HIGHWAY LOSS DATA INSTITUTE

Bulletin | Vol. 29, No. 5 : April 2012

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.
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> **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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