INSURANCE INSTITUTE
FOR HIGHWAY SAFETY

September 18, 2012

The Honorable David L. Strickland
Administrator
National Highway Traffic Safety Administration
1200 New Jersey Avenue, SE
Washington, DC 20590

Request for Comments on Research Report; Advanced Braking Technologies That Rely On Forward-Looking Sensors; Docket No. NHTSA-2012-0057

The Insurance Institute for Highway Safety (IIHS) welcomes the opportunity to comment on the National Highway Traffic Safety Administration's (NHTSA) research report on advanced braking technologies. We have reviewed the report, including its recommendations for tests intended to detect the presence of both Dynamic Brake Support (DBS) and Collision Imminent Braking (CIB) systems that can be effective toward helping drivers avoid or mitigate the consequences of front-to-rear collisions. IIHS has been engaged in efforts to measure the effectiveness of CIB systems and also has conducted testing similar to that reported by the agency. As such, we would like to share results of our research that may be relevant to NHTSA's deliberations concerning the promotion or regulation of advanced braking systems.

Effectiveness Estimates for CIB Systems

Since 2008, IIHS and its subsidiary the Highway Loss Data Institute (HLDI) have been analyzing insurance loss data to ascertain whether various crash avoidance technologies are indeed helping drivers avoid crashes. In July 2011, we published results of our initial assessment of the effectiveness of Volvo's City Safety, a low-speed CIB system that was standard equipment on the new XC60 midsize SUV. We found that in comparison with other midsize luxury SUVs, the XC60 had an insurance claim frequency under property damage liability (PDL) coverage that was 27 percent lower. PDL insurance pays for damage done to other vehicles struck by the insured vehicle through fault of its driver. As such, PDL claim frequency is a relatively sensitive measure of effectiveness relative to the types of crashes City Safety is intended to prevent or mitigate, that is, low-speed front-to-rear crashes. Consistent with the elimination of claims for crash damage, HLDI's analysis also found a reduction by half in the frequency of claims filed under bodily injury liability (BI) coverage for the XC60 compared with its counterparts. The reduction in injury claim frequency reflects both the avoidance of some crashes and the reduction in severity of others that occurred despite the intervention of City Safety's crash imminent braking. A copy of our report detailing this analysis is attached.

More recently, in July 2012, HLDI published reports that include estimates of the effectiveness of CIB systems available as optional equipment on some Acura, Mercedes-Benz, and Volvo vehicles. In comparison with the same models without these systems, vehicles equipped with CIB had PDL claim frequencies that ranged between 10 and 14 percent lower. Our estimate for Mercedes-Benz vehicles (14 percent reduction) includes the benefit of the DBS system that is included with the CIB system. These reductions range 1.4 times to double our estimates for earlier Volvo and Mercedes-Benz forward collision warning systems without CIB, respectively. Consistent with the elimination of claims for crash damage, HLDI's analysis also found a reduction in the frequency of claims filed under BI insurance. Copies of the three reports detailing these analyses are attached.

Our insurance-based estimates of the effectiveness of CIB systems are consistent with NHTSA's forecast that these systems have considerable potential to prevent crashes and associated injuries. Indeed, our research suggests they already are doing so. Consequently, IIHS also supports the agency's efforts to develop test procedures to measure the performance of CIB systems as a precursor to promoting these systems to consumers through its New Car Assessment Program or possibly requiring them on all passenger vehicles at some time in the future.

Testing of CIB Systems

IIHS has been engaged in testing vehicles equipped with CIB systems since November of last year and also has participated in international discussions about the development of tests for evaluating CIB systems. We have attempted to include in our testing, conditions that span the range of those being considered by others engaged in similar development efforts. Although only one of the many test conditions in our matrix matches those proposed by NHTSA, three others are similar enough to tests proposed by the agency that they may be relevant to its deliberations.

We have conducted tests in which the test vehicle (TV) approaches a stationary other vehicle (OV) at 40 km/h (25 mi/h), which is one of the test conditions proposed by NHTSA. The dummy OV in all tests was NHTSA's first generation foam vehicle (Figure 1). At least two trials with each of three different vehicle models fitted with systems studied by HLDI were recorded, and the maximum, minimum, and average results for each set are shown in Figure 2.[1] Only one of these models passed NHTSA's proposed velocity reduction of 15.8 km/h (9.8 mi/h): the 2011 Mercedes-Benz E350 with Distronic plus. Despite real-world estimates indicating that these systems prevent between 10 and 27 percent of insurer-reported crashes involving other vehicles, the Acura and Volvo[2] systems do not meet the proposed speed reduction for this test condition. Although tests of a Volvo S60 equipped only with City Safety were included among our tests, results for this test condition are not shown because City Safety does not intervene at speeds above about 30 km/h.

NHTSA proposes to include a test in which the TV travelling at 25 mi/h (40 km/h) approaches an OV moving at 10 mi/h (16 km/h). IIHS has conducted a series of tests in which the TV travelling at 40 km/h approaches an OV moving at 20 km/h (12 mi/h). Vehicles from Acura and Mercedes-Benz with CIB systems examined by HLDI were included in these tests. Neither avoided an impact with the OV as proposed by NHTSA despite the speed differential in the IIHS tests being less than that in the NHTSA-proposed test, as illustrated in Figure 3. Two different dummy OVs were used in our testing: NHTSA's first generation foam vehicle and the guided soft target developed by Dynamic Research Incorporated (Figure 4).

Figure 1
NHTSA First Generation Foam Vehicle

[1] Results of the individual test trials are listed in the Appendix, Table A-1.
[2] The 2010 Volvo XC with forward collision warning with autobrake was equipped with Volvo's earlier generation system, which was studied by HLDI, not its current system with full-autobrake.

Figure 2
Vehicle Speed Reduction, 40 km/h TV Against Stationary OV

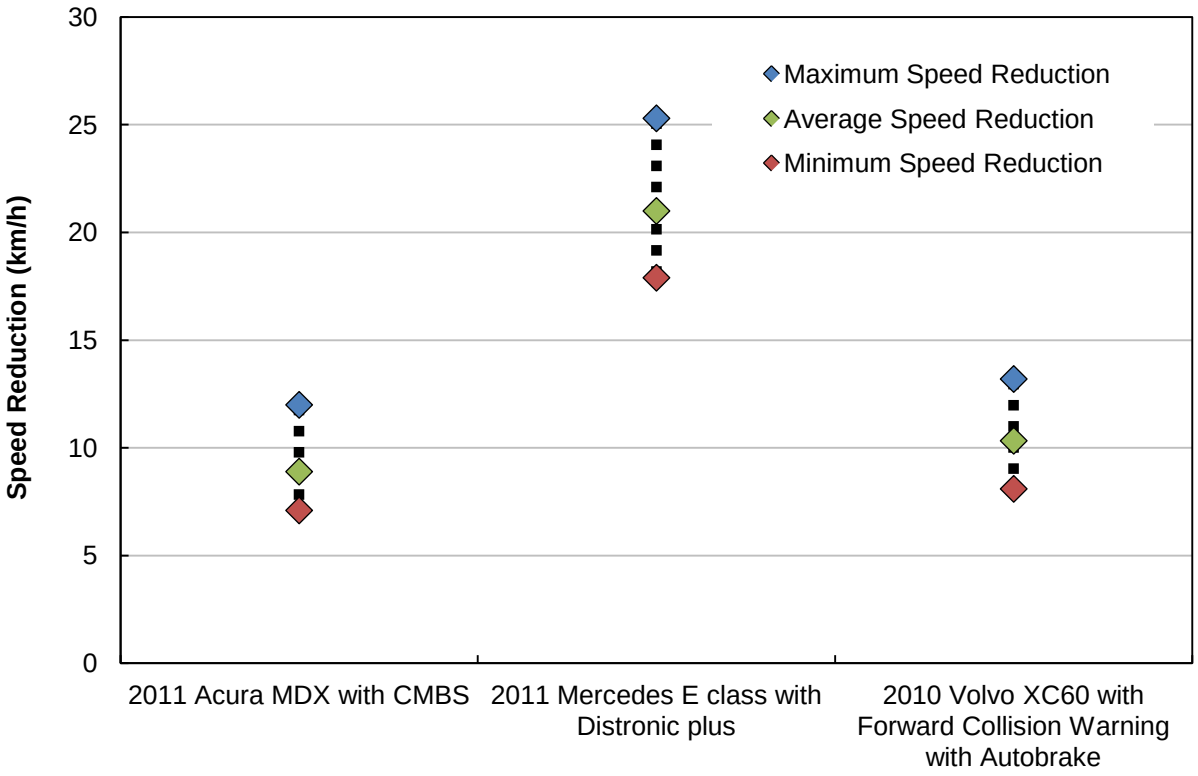


Figure 3
Speed Reductions in 40 km/h vs. 20 km/h Tests

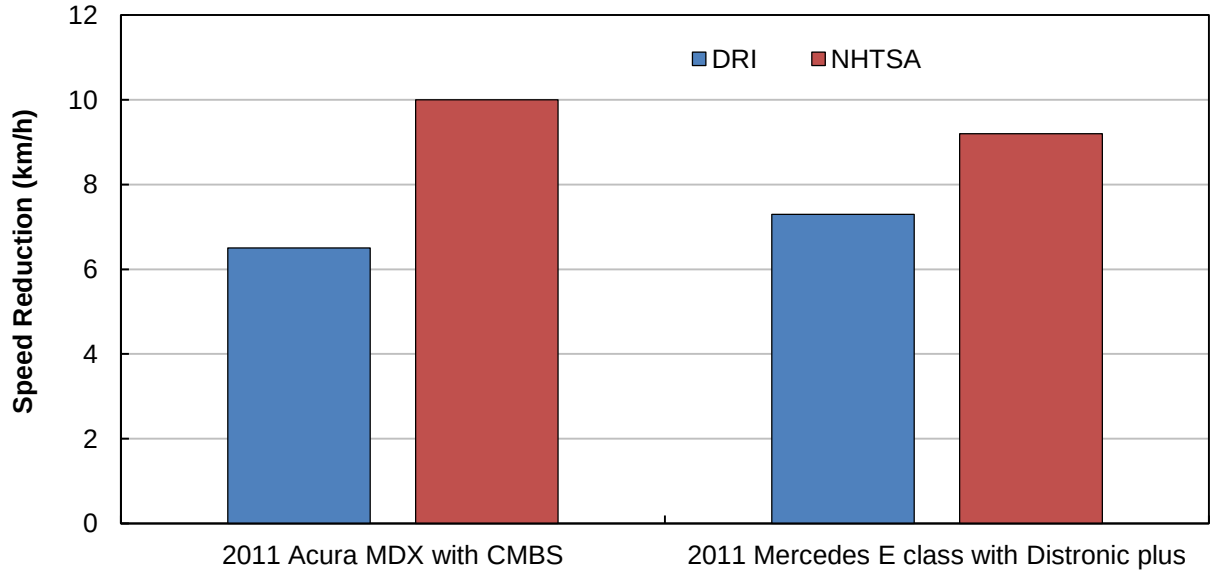
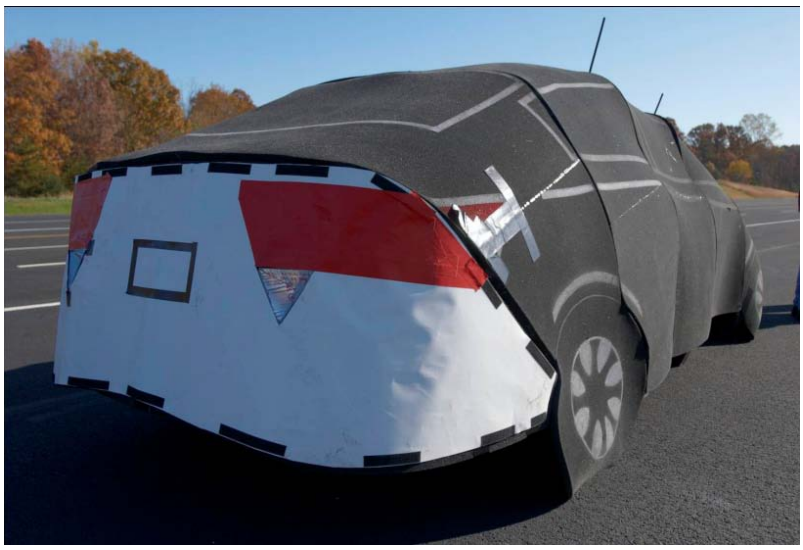
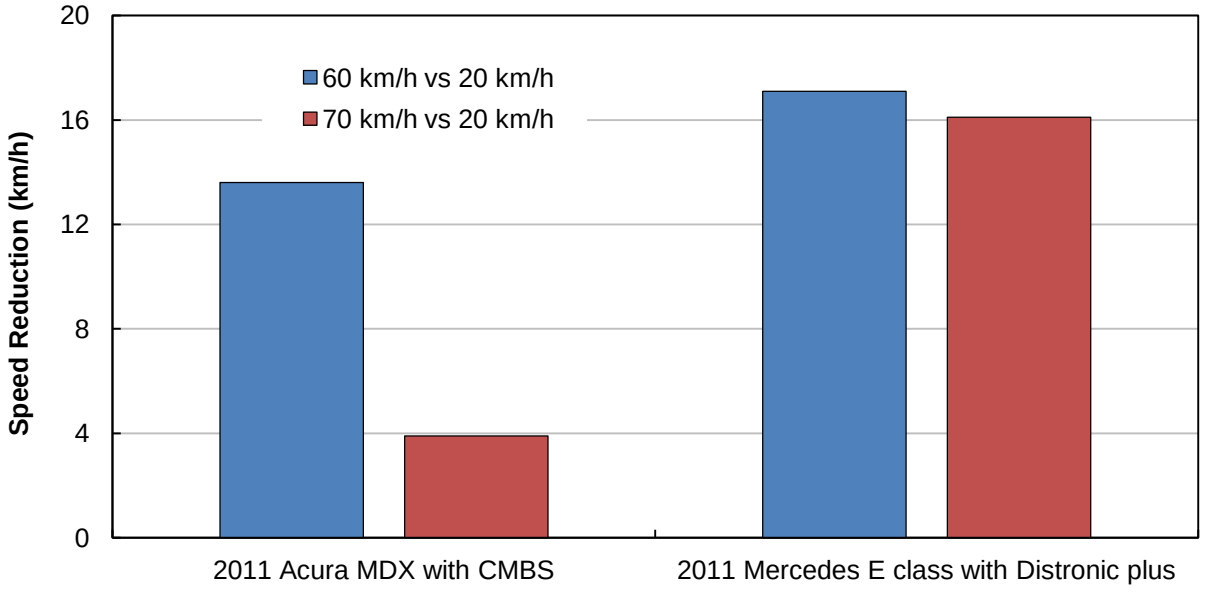


Figure 4
Dynamic Research Inc. Guided Soft Target



NHTSA also proposes to include a test in which the TV travelling at 45 mi/h (72 km/h) approaches an OV moving at 20 mi/h (32 km/h). IIHS has conducted tests with the same differential but different actual speeds (60 km/h TV approaching 20 km/h OV) and similar TV speed with somewhat higher speed differential (70 km/h TV approaching 20 km/h OV). Again, both the Acura and Mercedes-Benz systems examined by HLDI were included in this testing. Figure 5 shows that whereas the Mercedes-Benz E350 achieved speed reductions greater than NHTSA's proposed 9.8 mi/h (15.8 km/h) in both tests, the Acura MDX did not.

Figure 5
Speed Reductions in Moving Target Tests



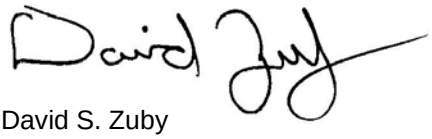
IIHS tests include vehicles with more advanced CIB systems than summarized in this comment. Some of these systems achieve better results in all of the NHTSA-proposed test conditions than the models we have highlighted. However, we are not aware of any estimates of the actual effectiveness of these more advanced and better performing systems.

The CIB performance requirements proposed by NHTSA seem to reflect a careful balance between what is possible with the latest CIB systems and what is needed to achieve their full safety potential. However, they do not reflect the latest available information about the actual effectiveness of CIB systems currently in the U.S. vehicle fleet. IIHS recommends that NHTSA take the results of HLDI's analyses into account in its deliberations concerning consumer information or regulatory actions toward CIB systems. Acura Collision Mitigation Braking System, Mercedes-Benz Distronic plus, and both Volvo City Safety and Collision Warning with Autobrake systems ought to meet the performance requirements for required or recommended systems, even if they do not achieve the highest marks in any possible rating system.

Summary

IIHS agrees with NHTSA that CIB systems have great potential to reduce the occurrence and consequences of crashes on U.S. roads. We commend the agency's efforts to forecast and measure the potential benefits of CIB, even if it does not currently reflect the actual benefits recently measured by IIHS and HLDI. We strongly urge NHTSA to take our evaluations into account as the agency deliberates its next steps with regard to CIB. Systems already proven to prevent and mitigate crashes should meet any requirements for mandatory or recommended systems, even if they do not earn the highest ratings in evaluation programs.

Sincerely,



David S. Zuby
Chief Research Officer

Attachments

Highway Loss Data Institute. 2011. Volvo City Safety loss experience: initial results. *Bulletin* 28(6). Arlington, VA.

Highway Loss Data Institute. 2011. Acura collision avoidance features: initial results. *Bulletin* 28(21). Arlington, VA.

Highway Loss Data Institute. 2012. Mercedes-Benz collision avoidance features: initial results. *Bulletin* 29(7). Arlington, VA.

Highway Loss Data Institute. 2012. Volvo collision avoidance features: initial results. *Bulletin* 29(5). Arlington, VA.

Appendix

Table A-1
Speed Reductions in Stationary Target Tests

	Test Run	Actual Closing Speed (km/h)	Speed Reduction (km/h)
2011 Acura MDX with Collision Mitigation Braking System	1	41.5	7.6
	2	38.9	12.0
	3	38.9	7.1
2011 Mercedes E class with Distronic plus	1	38.3	19.9
	2	38.7	18.8
	3	39.1	17.9
	4	39.8	19.7
	5	40.0	23.4
	6	40.1	21.2
	7	40.3	23.6
	8	40.4	25.3
	9	40.5	19.5
2010 Volvo XC60 with Forward Collision Warning with Autobrake	1	38.4	8.1
	2	39.1	9.7
	3	37.8	13.2

Highway Loss Data Institute Bulletin

Volvo City Safety Loss Experience – Initial Results

VOL. 28, NO. 6 JUNE 2011

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

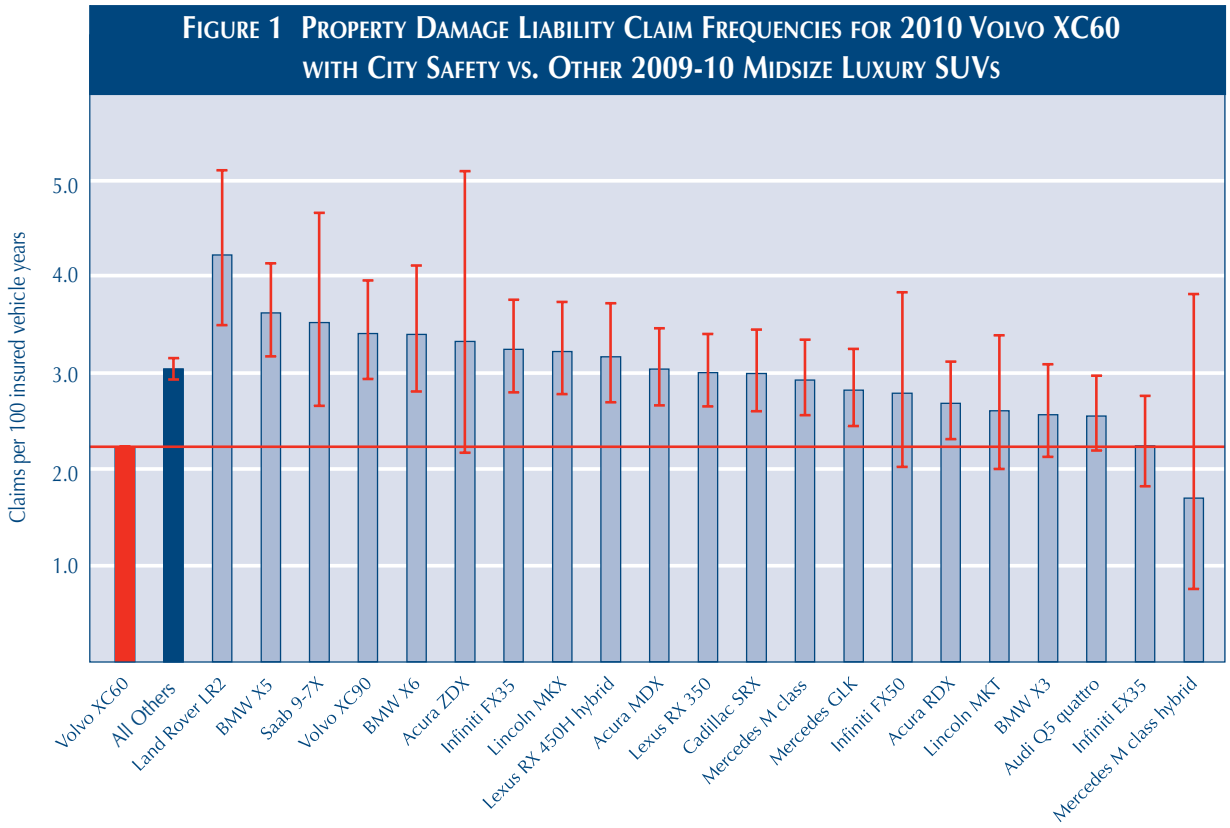
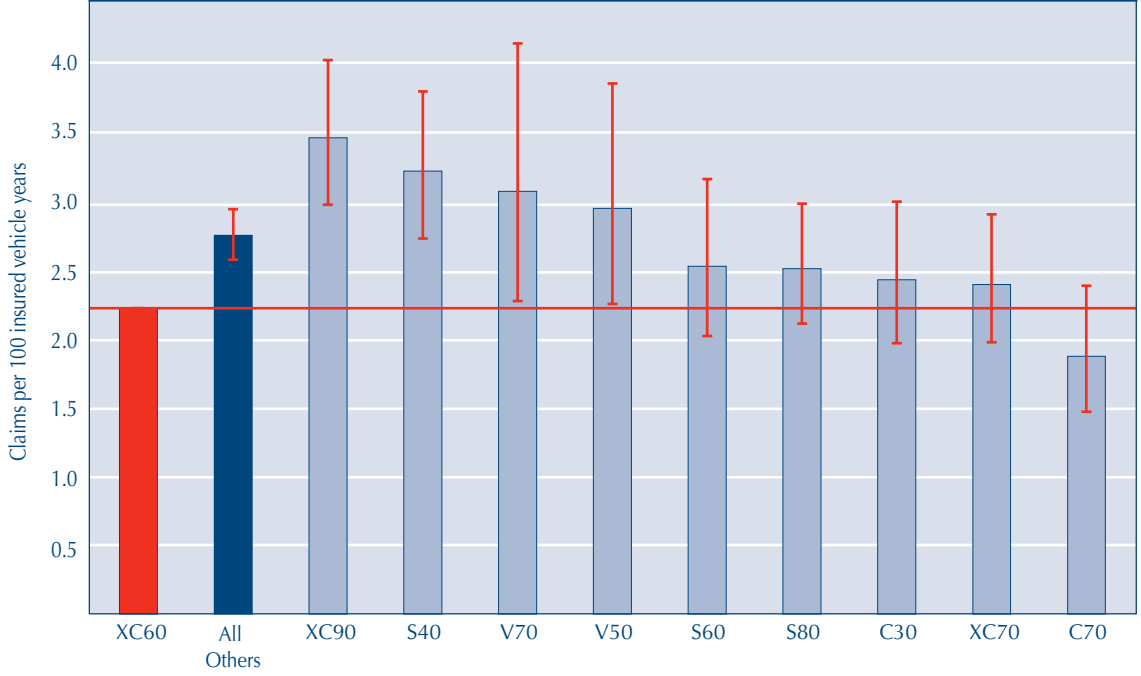


Figure 2 shows the property damage liability claim frequency for the 2010 Volvo XC60 compared with those for other Volvo vehicles. The estimated claim frequency for the Volvo XC60 (2.2 claims per 100 insured vehicle years) was 19 percent lower than that for all other Volvos combined (2.8 claims per 100 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

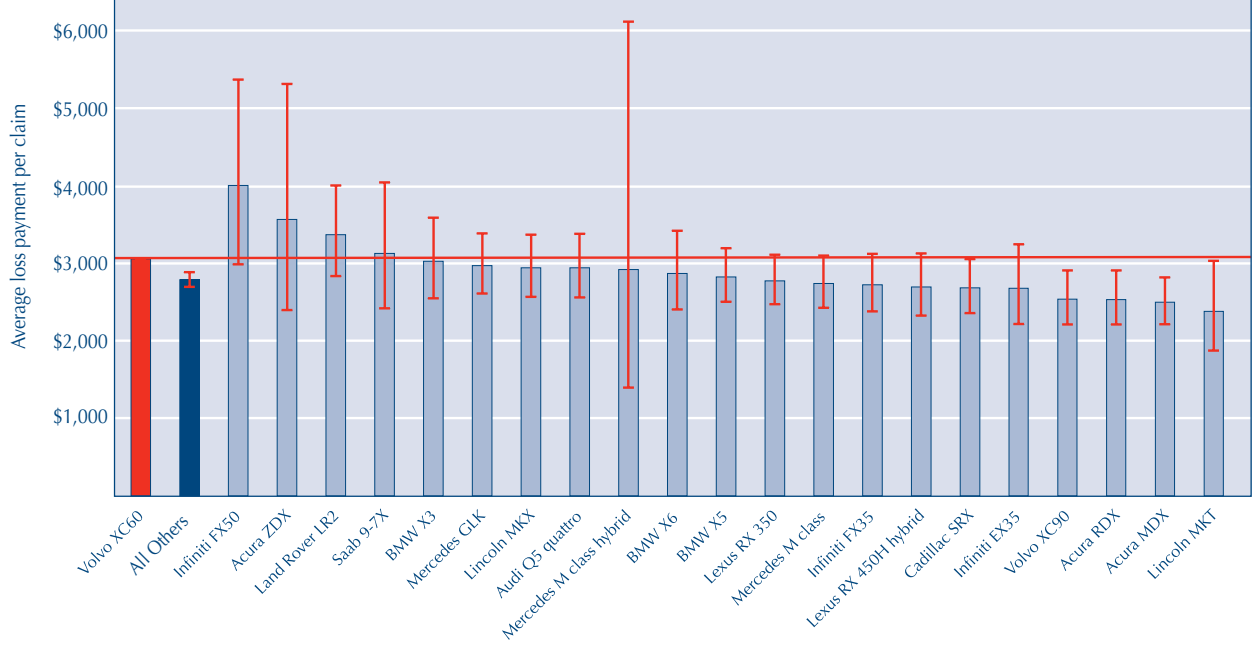
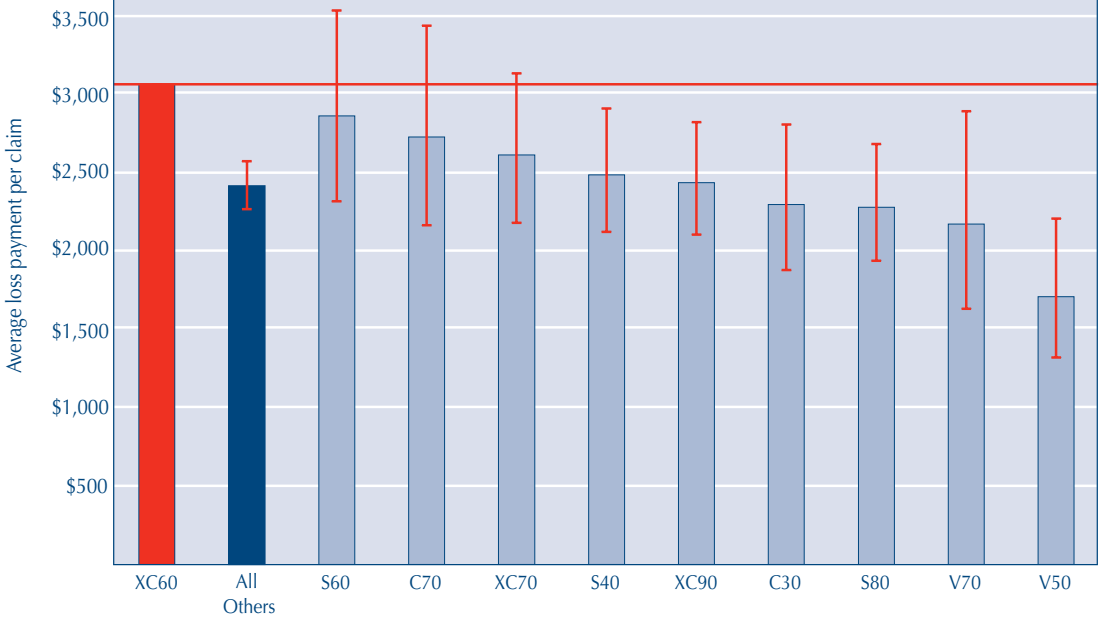


Figure 4 shows the property damage liability claim severity for the 2010 Volvo XC60 compared with those for other Volvo vehicles. The estimated claim severity for the Volvo XC60 was 27 percent higher than that for all other Volvos combined. At the 95 percent confidence level, this estimated increase 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.

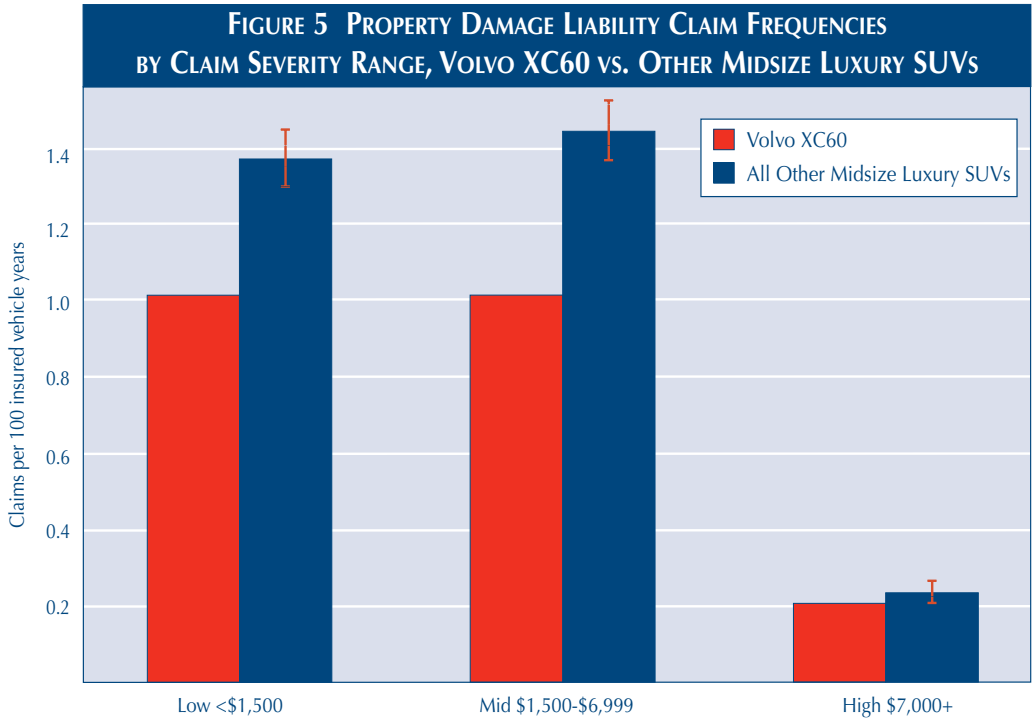
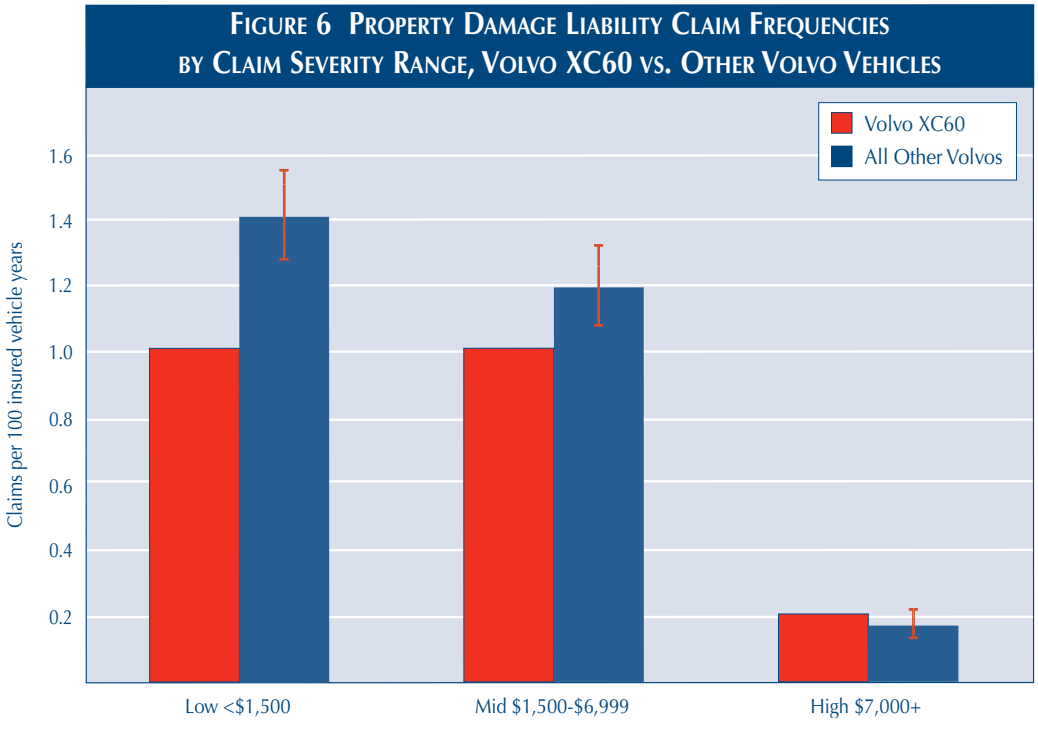


Figure 6 shows property damage liability claim frequencies for the 2010 Volvo XC60 by claim severity range compared with those for other Volvo vehicles. Claim frequencies exhibited a similar pattern to those in Figure 5. As the dollar value of claims increased, the difference in claim frequencies between the XC60 and other Volvos narrowed until the highest claim severity range, where there was no measurable difference.



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

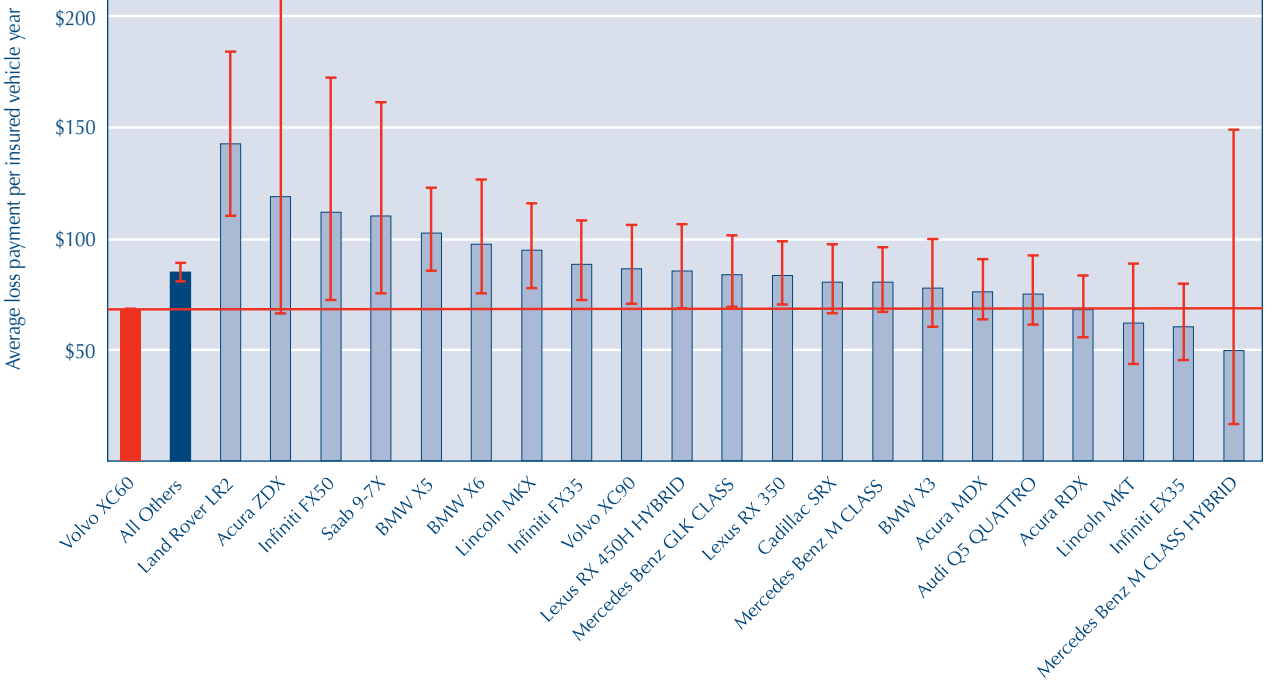


Figure 8 shows the property damage liability overall loss for the 2010 Volvo XC60 compared with those for other Volvo vehicles. The estimated overall loss for the Volvo XC60 was only 2 percent higher than that for all other Volvos combined. At the 95 percent confidence level, this estimate fell between 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

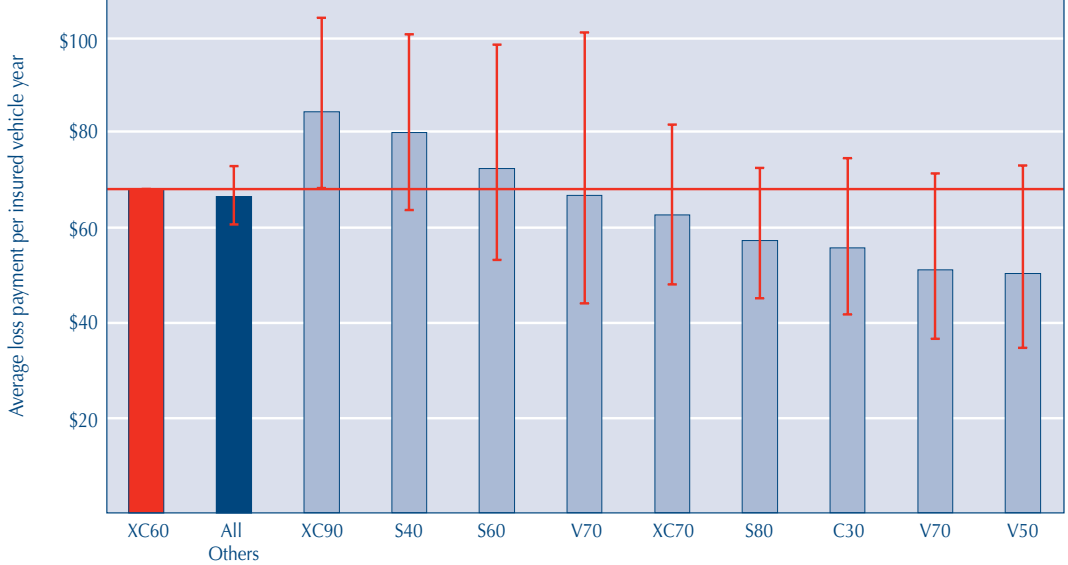


Table 8 summarizes results of the regression analysis conducted for bodily injury liability coverage. It includes estimates of claim frequency for other midsize luxury SUVs and other Volvo vehicles relative to the XC60. Detailed results of the regression analysis are listed in the Appendix.

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

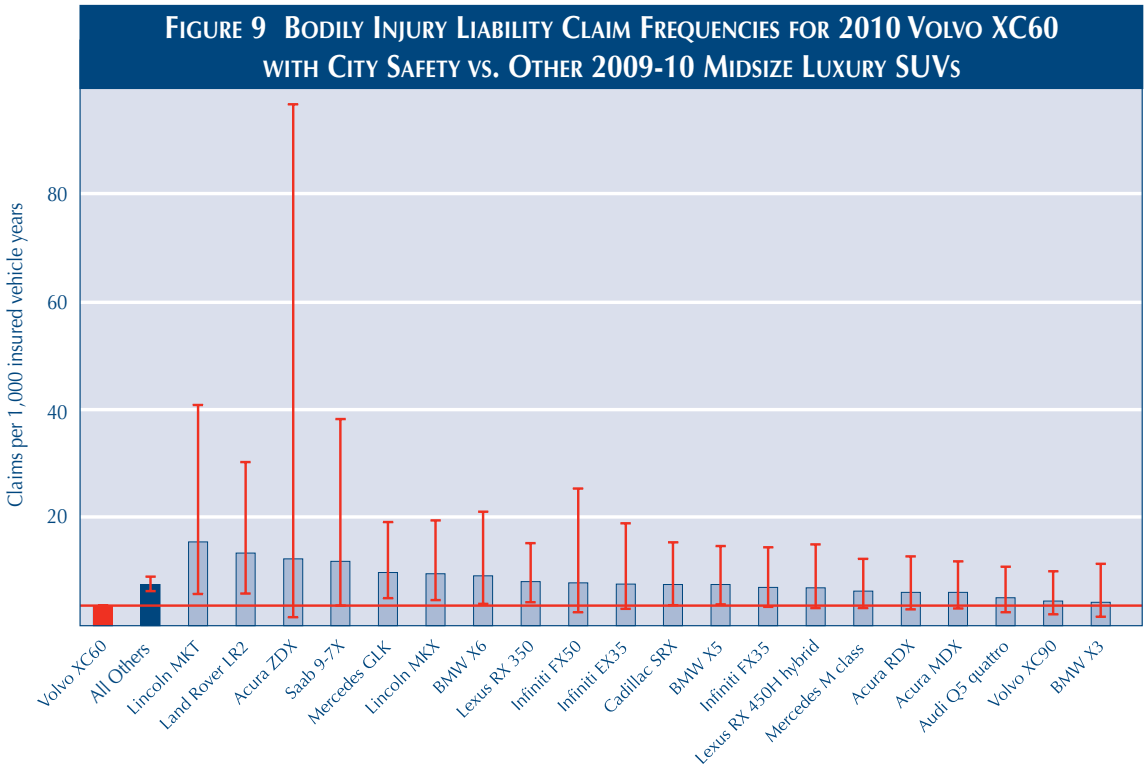


Figure 10 Bodily Injury Liability Claim Frequencies for 2010 Volvo XC60 with City Safety vs. Other 2009-10 Volvo Vehicles

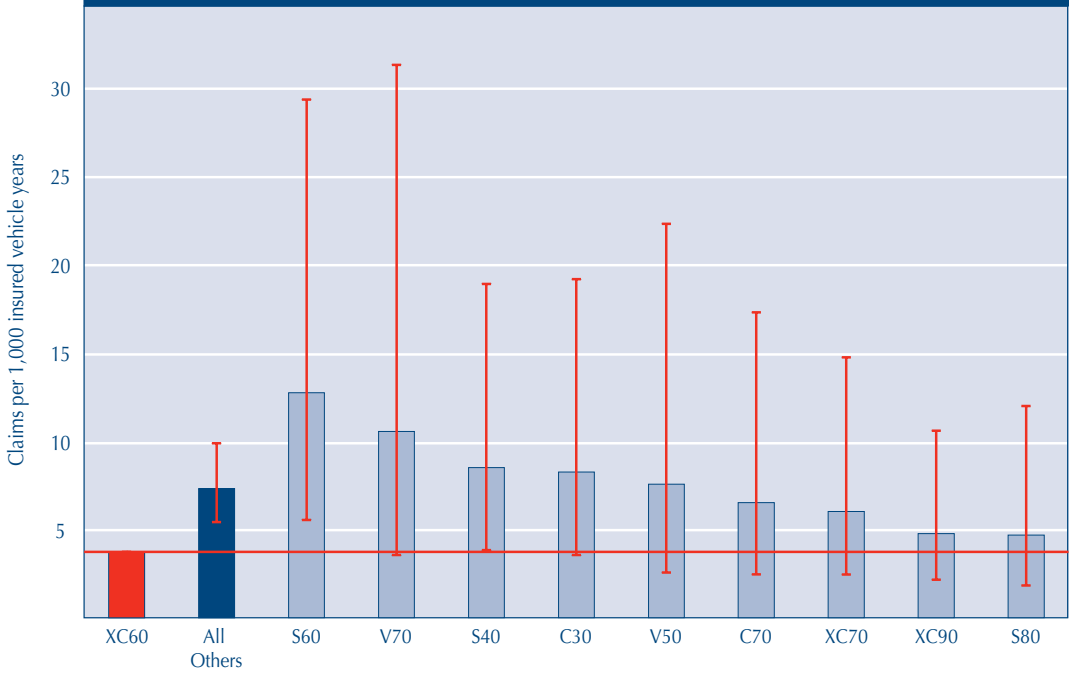


Table 9 summarizes results of the regression analysis conducted for collision coverage. It includes estimates of claim frequency, claim severity, and overall loss for other midsize luxury SUVs and other Volvo vehicles relative to the XC60. Detailed results of the regression analysis are listed in the 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

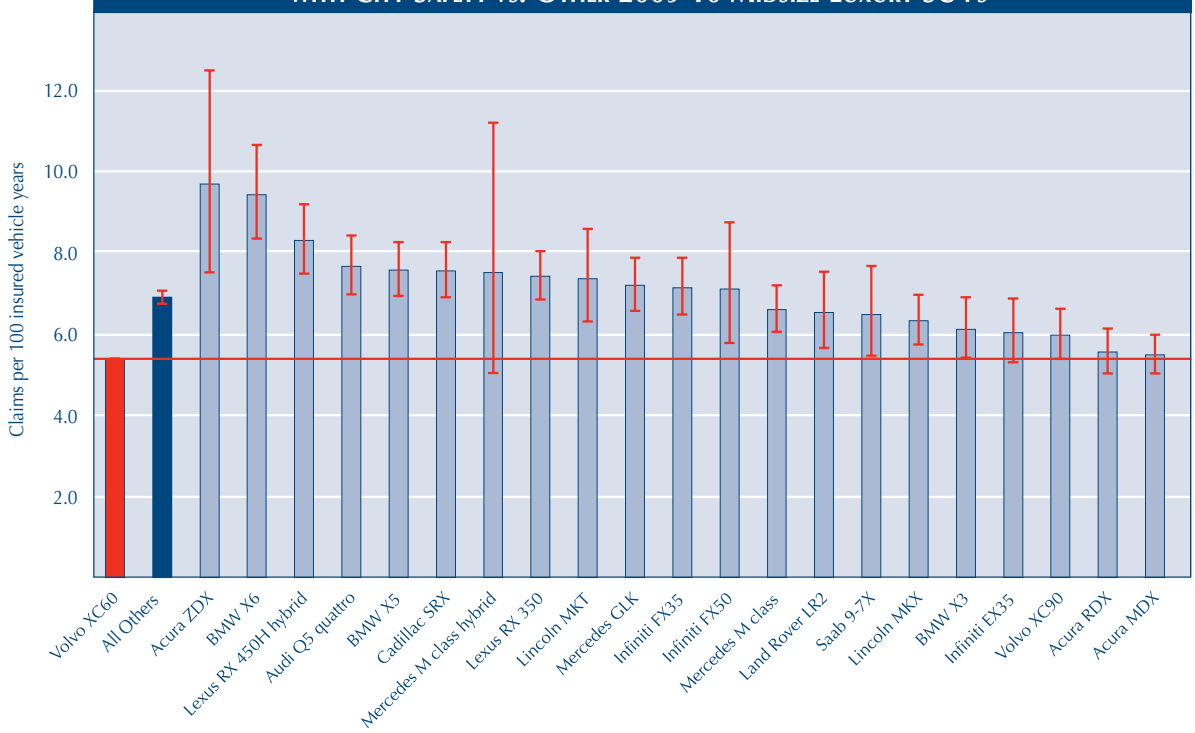
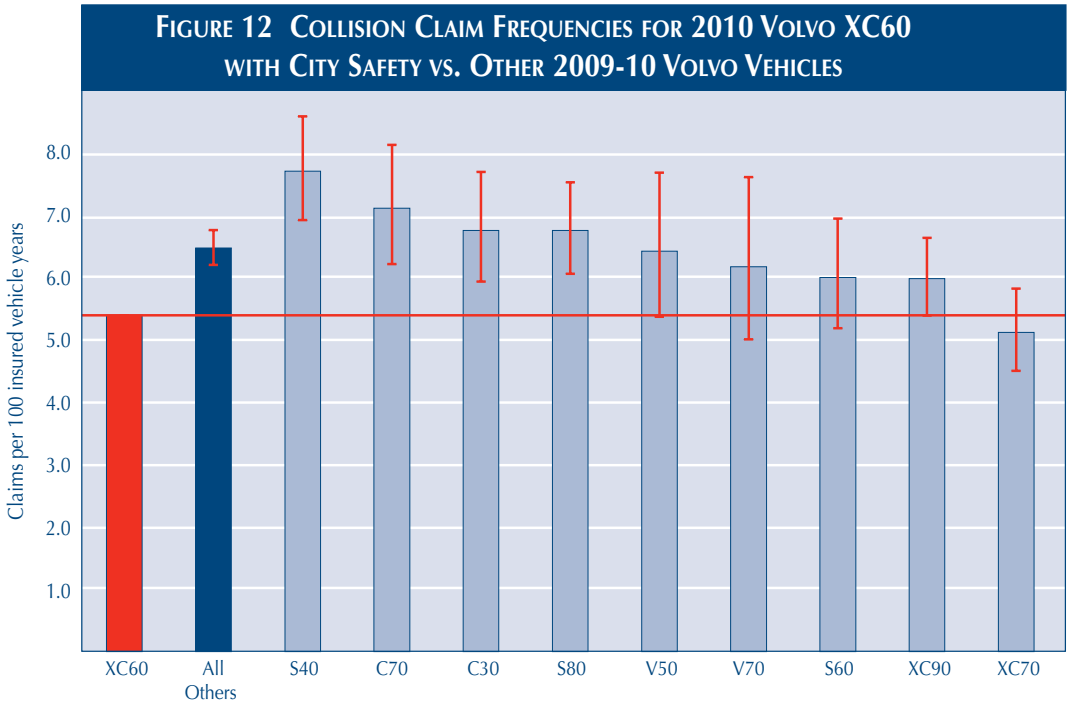


Figure 12 shows the collision claim frequency for the 2010 Volvo XC60 compared with those for other Volvo vehicles. The estimated claim frequency for the Volvo XC60 was 17 percent lower than that for all other Volvos combined. At the 95 percent confidence level, the range for this estimate was 13 to 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

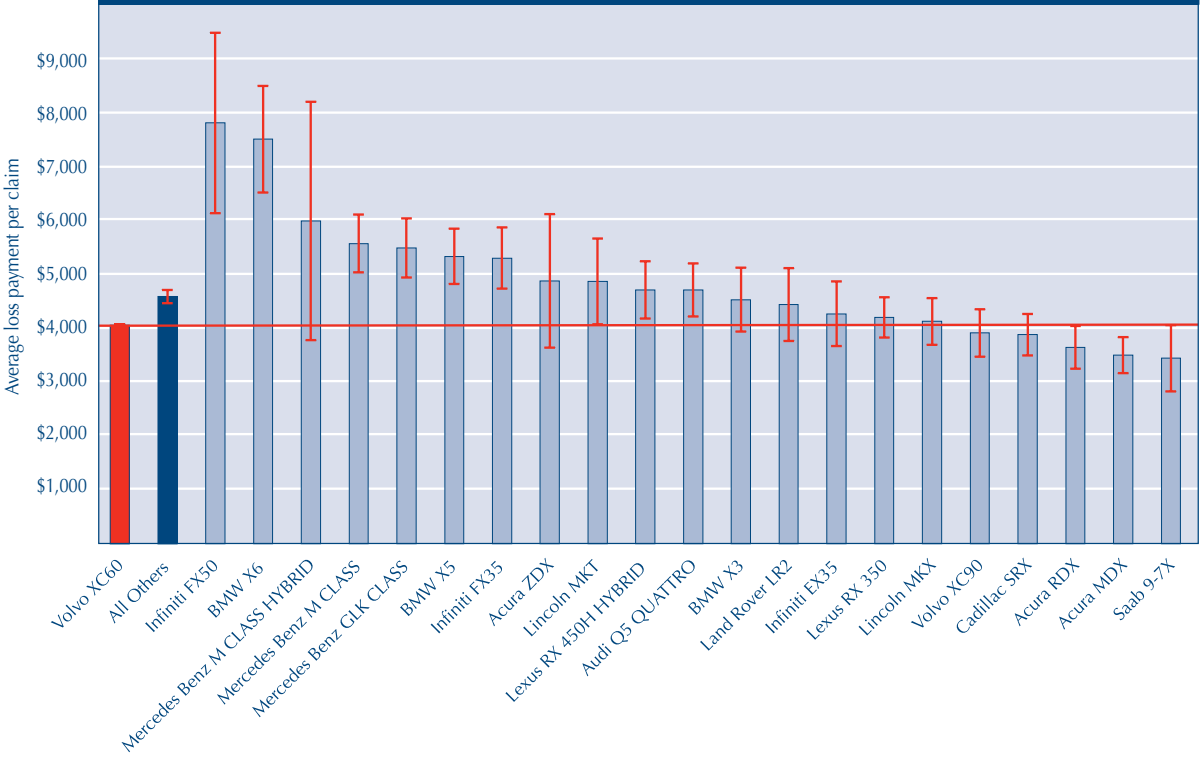
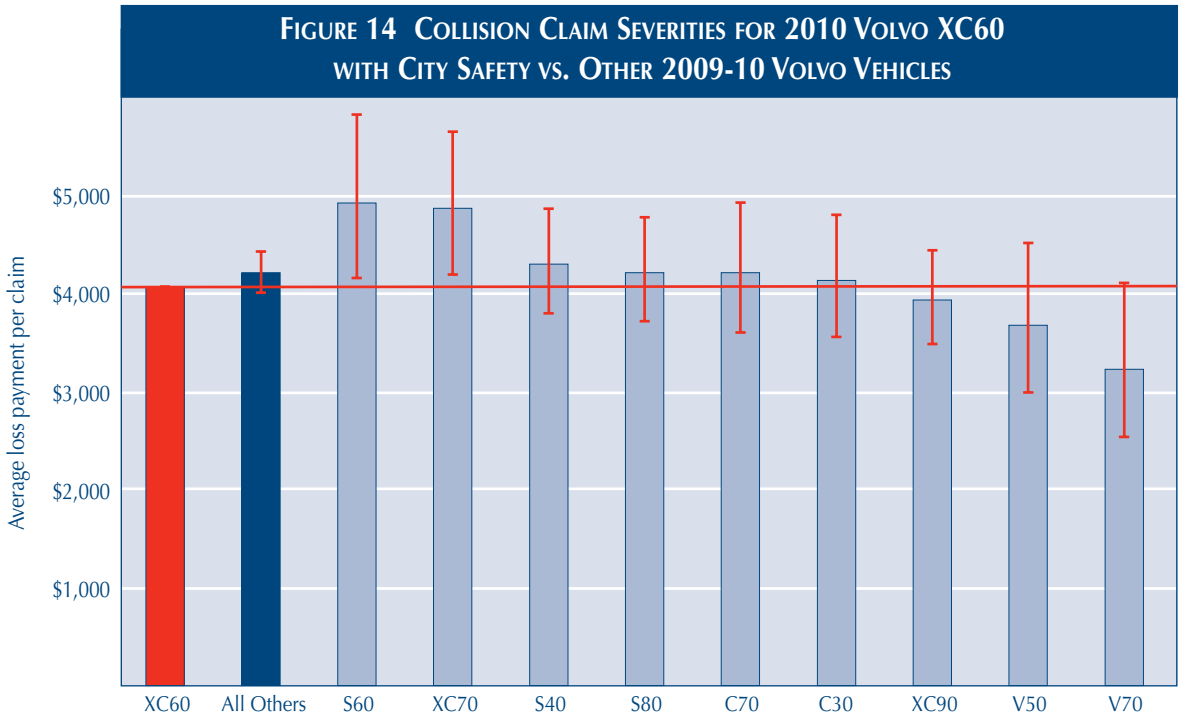


FIGURE 14 COLLISION CLAIM SEVERITIES FOR 2010 VOLVO XC60 WITH CITY SAFETY VS. OTHER 2009-10 VOLVO VEHICLES



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

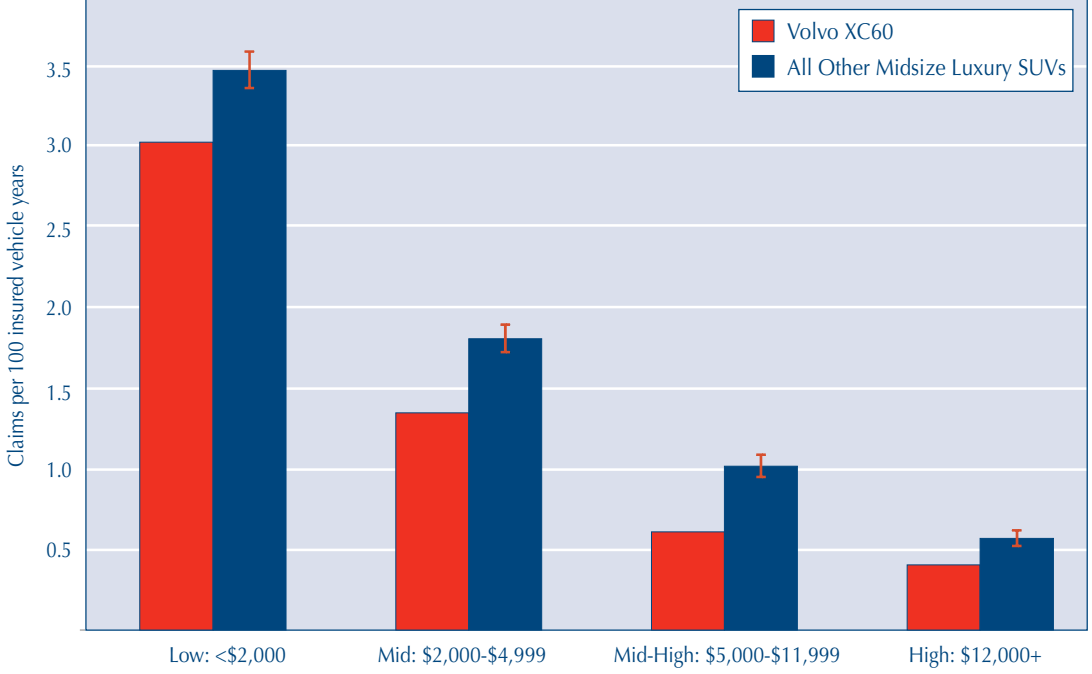
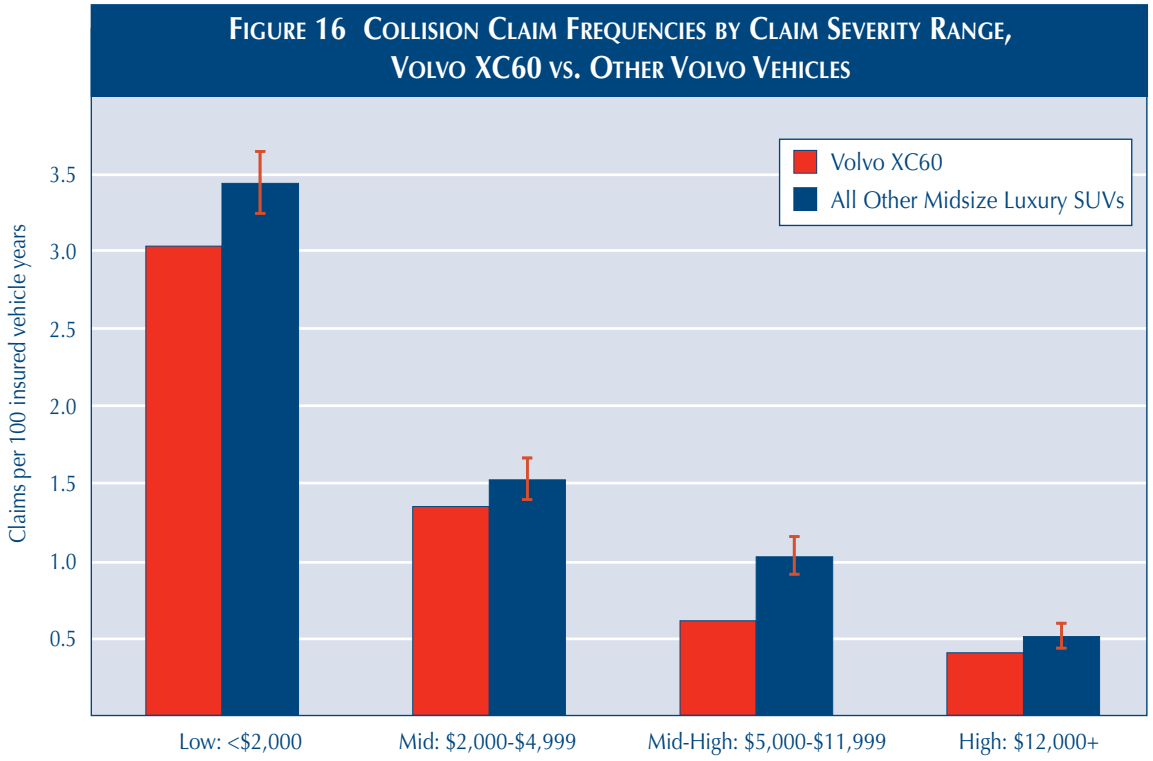


Figure 16 Collision Claim Frequencies by Claim Severity Range, Volvo XC60 vs. Other Volvo Vehicles



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

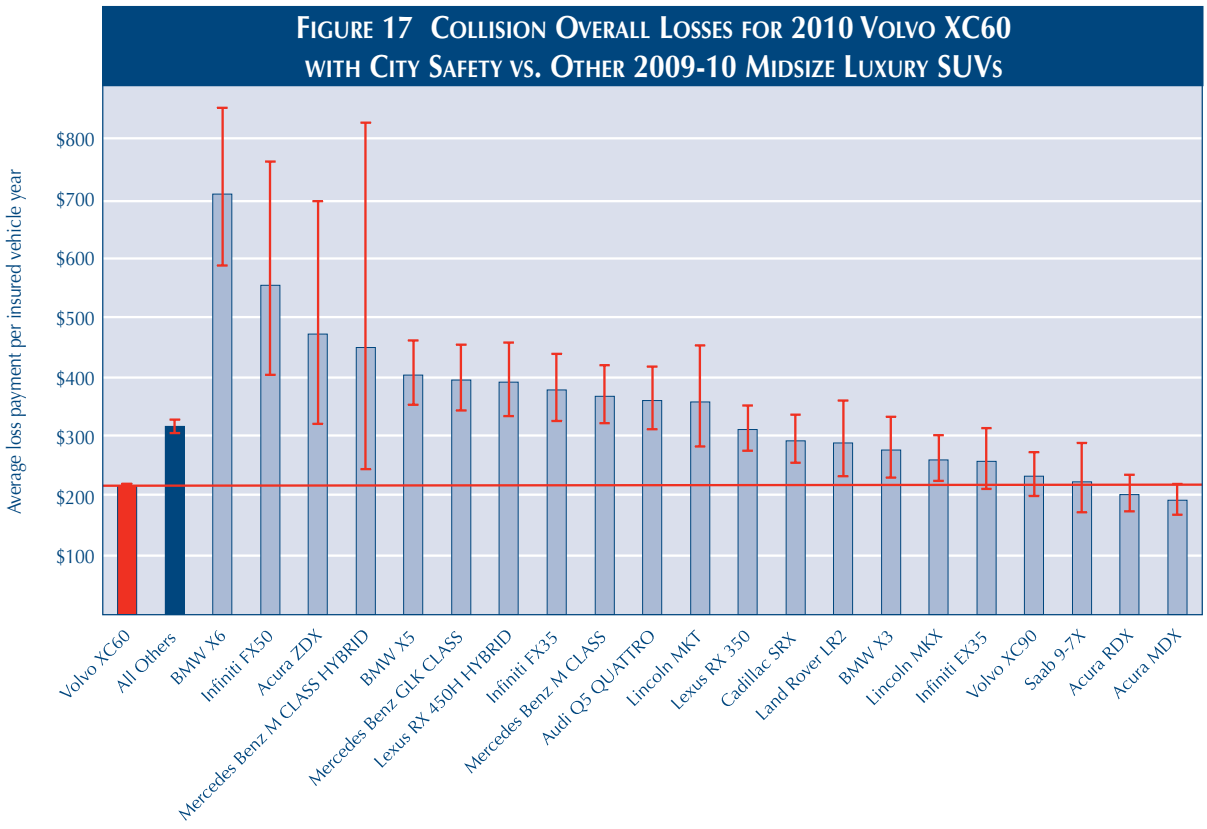
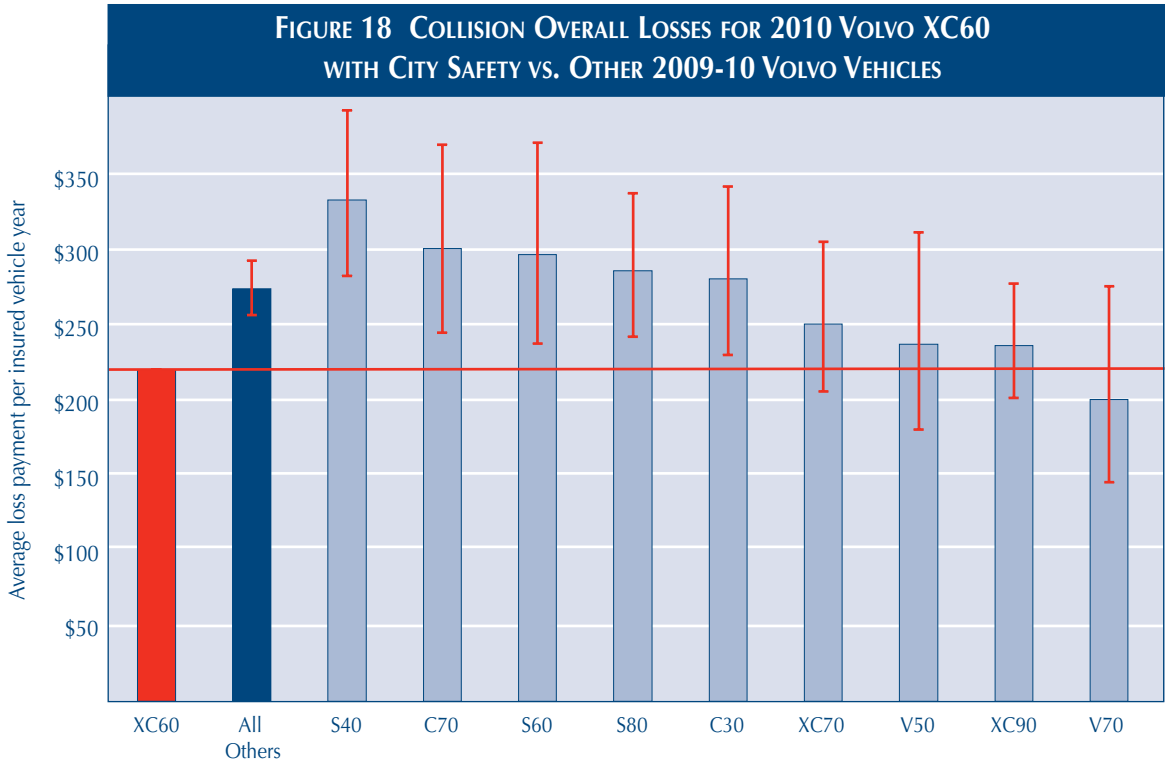


Figure 18 shows collision overall losses for the 2010 Volvo XC60 compared with those for other Volvo vehicles. The estimated overall loss for the Volvo XC60 was 20 percent lower than that for all other Volvos combined. At the 95 percent confidence level, the range for this estimate was 14 to 25 percent. 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.

References

Highway Loss Data Institute. 2006. Vehicle compatibility. *HLDI Bulletin* 23(5). Arlington, VA.

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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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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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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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

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)
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

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		

HIGHWAY LOSS DATA INSTITUTE

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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.