

# Highway Loss Data Institute Bulletin

## Volvo City Safety Loss Experience – Initial Results

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### INTRODUCTION

This Highway Loss Data Institute (HLDI) bulletin provides an initial look at the effects of Volvo's City Safety technology on insurance losses. The loss experience for Volvo XC60s equipped with City Safety was compared with losses for comparable vehicles without the system. Losses under property damage liability, bodily injury liability, and collision coverage were examined.

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

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

### METHOD

**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-wheel drive 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  $2.2 \times 1.096 = 2.4$  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 vehicles 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
<b>INTERCEPT</b>	1	-9.4684		0.0700	-9.6056	-9.3312	18296.3	<0.0001
<b>CALENDAR YEAR</b>								
2009	1	0.0480	4.9%	0.0179	0.0128	0.0831	7.16	0.0075
2010	0	0	0	0	0	0		
<b>VEHICLE MAKE AND SERIES</b>								
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



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 to the XC60, not the 95 percent confidence interval for that group's frequency estimate.

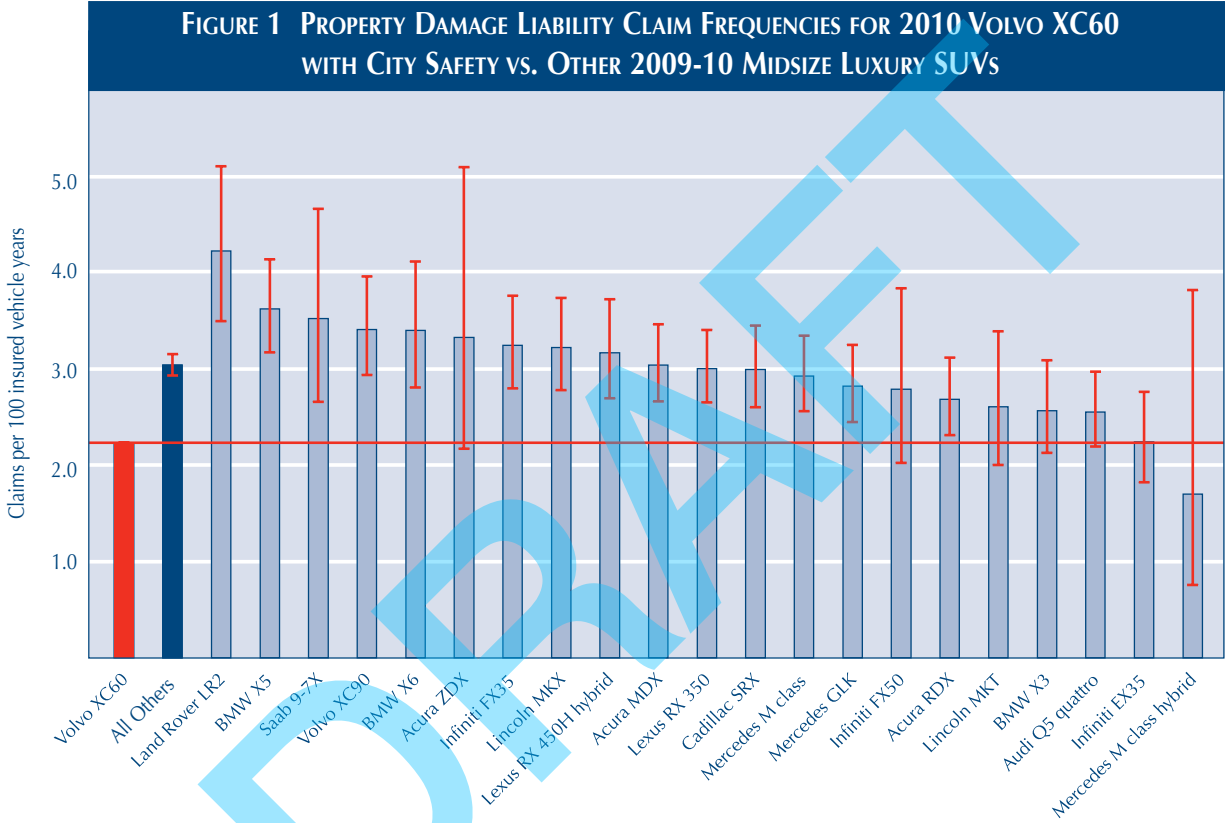
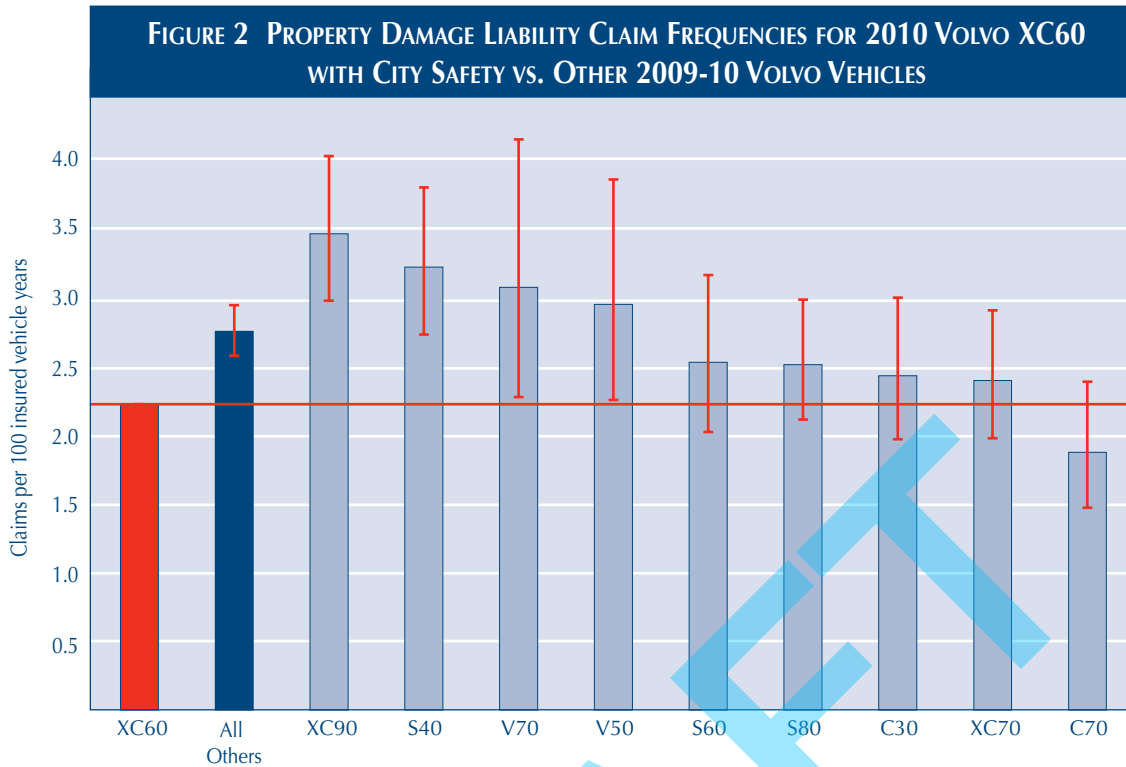


Figure 2 shows the property damage liability claim frequency for the 2010 Volvo XC60 compared with those for other Volvo vehicles. The estimated claim frequency for the Volvo XC60 (2.2 claims per 100 insured vehicle years) was 19 percent lower than that for all other Volvos combined (2.8 claims per 100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



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
<b>INTERCEPT</b>	1	7.9923		0.0645	7.8658	8.1187	15347.6	<0.0001
<b>CALENDAR YEAR</b>								
2009	1	0.0873	9.1%	0.0165	0.0550	0.1196	28.04	<0.0001
2010	0	0	0	0	0	0		
<b>VEHICLE MAKE AND SERIES</b>								
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		
<b>STATE</b>								
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		
<b>REGISTERED VEHICLE DENSITY</b>								
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		
<b>RATED DRIVER AGE</b>								
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		
<b>RATED DRIVER GENDER</b>								
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		
<b>RATED DRIVER MARITAL STATUS</b>								
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		
<b>RISK</b>								
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.

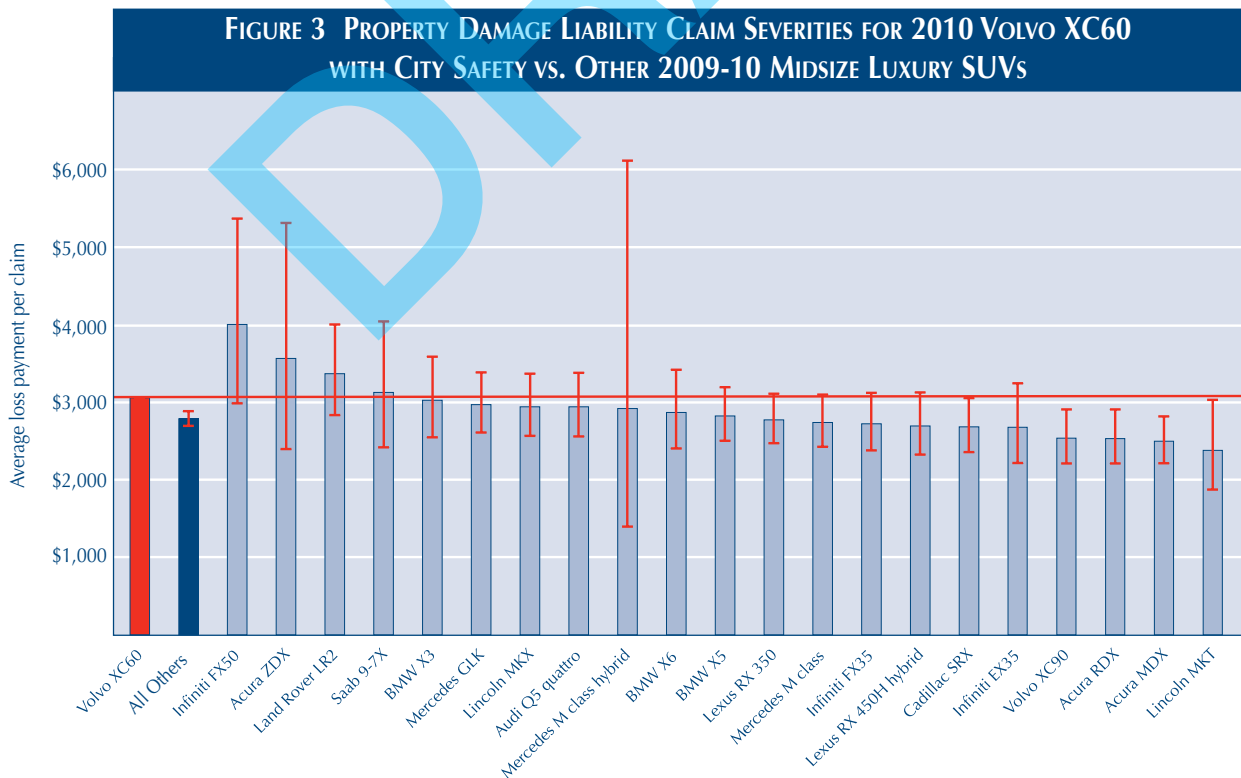
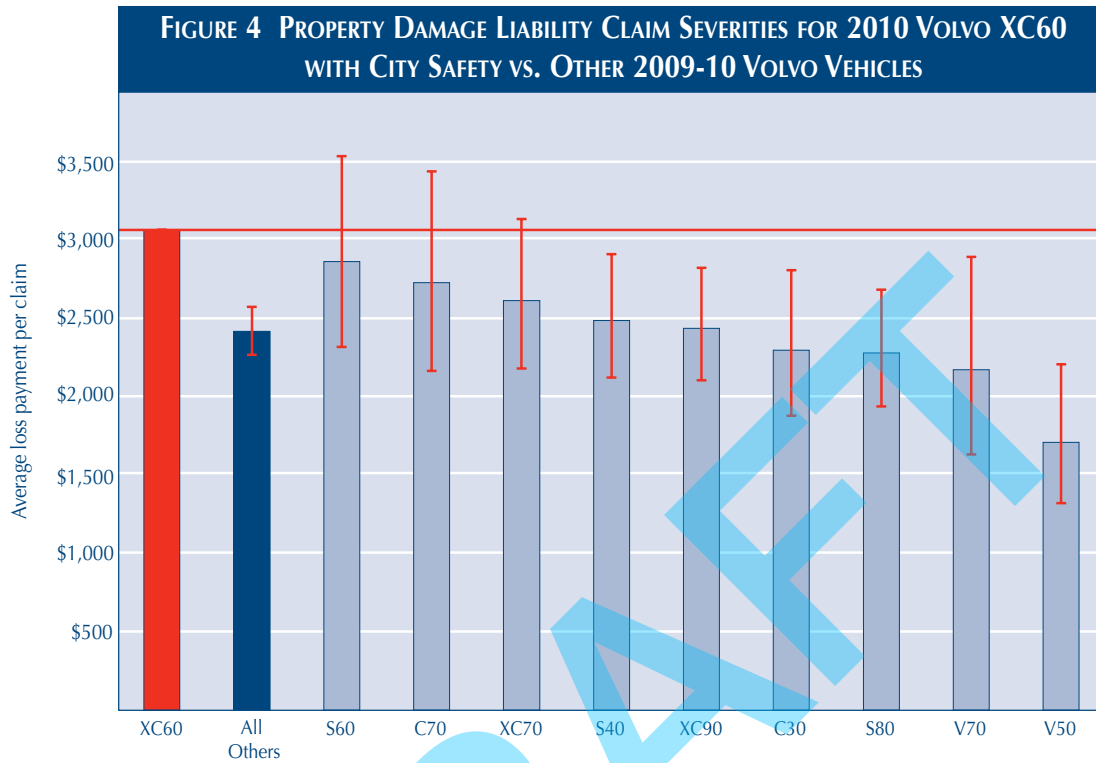


Figure 4 shows the property damage liability claim severity for the 2010 Volvo XC60 compared with those for other Volvo vehicles. The estimated claim severity for the Volvo XC60 was 27 percent higher than that for all other Volvos combined. At the 95 percent confidence level, this estimated increase fell between 35 and 19 percent. Additionally, the claim severity for the XC60 was higher than that for each individual Volvo vehicle.



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 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.

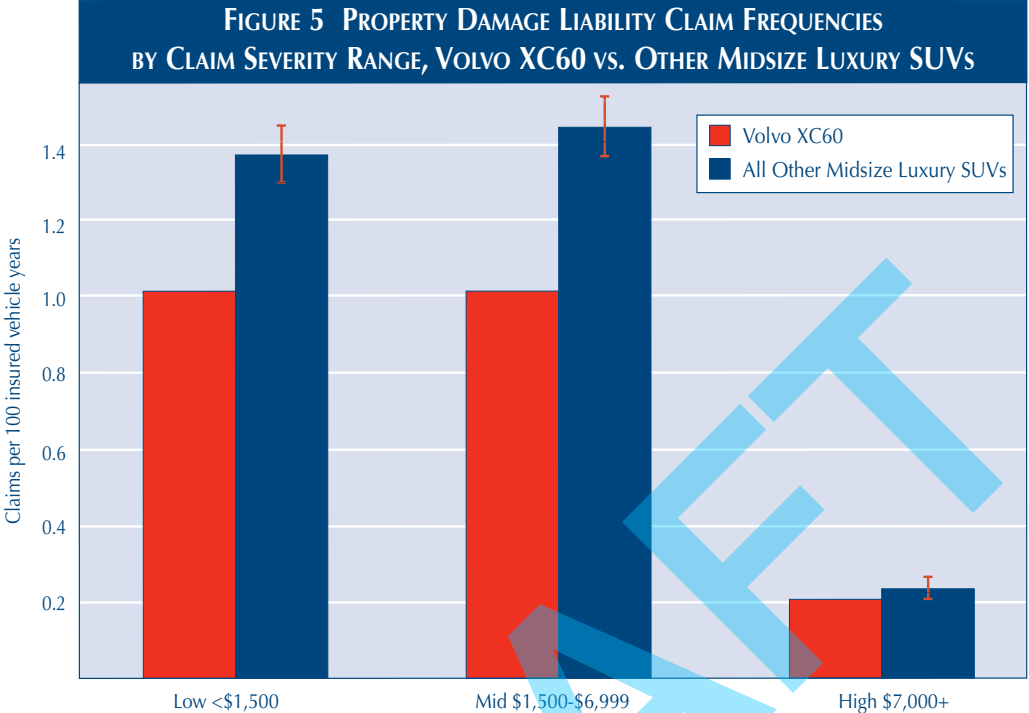
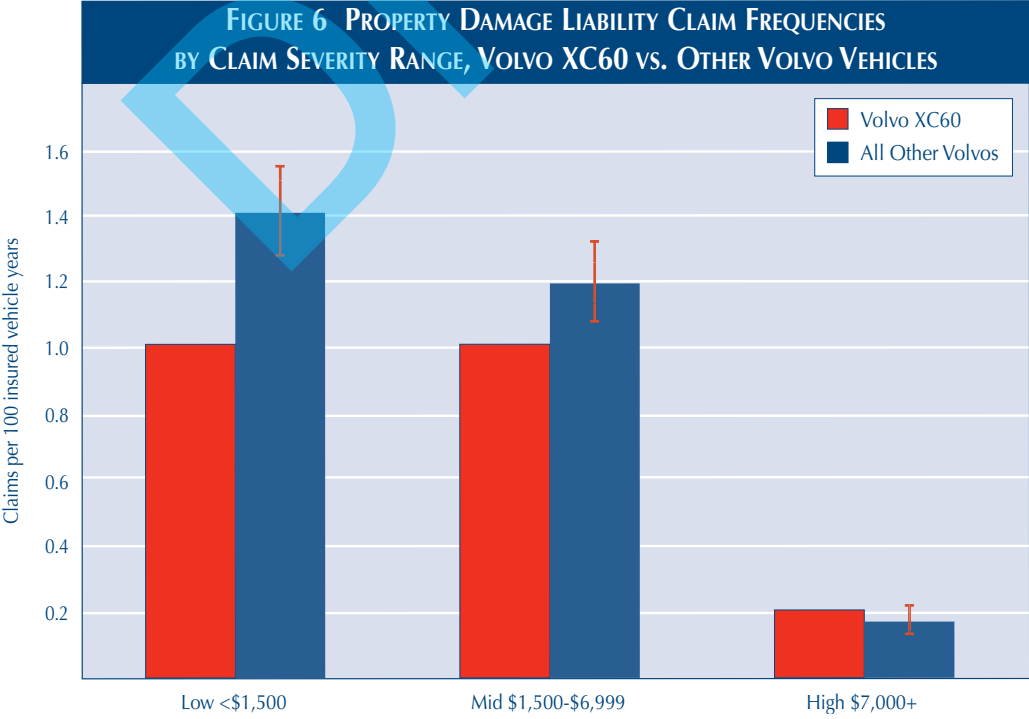


Figure 6 shows property damage liability claim frequencies for the 2010 Volvo XC60 by claim severity range compared with those for other Volvo vehicles. Claim frequencies exhibited a similar pattern to those in Figure 5. As the dollar value of claims increased, the difference in claim frequencies between 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
<b>INTERCEPT</b>	-1.4761	-77.1%	0.095185	-1.6627	-1.2895	<0.0001
<b>CALENDAR YEAR</b>						
2009	0.1353	14.5%	0.024345	0.0876	0.1830	<0.0001
2010	0	0	0	0	0	
<b>VEHICLE MAKE AND SERIES</b>						
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	
<b>STATE</b>						
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	
<b>REGISTERED VEHICLE DENSITY</b>						
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	
<b>RATED DRIVER AGE</b>						
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	
<b>RATED DRIVER GENDER</b>						
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	
<b>RATED DRIVER MARITAL STATUS</b>						
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	
<b>RISK</b>						
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
<b>CLAIM FREQUENCY</b>					
Midsize luxury SUVs	0.3095	0.0187	36%	31%	41%
Volvos	0.2138	0.0340	24%	16%	32%
<b>CLAIM SEVERITY</b>					
Midsize luxury SUVs	-0.0923	0.0171	-9%	-12%	-6%
Volvos	-0.2373	0.0324	-21%	-26%	-16%
<b>OVERALL LOSS</b>					
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.

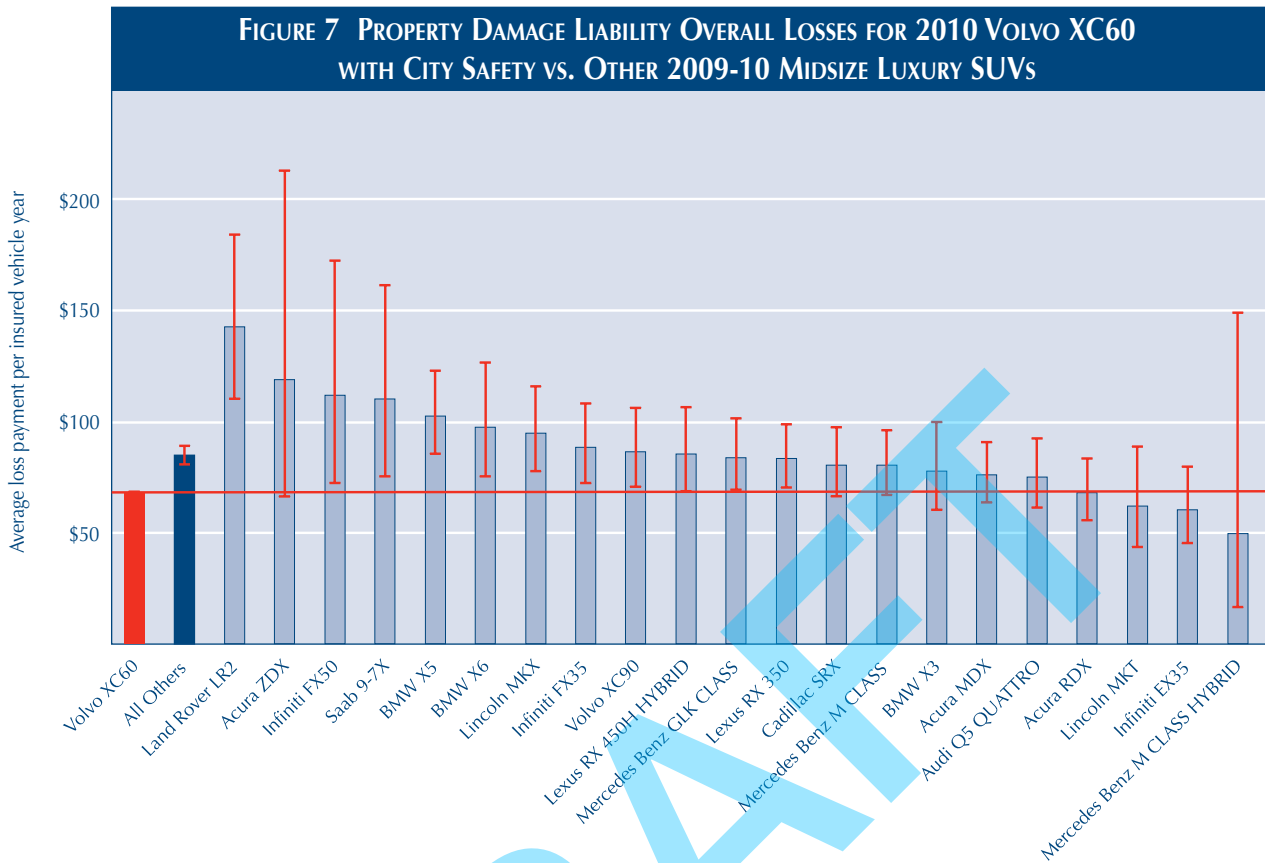


Figure 8 shows the property damage liability overall loss for the 2010 Volvo XC60 compared with those for other Volvo vehicles. The estimated overall loss for the Volvo XC60 was only 2 percent higher than that for all other Volvos combined. At the 95 percent confidence level, this estimate fell between a 12 percent increase and a 7 percent decrease. Additionally, the overall loss for XC60 was higher than those for most other Volvo vehicles.

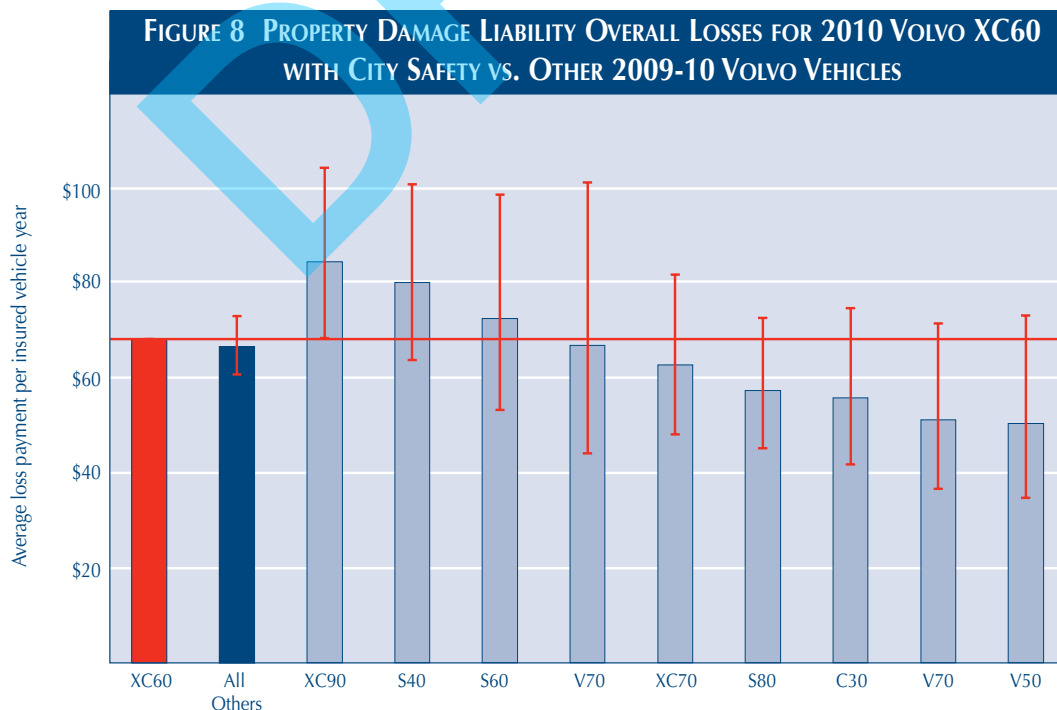
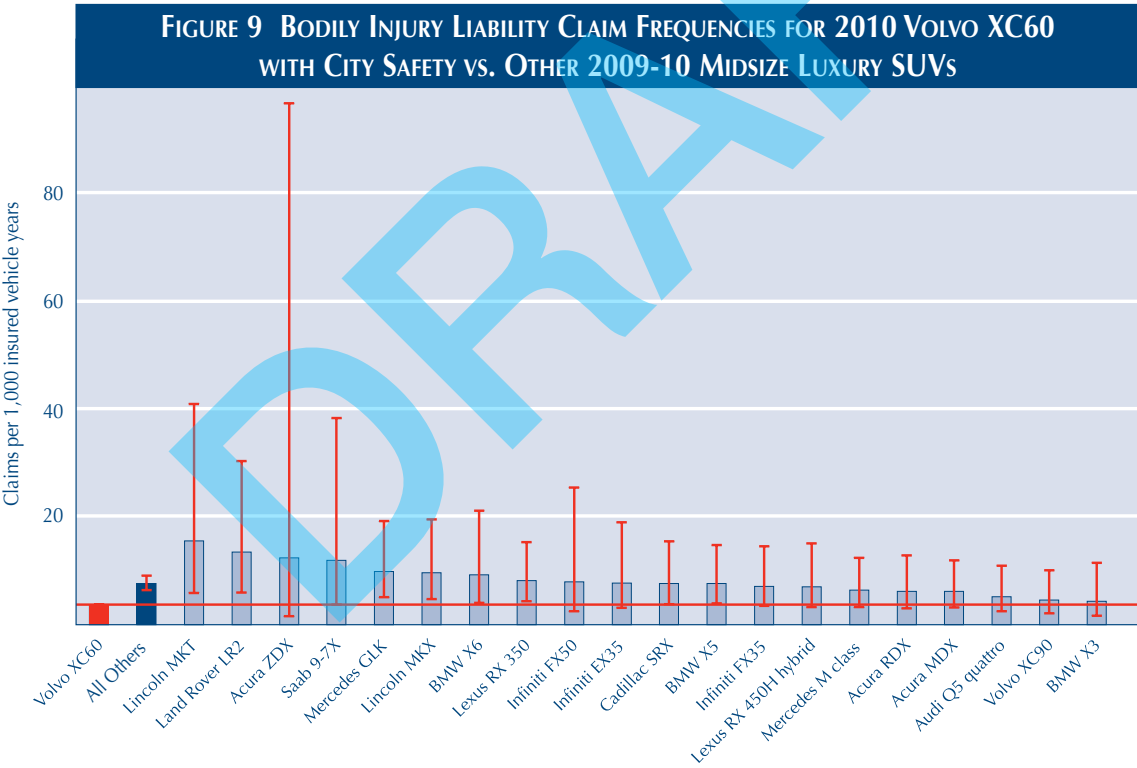


Table 8 summarizes results of the regression analysis conducted for bodily injury liability coverage. It includes estimates of claim frequency for other midsize luxury SUVs and other Volvo vehicles relative to the XC60. Detailed results of the regression analysis are listed in the appendix.

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.



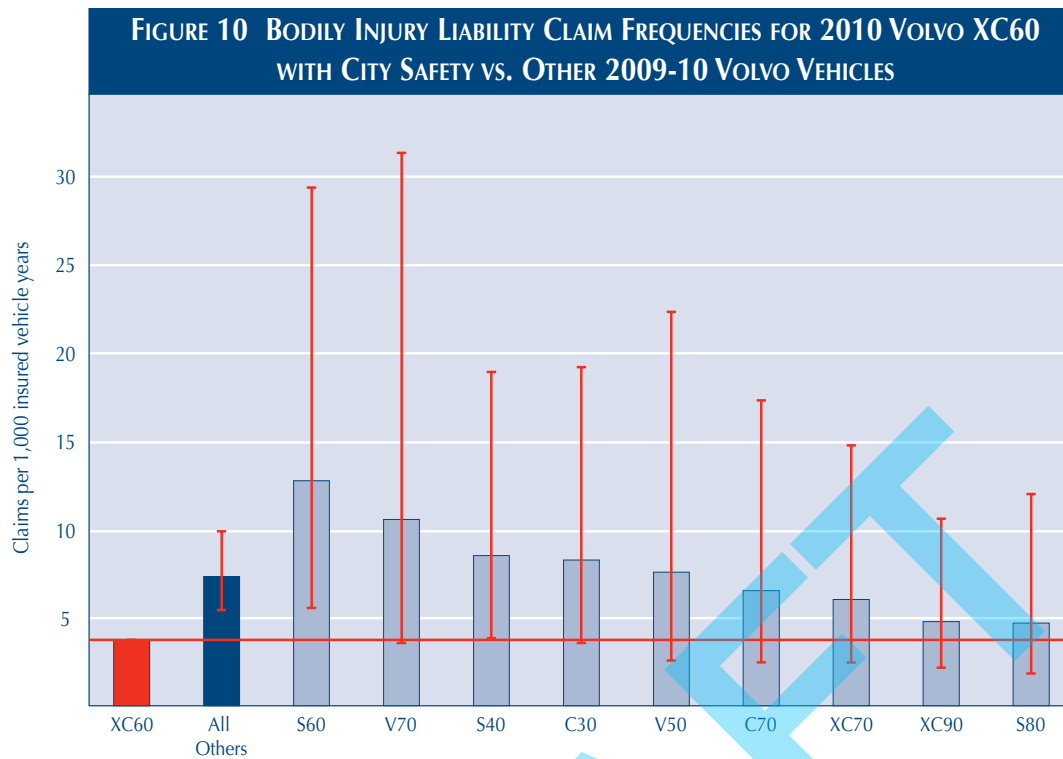


Table 9 summarizes results of the regression analysis conducted for collision coverage. It includes estimates of claim frequency, claim severity, and overall loss for other midsize luxury SUVs and other Volvo vehicles relative to the XC60. Detailed results of the regression analysis are listed in the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

**TABLE 9 ESTIMATED COLLISION LOSS RESULTS FOR COMPARISON GROUPS RELATIVE TO VOLVO XC60**

CONTROL GROUP	ESTIMATE	STANDARD ERROR	EFFECT	LOWER BOUND	UPPER BOUND
<b>CLAIM FREQUENCY</b>					
Midsize luxury SUVs	0.2482	0.0121	28%	25%	31%
Volvos	0.1824	0.0220	20%	15%	25%
<b>CLAIM SEVERITY</b>					
Midsize luxury SUVs	0.1196	0.0140	13%	10%	16%
Volvos	0.0355	0.0254	4%	-1%	9%
<b>OVERALL LOSS</b>					
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.

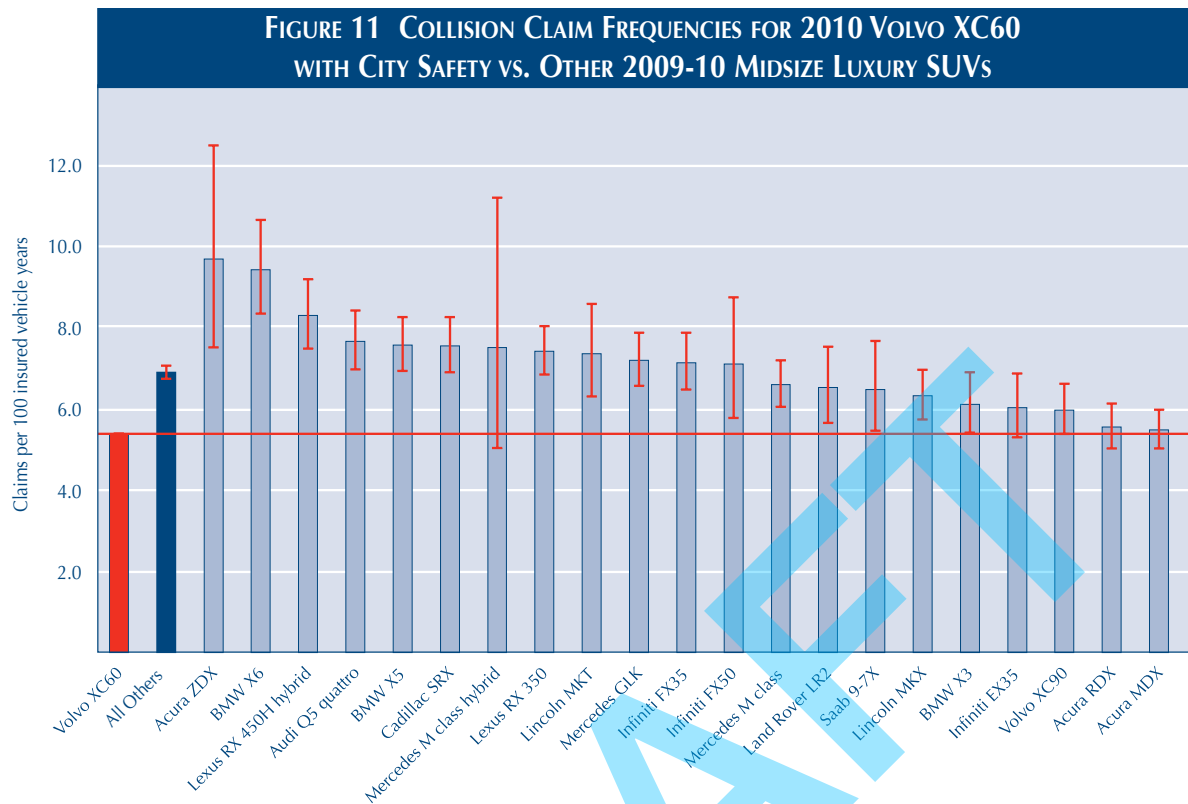
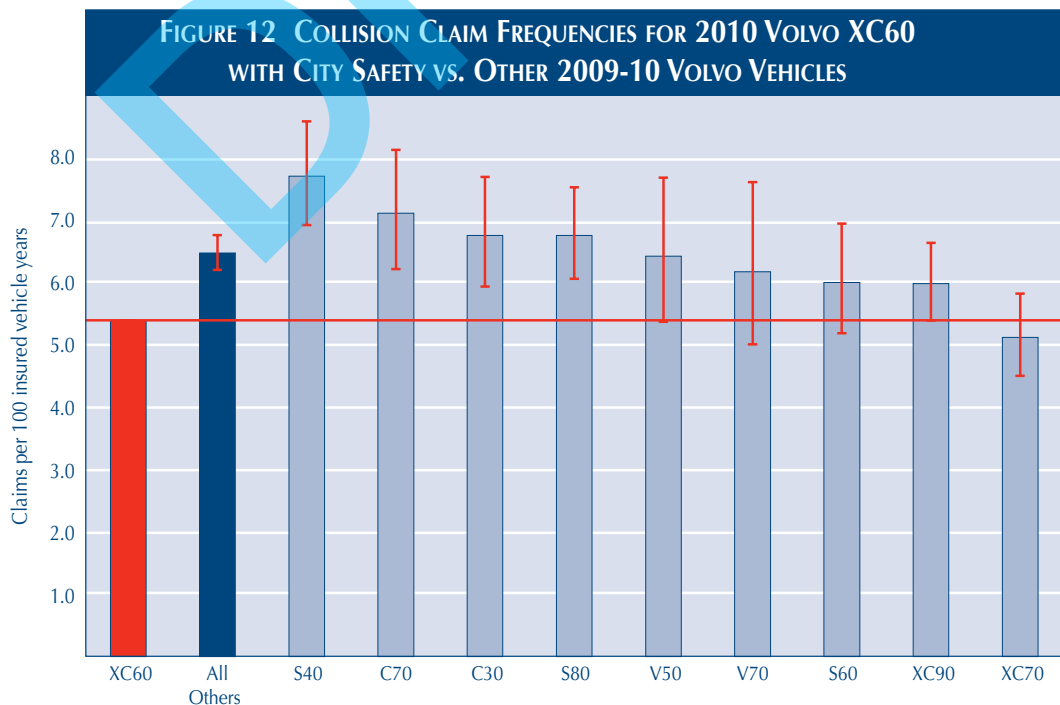
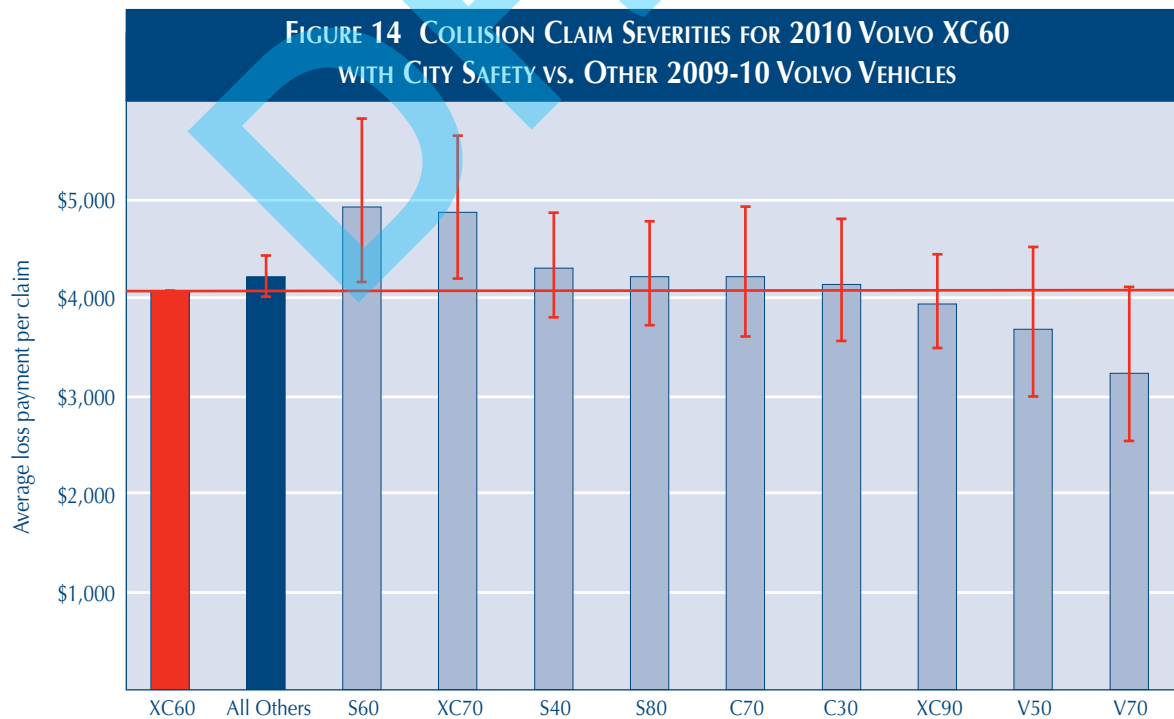
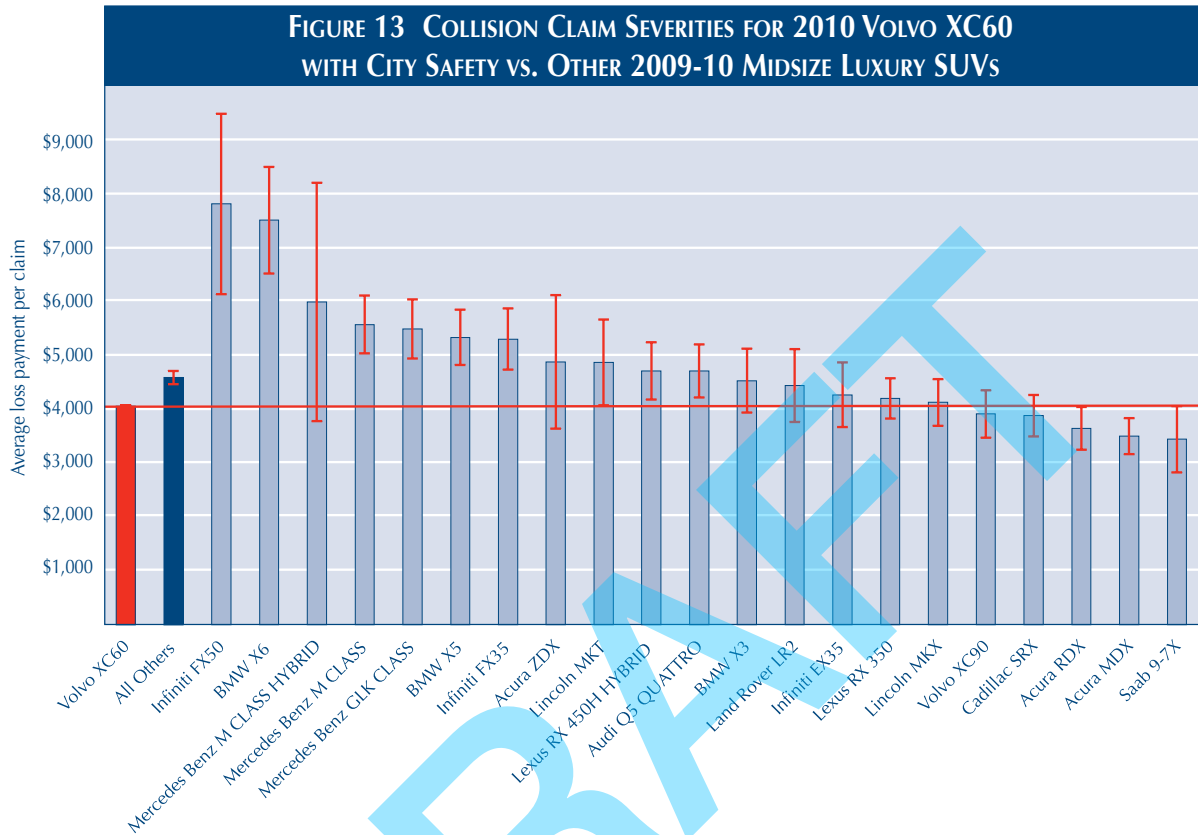


Figure 12 shows the collision claim frequency for the 2010 Volvo XC60 compared with those for other Volvo vehicles. The estimated claim frequency for the Volvo XC60 was 17 percent lower than that for all other Volvos combined. At the 95 percent confidence level, the range for this estimate was 13 to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



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 decrease. Results were mixed at the individual vehicle series level.

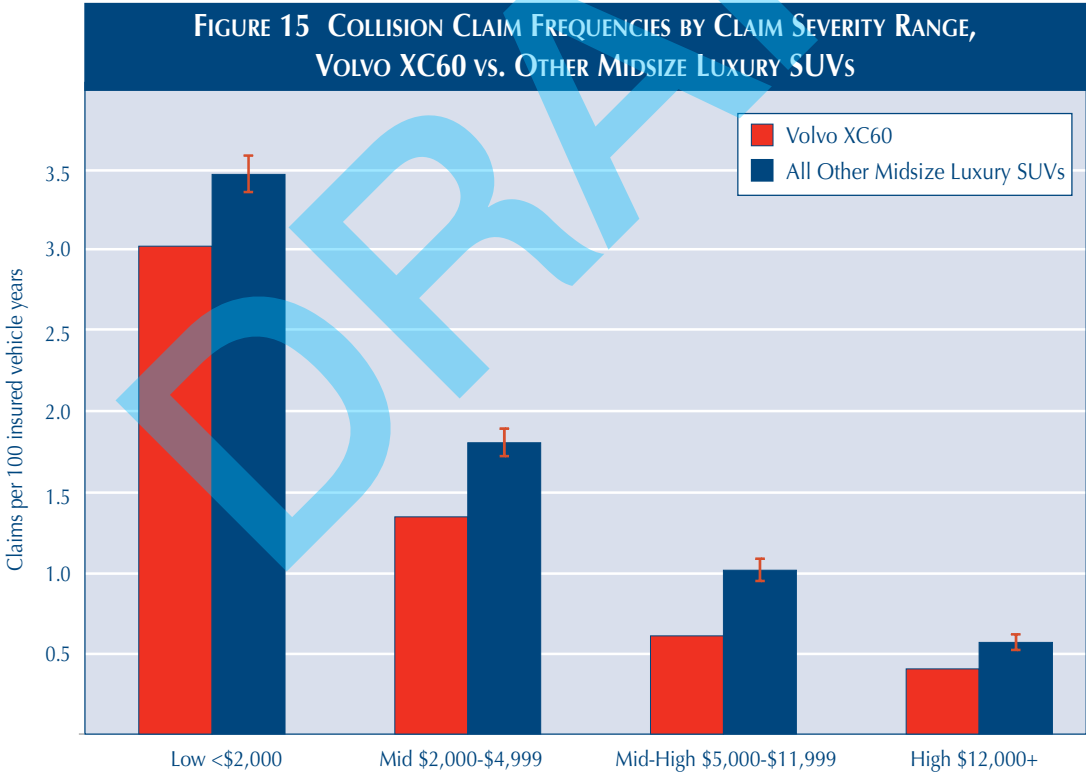




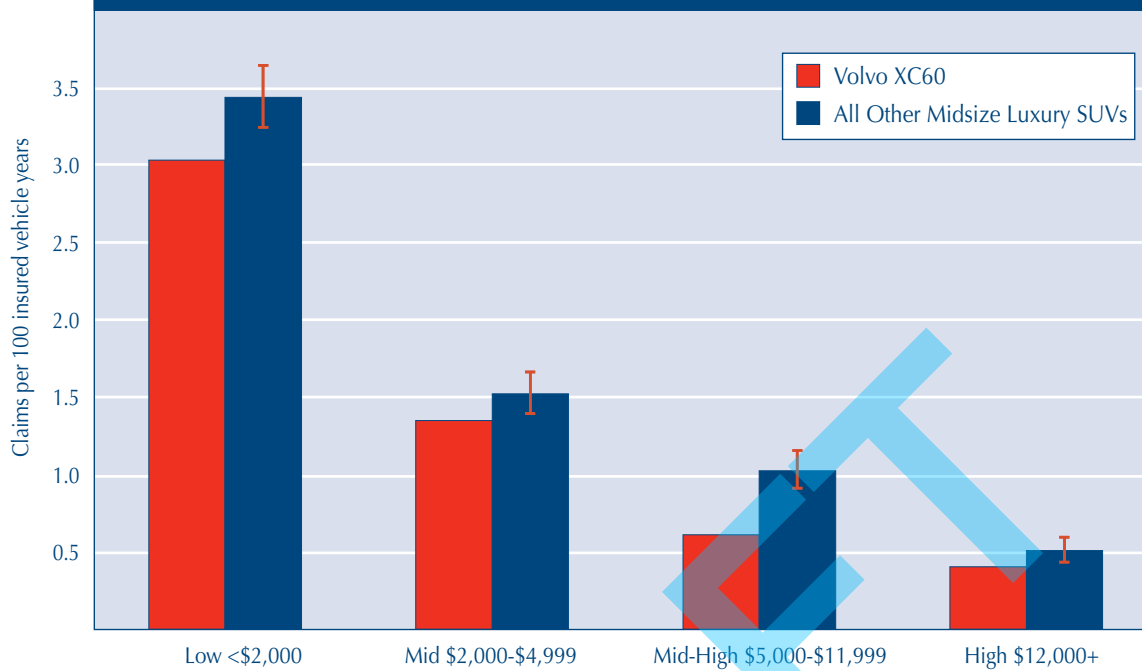
As with PDL severities, an analysis of claim frequency by severity ranges was performed. Table 10 summarizes the results; details of the results are listed in the appendix. The XC60 had lower frequencies than other Volvos or other midsize luxury SUVs in all ranges. However, the effect was greatest in the \$5,000 to \$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%

Figure 15 illustrates these results for the XC60 compared with those for other midsize luxury SUVs. Figure 16 shows these results for the comparison with other Volvos. In both comparisons, the smallest reduction is in the lowest cost band, claims less than \$2,000.



**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.

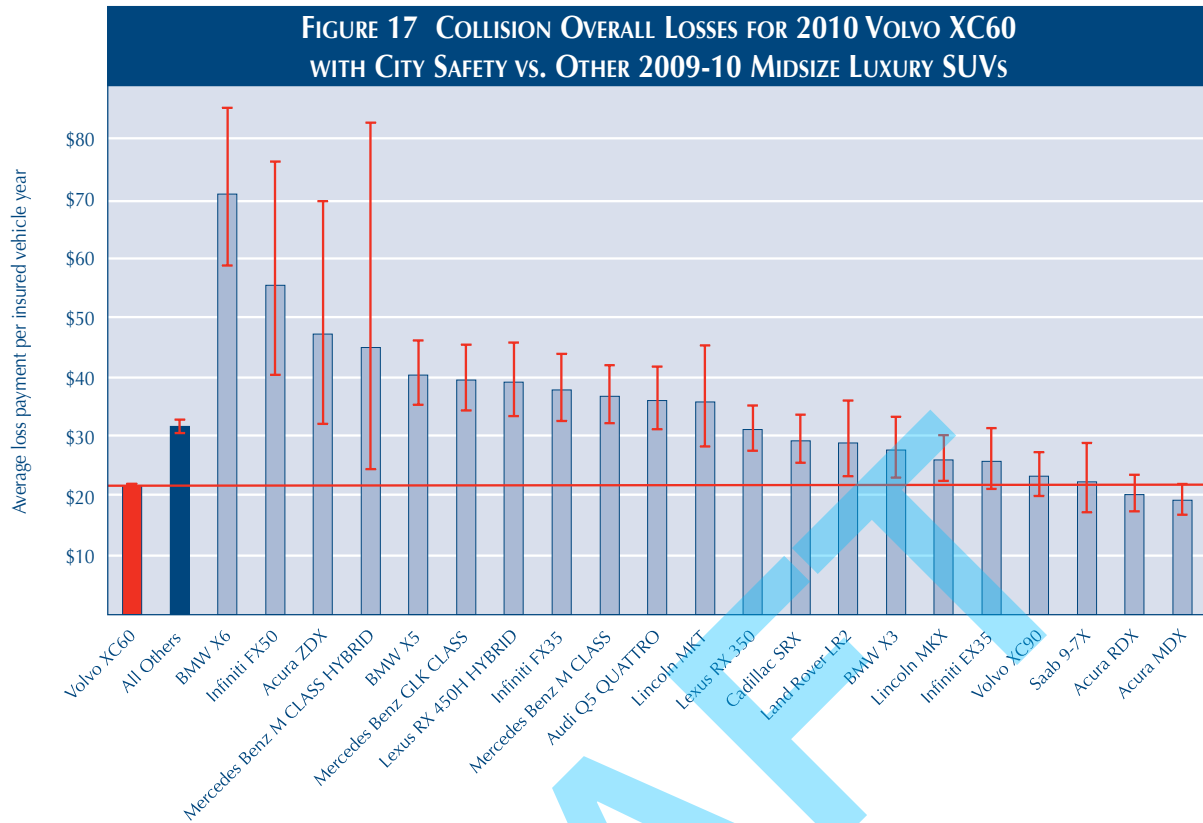
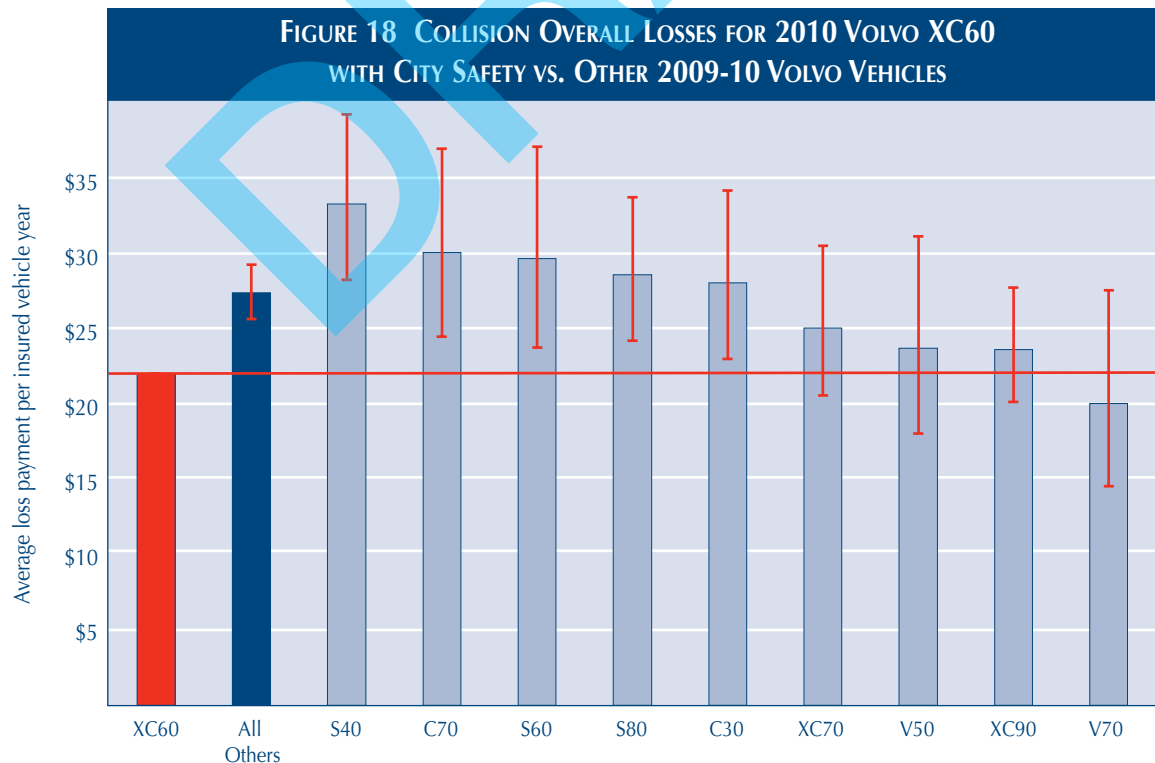


Figure 18 shows collision overall losses for the 2010 Volvo XC60 compared with those for other Volvo vehicles. The estimated overall loss for the Volvo XC60 was 20 percent lower than that for all other Volvos combined. At the 95 percent confidence level, the range for this estimate was 14 to 25 percent. Additionally, the overall loss for the XC60 was lower than those for all other Volvos except the V70.



## 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 the 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 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 the collision and property damage liability claim severities by the point of impact. Information on the point of impact was supplied by CCC Information Services, Inc. The study showed that the most expensive claims to repair are collision claims at the 12 o'clock position (front of the striking vehicle) with a severity of \$4,658. At the same time the least expensive claims to repair are property damage liability claims when struck at 6 o'clock (rear of the struck vehicle) with a severity of \$1,714. In other words, the average cost of a frontal strike collision claim is well over double the cost of a rear struck vehicle. The implication of this pattern is that, even though City Safety reduces the frequency of low severity front to rear collisions, the cost of those 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, the 2010 XC60 was the first available model year for this vehicle and the drivers of these early vehicles may differ in ways that we have not been able to adjust for. In order to fully understand the benefits of City Safety additional analysis will be required as additional loss data becomes available. Therefore, it will be important to continue to monitor the performance of City Safety as more and potentially different drivers insure the vehicle.

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DRAFT

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Arlington, VA 22201