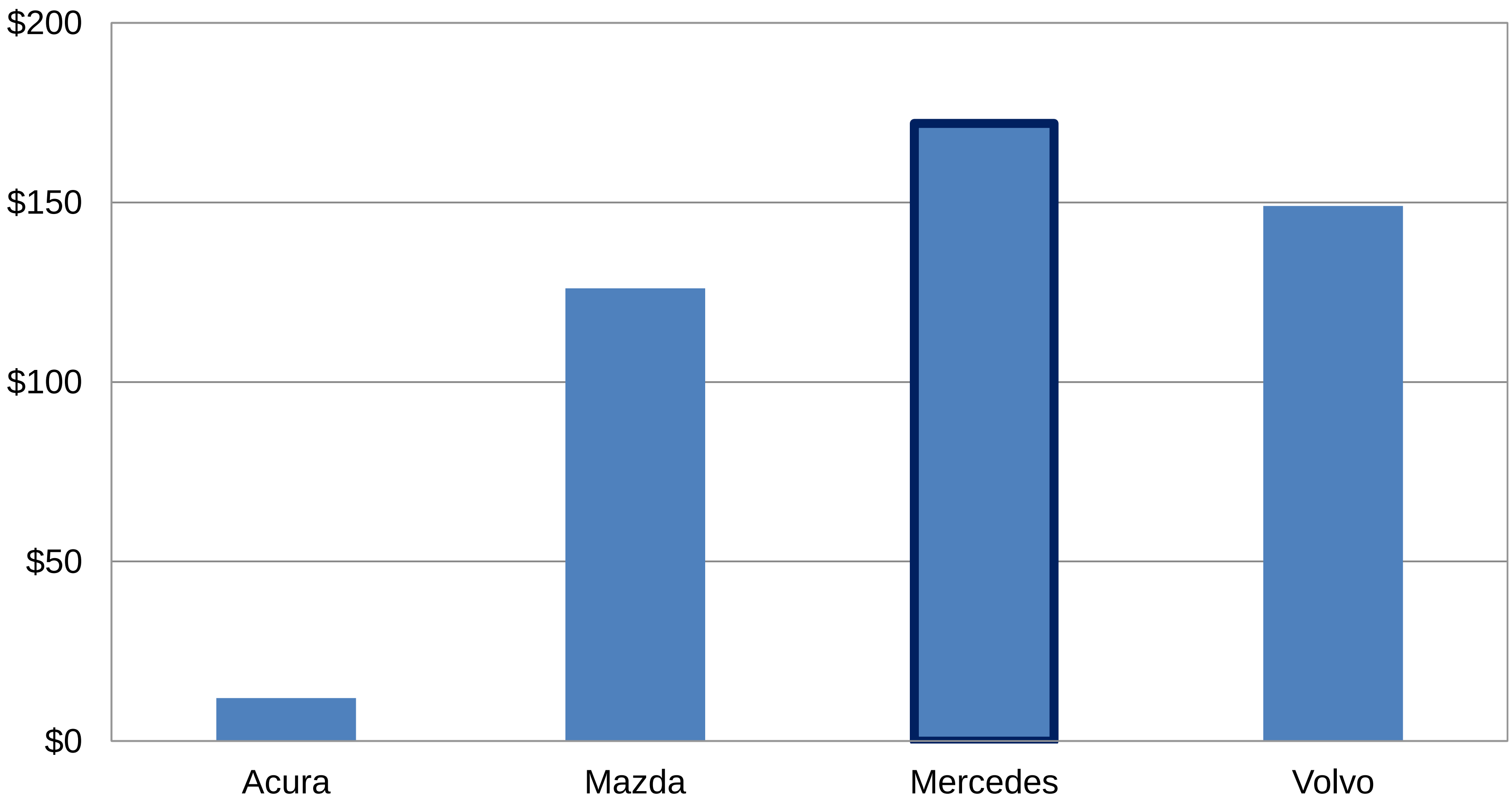
Adaptive headlights

Bodily injury claim frequency by manufacturer



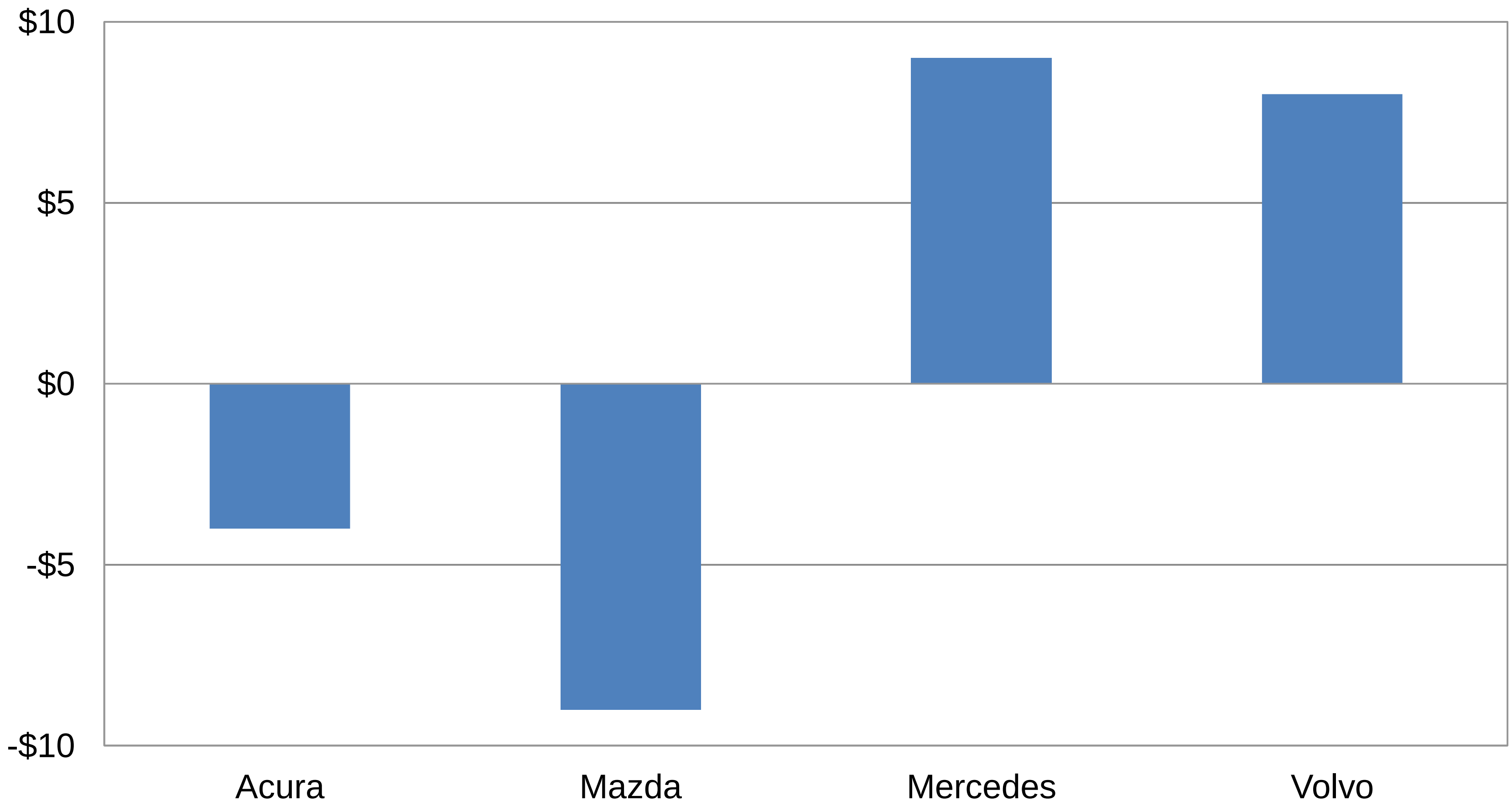
Adaptive headlights

Collision claim severity by manufacturer



Adaptive headlights

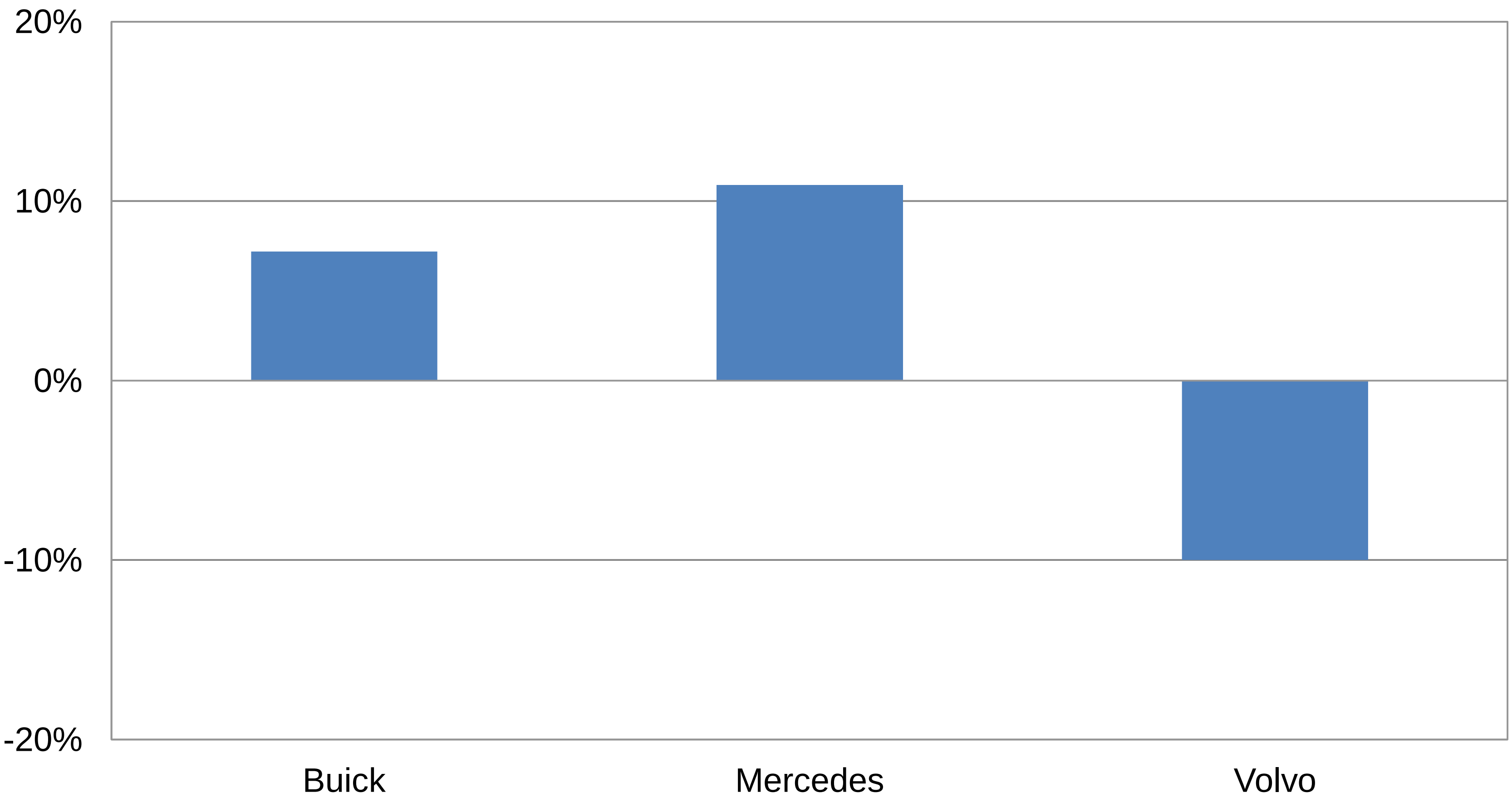
Overall collision losses by manufacturer



Lane departure warning

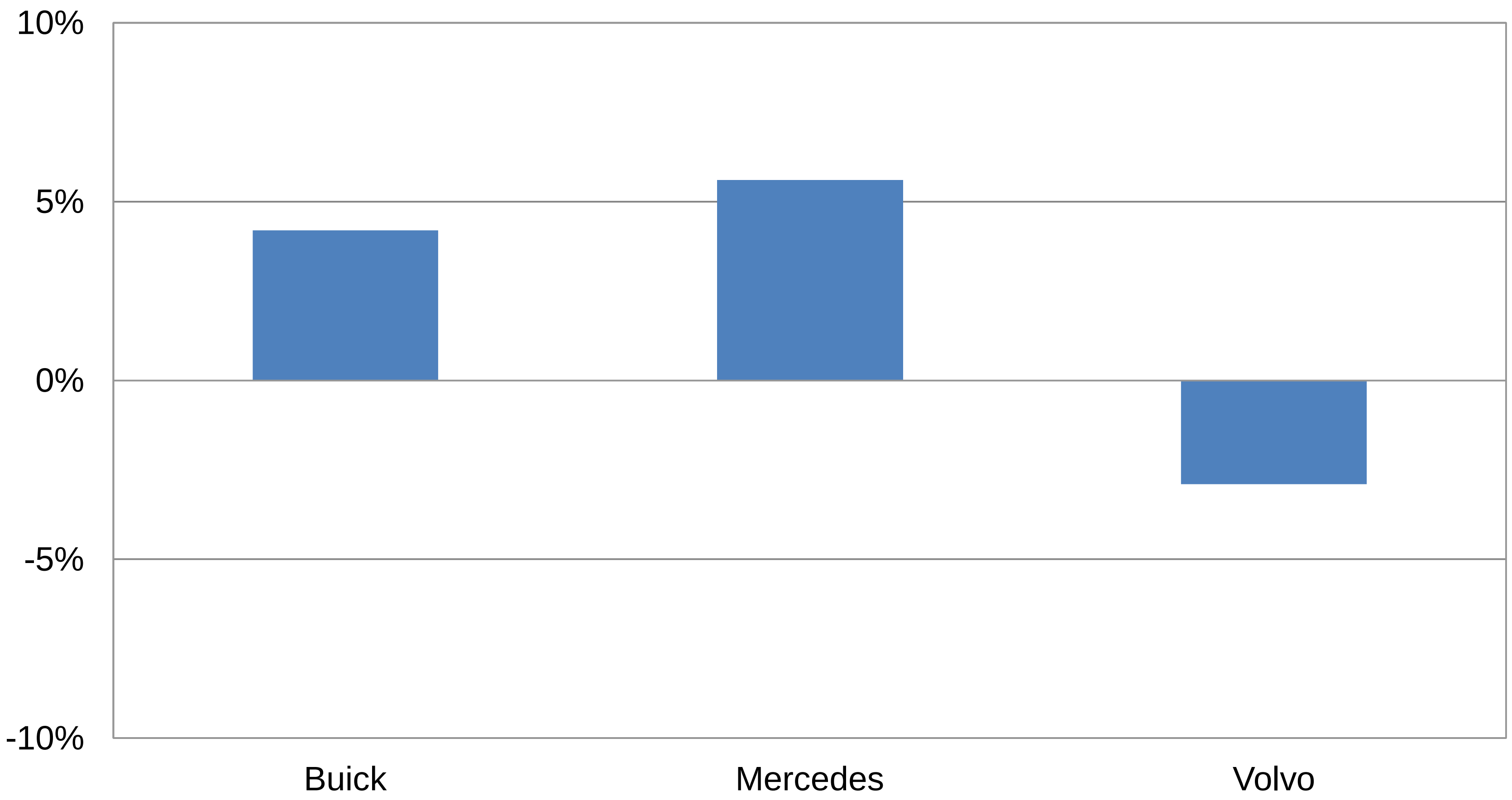
Lane departure warning without active assist

Property damage liability claim frequency by manufacturer



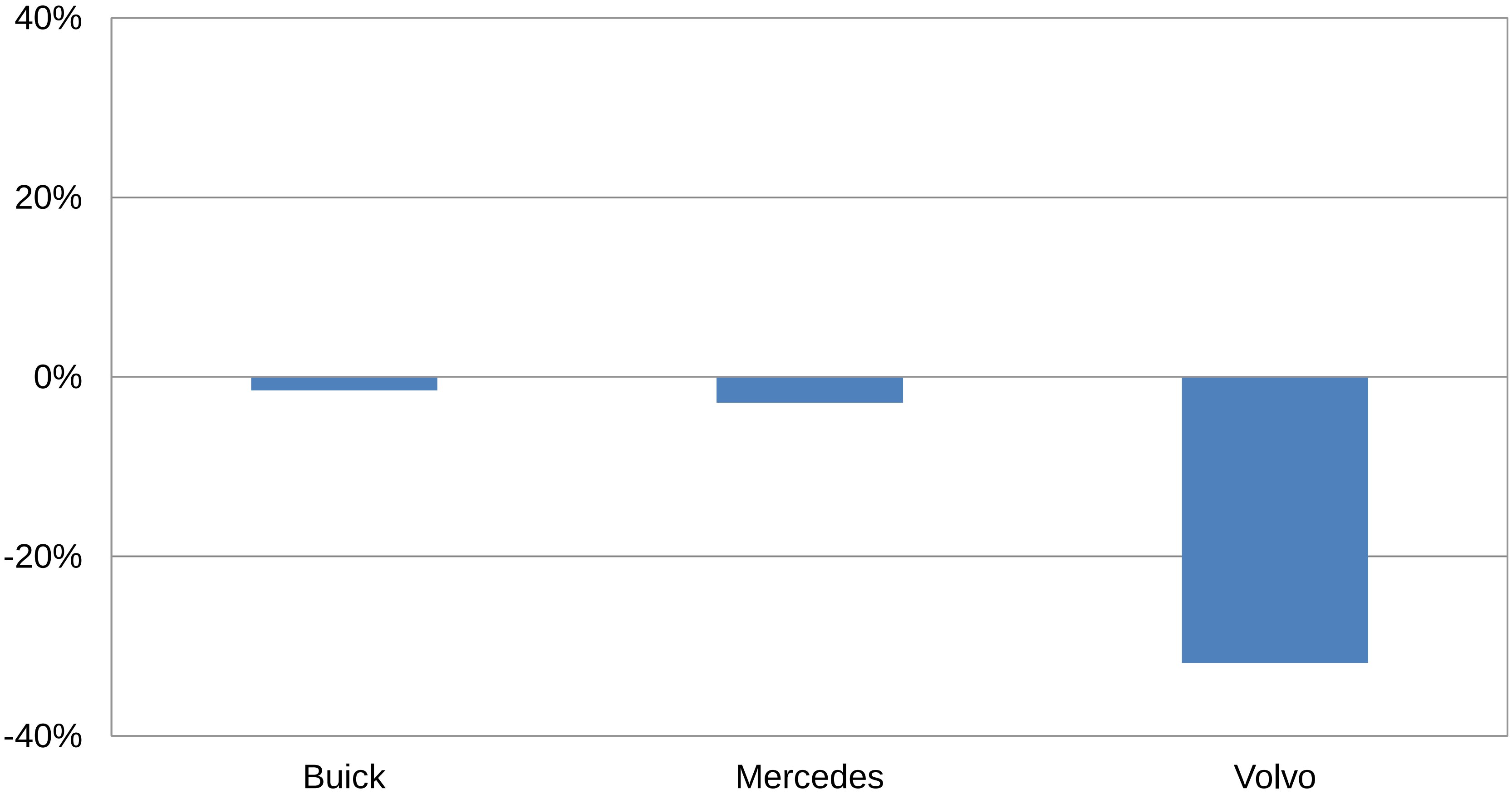
Lane departure warning without active assist

Collision claim frequency by manufacturer



Lane departure warning without active assist

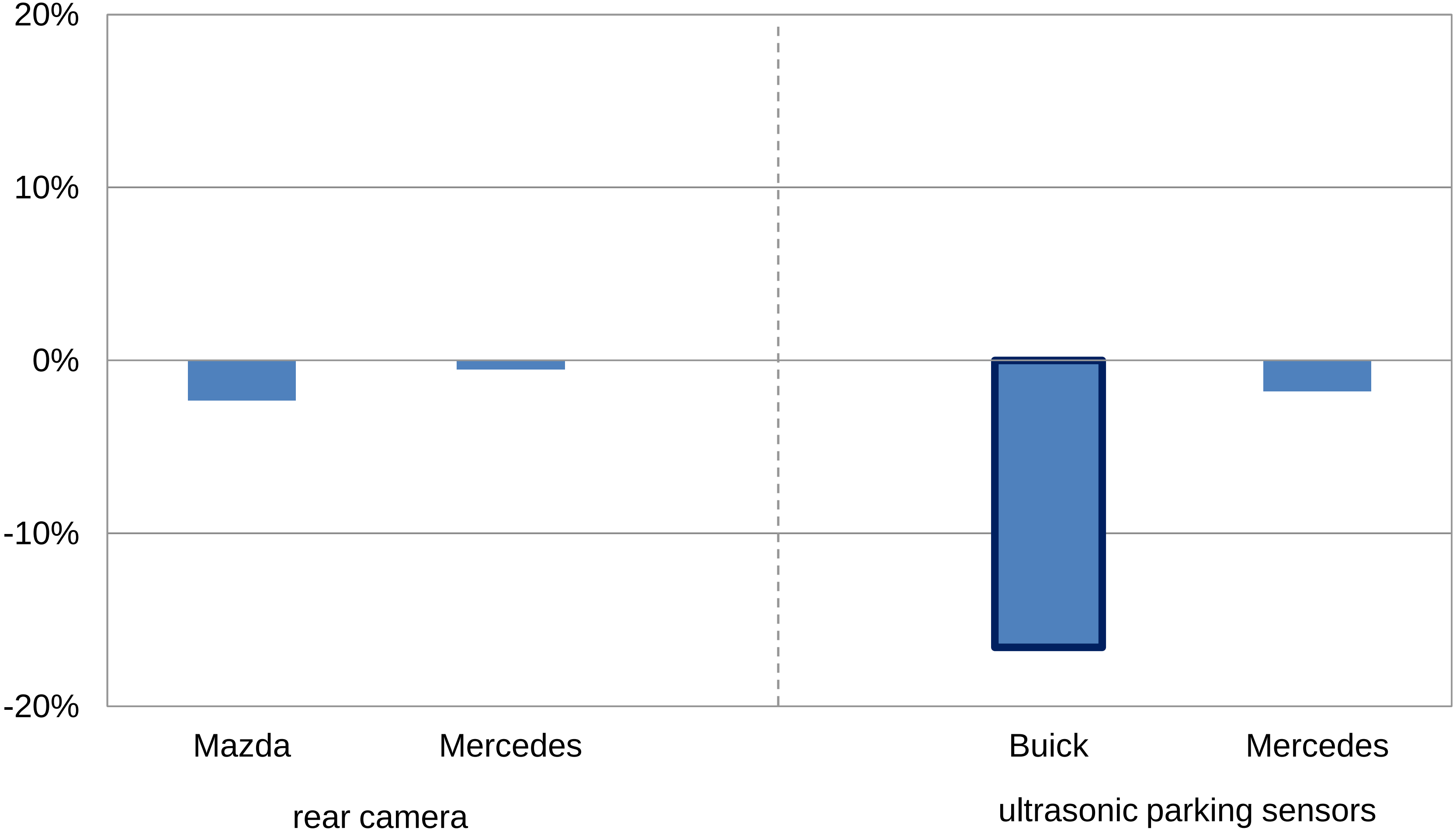
Bodily injury liability claim frequency by manufacturer



Parking assistance systems

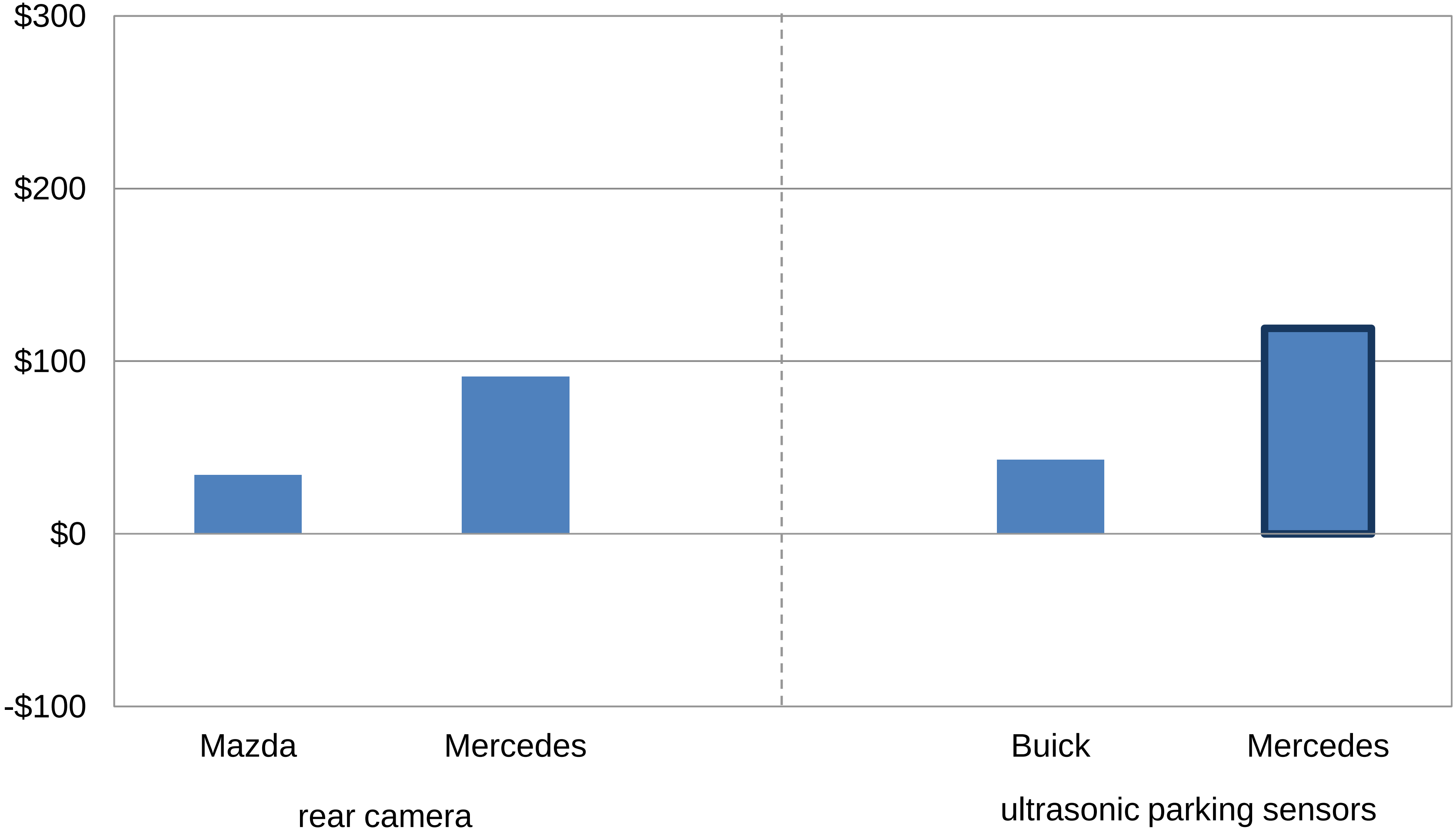
Property damage liability claim frequency for rear camera and parking sensors

By manufacturer



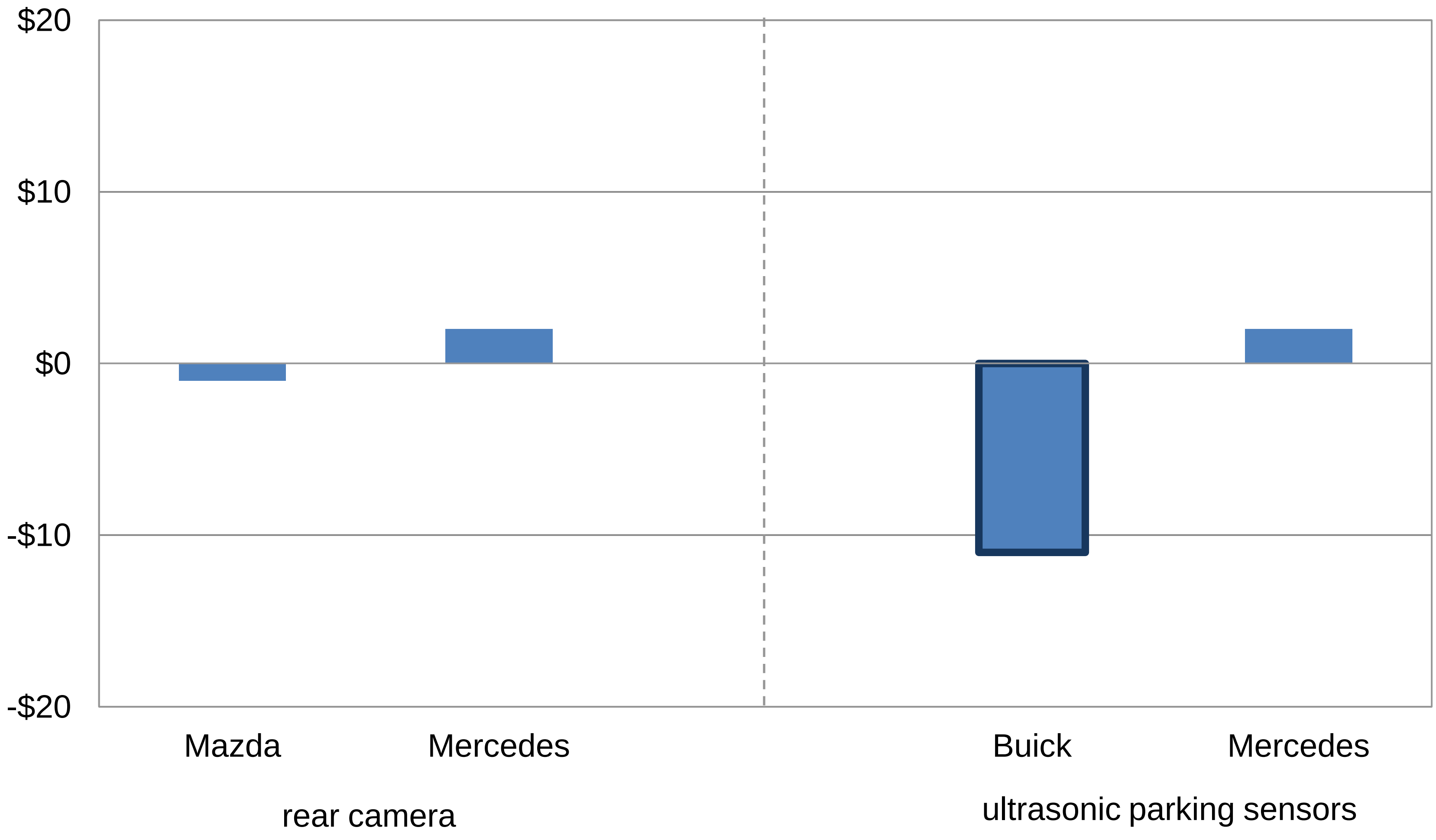
Property damage liability claim severity for rear camera and parking sensors

By manufacturer



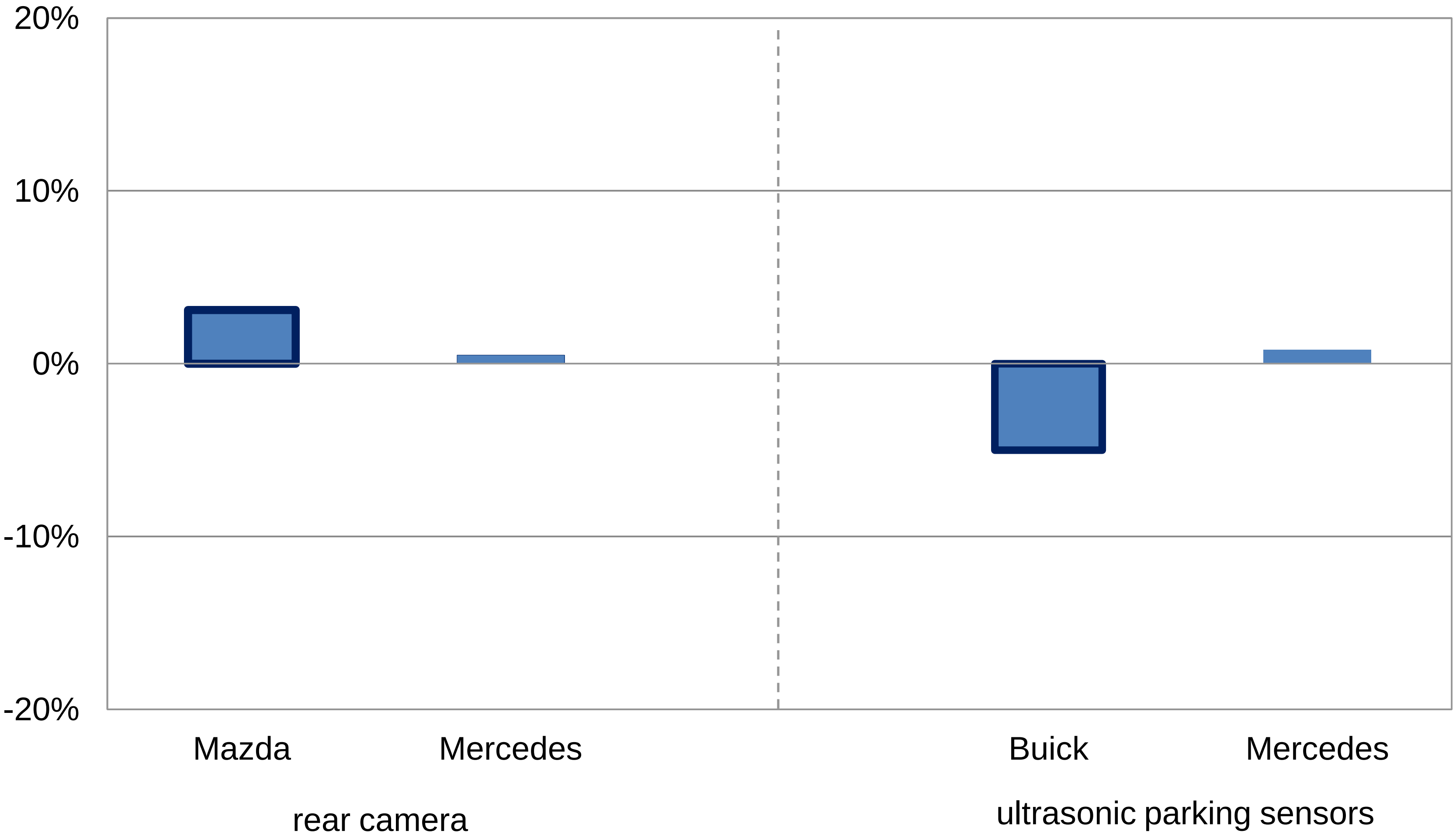
Property damage liability claim overall losses for rear camera and parking sensors

By manufacturer



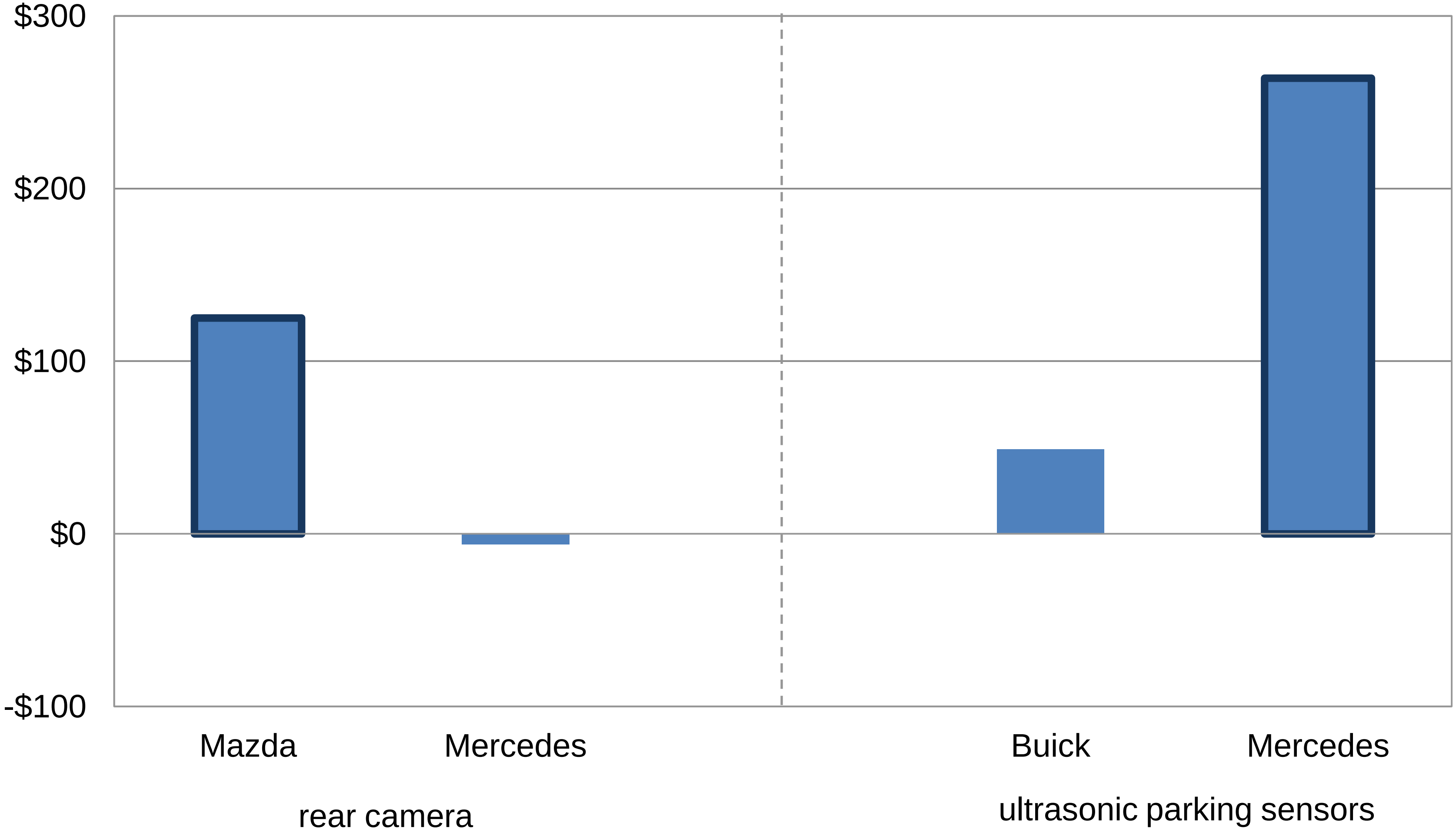
Collision claim frequency for rear camera and parking sensors

By manufacturer



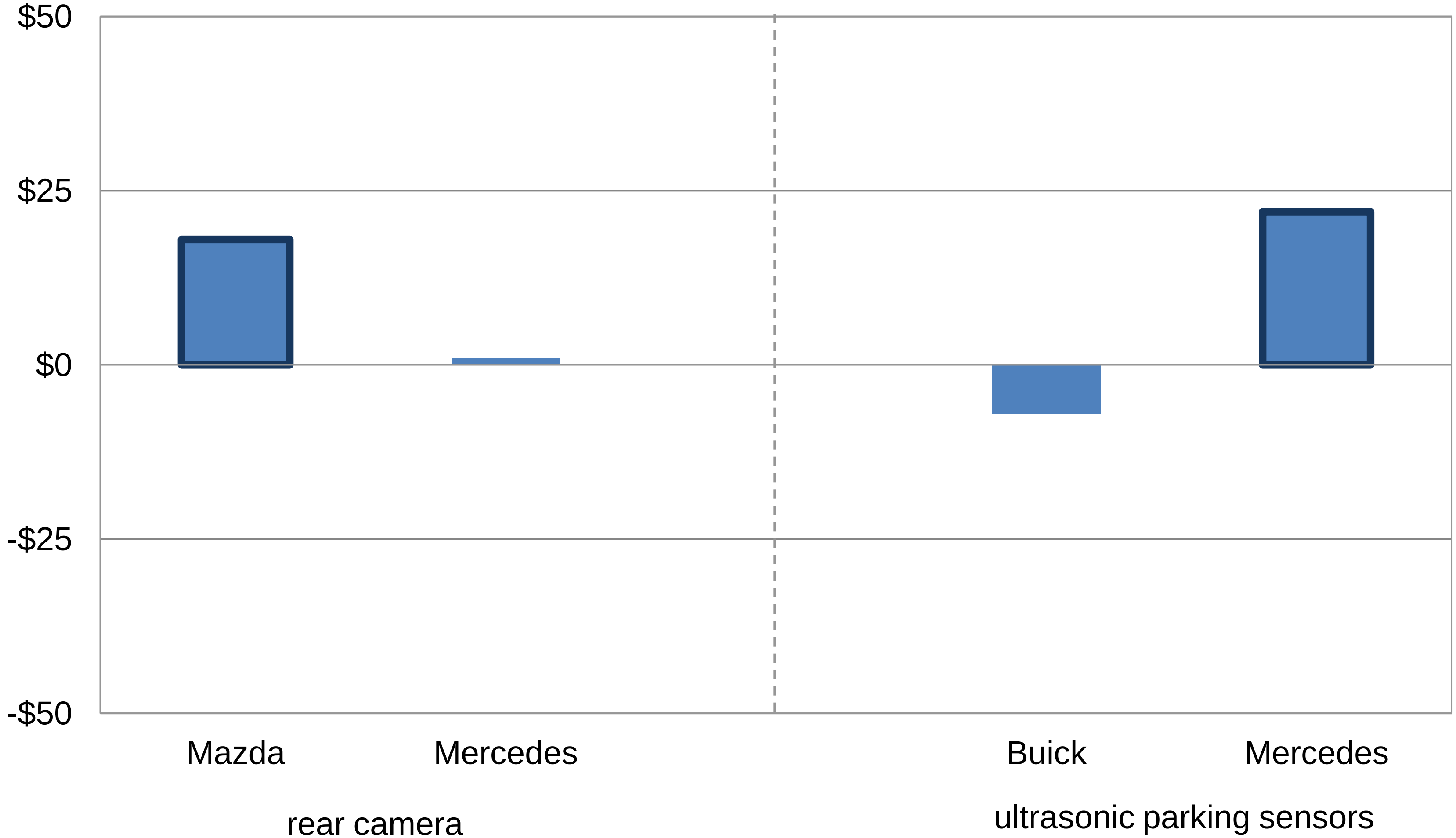
Collision claim severity for rear camera and parking sensors

By manufacturer



Collision claim overall losses for rear camera and parking sensors

By manufacturer



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Bulletin | Vol. 31, No. 15 : September 2014

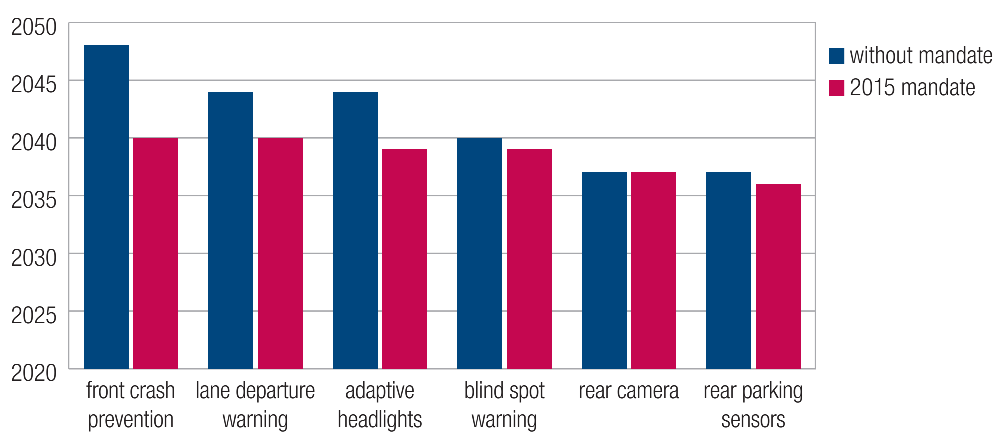
Predicted availability of safety features on registered vehicles – an update

Prior Highway Loss Data Institute (HLDI) studies have indicated that some collision avoidance systems are reducing insurance claims. Claim frequency reductions were found across all of the crash related coverages for front crash prevention systems. Reductions in bodily injury liability claims indicate the systems are functioning as intended because the systems are designed to prevent or mitigate the severity of front-to-rear crashes, the type of crash that typically results in a bodily injury liability claim. Initial evaluations of forward collision warning systems estimated reductions in bodily injury liability claim frequencies of 4–9 percent. Benefits were even greater for those systems that added autonomous braking. Systems that provided autonomous braking reduced bodily injury liability claim frequency by 14–32 percent. While the reductions are sizable, these systems were first introduced on a small number of luxury vehicles. Consequently, the impact of these systems on the population of all crashes has been limited.

Sensing technologies are evolving. Early front crash prevention systems were radar based while newer systems use radar, lasers, cameras, and/or a fusion of different sensing technologies. As the sensing technologies have evolved, the price of the systems have dropped and, as a consequence, some non-luxury vehicles are now available with these technologies. For example, the 2013 Honda Accord was offered with a camera-based front crash prevention system and lane departure system. A study of that system found reductions in claim frequencies across all of the crash related coverages. The bodily injury liability reduction was a statistically significant 40 percent. The Honda Accord is one of the best-selling cars in the United States. Given the high sales volume of this vehicle, the effectiveness of the front crash prevention system on the Accord could have an impact on gross insurance losses. Honda's decision to equip Accords with this technology may cause other manufacturers to equip comparable vehicles with comparable technologies causing a surge in the number of vehicles with available front crash prevention systems.

A prior report from HLDI (2012) showed that it typically takes approximately three decades for technologies to spread through the fleet. The current analysis uses similar methodology but focuses on collision avoidance features. The analysis shows that it typically takes decades before most vehicles on the road could have a given feature, either because it came as standard equipment or was offered as an option. For example, it will not be until 2037 that 95 percent of all registered vehicles could have rear park assist, which was rolled out in the United States in 1995. Front crash prevention systems, which rolled out in the United States in 2000, could take even longer. If it continues to follow its current trajectory, the crash avoidance technology will not be available in 95 percent of registered vehicles until 2048. Federal mandates would accelerate the fitment of these features. As shown below, a mandate for 2015 model vehicles could speed up the penetration of some features in the fleet by as much as 8 years.

Calendar year features reach 95% of registered vehicle fleet with and without mandate



Introduction

Given the potential and proven benefits of collision avoidance systems, it is almost certain that these systems will reduce the number of crashes and insurance claims. While estimating the efficacy of available systems is an important part of understanding the long-term impact of these systems, it is also important to understand the prevalence of these systems in the current fleet and to estimate their growth in the fleet over time. The purpose of this bulletin is to quantify the prevalence of vehicle features in the registered vehicle fleet, trace that prevalence from introduction through the most current registration data, and then to predict the prevalence in the future.

Methods

This bulletin combines vehicle feature information from the Highway Loss Data Institute (HLDI) with vehicle registration data from R.L. Polk and Company. For each feature studied there are three figures:

- The **first figure** illustrates the percentage of new vehicle series with a given feature by model year. In this figure, each new vehicle series (model year, make, series) is a single observation. The observations have not been weighted by insurance exposure or vehicle registration information. Using new vehicle series to illustrate how common a feature is can be deceiving because new safety features typically appear initially on luxury vehicles, which tend to be sold in lower volumes than non-luxury vehicles.
- The **second figure** for each feature illustrates the percentage of registered vehicles with a feature by calendar year. In this figure, each observation (model year, make, series) is weighted by the number of registered vehicles.
- The **third figure** for each feature illustrates the predicted availability for that feature. The actual availability is also displayed for comparison. This figure helps to provide insight into the time required for the presence of a feature to build in the registered vehicle fleet.

The following features are included in this bulletin: electronic stability control (ESC), rear park assist, front crash prevention systems, rear camera, adaptive front lighting systems, lane departure warning (LDW), and blind spot monitor.

Vehicle feature information was obtained by HLDI. The feature information is structured by model year, make, and series. The same three variables were mapped to the registration data from R.L. Polk. For each model year- make-series combination, one of three possible feature values are provided: “standard,” “optional,” and “not available.”

Registration counts belonging to either of the first two groups are hereafter referred to as “available.” For example, in calendar year 2008, 9.7 percent of registered vehicles had standard ESC and another 10.8 percent had it as an option, so it is said that ESC was available in 20.5 percent of the 2008 registered vehicles.

The most recent R.L. Polk data available to HLDI contains calendar years 1976 to 2013. For each calendar year, a number of recent model years is available, ranging from 9 model years for calendar year 1976 to 37 model years for calendar year 2013. The number of model years included in each calendar year has increased over time. For calendar years 2003 and later, the 37 most recent model years were available. For calendar years 1996 to 2002, 30 of the most recent model years were in the dataset. This covered at least 95 percent of the overall fleet in calendar years where safety features started to gain popularity. There are model years that are present in earlier calendar years, age out of the dataset, and then re-enter when the dataset was expanded. To increase the amount of usable data, missing values were extrapolated based on existing values. Polk has restated some of its data. In this report, original data was used from 1976 to 2008 while restated data was used for calendar years 2009–13.

Approach used to estimate the number of new vehicles: In order to estimate the number of new vehicles in 2014, registrations for new vehicles for the prior 5 calendar years (2009–13) were averaged. New vehicles are defined as vehicles aged 0 and -1. For example, a 2012 model year in calendar year 2012 would have a vehicle age of 0 while a 2013 vehicle in the same calendar year would be aged -1. To predict new vehicle registrations for calendar years 2015–50, a 30-year past trend in new vehicle registrations was studied. Over this period, new vehicle registrations increased on average 1.4 percent per calendar year. New vehicle counts for 2015 and beyond were calculated by adding 1.4 percent to the prior year registration counts.

Approach used to estimate attrition rates: Attrition rates were calculated for each calendar/model year combinations through 2013 and applied to future years (2014–50) and vehicles of the same age. Additionally, to account for changes in attrition, a 30-year past trend was studied. Over this time period, attrition rates declined on average 0.2 percent per calendar year. Based on this, the attrition was estimated to be slower by 3.8 percentage points (0.2% * (1+37)/2) on average in the future years (2014–50). Different attrition rates were explored and can be seen in the **Appendix**. For the next 20 years, there was little difference between the rates. The attrition assumptions will be monitored, refined, and modified as needed for future analysis.

The estimation procedure was conducted separately for each feature in the study. The procedure involved running a logistic regression model (assuming a binomial distribution with a probit link) on the past year data where feature prevalence is known and then applying the model estimates to predict the feature prevalence for future years.

The dependent variable in the model was the ratio of the registration count where the feature was available to the total registration count. The only two independent variables were calendar year and model year.

Results

Figure 1: Percentage of new vehicle series with ESC

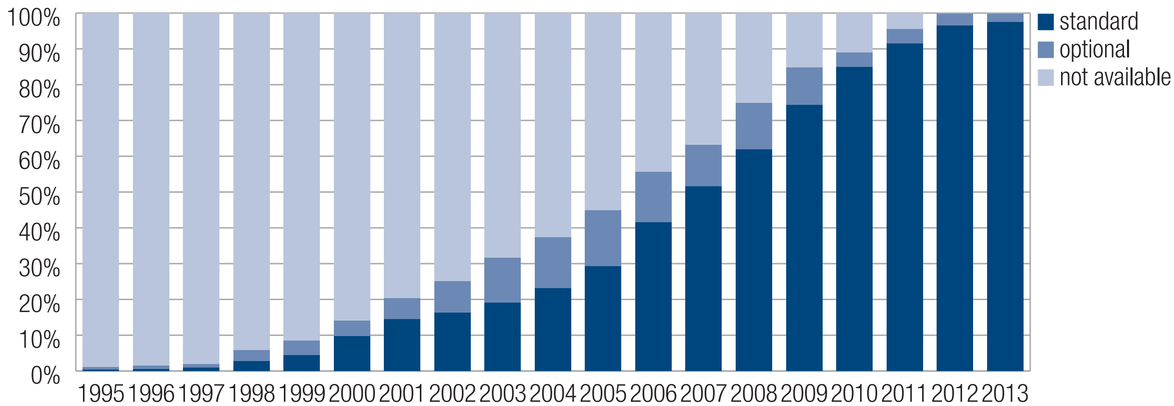


Figure 1 shows the percentage of vehicle series by model year with either standard or optional ESC. ESC was introduced in model year 1995 and by the 2004 model year had become standard on 23 percent and optional on 14 percent of vehicle series. For the 2013 model year, ESC was standard on 97 percent and optional on 2 percent of vehicle series. ESC has been required on all light duty vehicles beginning September 1, 2011. In model year 2013, the only vehicles that do not have standard ESC are very large pickup trucks weighing more than 10,000 pounds and not subject to the regulation.

Figure 2: Percentage of registered vehicles with ESC

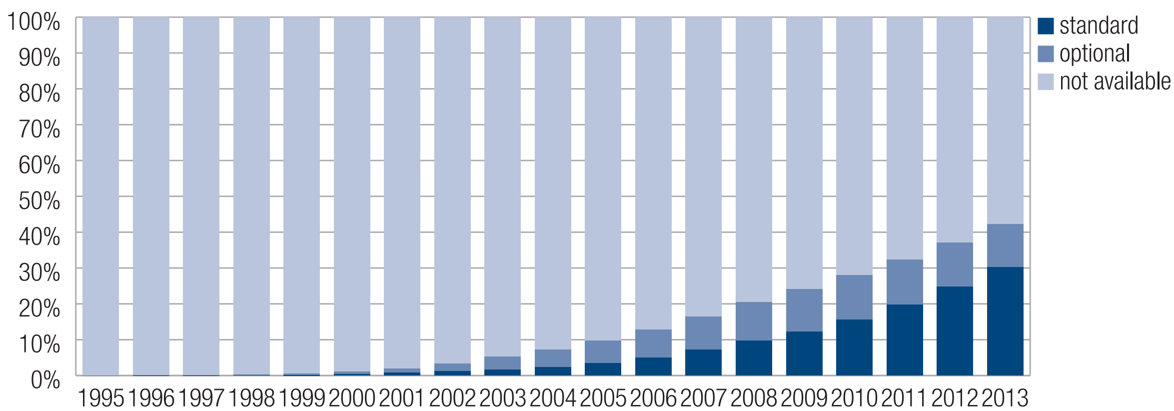


Figure 2 shows the percentage of registered vehicles by calendar year with either standard or optional ESC. By 2004, ESC had become standard on 2 percent and optional on 5 percent of registered vehicles. By 2013, ESC was standard or optional on 42 percent of registered vehicles.

Figure 3: Predicted percentage of registered vehicles with ESC

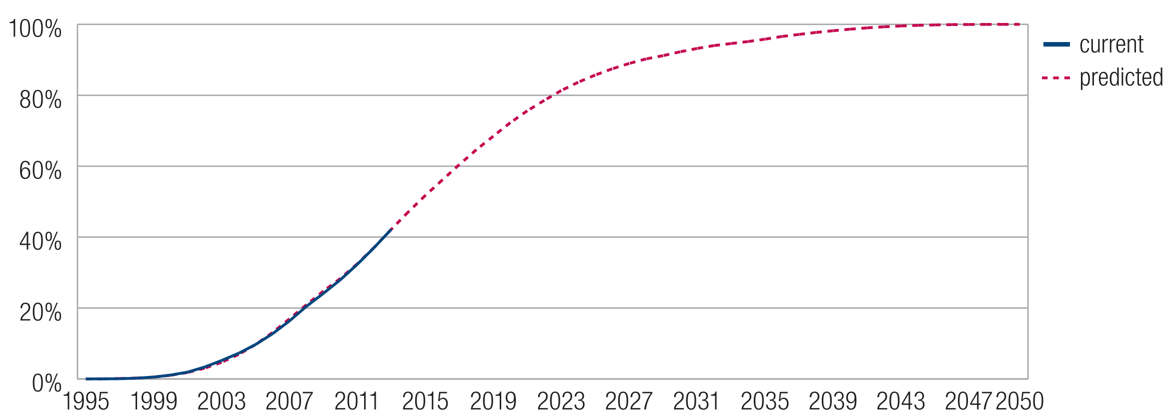


Figure 3 shows the percentage of predicted registered vehicles by calendar year with either standard or optional ESC. It is predicted that ESC will be standard or optional on 95 percent of registered vehicles in 2033.

Figure 4: Percentage of new vehicle series with rear park assist

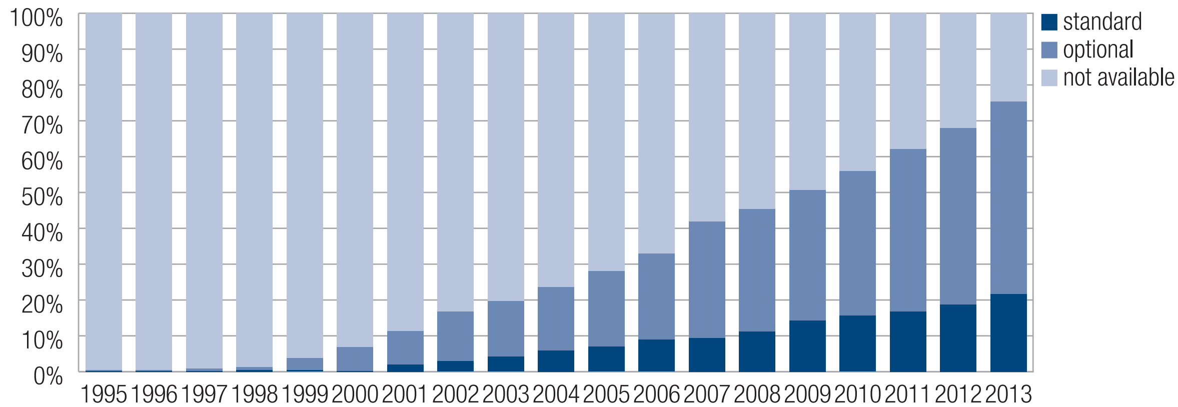


Figure 4 shows the percentage of vehicle series by model year with either standard or optional rear park assist. Rear park assist was introduced in model year 1995 and by the 2004 model year had become standard on 6 percent and optional on 18 percent of vehicle series. For the 2013 model year, rear park assist was standard on 22 percent and optional on 54 percent of vehicle series.

Figure 5: Percentage of registered vehicles with rear park assist

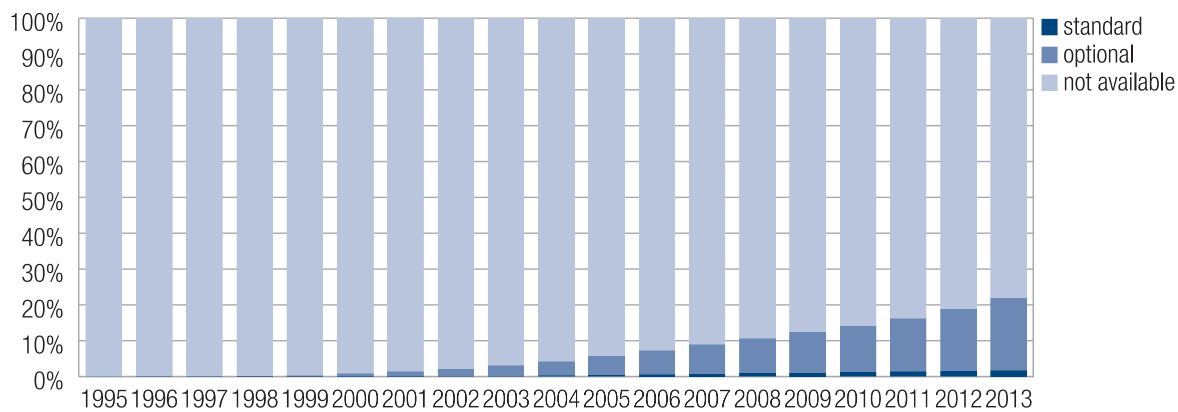


Figure 5 shows the percentage of registered vehicles by calendar year with either standard or optional rear park assist. By 2004, rear park assist had become standard on less than 1 percent and optional on 4 percent of registered vehicles. By 2013, rear park assist was standard or optional on 22 percent of registered vehicles.

Figure 6: Predicted percentage of registered vehicles with rear park assist

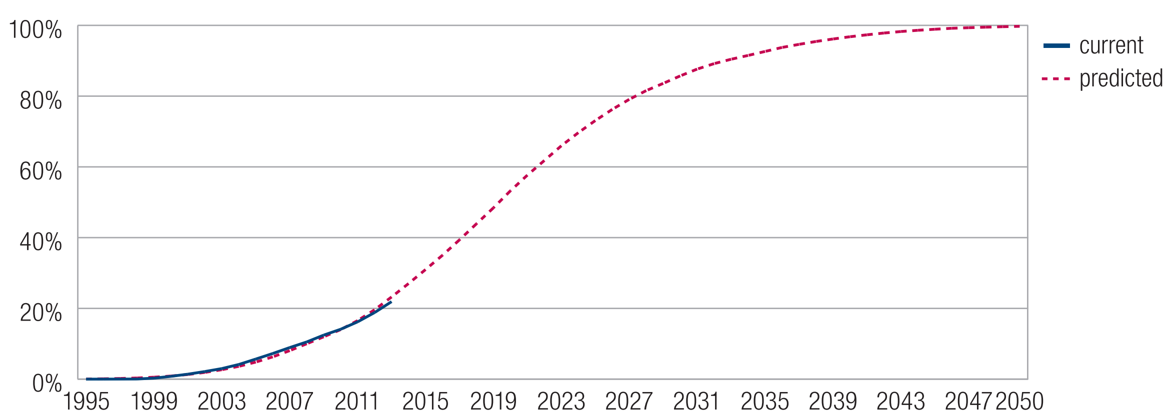


Figure 6 shows the percentage of predicted registered vehicles by calendar year with either standard or optional rear park assist. It is predicted that rear park assist will be standard or optional on 95 percent of registered vehicles in 2037.

Figure 7: Percentage of new vehicle series with front crash prevention

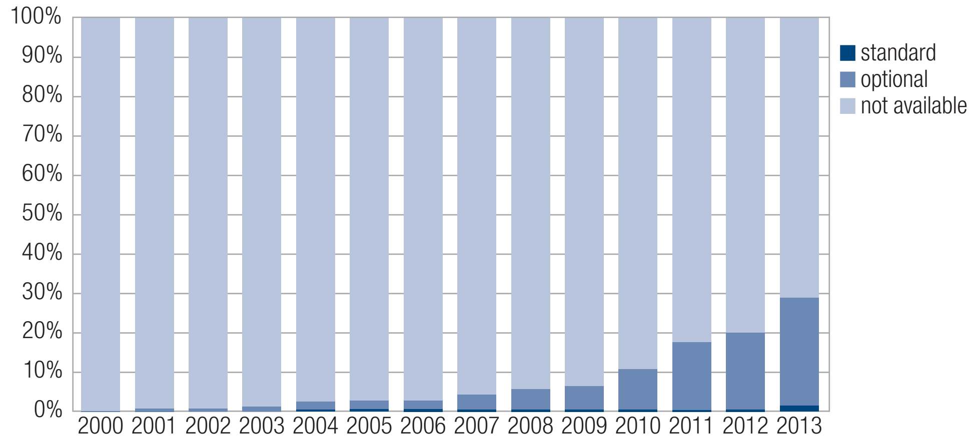


Figure 7 shows the percentage of vehicle series by model year with either standard or optional front crash prevention. Front crash prevention was introduced in model year 2000 and by the 2006 model year had become standard on 1 percent and optional on 2 percent of vehicle series. For the 2013 model year, front crash prevention was standard on 2 percent and optional on 27 percent of vehicle series.

Figure 8: Percentage of registered vehicles with front crash prevention

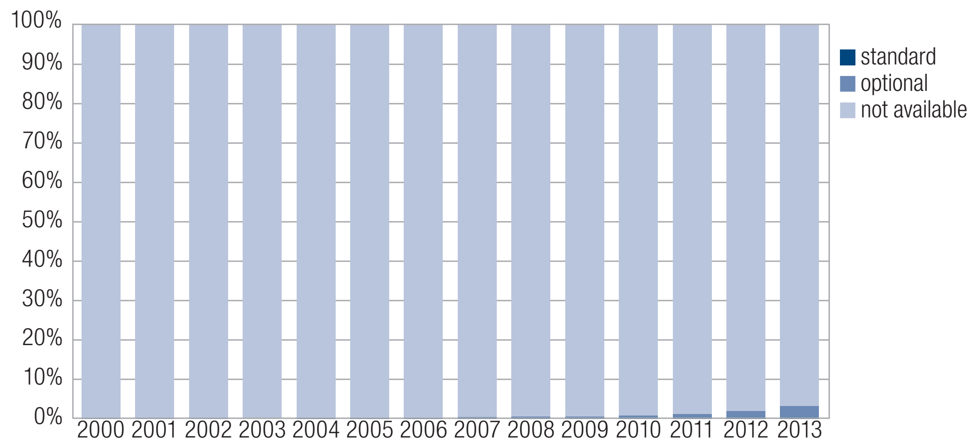


Figure 8 shows the percentage of registered vehicles by calendar year with either standard or optional front crash prevention. By 2006, front crash prevention had become standard on less than 1 percent and optional on less than 1 percent of registered vehicles. By 2013, front crash prevention was standard or optional on 3 percent of registered vehicles.

Figure 9: Predicted percentage of registered vehicles with front crash prevention

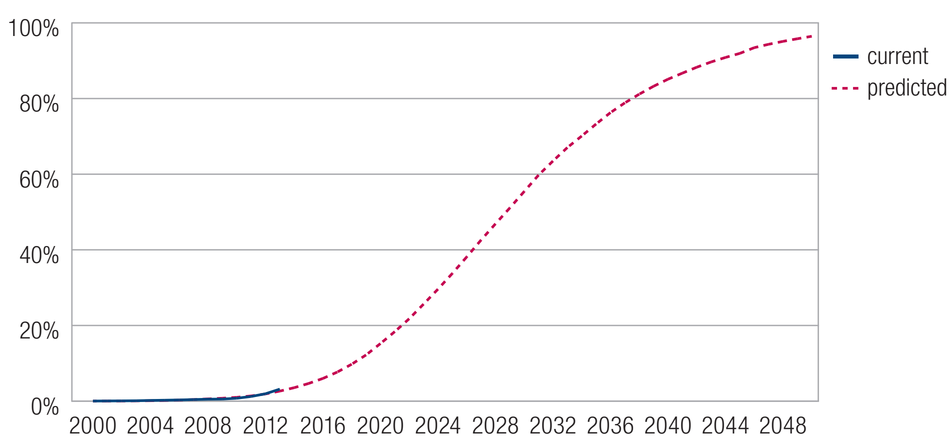


Figure 9 shows the percentage of predicted registered vehicles by calendar year with either standard or optional front crash prevention. It is predicted that front crash prevention will be standard or optional on 95 percent of registered vehicles in 2048.

Figure 10: Percentage of new vehicle series with rear camera

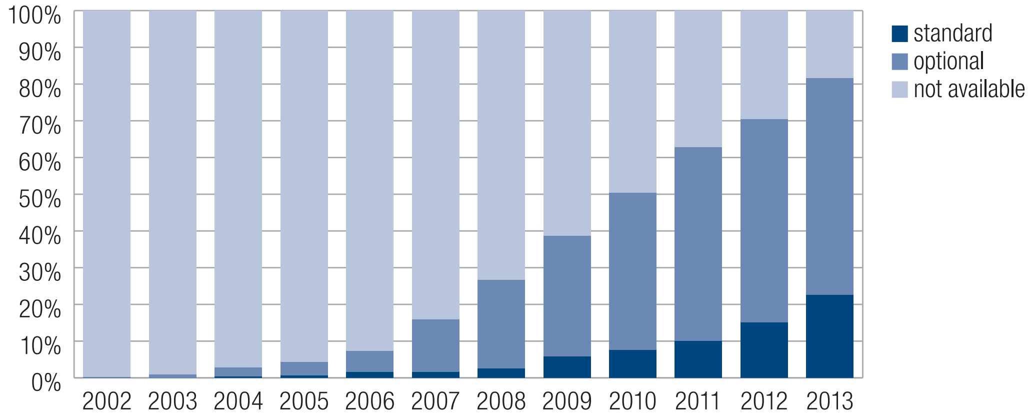


Figure 10 shows the percentage of vehicle series by model year with either standard or optional rear cameras. Rear cameras were introduced in model year 2002 and by the 2007 model year had become standard on 2 percent and optional on 14 percent of vehicle series. For the 2013 model year, rear cameras were standard on 23 percent and optional on 59 percent of vehicle series. Rear cameras will be required in all new vehicles starting May 1, 2018.

Figure 11: Percentage of registered vehicles with rear camera

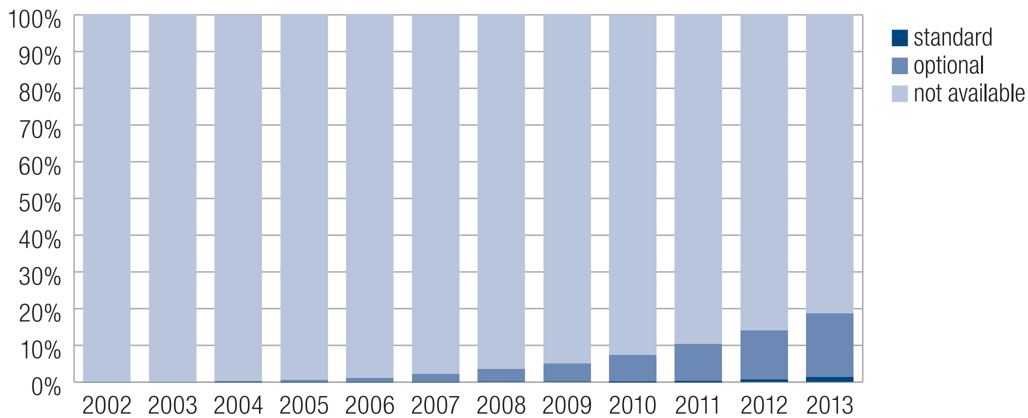


Figure 11 shows the percentage of registered vehicles by calendar year with either standard or optional rear cameras. By 2007, rear cameras had become standard on less than 1 percent and optional on 2 percent of registered vehicles. By 2013, rear cameras were standard or optional on 19 percent of registered vehicles.

Figure 12: Predicted percentage of registered vehicles with rear camera

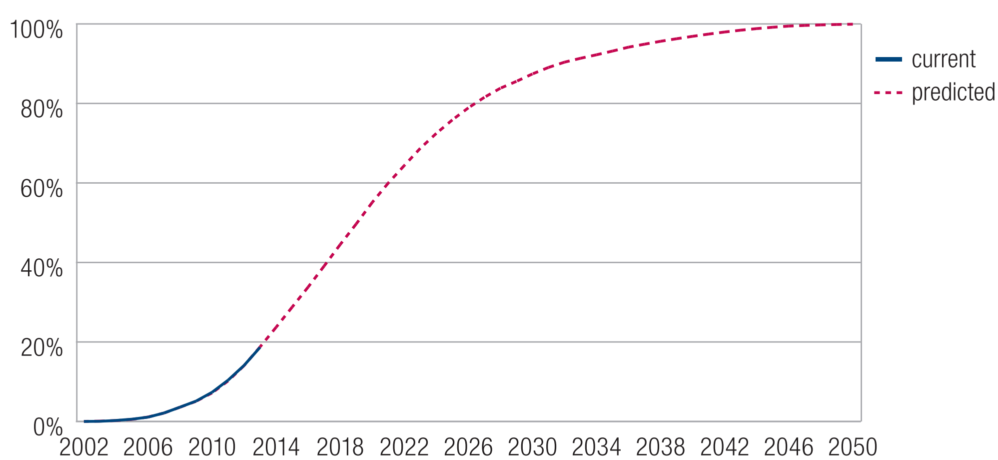


Figure 12 shows the percentage of predicted registered vehicles by calendar year with either standard or optional rear cameras. It is predicted that rear cameras will be standard or optional on 95 percent of registered vehicles in 2037.

Figure 13: Percentage of new vehicle series with adaptive headlights

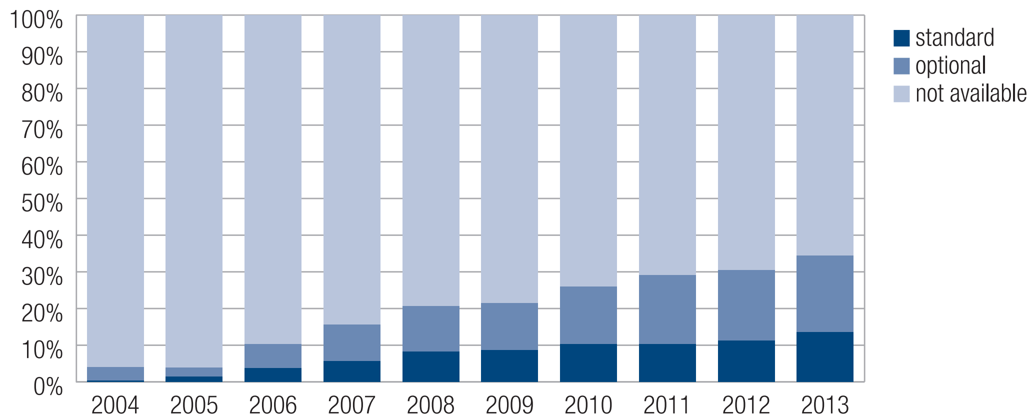


Figure 13 shows the percentage of vehicle series by model year with either standard or optional adaptive headlights. Adaptive headlights were introduced in model year 2004 and by the 2008 model year had become standard on 8 percent and optional on 12 percent of vehicle series. For the 2013 model year, adaptive headlights were standard on 14 percent and optional on 21 percent of vehicle series.

Figure 14: Percentage of registered vehicles with adaptive headlights

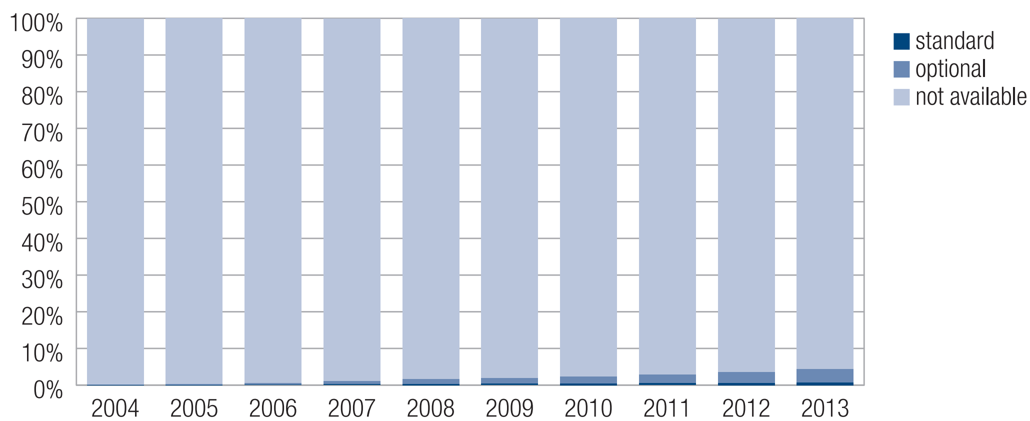


Figure 14 shows the percentage of registered vehicles by calendar year with either standard or optional adaptive headlights. By 2008, adaptive headlights had become standard on less than 1 percent and optional on 1 percent of registered vehicles. By 2013, adaptive headlights were standard or optional on 4 percent of registered vehicles.

Figure 15: Predicted percentage of registered vehicles with adaptive headlights

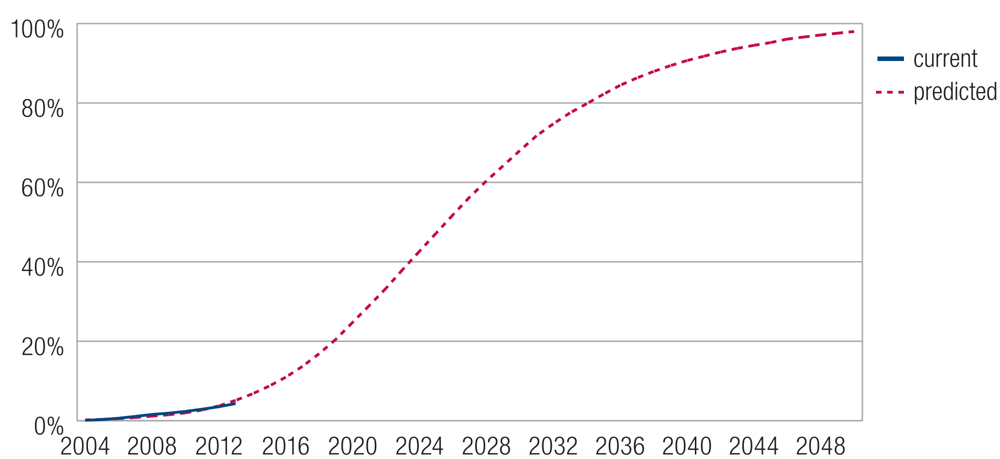


Figure 15 shows the percentage of predicted registered vehicles by calendar year with either standard or optional adaptive headlights. It is predicted that adaptive headlights will be standard or optional on 95 percent of registered vehicles in 2044.

Figure 16: Percentage of new vehicle series with lane departure warning

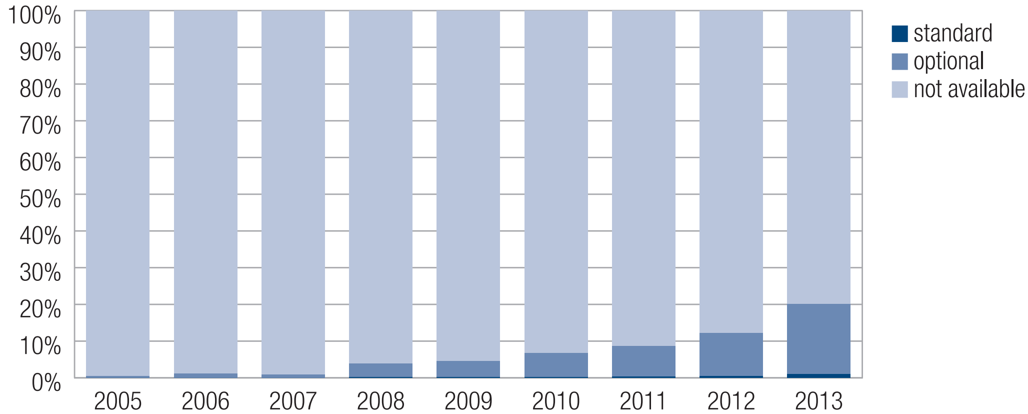


Figure 16 shows the percentage of vehicle series by model year with either standard or optional lane departure warning. Lane departure warning was introduced in model year 2005 and by the 2009 model year had become standard on less than 1 percent and optional on 4 percent of vehicle series. For the 2013 model year, lane departure warning was standard on 1 percent and optional on 19 percent of vehicle series.

Figure 17: Percentage of registered vehicles with lane departure warning

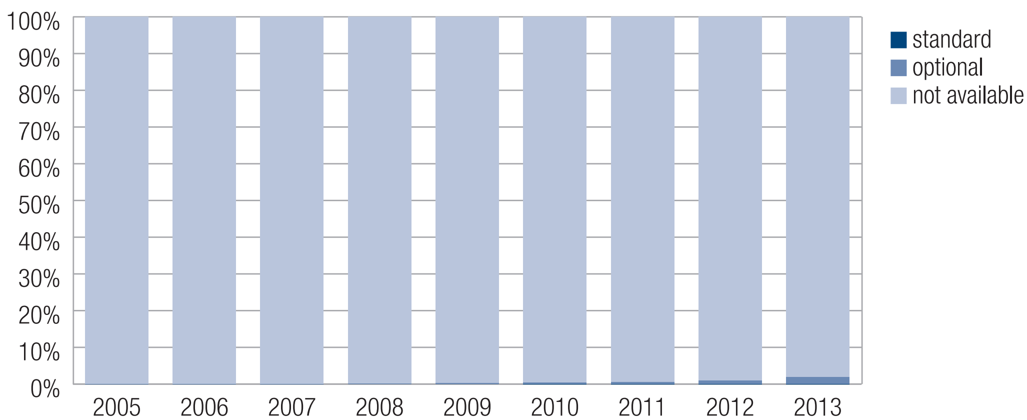


Figure 17 shows the percentage of registered vehicles by calendar year with either standard or optional lane departure warning. By 2009, lane departure warning had become standard on less than 1 percent and optional on less than 1 percent of registered vehicles. By 2013, lane departure warning was standard or optional on 2 percent of registered vehicles.

Figure 18: Predicted percentage of registered vehicles with lane departure warning

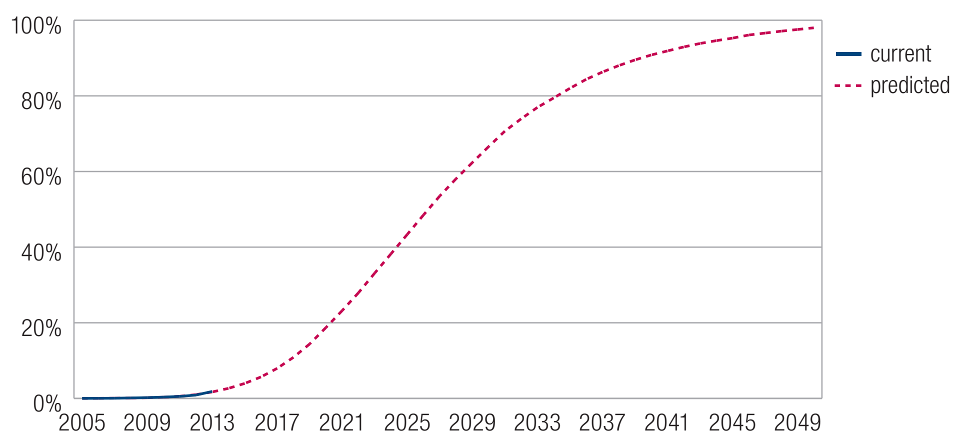


Figure 18 shows the percentage of predicted registered vehicles by calendar year with either standard or optional lane departure warning. It is predicted that lane departure warning will be standard or optional on 95 percent of registered vehicles in 2044.

Figure 19: Percentage of new vehicle series with blind spot monitor

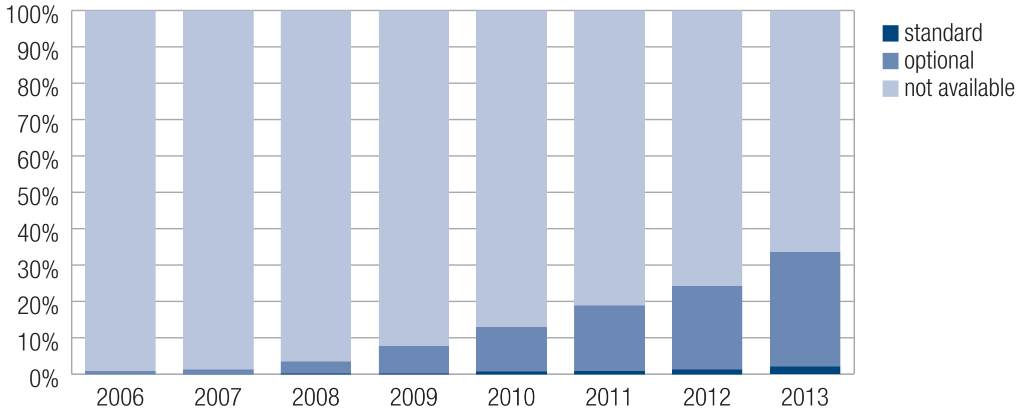


Figure 19 shows the percentage of vehicle series by model year with either standard or optional blind spot monitor. Blind spot monitor was introduced in model year 2006 and by the 2009 model year had become standard on less than 1 percent and optional on 8 percent of vehicle series. For the 2013 model year, blind spot monitor was standard on 2 percent and optional on 31 percent of vehicle series.

Figure 20: Percentage of registered vehicles with blind spot monitor

Figure 20 shows the percentage of registered vehicles by calendar year with either standard or optional blind spot monitor. By 2009, blind spot monitor had become standard on less than 1 percent and optional on less than 1 percent of registered vehicles. By 2013, blind spot monitor was standard or optional on 4 percent of registered vehicles.

Figure 21: Predicted percentage of registered vehicles blind spot monitor

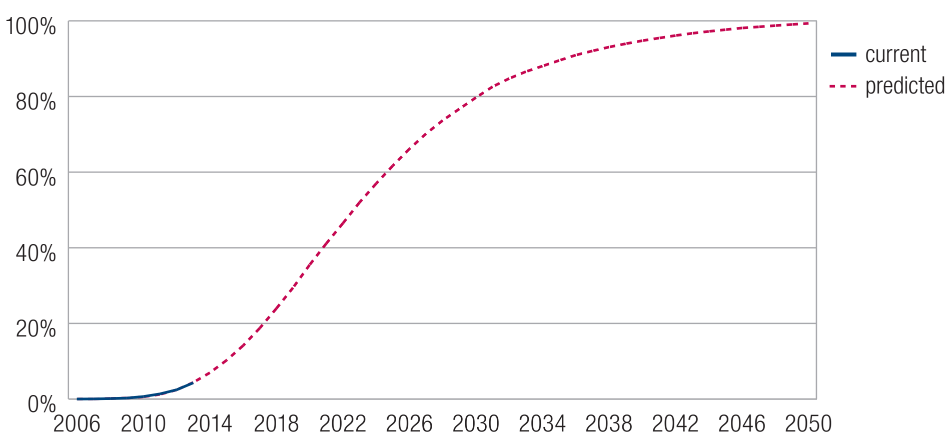
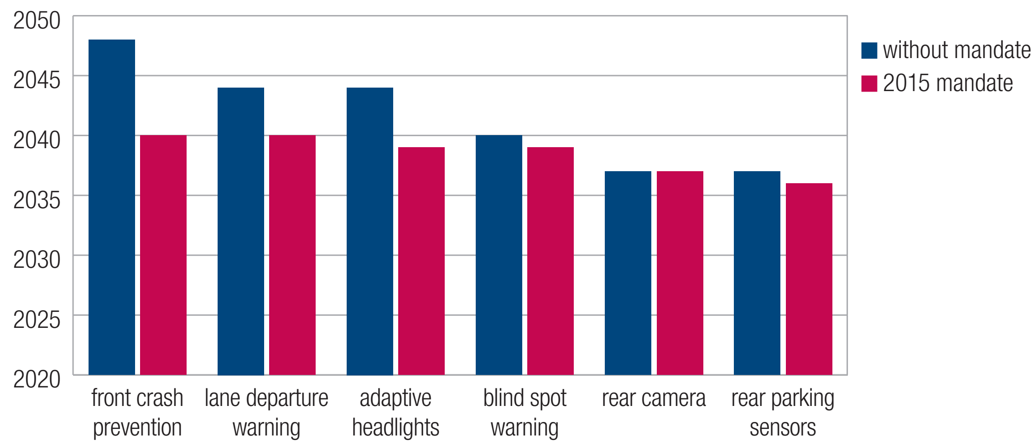


Figure 21 shows the percentage of predicted registered vehicles by calendar year with either standard or optional blind spot monitor. It is predicted that blind spot monitor will be standard or optional on 95 percent of registered vehicles in 2040.

Discussion

It takes a long time for new vehicle features to spread through the registered vehicle fleet. Even when features are required by NHTSA, it takes many years for features to be available on all vehicles. ESC for example, was first available to consumers in 1995 and shown to be effective in reducing insurance losses and deaths. It has been required on all light duty vehicles since September 1, 2011. However, even with that requirement in place for several years only 42 percent of the vehicle fleet had this feature available in 2013. It will take until 2033 for 95 percent of the fleet to be equipped with ESC. Many collision avoidance features have been recently introduced to the fleet and to date only rear cameras have been mandated by NHTSA. Figure 22 demonstrates the length of time it takes a feature to reach 95 percent of the fleet. Front crash prevention, for example, will not reach 95 percent until 2048, and a 2015 mandate would only accelerate the time by 8 years. While these collision avoidance features may be reducing collisions and losses, it will be many years before vehicles fitted with them represent a significant portion of the vehicle fleet.

Figure 22: Calendar year features reach 95% of registered vehicle fleet with and without mandate

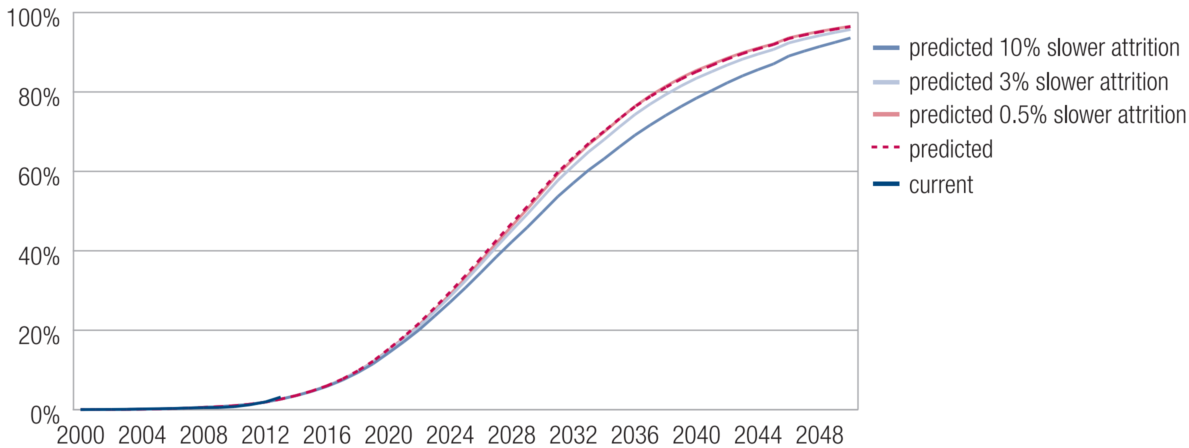


Limitations

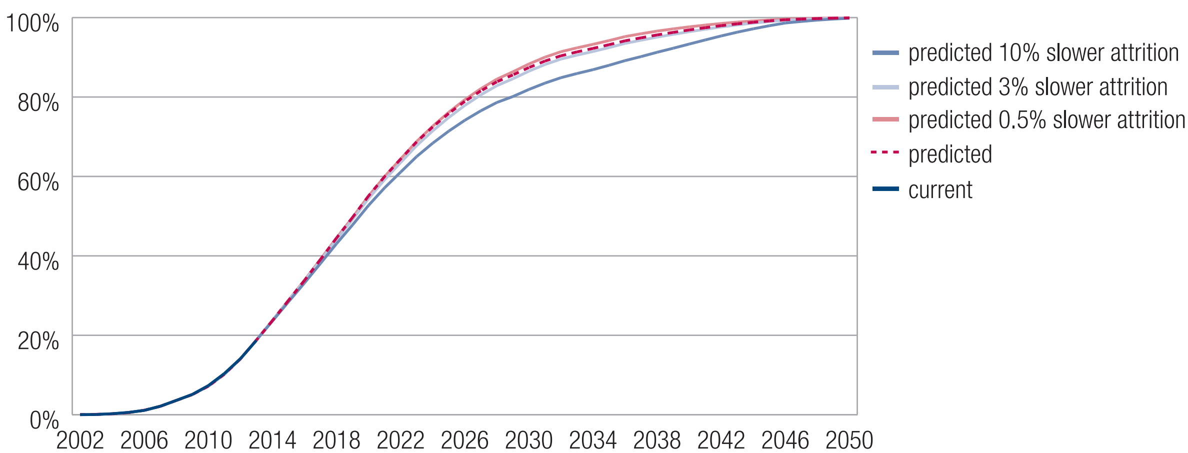
One limitation of the logistic model with a probit link is that it assumes a distribution with an asymptote of 100 percent, which it approaches slowly towards the end of the distribution. When a given feature's prevalence reaches 95 percent, its growth substantially slows and it takes a number of years to capture the remaining 5 percent. It is not known how this remaining small percentage will be captured since no feature has reached 100 percent prevalence yet. The model was carefully chosen to fit the existing (past year) data well, and there is reason to believe that it does not adequately describe the future data. It may be the case that the full 100 percent prevalence is never reached, as some people tend to keep old cars as collectable vehicles. Even if so, the goal of the study was to estimate when each feature will be available for the vast majority of the fleet, not 100 percent of the fleet.

Another limitation is that the prediction was based on the coarse calendar/model year registration counts rather than stratified by make and series. However, the stratified approach would be difficult if not impossible to accomplish. The future is uncertain, and so is the future new model fleet. Even with the present approach, a bold assumption of stalled vehicle sales had to be made. Making further assumptions on which makes and series will be popular in the future or which manufacturers will introduce safety features more aggressively is beyond the scope of this analysis. However, as mentioned previously and reflected in the graphs, the model fits the existing data well, and consequently it is reasonable to believe that the predictions for the future fleet are the best possible.

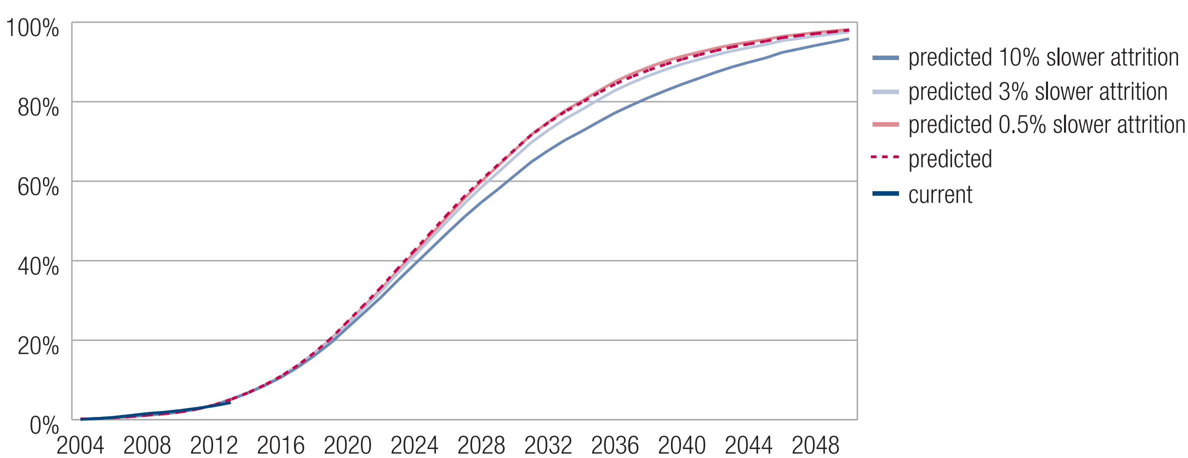
Appendix Figure 1: Predicted percentage of registered vehicles with front crash prevention



Appendix Figure 2: Predicted percentage of registered vehicles with rear camera



Appendix Figure 3: Predicted percentage of registered vehicles with adaptive lights



References

Highway Loss Data Institute. 2012. Predicted availability of safety features on registered vehicles. *Loss Bulletin*. Vol. 28, No 26. Arlington, VA.

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Do Smart Cars Equal Safer Roads?

Property Casualty Insurers Association of America
Capital Engagement Series
Washington D.C. ● July 29, 2014

David S. Zuby
EVP/Chief Research Officer, IIHS

The Insurance Institute for Highway Safety,

founded in 1959, is an independent, nonprofit, scientific, and educational organization dedicated to reducing the losses — deaths, injuries, and property damage — from crashes on the nation's roads.

The Highway Loss Data Institute,

founded in 1972, shares and supports this mission through scientific studies of insurance data representing the human and economic losses resulting from the ownership and operation of different types of vehicles and by publishing insurance loss results by vehicle make and model.

Both organizations are wholly supported by auto insurers.

IIHS/HLDI members write 85% of U.S. private passenger market.

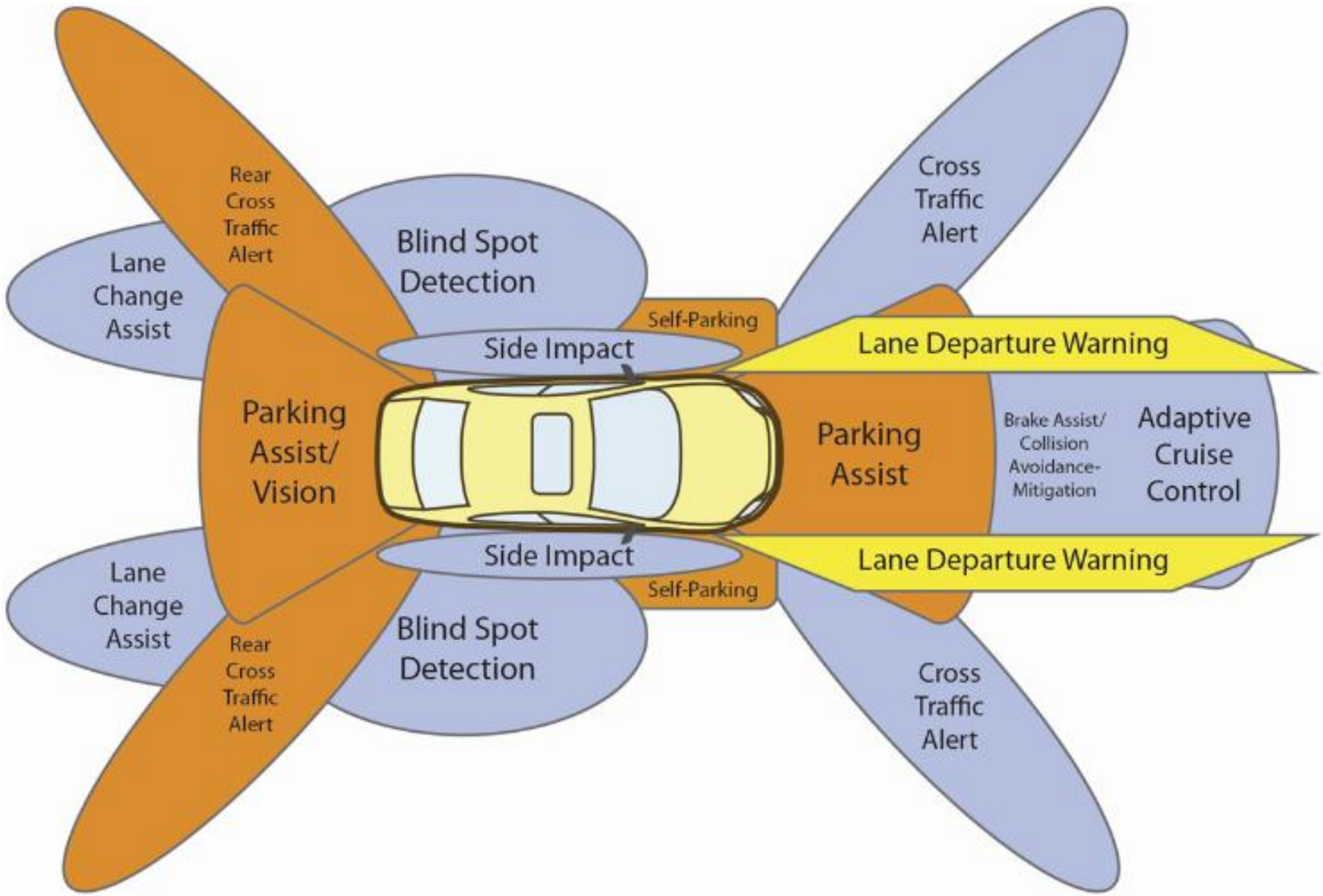
Rationale for smart cars

People don't always "just drive"

- 1979 – Indiana "Tri-Level Study" estimated "driver error" to be proximate cause of 9 out of 10 crashes
  - 15 percent of crashes associated with driver inattention
    - Changing audio tapes/CDs
    - Eating/drinking
    - Children, bugs, animals in vehicle
    - Reading, shaving, and applying makeup
- 2011 – NHTSA estimated that distraction was a factor in15 percent of police reported crashes
- 2012 – 3,328 were killed and 421,000 were injured in crashes involving distracted driver in the U.S.

Driver assistance features

Radar, LIDAR, ultrasonic, infrared, cameras, GPS



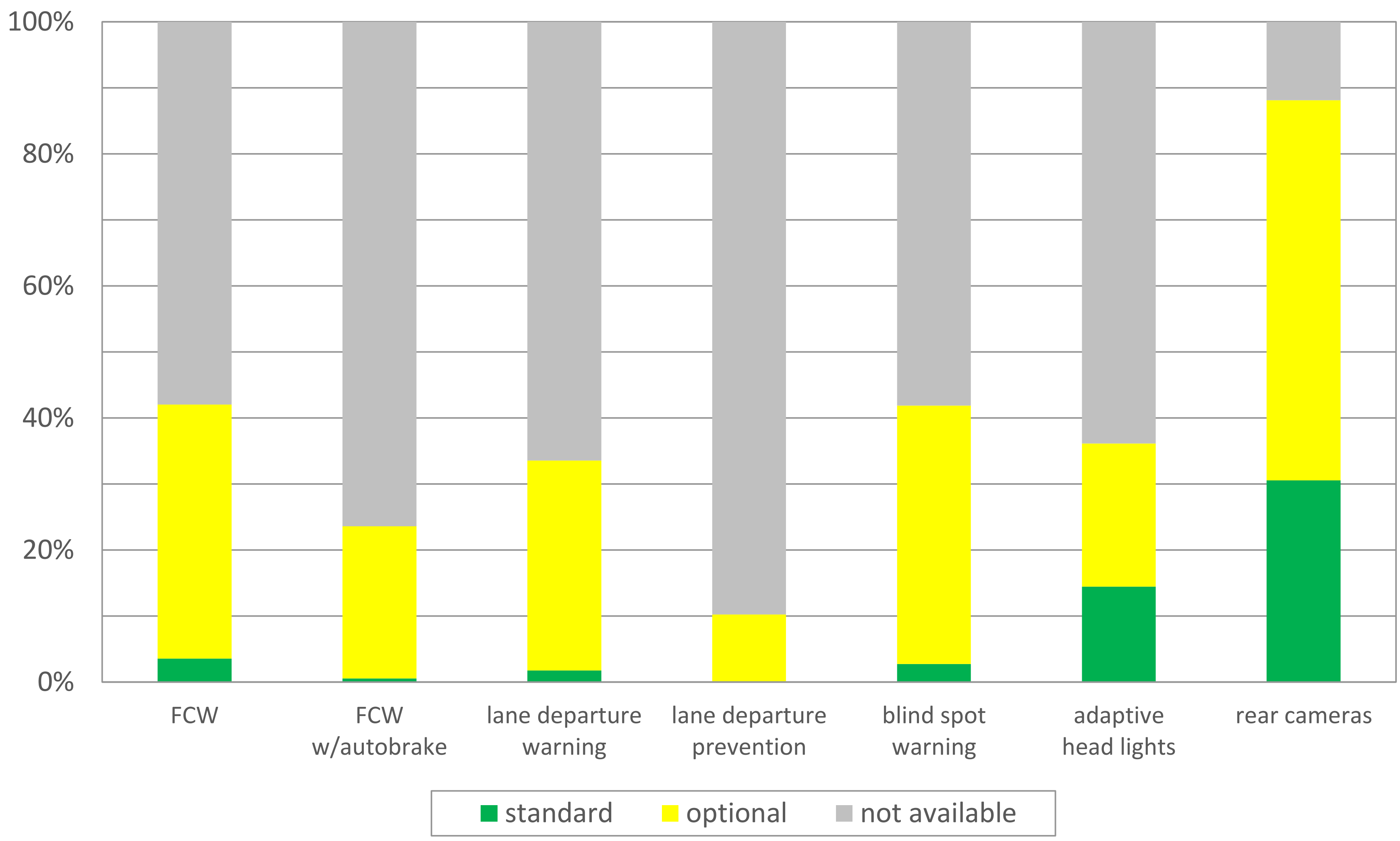
Annual relevance of driver assistance technology

By type of system

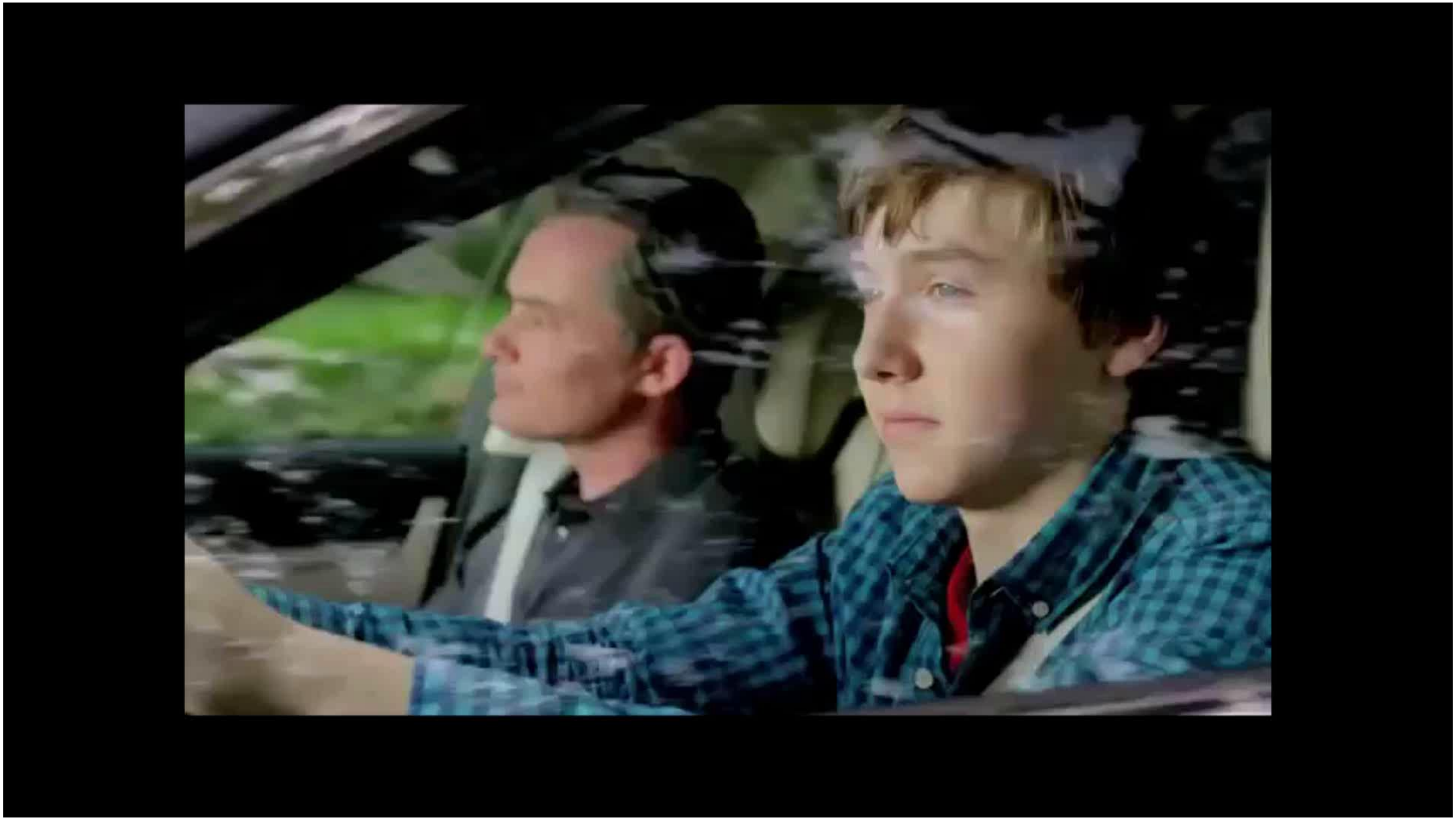
	all	injury	fatal
forward collision warning	1,165,000	66,000	879
lane departure warning	179,000	37,000	7,529
side view assist	395,000	20,000	393
adaptive headlights	142,000	29,000	2,484
total unique crashes	1,866,000	149,000	10,238

Availability of driver assistance technology

Percent of vehicle series in 2014

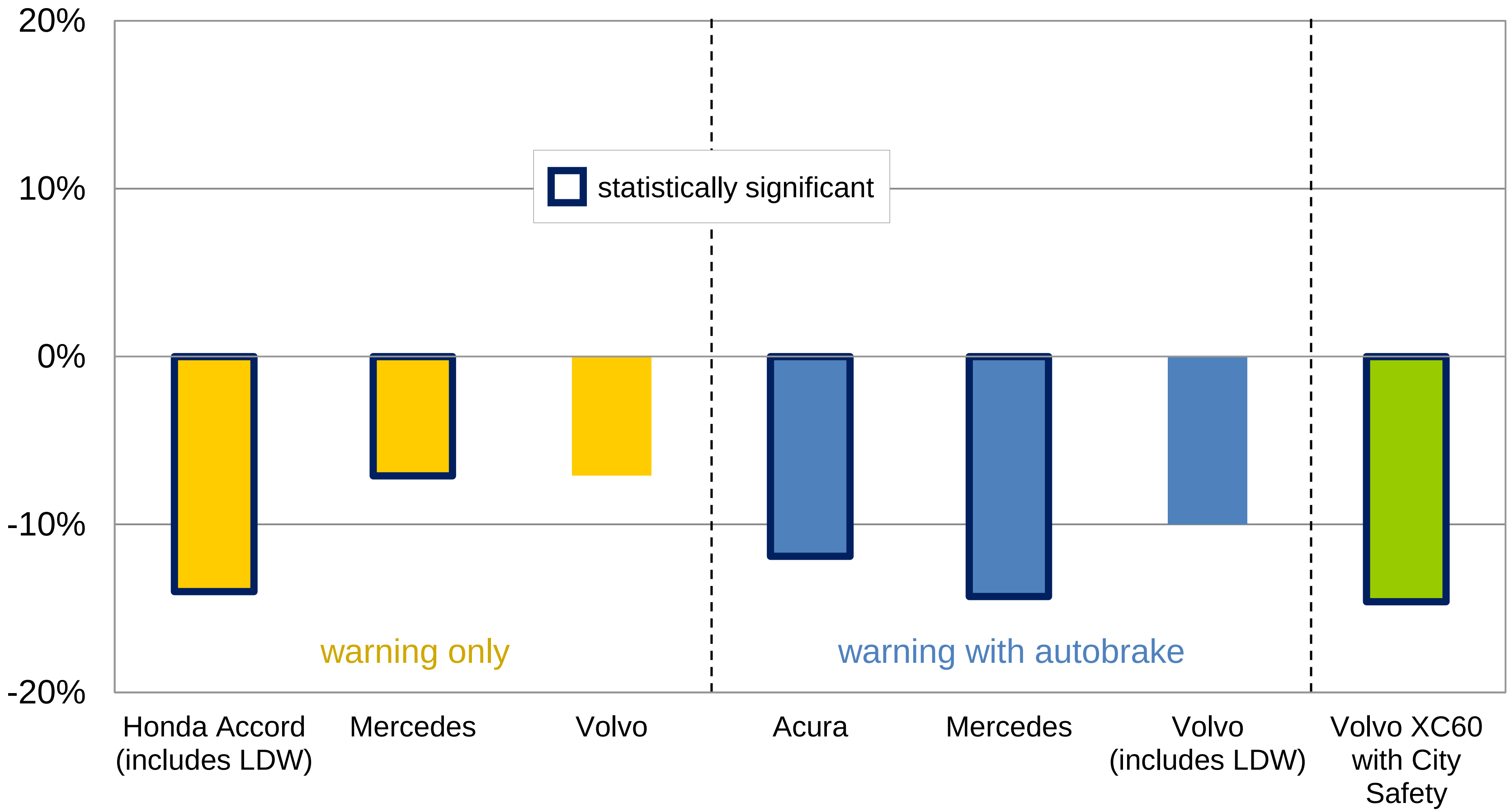


- Front crash prevention systems are working
- Adaptive headlights are working
- The benefits of these systems are less clear –
  - Lane departure warning
  - Blind spot warning
  - Rearview cameras
  - Parking proximity sensors



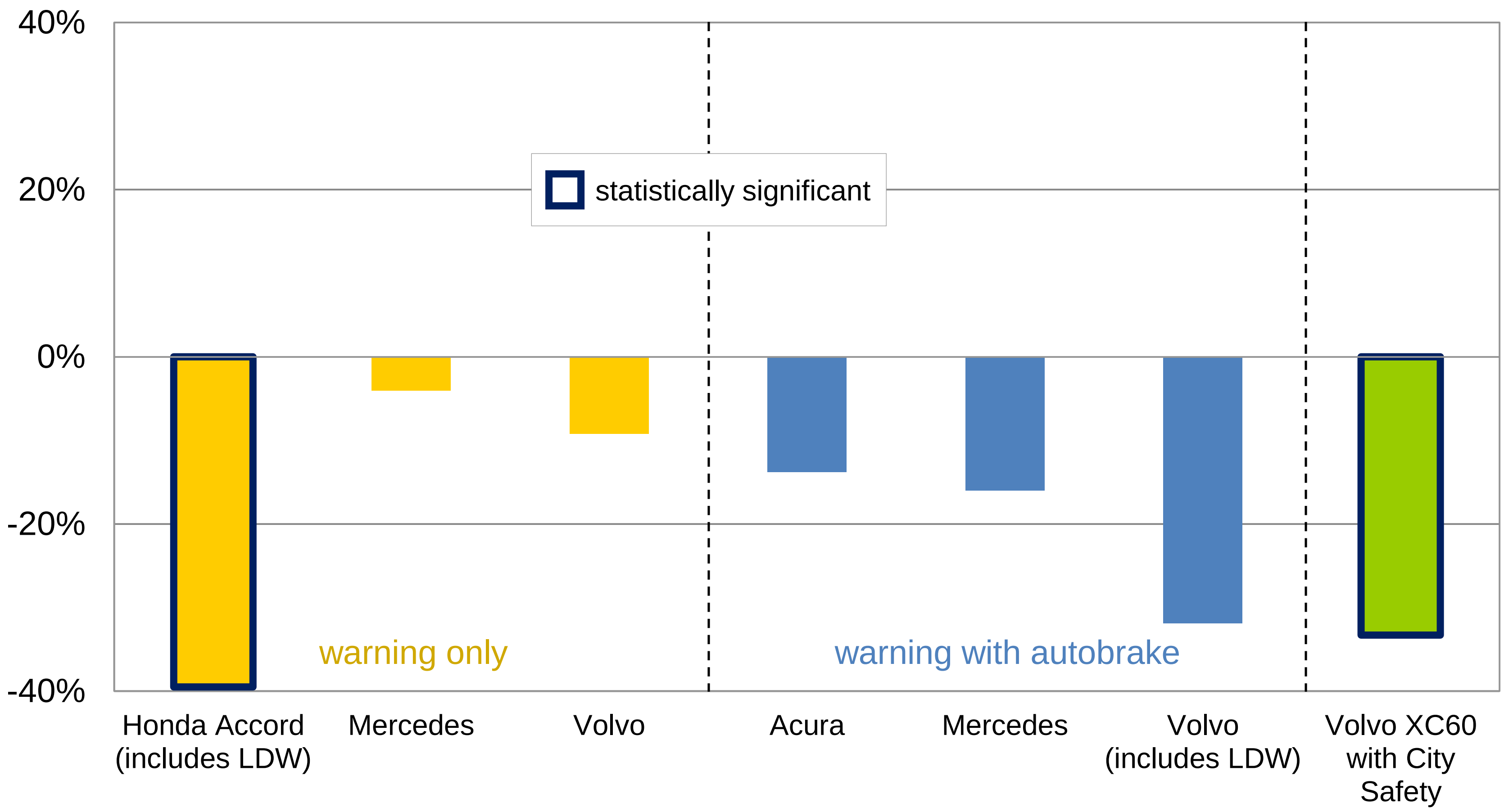
Effect of front crash prevention on property damage liability claim frequency

By manufacturer



Effect of front crash prevention on bodily injury liability claim frequency

By manufacturer

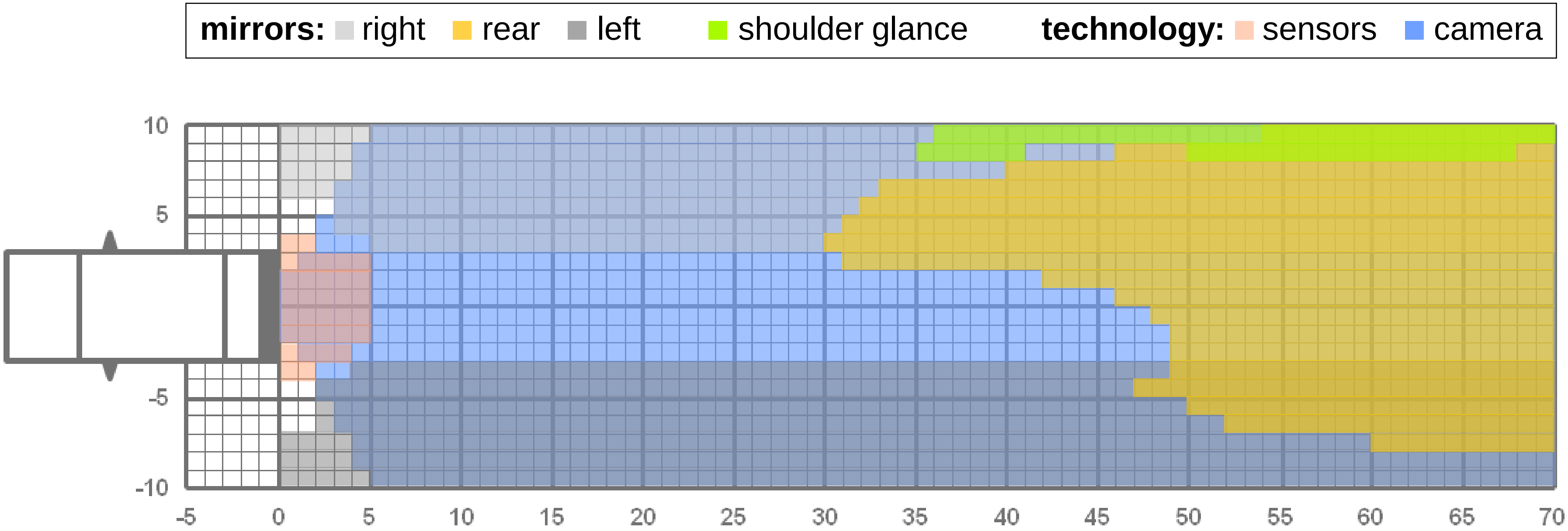


Rear cameras and other backing aids

- Enhance the drivers' perception of areas not otherwise visible
- Experiments indicate benefits
- The real-world efficacy is unclear
- Cameras will be required on new vehicles beginning 2016
  - Phase-in complete in 2018

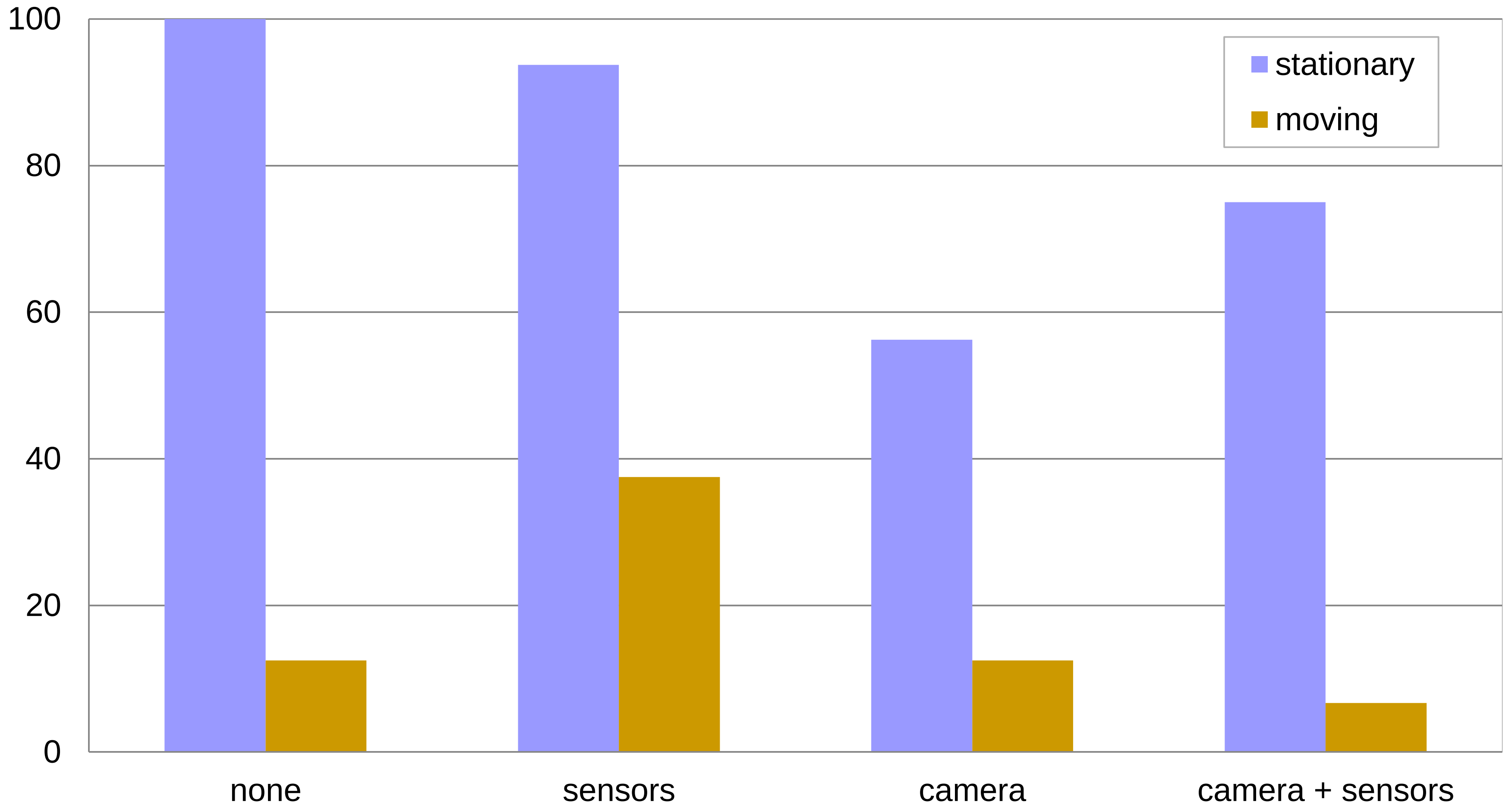
Visibility advantage provided by technology

Rear visibility in typical SUV: 2013 Chevrolet Equinox LTZ

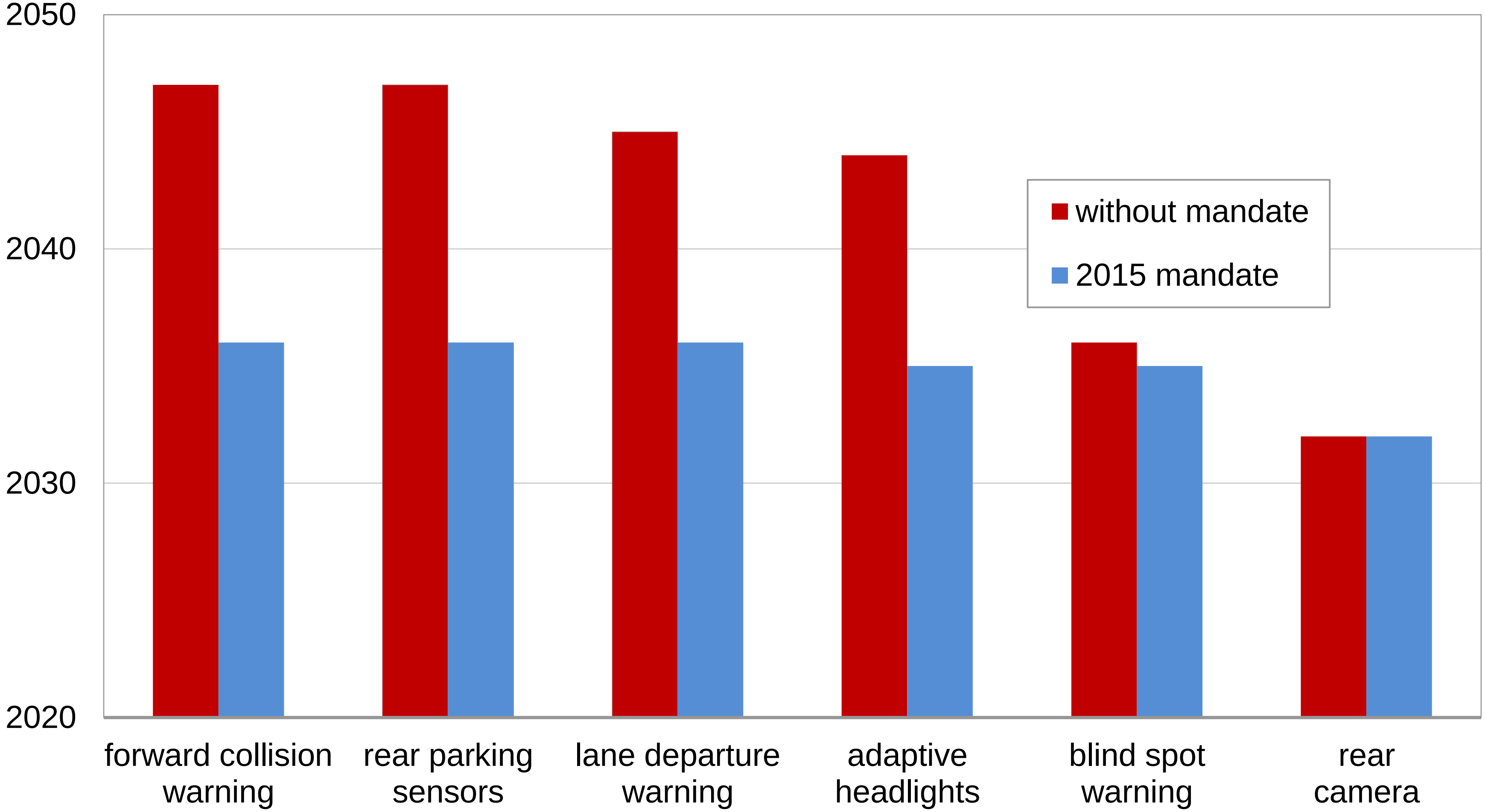


Cameras prevented crashes with stationary object

Percent of participants who hit the object,
by technology and object motion



Calendar year features reach 95% of registered vehicle fleet with and without mandate



Summary

- Automated driving will help prevent and mitigate crashes
  - Actual effectiveness of partial automation has been documented
  - Ideal automated systems cannot be distracted as drivers can be
- Wide spread automated driving will take time
  - Current partial automated systems are evolving quickly, but
  - Older vehicles are replaced by state-of-the-art vehicles slowly

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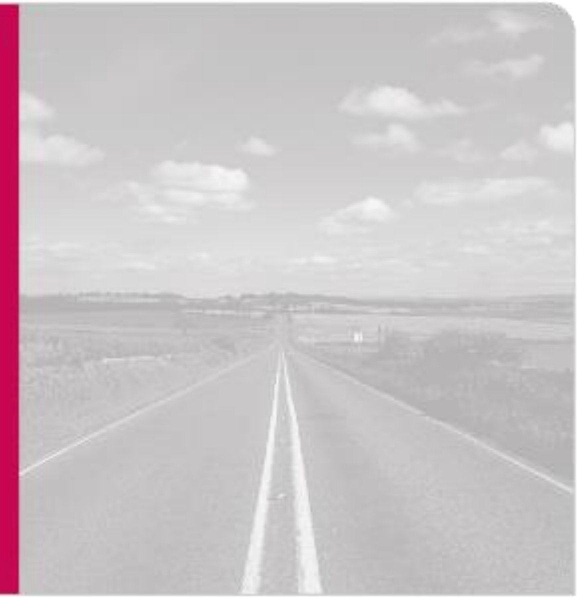

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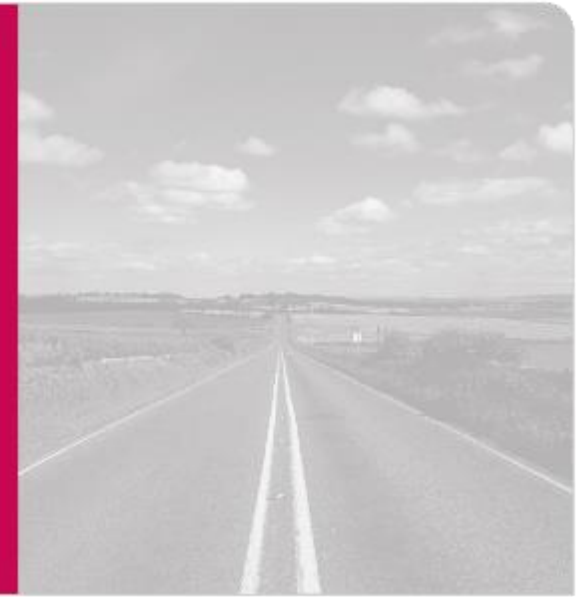

Vehicle Safety: Where It's Been and Where It's heading

www.iihs.org

Washington Automotive Press Association
Washington, D.C. ● January 15, 2015

Adrian K. Lund, Ph.D.
President, IIHS and HLDI

50th Anniversary crash test

1959 Bel Air vs. 2009 Malibu

Who are we?

The Insurance Institute for Highway Safety,
founded in 1959, is an independent, nonprofit, scientific, and educational organization dedicated to reducing the losses — deaths, injuries, and property damage — from crashes on the nation’s roads.

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IIHS members write 85% of private passenger market

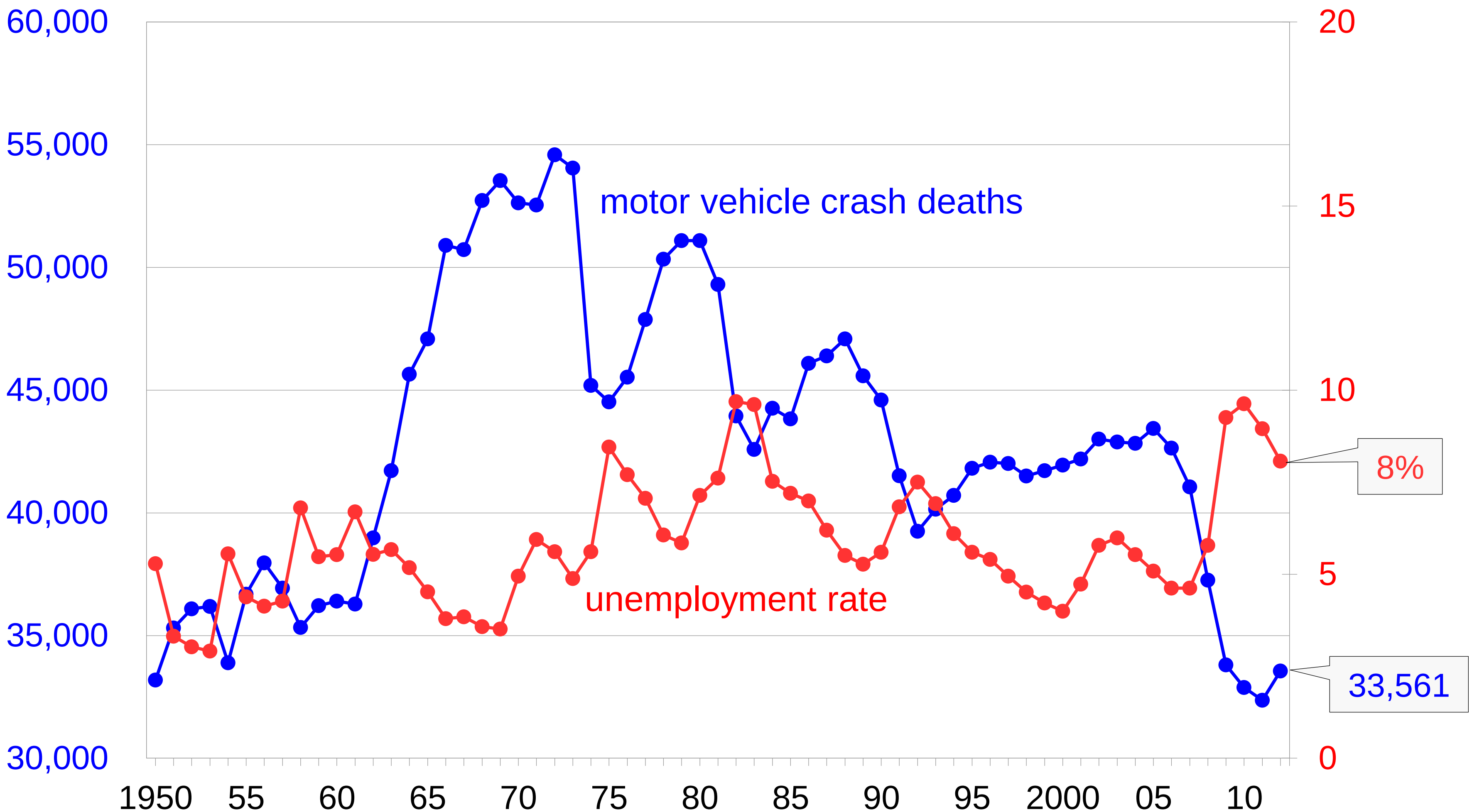
- Acceptance Insurance
- ACE Private Risk Services
- Affirmative Insurance
- Alfa Alliance Insurance Corporation
- Alfa Insurance
- Allstate Insurance Group
- American Family Mutual Insurance
- American National Property and Casualty Company
- Ameriprise Auto & Home
- Amica Mutual Insurance Company
- Auto Club Enterprises
- Auto Club Group
- Auto-Owners Insurance
- Aviva Insurance
- Bankers Insurance Group
- Bituminous Insurance Companies
- California Casualty Group
- California State Auto Group
- Capital Insurance Group
- Chubb & Son
- Colorado Farm Bureau Mutual Insurance Company
- Commonwealth Mutual Insurance Company of America
- Concord Group Insurance Companies
- COUNTRY Financial
- CSAA Insurance Group
- CSE Insurance Group
- Direct General Corporation
- Erie Insurance Group
- Esurance
- Farm Bureau Financial Services
- Farm Bureau Insurance of Michigan
- Farm Bureau Mutual Insurance Company of Idaho
- Farmers Insurance Group of Companies
- Farmers Mutual Hail Insurance Company of Iowa
- Farmers Mutual of Nebraska
- Florida Farm Bureau Insurance Companies
- Frankenmuth Insurance
- Freestone Insurance Company
- Gainsco Insurance
- GEICO Group
- The General Insurance
- Georgia Farm Bureau Mutual Insurance Company
- Goodville Mutual Casualty Company
- Grange Insurance
- Hallmark Insurance Company
- Hanover Insurance Group
- The Hartford
- Haulers Insurance Company, Inc.
- Horace Mann Insurance Companies
- ICW Group
- Imperial Fire & Casualty Insurance Company
- Indiana Farmers Mutual Insurance Company
- Infinity Property & Casualty
- Kemper Preferred
- Kentucky Farm Bureau Insurance
- Liberty Mutual Insurance Company
- Louisiana Farm Bureau Mutual Insurance Company
- Maryland Automobile Insurance Fund
- Mercury Insurance Group
- MetLife Auto & Home
- Michigan Millers Mutual Insurance Company
- MiddleOak
- Mississippi Farm Bureau Casualty Insurance Company
- MMG Insurance
- Mutual of Enumclaw Insurance Company
- Nationwide
- New Jersey Manufacturers Insurance Group
- Nodak Mutual Insurance Company
- Norfolk & Dedham Group
- North Carolina Farm Bureau Mutual Insurance Company
- Northern Neck Insurance Company
- Ohio Mutual Insurance Group
- Old American County Mutual Fire Insurance
- Old American Indemnity Company
- Oregon Mutual Insurance
- Pekin Insurance
- PEMCO Insurance
- Plymouth Rock Assurance
- Progressive Corporation
- QBE
- The Responsive Auto Insurance Company
- Rockingham Group
- Safe Auto Insurance
- Safeco Insurance
- Samsung Fire & Marine Insurance Company
- SECURA Insurance
- Sentry Insurance
- Shelter Insurance
- Sompo Japan Insurance Company of America
- South Carolina Farm Bureau Mutual Insurance Company
- Southern Farm Bureau Casualty Insurance Company
- State Auto Insurance Companies
- State Farm
- Tennessee Farmers Mutual Insurance Company
- Texas Farm Bureau Insurance Companies
- Tower Group Companies
- The Travelers Companies
- United Educators
- USAA
- Utica National Insurance Group
- Virginia Farm Bureau Mutual Insurance
- West Bend Mutual Insurance Company
- Western National
- Westfield Insurance
- XL Group plc
- Zurich North America

Where are we?

Location of IIHS/HLDI and Vehicle Research Center

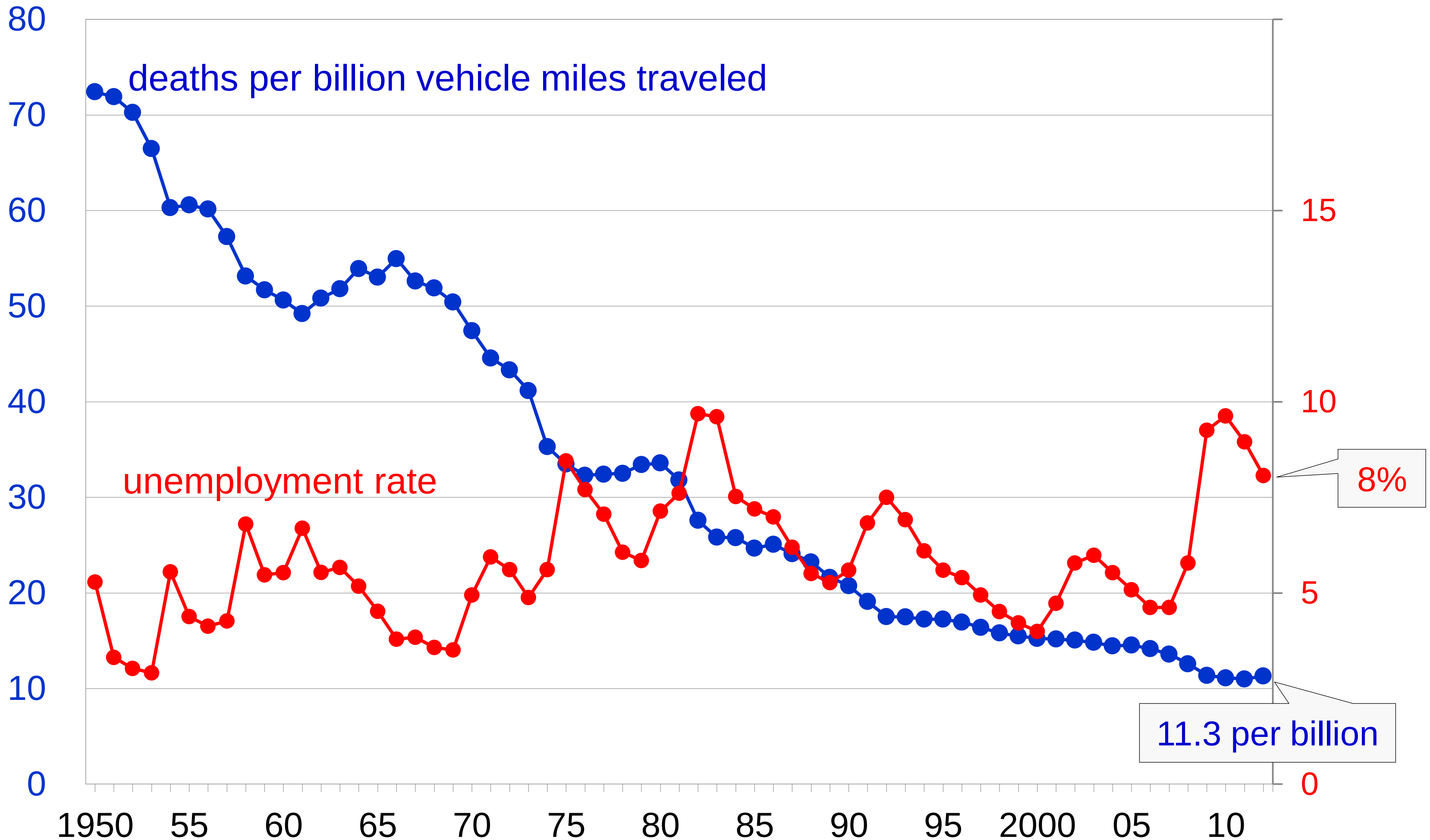
US motor vehicle crash deaths and unemployment rate

1950-2012



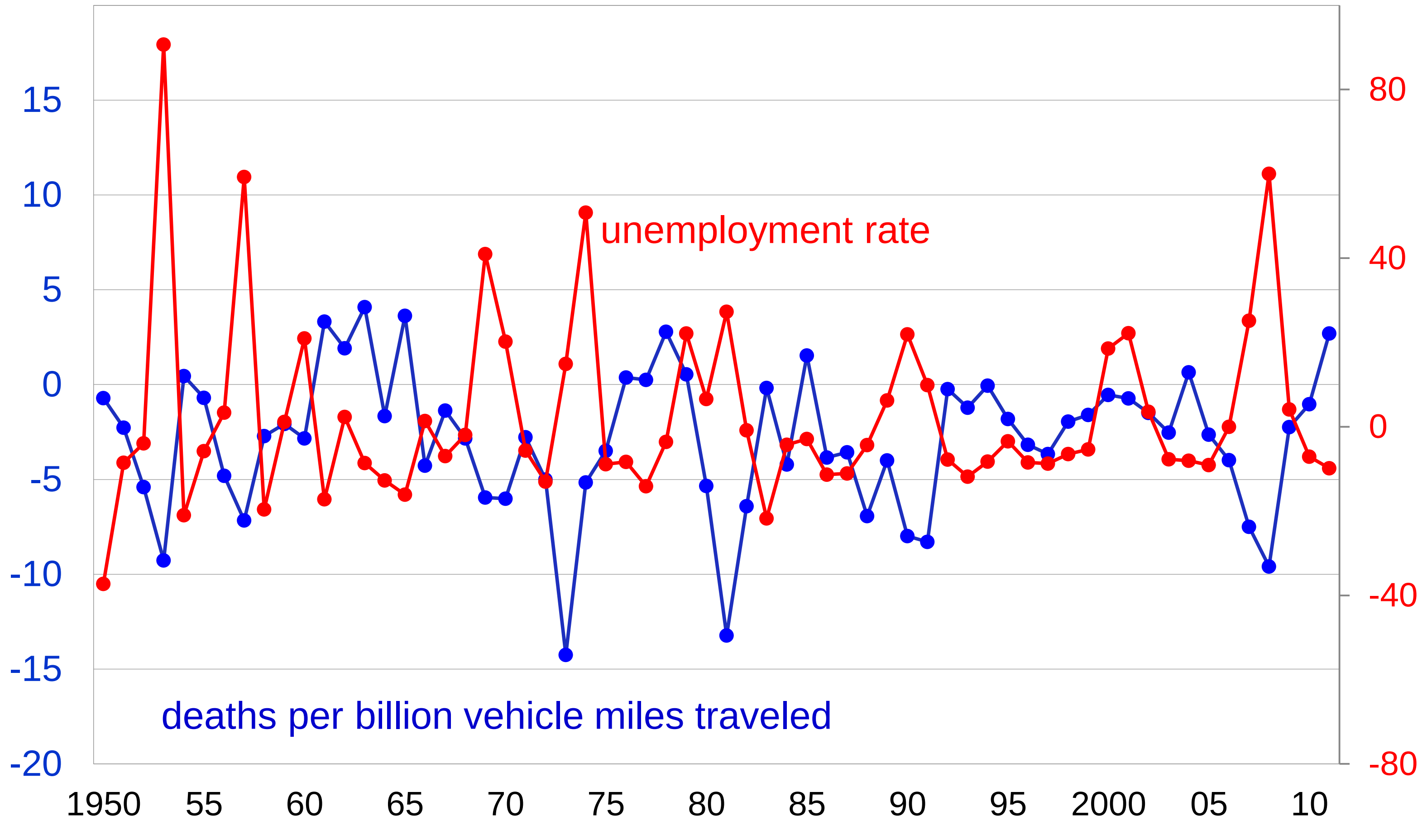
US motor vehicle crash deaths per billion vehicle miles traveled and unemployment rate

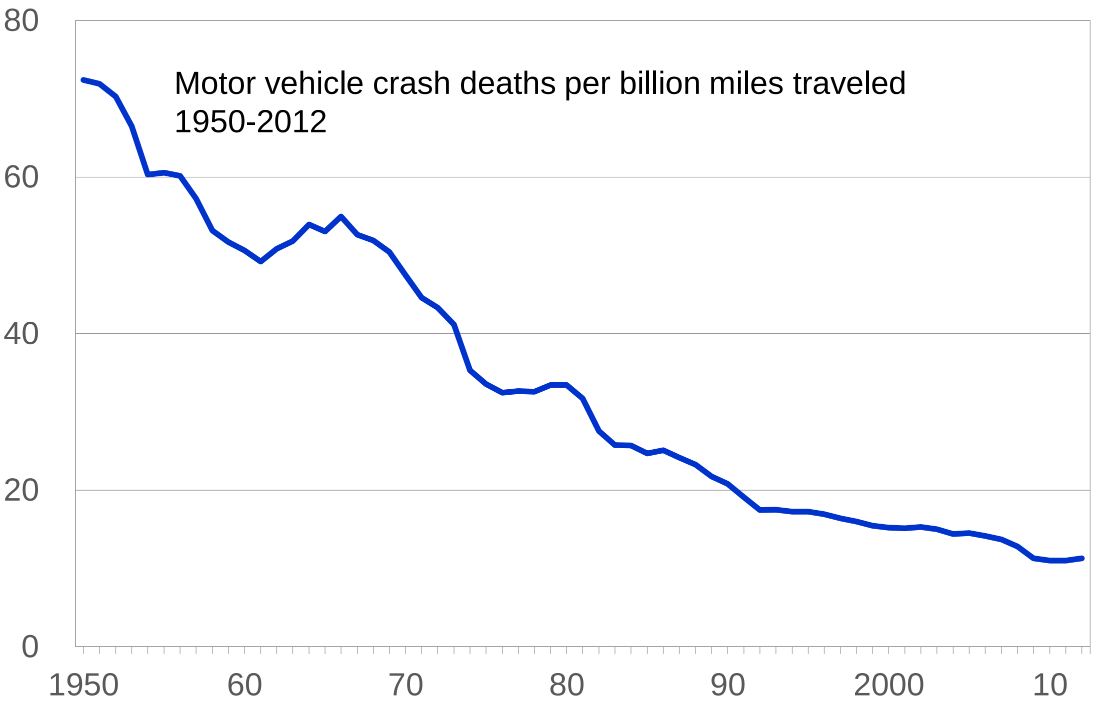
1950-2012



Year-to-year percent changes in US motor vehicle crash deaths per billion vehicle miles traveled and unemployment rate

1951-2012

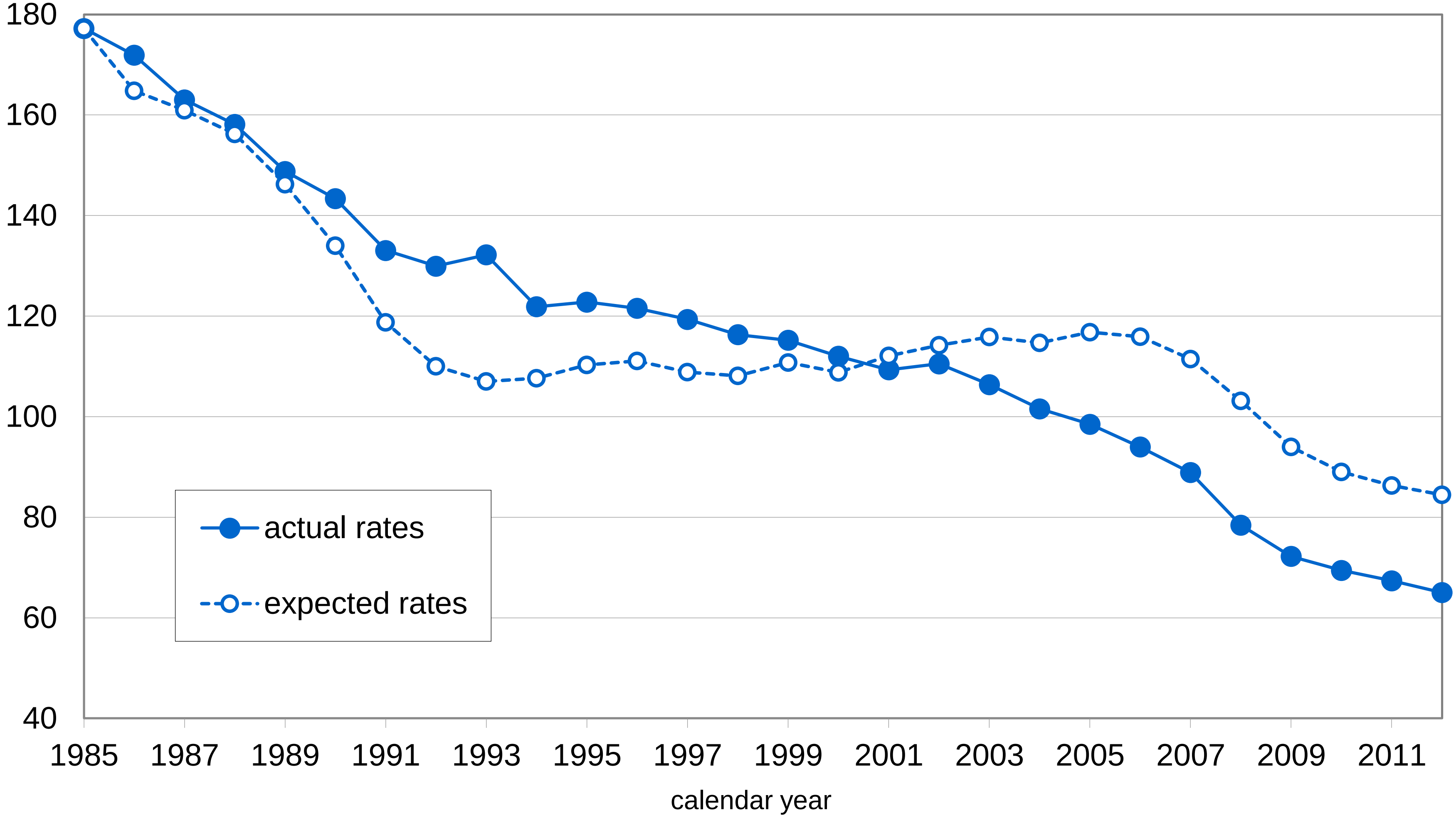




Vehicle improvements have been key to reductions in motor vehicle crash fatality risk

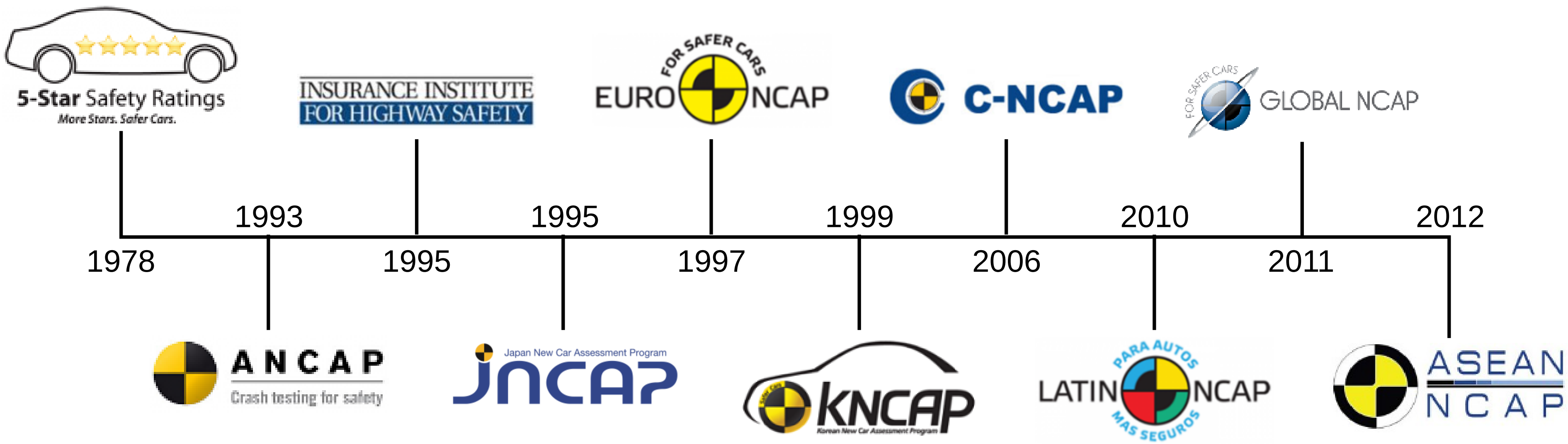
Vehicle and non-vehicle factors and highway safety

Fatal crash rates per million vehicles, actual vs. expected for 1985 fleet



New car assessment programs (NCAPs)

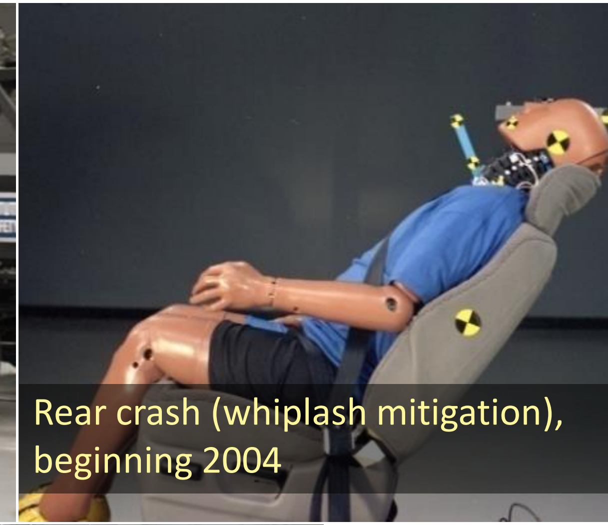
By year of inception

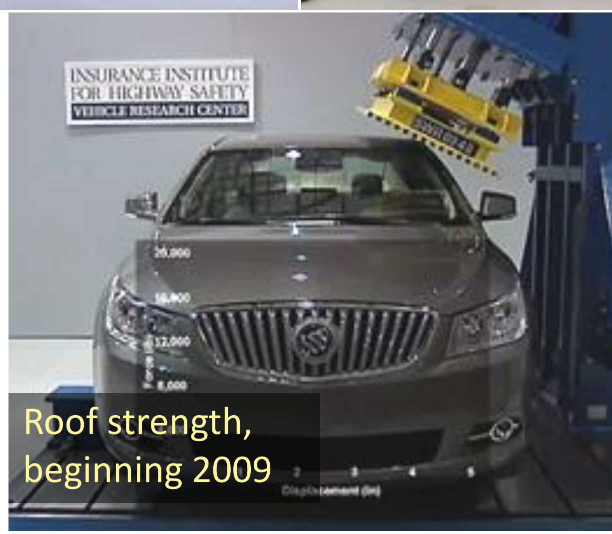


IIHS crashworthiness tests

Front moderate overlap, beginning 1995

Side impact, beginning 2003


Rear crash (whiplash mitigation), beginning 2004

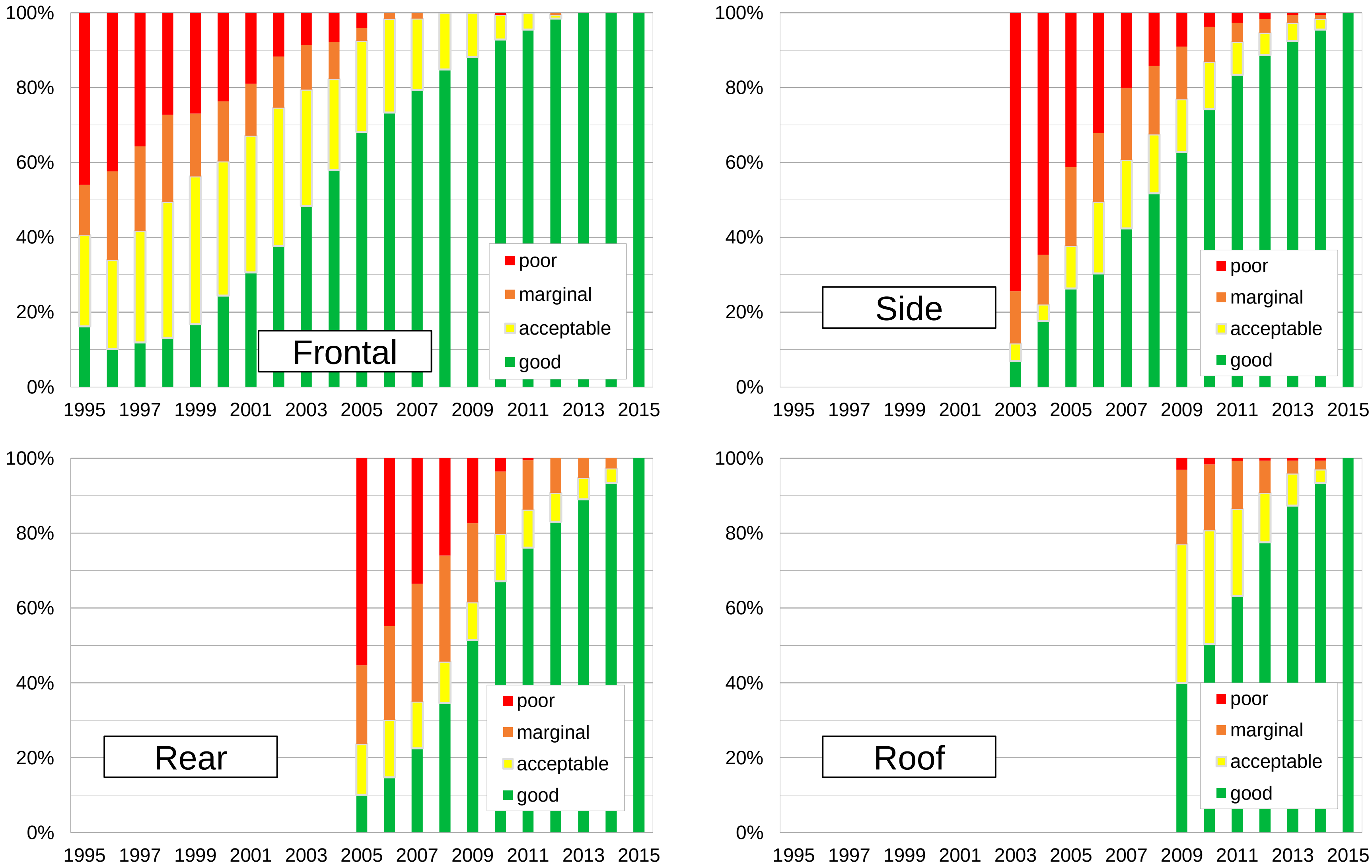


Roof strength, beginning 2009

Front small overlap, beginning 2012

Crash protection ratings by model year

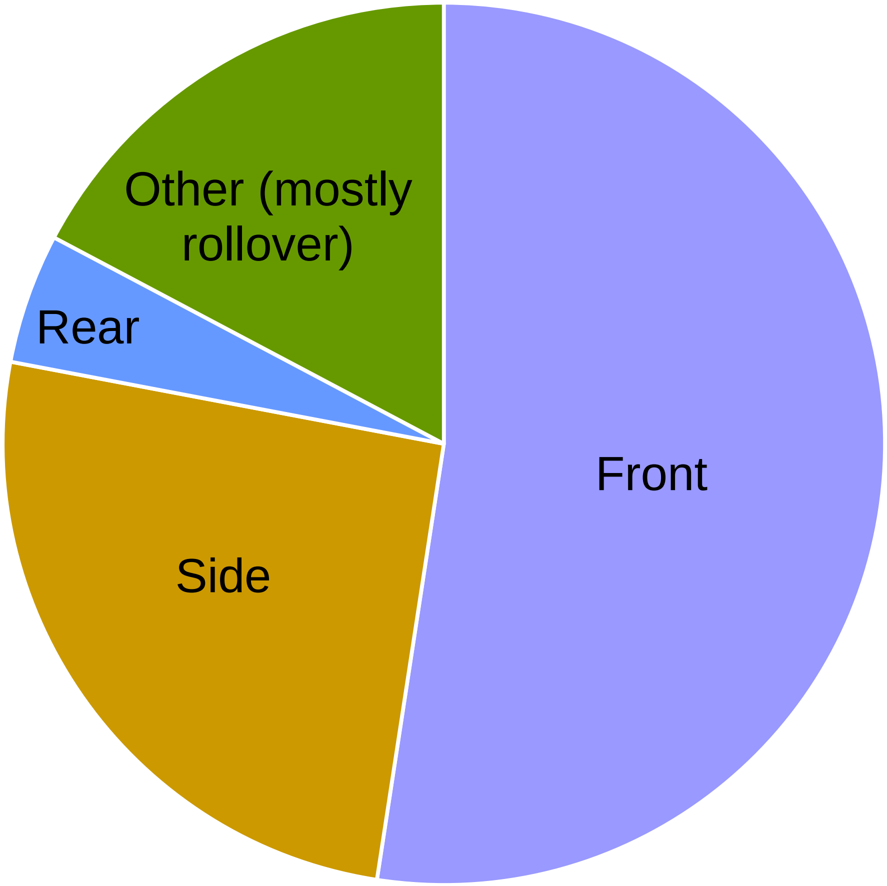
Improvements: Beginning in 1995



Small overlap crashes

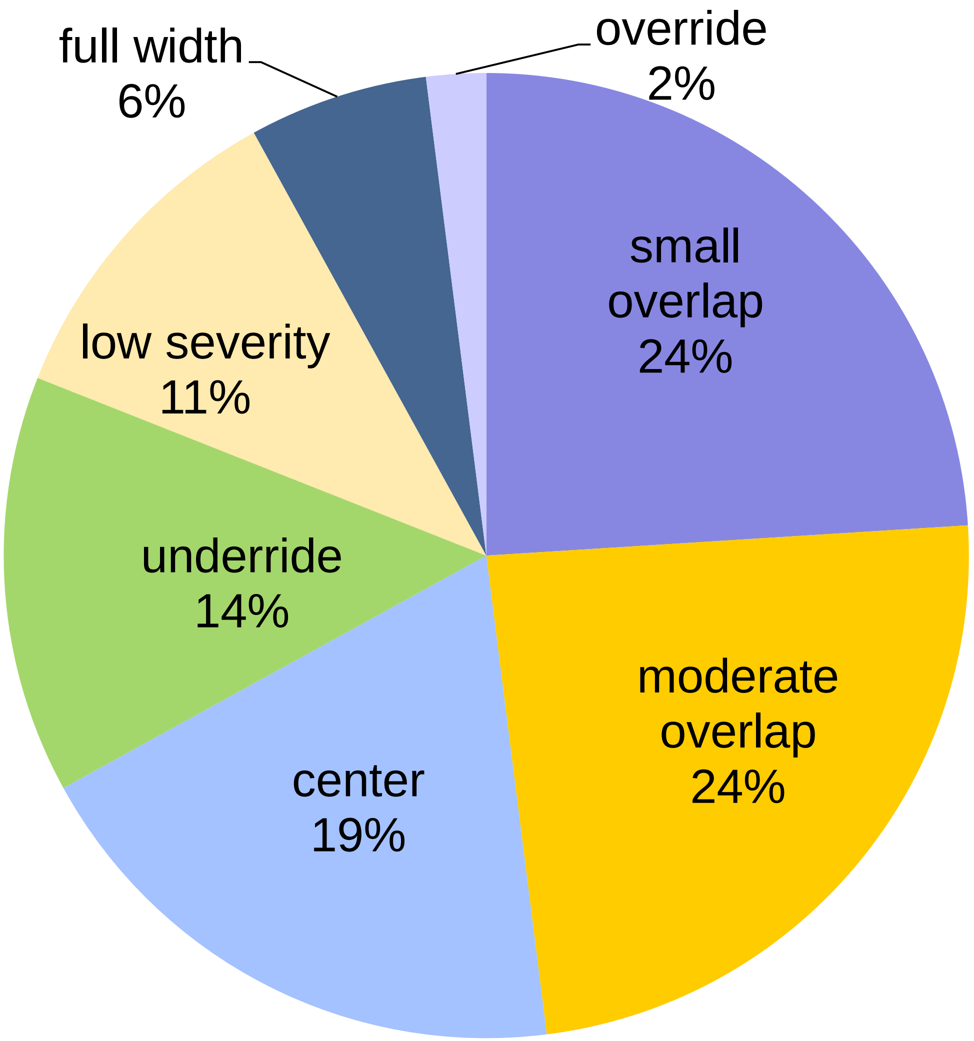
Vehicle occupant deaths by point of impact, 2012

11,426 died in frontal crashes



Serious injuries in frontal crashes, by configuration

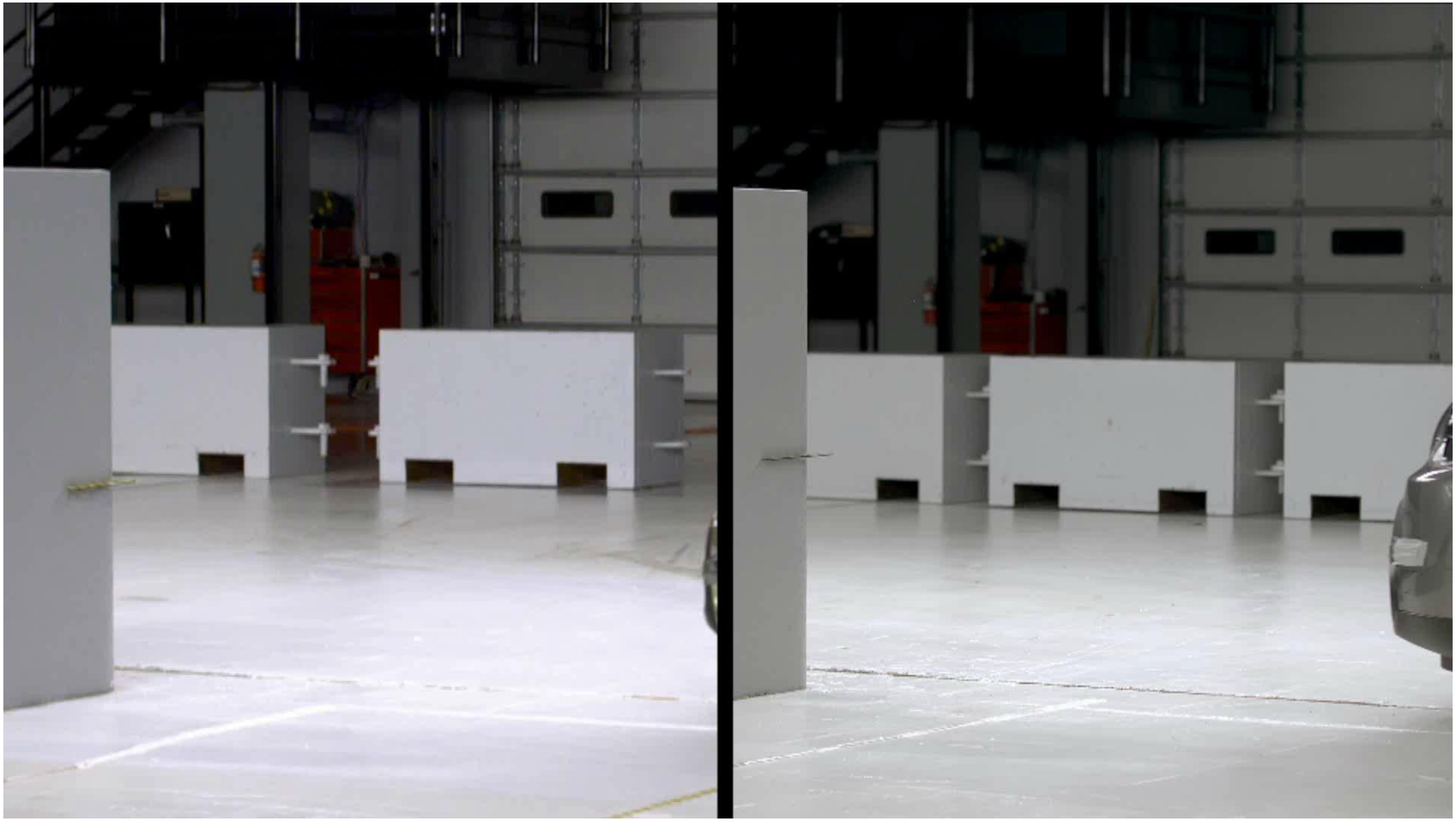
Vehicles rated good in IIHS moderate overlap crash test




Status Report
Insurance Institute for Highway Safety | Highway Loss Data Institute
2014 NISSAN QUEST
INSURANCE INSTITUTE FOR HIGHWAY SAFETY
CEN1445
Minivans with a major flaw
3 models have dire results in small overlap crash test
ALSO IN THIS ISSUE
Vol. 49, No. 10
November 20, 2014
Crash tests show how cars sold in India fall short of safety norms
Motorcycle ABS benefits both high-risk and low-risk riders
How to find motorcycles equipped with antilocks


Television coverage:
Small overlap crash tests
minivans
DEVELOPING STORY
POOR RATINGS FOR POPULAR MINIVANS
CRASH-TESTS REVEAL SAFETY CONCERNS
TODAY
ERDAY AFTER DISCOVERING A HUNTING RIFLE, DOZENS OF ROUNDS OF AMMUNI
7:34 | 35°

Kia Soul



P G

Kia Soul

2013 model

P

2015 model

G

Front small overlap tests since 2012

- 134 small overlap front tests conducted since 2012
  - Cars: minicars, small, midsize, midsize luxury, large luxury
  - SUVs: small, midsize, midsize luxury
  - Minivans
- 19 models tested twice
  - 17 redesigns and modifications improved structural rating
  - 17 improved overall rating

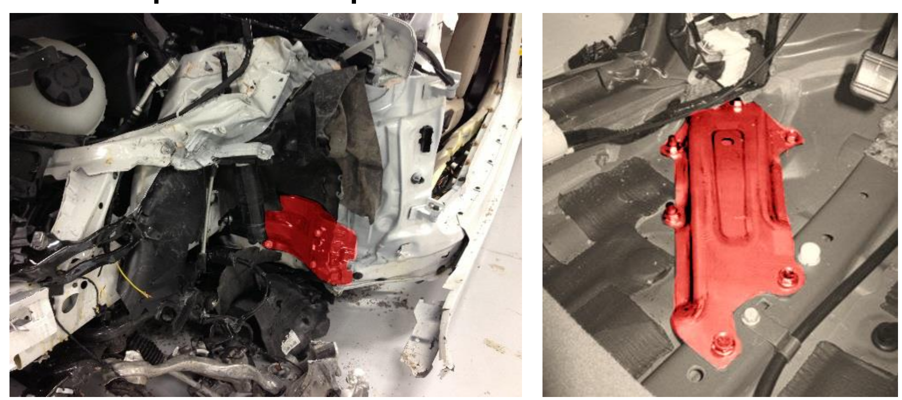
Examples of structural modifications

engagement structures attached to frame rail

side frame structure

bumper beam reinforcement

occupant compartment reinforcement

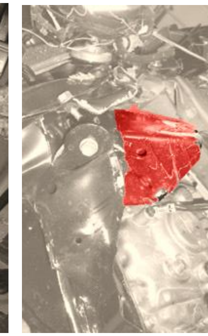


Weight change associated with improved structure

	Weight increase (lbs.)
Rogue	114
Q50	112
Soul	106
Legacy	97
CR-V	95
Odyssey	59
Jetta	59
Sonata	44
Camry	11
CX-5	2
Accord	-7
Fit	-9
Forte	-18

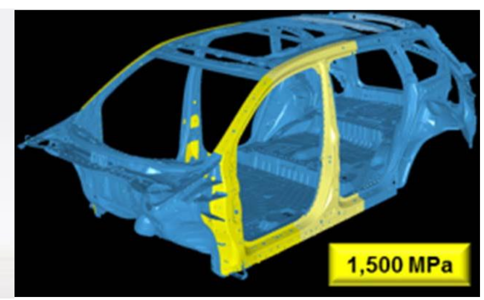
+114 pounds

floor support



underbody deflector

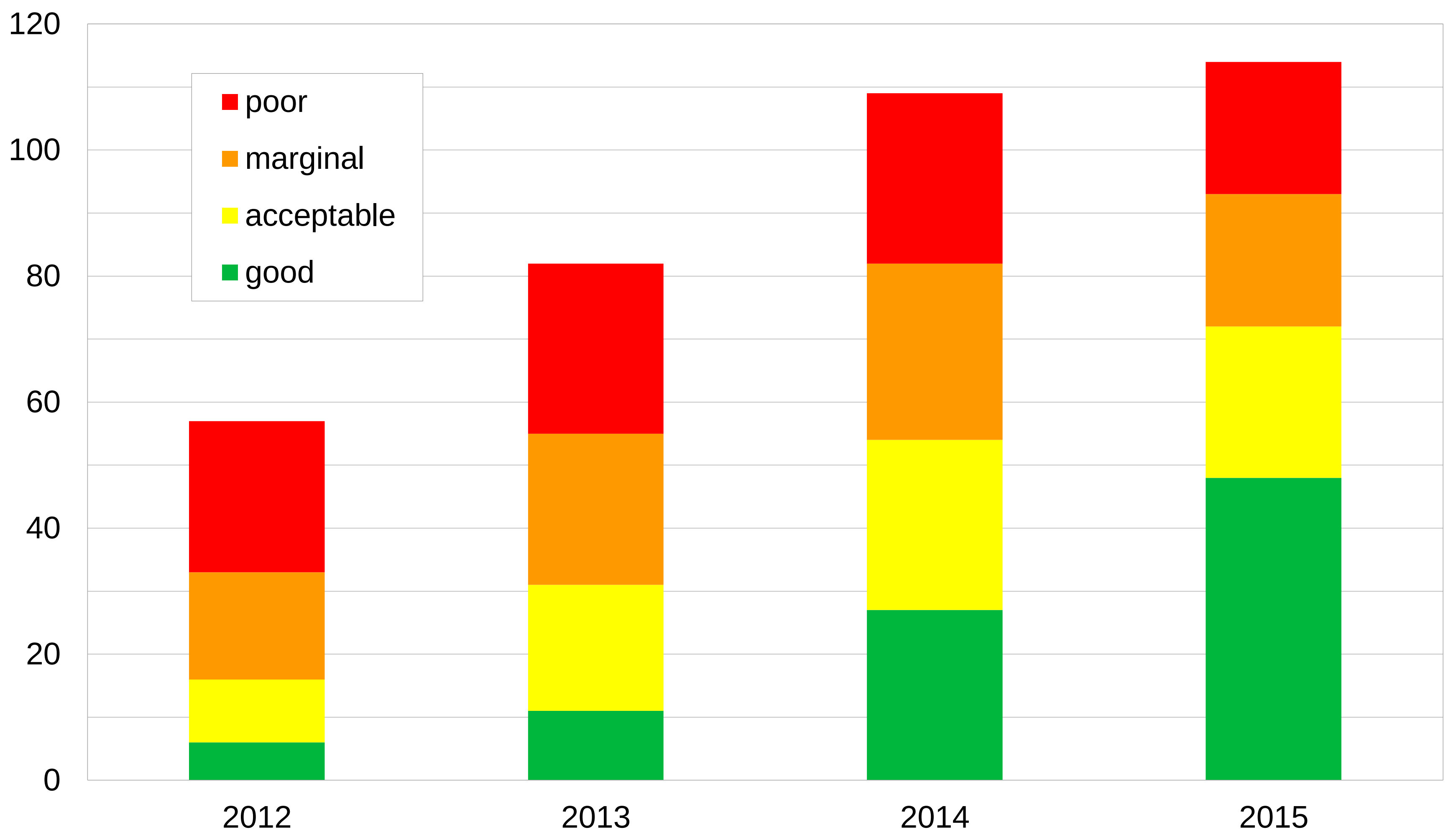
-9 pounds



Honda developed single-piece hot-stamped door-stiffener ring

Small overlap ratings by model year

January 2015




TOP SAFETY PICK
Advertisements

ConsumerReports.org

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New Cars | Used Cars | Car Buying & Pricing | Maintenance & Repair | Car Safety

Home > Cars > Poor crash-test performance costs the Nissan Quest its Consumer Reports' recommendation

Poor crash-test performance costs the Nissan Quest its Consumer Reports' recommendation

Minivans struggle in latest IIHS small-overlap front crash test

Published: November 20, 2014 12:01 AM

The Nissan Quest in the Insurance Institute for Highway Safety's small-overlap test.

Consumer Reports has suspended its recommendation of the otherwise high-scoring Nissan Quest minivan because it performed very poorly in a small overlap front crash test conducted by the Insurance Institute for Highway Safety.

An IIHS press release stated that the Quest driver's compartment collapsed so completely that both of the crash-test dummy's legs were trapped. In fact, to extract the dummy, IIHS technicians "had to cut the entire seat out and then use a crowbar to free the right foot." The IIHS's Chief Research Officer, David Zuby, is quoted as saying, "A real person experiencing this would be lucky to ever walk normally again."

Nissan Quest

Volkswagen USA News
@VWnews

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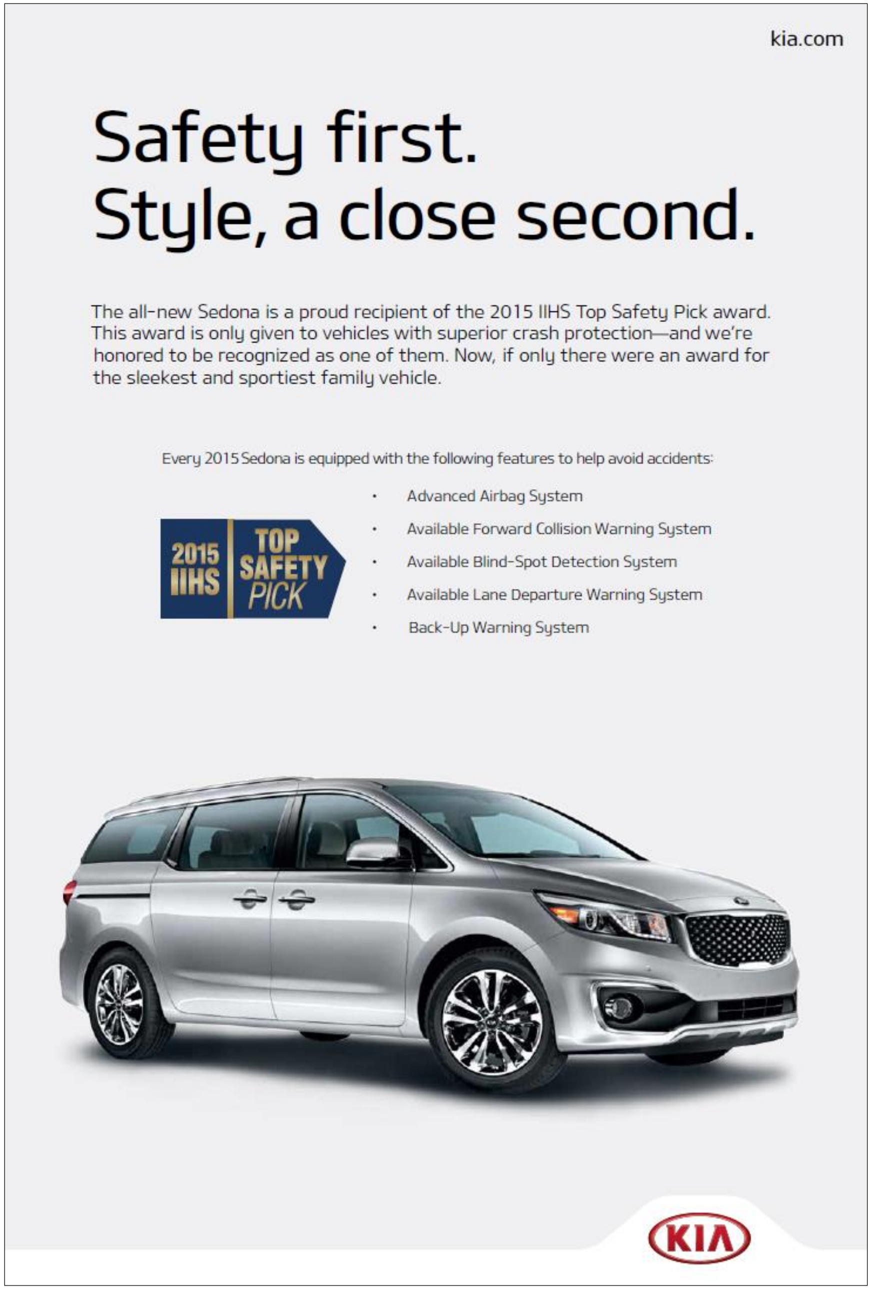
7:35 AM - 18 Sep 2014

Flag media


BIG ON SPACE.
BIGGER ON SAFETY
FEATURES.
MINI
• Four doors
• Seating for five
• All-Wheel Drive
Optional
• IIHS Top Safety Pick
4 years in a row
The MINI Cooper
Countryman S ALL4
2014
IIHS
TOP
SAFETY
PICK
MINI COUNTRYMAN



2015 Kia Sedona

Santa Claus delivers 2015 *TOP SAFETY PICKs*

Public release December 23

Requirements for 2015 *TOP SAFETY PICK* awards

G rating in moderate overlap front, side, roof strength and head restraint tests

&

G or **A** rating in small overlap front test

meet *TOP SAFETY PICK* criteria

&

Advanced or Superior rating for front crash prevention

TSP+ criteria change to reflect new technology

Higher bar encourages improvement

- 2012-13 TSP+ criteria based on crash test performance only
  - Many models offered front crash prevention systems
- 2014 TSP+ added **Basic** or better FCP rating
  - 60 models now offer higher FCP performance
- Change for 2015 TSP+
  - **Advanced** or **Superior** FCP rating
  - Basic FCP rating still eligible for TSP

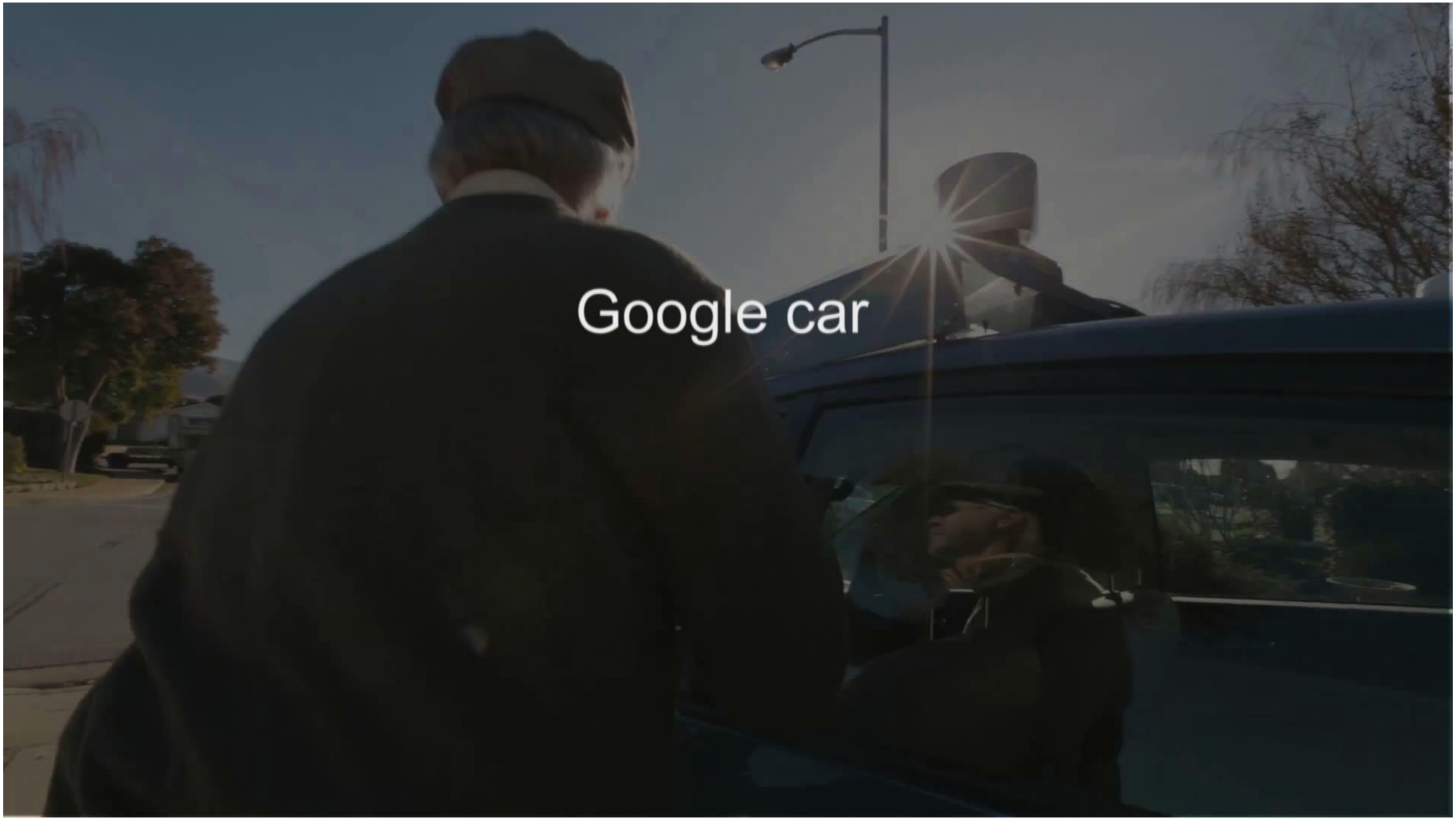
TOP SAFETY PICK winners by calendar year

year		
2006	9 Gold	12 Silver
07	23	
08	64	
09	94	
10	58	
11	102	
12	136	
13	30 TSP+	126 TSP
14	43 TSP+	25 TSP
15	33 TSP+	38 TSP

Can new crash avoidance technology help in the same way as crashworthiness?

The Google vision

Autonomous vehicles delivering occupants to pre-set destinations



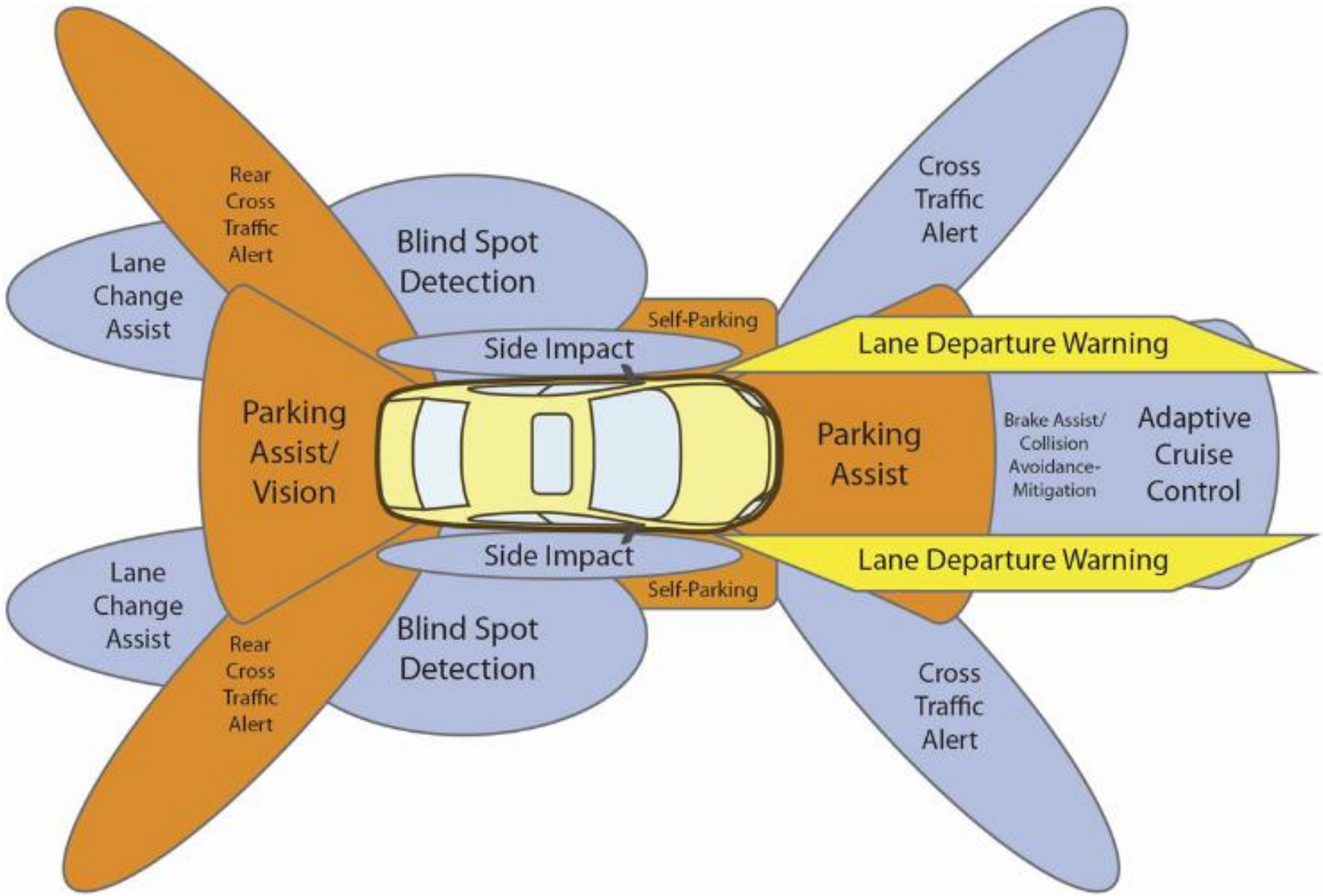
Google car

Audi Piloted Driving

San Francisco to Las Vegas, January 4-5, 2015

Driver assistance features

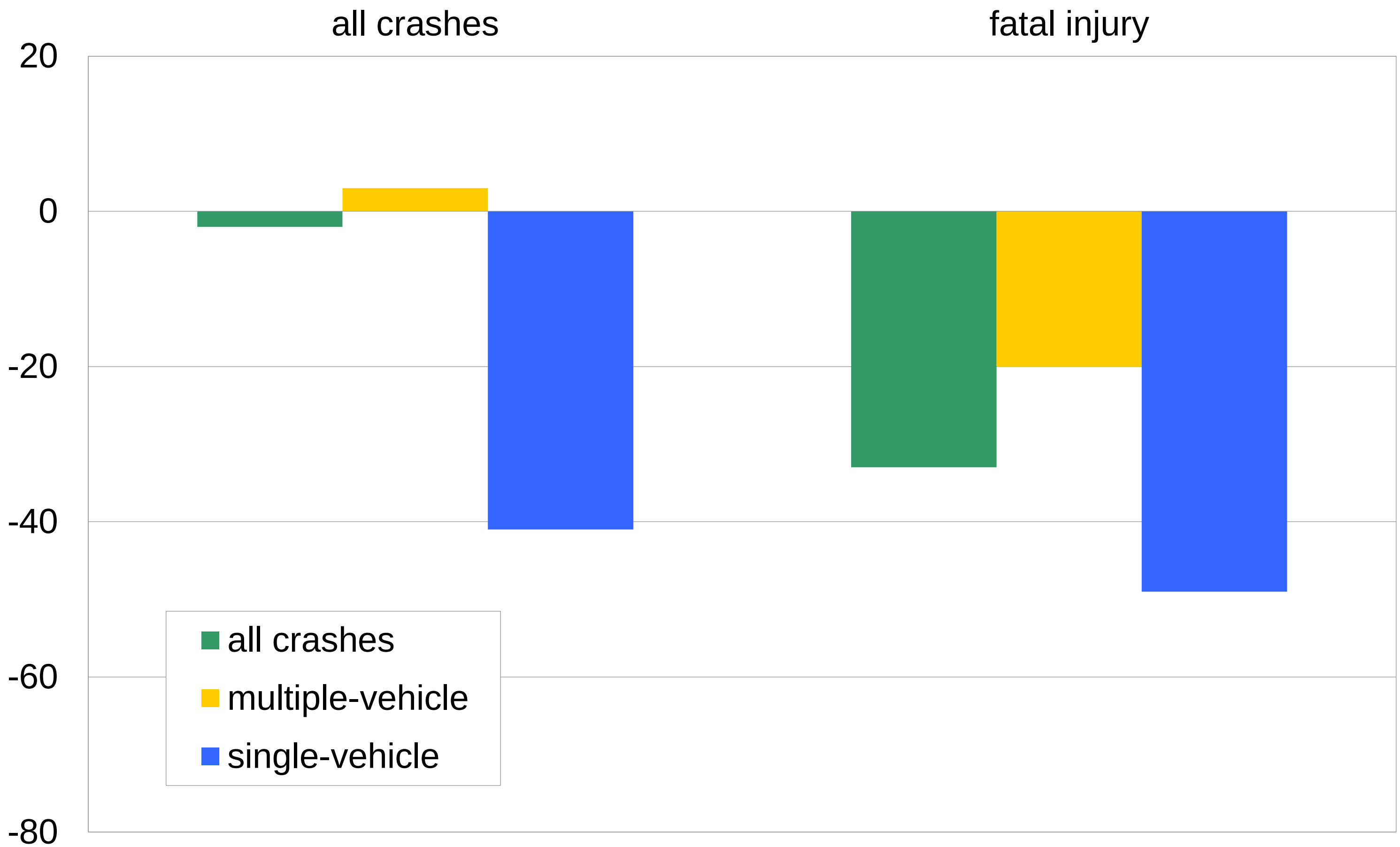
Radar, LIDAR, ultrasonic, infrared, cameras, GPS



Vehicles without and with ESC

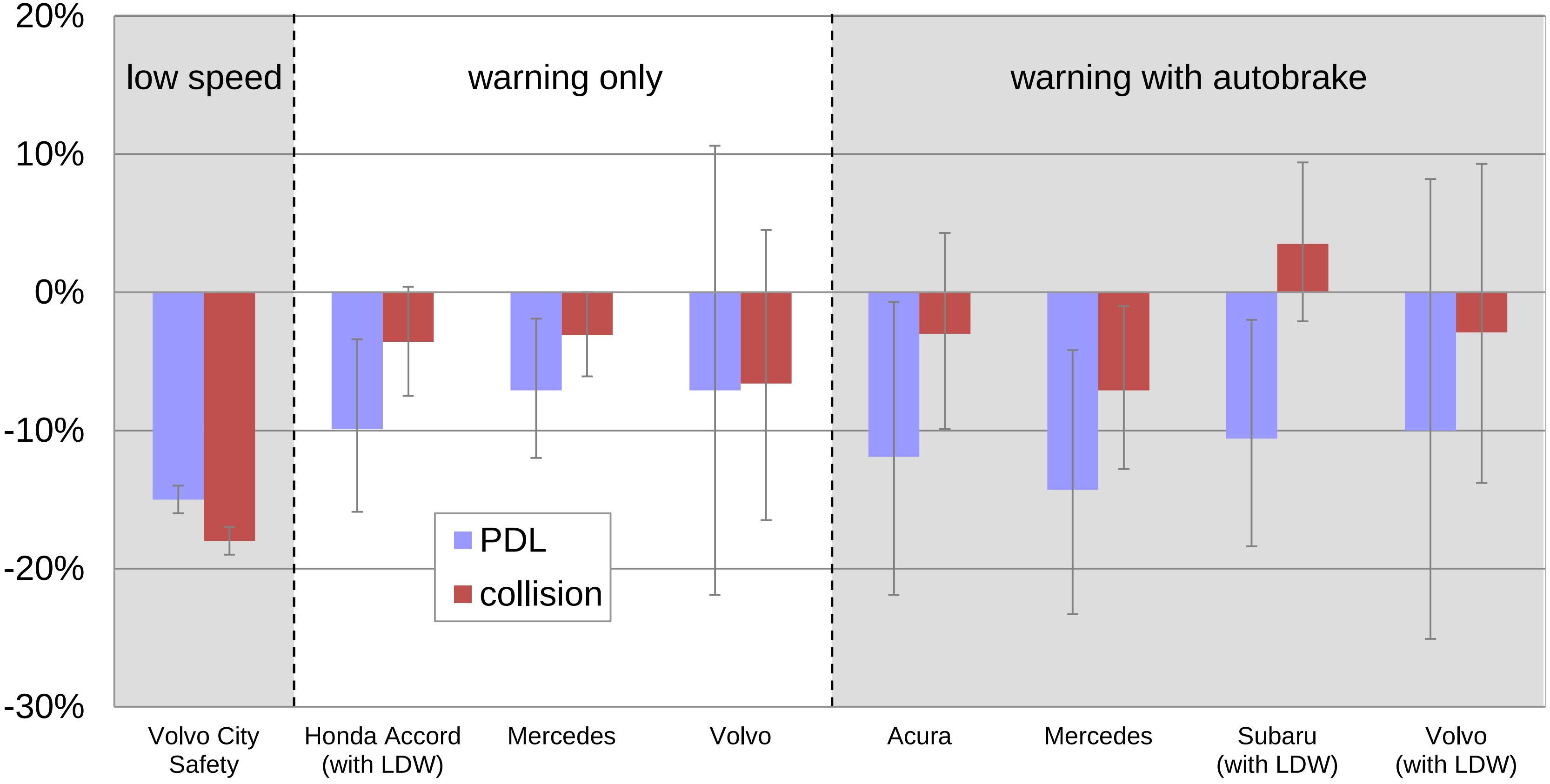
Effects on crash risk

Percent change in crash rates for vehicles with standard ESC vs. optional or no ESC, updated May 2010

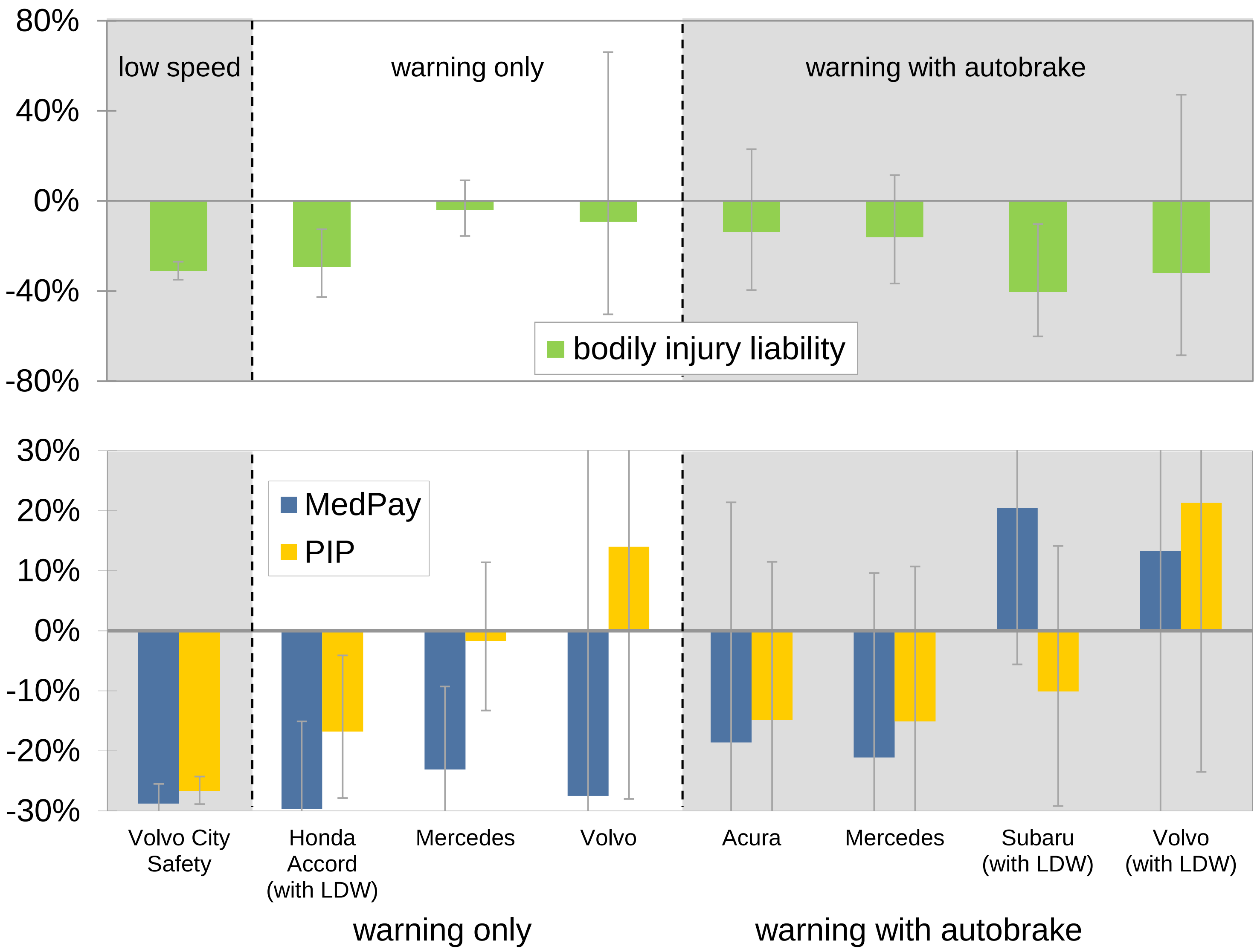


Front crash prevention systems are reducing front to rear crashes

Changes in physical damage claim frequency for front crash prevention systems



Changes in injury claim frequency for front crash prevention systems



Front crash prevention

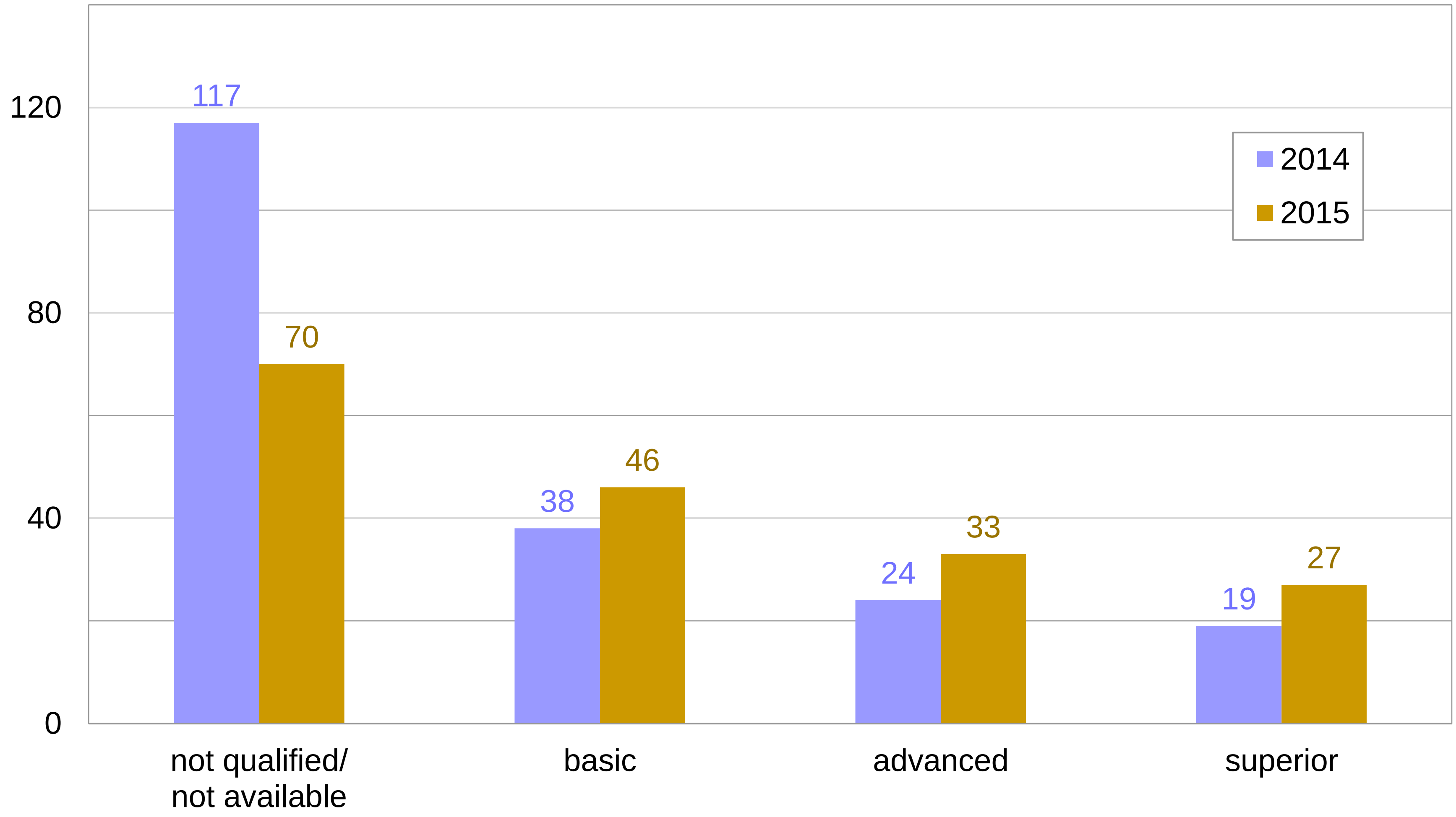
Automatic braking tests at 12 mph and 25 mph

BMW comparison video

12 mph tests

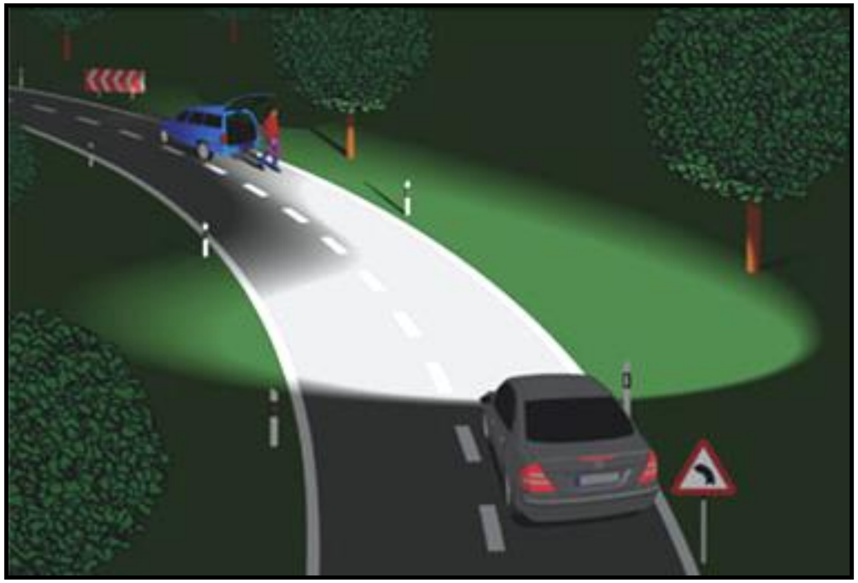
Front crash prevention ratings

2014 and 2015 models



Adaptive headlights

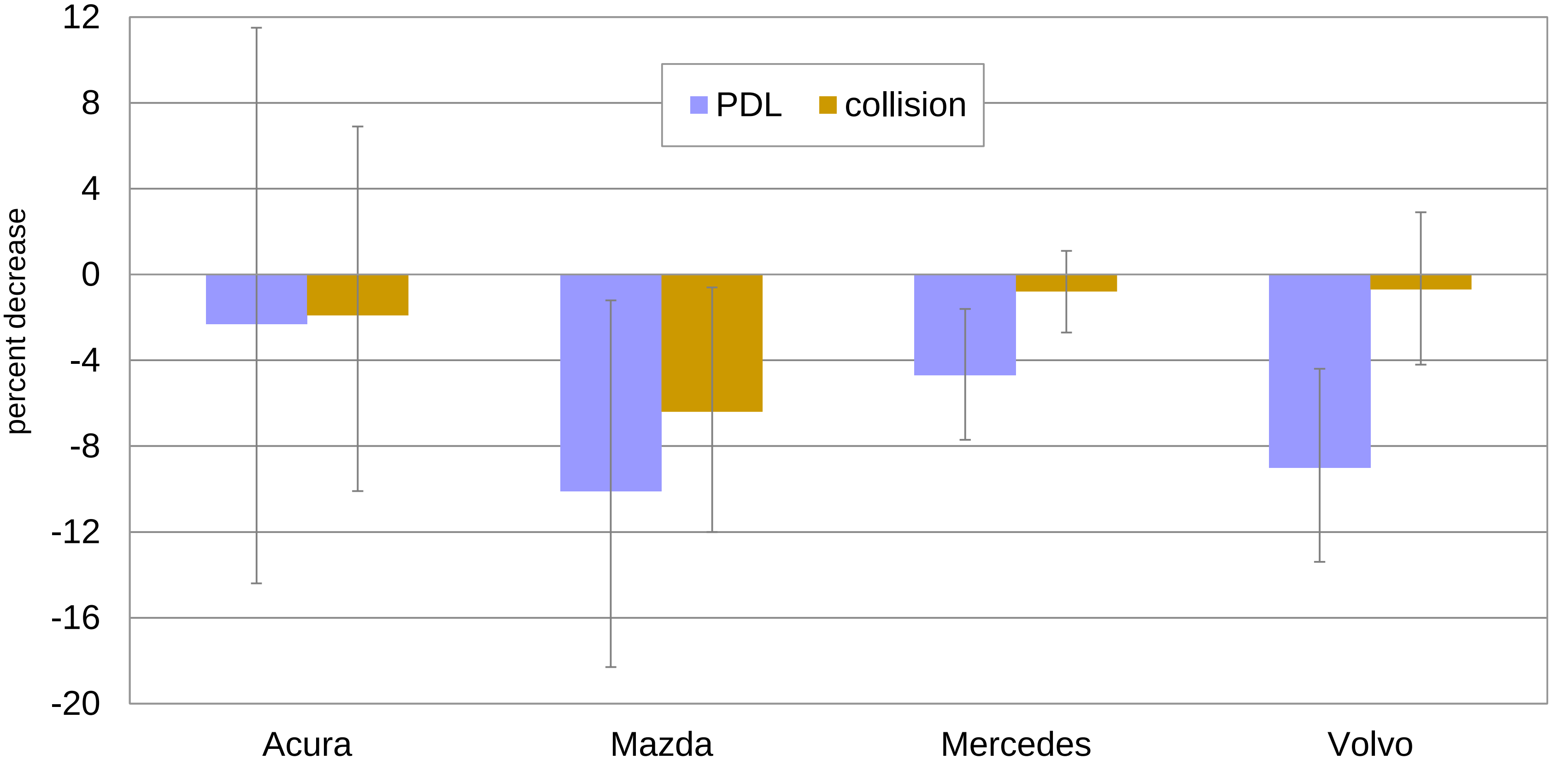
without



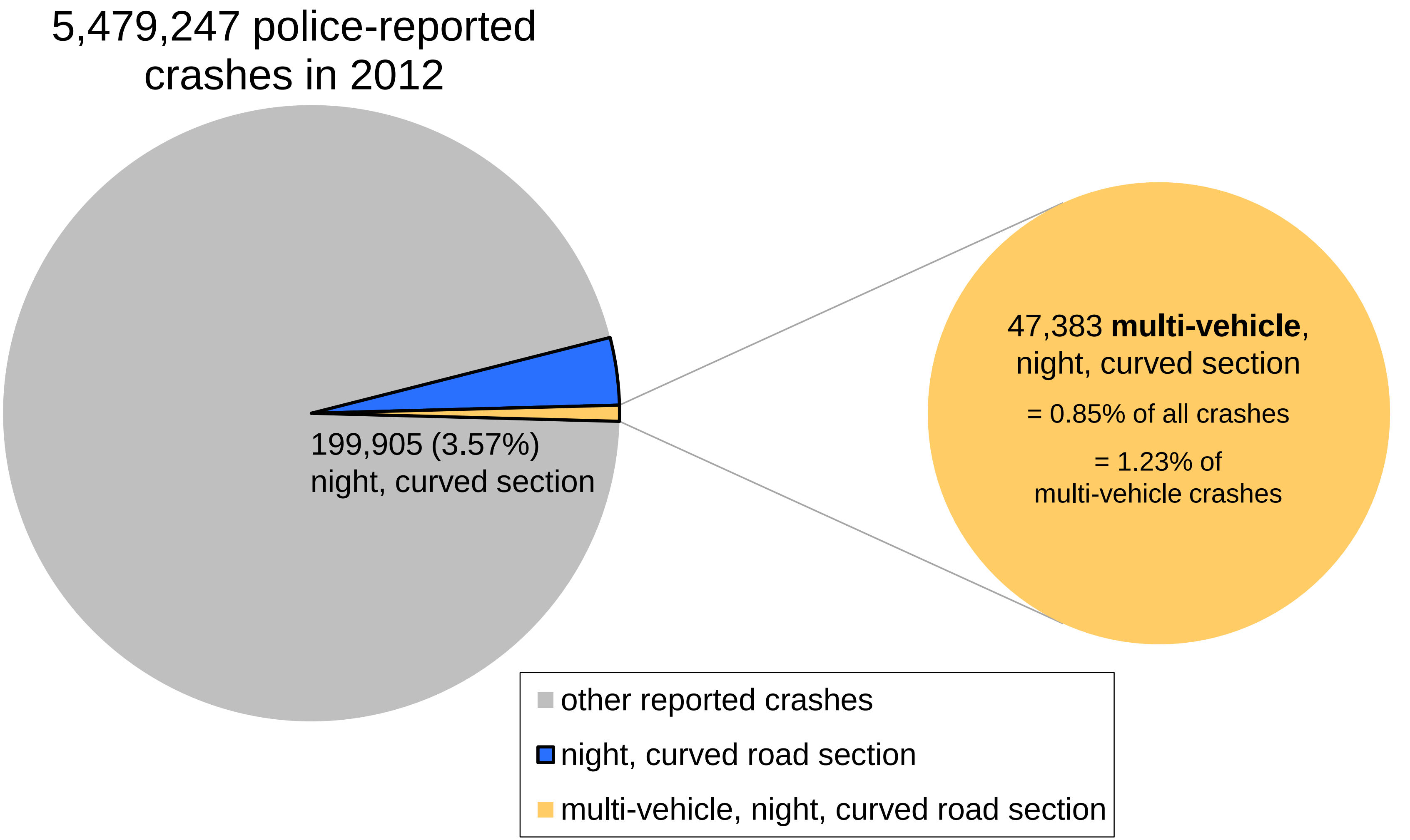
with

Adaptive headlights

Percent change in vehicle damage claims per insured vehicle year

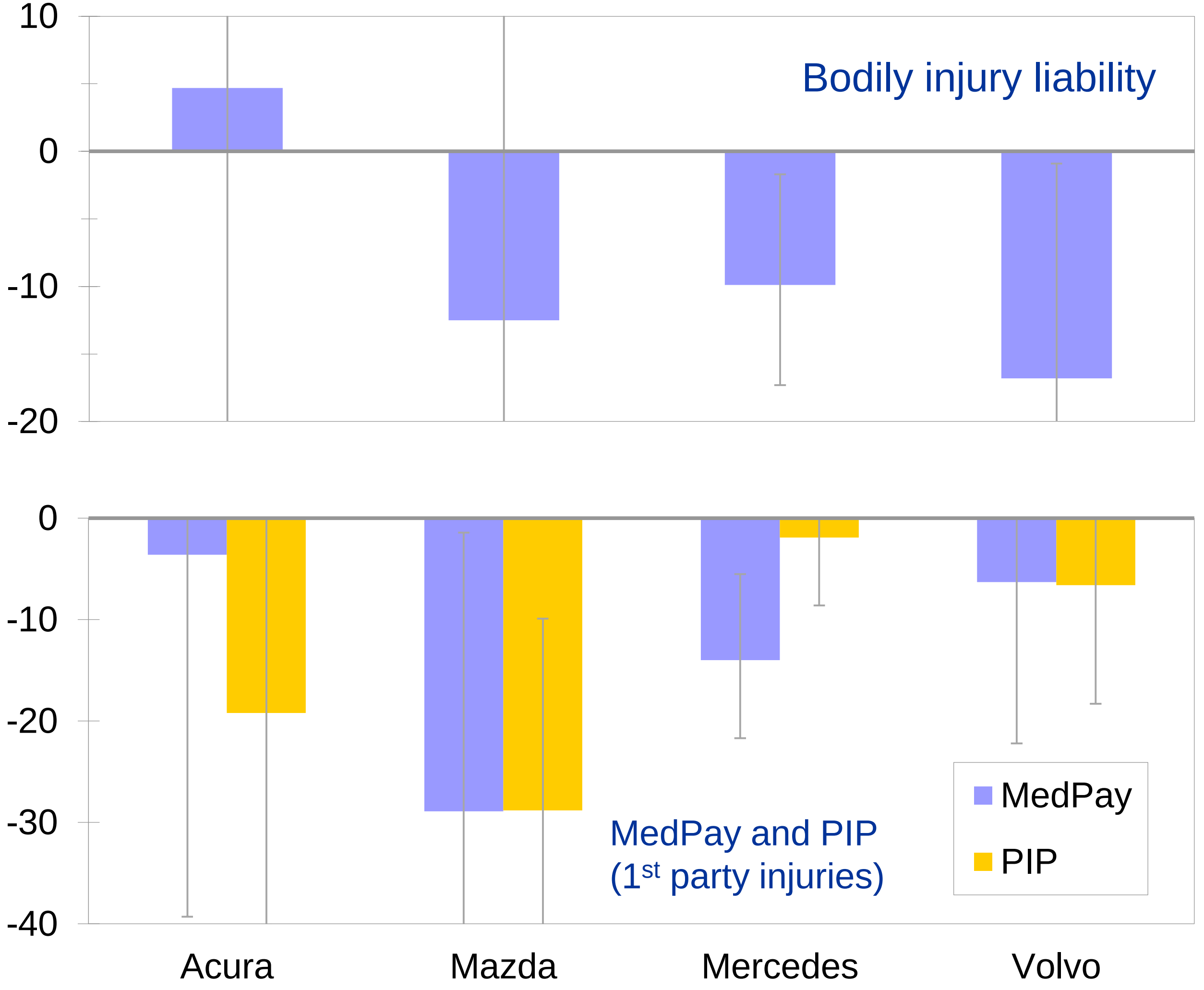


Nighttime (6 pm to 6 am) crashes on curves



Adaptive headlights

Percent change in injury claims per insured vehicle year

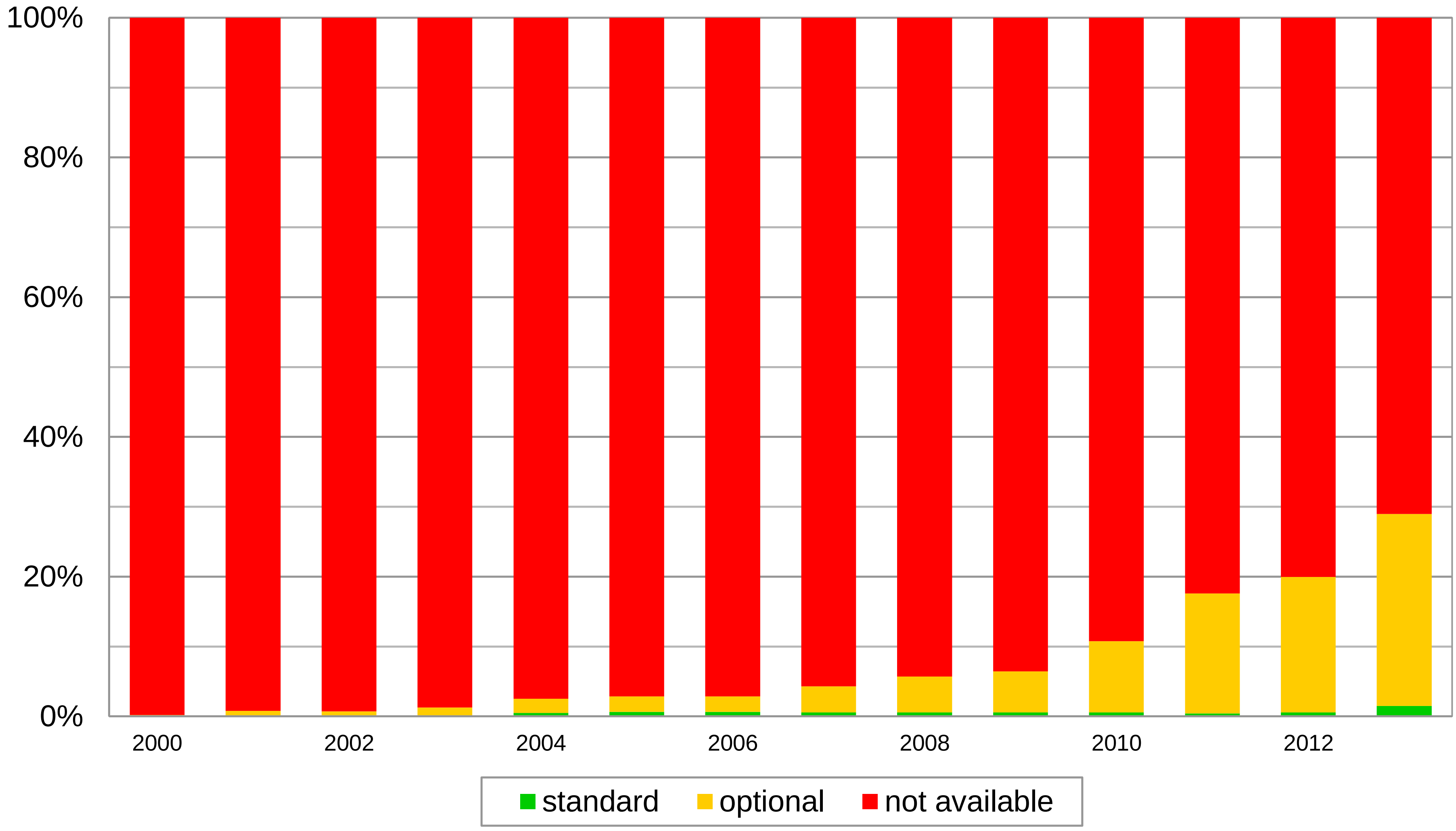


Pedestrian detection

The impact of advanced driver assist systems on insurance (and safety) will occur gradually as technology penetrates the fleet

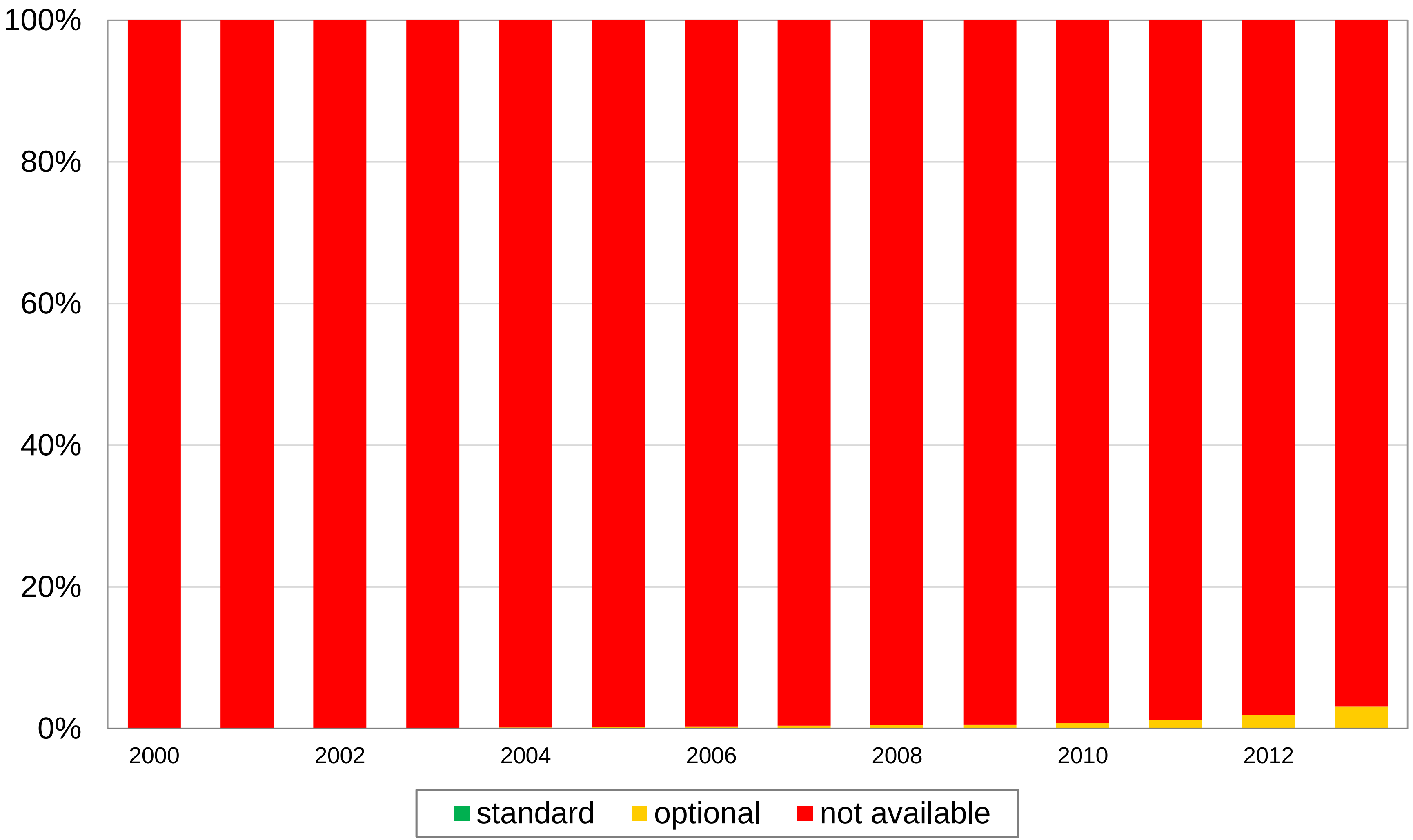
New vehicle series with front crash prevention

By model year



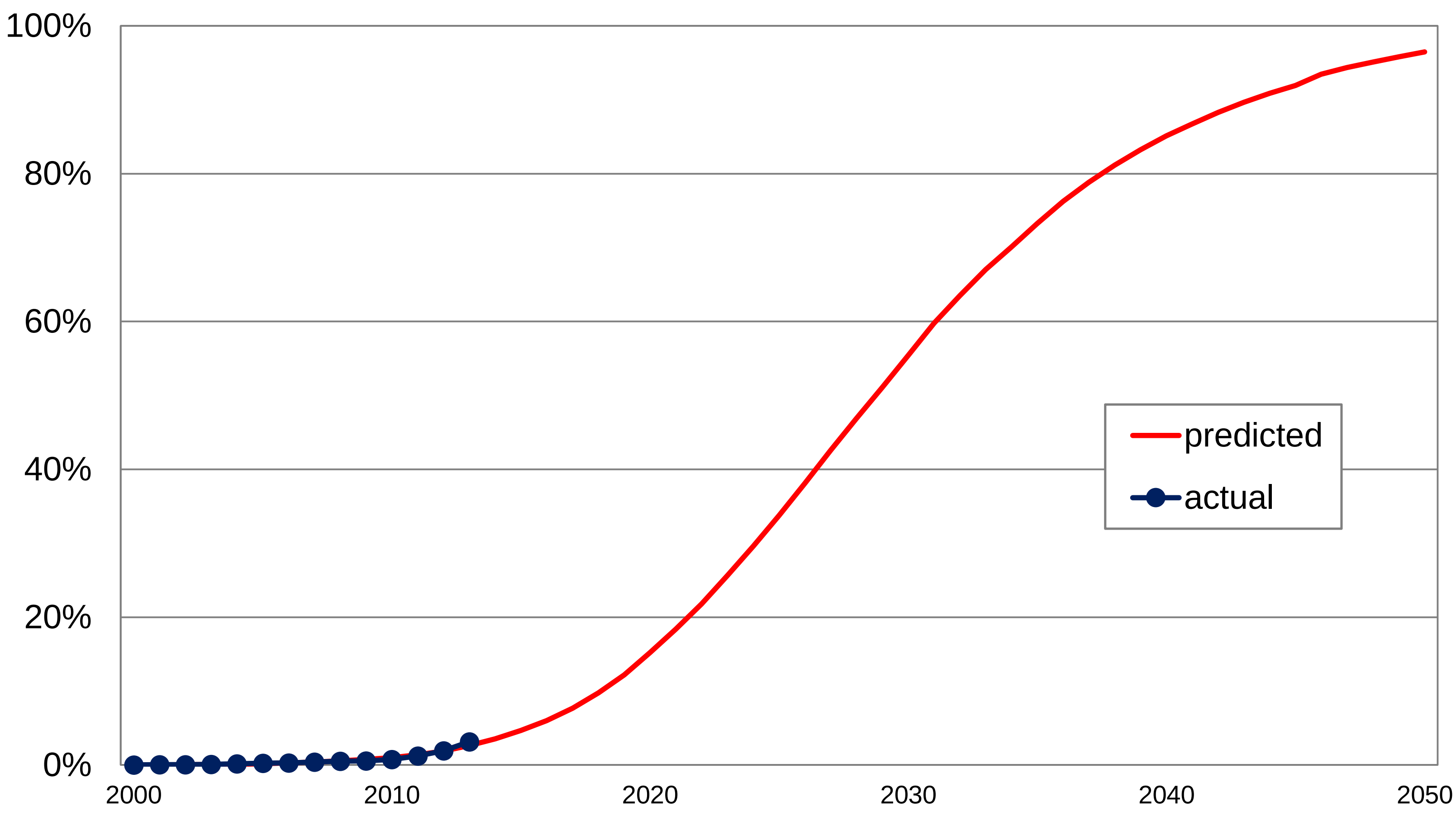
Registered vehicles with front crash prevention

By calendar year

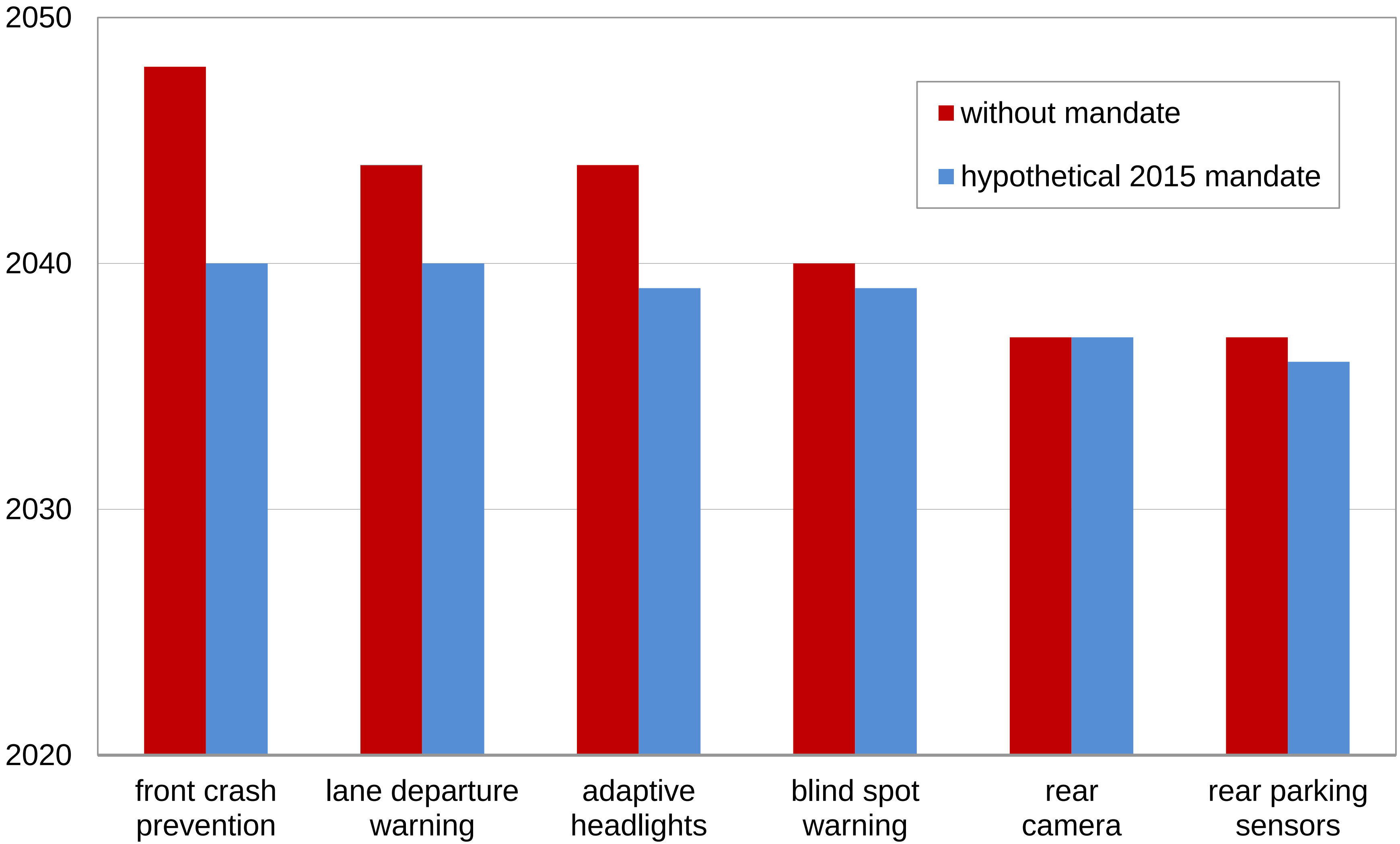


Registered vehicles with front crash prevention, actual and predicted

By calendar year



Calendar year features reach 95% of registered vehicles with and without hypothetical mandate



In the meantime, there are other actions we can take to achieve Vision Zero that can mitigate driver distraction and error


STATUS REPORT
INSURANCE INSTITUTE FOR HIGHWAY SAFETY
Vol. 46, No. 7, Aug. 18, 2011
LOW-HANGING FRUIT
Oftentimes saving a life on the road is as basic as getting people to slow down, buckle up, or don a helmet. Tried and true countermeasures like these usually don't grab headlines, but if they were more widely propagated across the nation they would yield an immediate reduction in motor vehicle crash deaths.
The number of people who die in crashes in the United States is at a record low. Still, there were an estimated 32,788 motor vehicle crash deaths last year, according to a preliminary projection by the National Highway Traffic Safety Administration (NHTSA). Vehicles are safer than ever, and emerging technologies

August 2011

Low-hanging fruit

- Roundabouts
- Primary safety belt use laws
- Mandatory helmet use for all motorcyclists
- Strengthen graduated driver licensing laws
- Lower speed limits
- Automated enforcement of red light running and speeding
- Sobriety checkpoints

These are proven countermeasures that can reduce deaths and injuries on our highways as soon as implemented.


Video on
roundabouts

If 10 percent of signalized intersections in the United States were converted to roundabouts

- Approximately 46,000 crashes prevented in 2012 including:
  - 184 fatal crashes
  - 31,000 injury crashes
- Vehicle delays reduced by more than 900 million hours
- Fuel consumption reduced by more than 600 million gallons

Fatalities in red light running crashes

2011

	number
Driver in red light running vehicle	247
Passenger in red light running vehicle	83
Occupants non-red light running vehicle	341
Pedestrian, bicyclist and personal conveyance	**43**
TOTAL	714

Percent difference in actual fatal crash rates during 2004-08 in 14 large cities with red light cameras vs. expected rates without cameras

Driver fails to stop for red traffic light

Dedicated to reducing deaths, injuries, and property damage on the highway

www.iihs.org