INSURANCE INSTITUTE
FOR HIGHWAY SAFETY

July 3, 2013

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

Request for Comments; 49 CFR Part 575 Consumer Information; New Car Assessment Program (NCAP); Docket No. NHTSA-2012-0180

Dear Administrator Strickland:

The Insurance Institute for Highway Safety (IIHS) welcomes the opportunity to comment on the National Highway Traffic Safety Administration's (NHTSA) plans to modify its New Car Assessment Program (NCAP). NCAP and the IIHS crashworthiness evaluations are important sources of safety information for consumers considering buying a new vehicle, and consequently these programs provide automakers an incentive to continually improve their products. The safety ratings and other information these programs generate should reflect the latest knowledge about how to make vehicles safer. It is appropriate, in fact crucial, that NHTSA begin planning the next phases of NCAP even as its latest changes took effect a little more than 2 years ago.

NHTSA's request for comments about the future of NCAP was divided into three major areas of consideration: crash avoidance technologies, crashworthiness evaluations, and improving communication with consumers. IIHS has information relevant to several topics in each of these main areas that NHTSA may want to consider in its deliberations.

Crash Avoidance Technologies

NHTSA is considering which driver assistance technologies to promote to consumers through NCAP. Our research on the effectiveness of various technologies indicates that collision imminent braking (CIB) and adaptive lighting systems (ALS) are helping drivers avoid crashes. These technologies warrant efforts by consumer information programs to promote their safety benefits. Blind spot detection systems (BDS), which also are being considered for promotion through NCAP, are showing mixed results, with some automakers' systems appearing to be beneficial while others do not. These results would suggest the need for additional research to ascertain the characteristics of successful implementation of BDS technology.

Collision Imminent Braking

IIHS has completed analyses of the effectiveness of various collision imminent braking systems through its Highway Loss Data Institute (HLDI). HLDI collects data from companies representing about 80 percent of the market for private passenger vehicle auto insurance. The database includes payments for claims filed under collision, property damage liability, bodily injury liability, medical payment, and personal injury protection coverage types. We have compared insurance losses for Volvo models (S60 and XC60) equipped with a low-speed CIB system known as City Safety with losses for competitor models. We also have compared losses for Acura, Mercedes-Benz, and Volvo models equipped with optional CIB with their same year/make/series counterparts without the feature.

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The frequency of claims per insured vehicle year filed under property damage liability[1] coverage was estimated to be 15 percent lower than relevant control vehicles for the XC60 and 16 percent lower for the S60. Collision claim[2] frequencies were reduced by an estimated 20 percent for the XC60 and 9 percent for the S60. Both vehicles also showed reductions in the overall cost of losses per insured vehicle year for both collision and property damage liability coverage types. Front-to-rear collisions also result in many claims for minor injuries such as whiplash and back sprains to the occupants of the struck vehicles. Bodily injury liability[3] insurance pays for these injuries, and the frequency of these claims was 33 percent lower for the XC60 and 18 percent lower for the S60. Thus, despite only working at speeds up to approximately 30 km/h, City Safety is helping drivers avoid rear ending vehicles in front of them. Even when crashes are not avoided completely, the reduction in crash energy through automatic braking appears to be preventing injuries. A copy of our report on this analysis is attached for your information.

HLDI examined forward collision prevention systems offered as options on Acura, Mercedes-Benz, and Volvo vehicles. Property damage liability frequencies for Acura and Mercedes models were 14 percent lower when the vehicles were equipped with Forward Collision Warning (FCW) and CIB than when they were not. Volvo's FCW with CIB also reduced the claim rate 10 percent, but that finding was not statistically significant. These reductions in crash claim frequencies are double what HLDI found for vehicles equipped with FCW alone. As with City Safety, our analyses also found reductions in the frequencies of claims for injuries. Bodily liability claim frequency was reduced 4-32 percent, and though these estimates were not statistically significant, the consistency across vehicles from three different automakers suggests the reductions are real. Copies of the reports of our analyses of the effectiveness of optional crash avoidance features are attached for your information.

We understand that NHTSA is in the process of deciding whether to require CIB or promote it through NCAP. We encourage the agency to consider our research findings on the efficacy of such systems in making its decision and would welcome the opportunity to discuss them further if it would be helpful to the agency.

Adaptive Lighting Systems

HLDI also has examined the effectiveness of adaptive lighting systems, which aim the headlight beam in the direction that the driver is steering to improve visibility on curved roads at night. Analyses of ALS on vehicles from four different automakers (Acura, Mazda, Mercedes-Benz, and Volvo) show reductions in the frequency of claims under both collision and property damage liability coverage types. The frequency of claims filed under collision coverage was reduced 1-6 percent, and property damage liability clam frequency was reduced 5-10 percent. Also, all but one estimate for injury claim frequency indicate reductions for vehicles equipped with ALS compared with their counterparts without the feature.

The result for property damage liability claims is surprising, given that only about 7 percent of police-reported crashes occur between 9 p.m. and 6 a.m. and involve more than one vehicle. An even smaller percentage are multiple-vehicle, nighttime crashes occurring on curves, where adaptive headlights would be expected to have the greatest effect. It is possible that differences other than steerability between the adaptive headlights and conventional ones, for example, in brightness or range, may have played a role in reducing crashes with other vehicles. In fact, our report about collision avoidance features on Mercedes-Benz vehicles indicates that nearly all changes intended to improve a driver's ability to see at

[1] Property damage liability insurance pays to repair vehicles struck by the insured vehicle when the insured vehicle driver is at fault.
[2] Collision insurance pays to repair the insured vehicle when the insured vehicle driver is at fault.
[3] Bodily injury liability insurance pays for medical expenses associated with injuries to people outside the insured vehicle when the insured vehicle driver is at fault.

night result in reduced insurance claim frequency. For example, high-intensity discharge (HID) lights had lower property damage liability and injury claim frequencies than baseline halogen lights on the comparison vehicles. All of the steerable lights we studied were based on HID technology. So it seems that promoting advanced lighting systems through consumer information programs would be appropriate, but additional research may be needed to understand which qualities of advanced lighting are most beneficial to drivers.

Blind Spot Detection

The results of our analyses of the effectiveness of BSD are inconclusive. For Mazda vehicles, we estimated a significant reduction in the frequency of property damage liability claims, which are the types of claims that would be expected when a driver causes a crash after encroaching into occupied adjacent lanes. Given that blind spot monitoring is intended to assist with lane changes that typically occur on multilane roads, many of which are higher speed roads, it is expected that the system would help prevent higher speed crashes and related injuries. All of the injury coverages have statistically significant reductions in claim frequency, with larger reductions occurring for the more severe claims.

However, the results for BSD on Mercedes-Benz and Volvo vehicles as well as its effect in combination with lane departure warning on Buick models show little indication of preventing crashes. Estimates for BSD's effect on damage claim frequency (both first party and liability) are small, with some indicating increases and others indicating decreases. Six of nine estimates for injury claim frequencies indicate reductions, but large confidence intervals suggest the need for more data to establish BSD's true effect on injuries.

BSD is a promising technology that possibly could address as many as 395,000 crashes, including 20,000 injury crashes and nearly 400 fatalities (Jermakian, 2011). Our surveys of early-adopter experience with this technology indicate a high level of satisfaction (Braitman et al., 2010). However, the inconclusive results from analyses of effectiveness suggest that more research is needed to determine the characteristics that make these systems effective before promoting them to consumers through consumer information programs.

Crashworthiness

Silver Cars

NHTSA announced its interest in developing a Silver Cars rating to address concerns that older vehicle occupants, an increasing segment of the population, are more susceptible to injury than younger people. The idea of a Silver Cars rating would be to provide older consumers with information on which vehicles might better protect them, in addition to NCAP's 5-star ratings. This suggests that NHTSA believes there could be different crash protection strategies for older and younger people or that some crashworthiness features or strategies may be more beneficial to older drivers. Although it is possible that some crash protection designs might protect older and more fragile people better than other designs, it is unclear that such designs also would not better protect younger people. A previous analysis of driver death rates explores the possibility that the vehicles providing the best protection for older populations are different than the models providing the best protection for younger populations.

In 2011, IIHS published one in a series of occasional analyses of driver death rates per vehicle registrations by vehicle make and model (see attached report). For the first time, these rates reflected adjustments for calendar year, vehicle age, driver age and gender, and the vehicle density in the areas where each vehicle is typically registered. All of these factors are known to affect both the likelihood of a vehicle being in a crash and the likelihood that the crash will be fatal, so that differences in these variables can affect driver death rates in ways that do not reflect the vehicle's inherent safety. A statistical model was constructed to estimate the effects on death rates of these factors. The estimated effects were then used to calculate death rates standardized to a common distribution of these variables for all the models in the analysis. A detailed explanation of this method also is attached.

We recalculated the standardized driver death rates for two different hypothetical populations: an elderly population of drivers 65 and older, and a nonelderly population with 8 percent of drivers younger than 25 and the remaining between ages 25 and 64. As expected, the estimated driver death rates for every model were higher for the elderly population than the nonelderly population and the original population meant to represent the age distribution in the general population. However, the rank order of models according to driver death rate for the elderly population and each of the other two populations was highly correlated with only slight changes in the rankings among the three lists. Among the 20 models with the lowest death rates, only three have a slightly different position when the population is assumed to be elderly compared with nonelderly or typical of the general population. This was not surprising because the effects associated with driver age and gender in the statistical model were small relative to the effects associated with vehicle age and calendar year. The rank ordered lists and estimated driver death rates for the three different hypothetical populations are attached.

This analysis of fatality rates per million registered vehicle years does not account for all nonvehicle effects on the likelihood of crashing or being killed in a crash. For example, the possibility that some vehicles may attract riskier drivers cannot be fully accounted for. Nevertheless, the similarity of ranked driver death rates for the different hypothetical populations calls into question the notion that vehicle crashworthiness rating systems should be different for older people and younger people. The fundamental principles of occupant protection are the same for all ages — retaining occupants in the vehicle, reducing the forces required to slow them from travel speeds, and distributing the restraint forces over large areas of the strongest parts of the body. It is likely that the best recommendation for the most fragile members of the population, as for all other segments of the population, would be to seek out the relatively small number of vehicles that have the most crashworthy designs as indicated by a 5-star NCAP rating plus an IIHS *Top Safety Pick+* award.

Moving Barrier Frontal Test

The request for comments indicates that NHTSA is considering modifying its front crashworthiness ratings test to provide comparative ratings across different vehicle weight categories. This would be a change from the ratings based on same-speed crashes into an unmoving barrier, which cannot be compared across weight categories because the kinetic energy available to cause damage in the test depends on the mass of the test vehicle. Although it seems desirable to offer crashworthiness ratings that can be compared across disparate vehicle weight categories, the extent to which consumers actually compare widely different models when shopping for a new vehicle is unknown. The obvious way to achieve ratings that could be compared across weight categories would be to adopt a moving barrier test in which the moving barrier has the same kinetic energy regardless of the vehicle being evaluated. A potential drawback of this approach is that important differences among vehicles at either extremes of the weight range could be obscured.

Crash tests conducted by IIHS in 2009 illustrate how crashworthiness differences among the smallest vehicles could be obscured by tests representing what happens in a crash with a vehicle of average weight. We conducted car-to-car frontal offset crashes between minicars and midsize cars from the same manufacturer. The Honda Fit, Smart Fortwo, and Toyota Yaris were selected as being among the most crashworthy vehicles in this class. All received good frontal crashworthiness ratings from IIHS, whereas other models in this class did not rate as high. In crashes against the Honda Accord, Mercedes-Benz C250, and Toyota Camry respectively, all three minicars crushed more and caused higher injury measures to be recorded by the driver dummy than in the 40 mph frontal offset crashes against the barrier. Applying the same rating criteria to the car-to-car crashes as used in our crashworthiness evaluations would have resulted in poor ratings for all three, and it is unlikely that the lesser rated minicars would have fared better in similar tests. Thus, although the barrier test results give potential minicar buyers a reason to choose the Fit, Fortwo, or Yaris over their competitors, the tests representing a crash with a typical midsize car obscures these differences. Adopting a similar test in NCAP could give consumers information currently not available, but it may be necessary to continue running barrier crash tests to preserve the information that could be lost without them. A copy of our *Status Report* newsletter describing these tests is attached.

Improving Consumer Information Communication

Publicizing NCAP Ratings

The effect of consumer safety ratings on vehicle safety is well documented in research published by IIHS and NHTSA (Farmer, 2005; Farmer et al., 2008; Kahane, 1994; Newstead et al., 2003; Teoh and Lund, 2011), but until recently little was known about how safety ratings affect consumer behavior. Results of our release last year of the first ratings in our new small overlap frontal crash test illustrate this relationship. IIHS's August 2012 announcement of results for midsize luxury cars was featured in 2,550 television broadcasts and seen by an estimated 204 million viewers. Traffic on the IIHS website spiked from a daily average of about 10,000 visits to more than 60,000 on the day of the release. Most importantly, an IIHS telephone survey of more than 150 Volvo dealerships in the United States documented 23 percent more interest in Volvo's S60 model (one of only two midsize luxury cars to earn the highest rating of good) and a 41 percent increase in sales of the S60 in the week after the announcement compared with the week before (see attached). The survey results are a testament to the power of well-publicized consumer information.

IIHS encourages NHTSA to raise the profile of its safety ratings. One way to generate more consumer interest is to highlight crash test results showing big differences in performance among vehicles. By doing this, IIHS vehicle ratings receive considerable media coverage. In contrast, NHTSA does not seem to widely publicize its test results. A review of the agency's 2012 and 2013 press releases (www.nhtsa.gov/About+NHTSA/Press+Releases) includes only one entry concerning NCAP — an announcement of models to be tested in 2013. Although this information may be helpful to automakers, it does not alert consumers to newly posted ratings or direct their attention to those models that offer the highest levels of safety as recommended by NCAP. IIHS experience suggests that NHTSA could improve public awareness of its ratings by releasing test results for groups of competitor models to highlight differences in ratings or the availability of recommended technologies.

Carry-Back Ratings

In its request for comments, NHTSA mentions that it is considering whether to carry back its ratings to cover earlier models than the one tested. IIHS has been doing this since we began publishing crashworthiness ratings in 1995. This is an economical way of helping used-vehicle buyers base their choices on safety. We have always extended our ratings to earlier models as long as there are no significant changes to the structure or restraint systems that would likely affect the test results. The following table summarizes the additional ratings coverage this practice has created. The pattern of visits to the IIHS website indicates that consumers appreciate having this information. During the past year, our ratings summary pages have received an average of 90,000 page views per month, with 79,000 viewing current model summaries and 11,000 viewing earlier model summaries. We expect consumers using NHTSA's Safercar.gov would find similar utility if the agency were to carry-back its safety ratings where appropriate.

Rating type	Number of models with carry-back ratings	Total number of carry-back model years
Front moderate overlap	119	219
Front small overlap	26	83
Side impact	140	324
Roof strength	24	112

Monroney Label

The request for comment also indicates that NHTSA is contemplating changes to the safety ratings section of the Monroney label. We have two suggestions to improve the information available there. Firstly, information about crashworthiness is incomplete without also including IIHS crashworthiness ratings. IIHS ratings are based on different tests than NHTSA conducts and as such provide complementary information. Sometimes vehicles with similar NCAP scores have very different IIHS ratings, or vice versa. For example, the 2013 Honda Accord and Toyota Camry are both rated 5 stars overall with 4 stars for front and 5 stars for side. They both also earn good ratings in our moderate overlap front, side, roof strength, and rear tests. In the new small overlap front test, the Accord earned a good rating whereas the Camry earned a poor rating. In this case, only IIHS's newest crash test gives consumers a reason to choose one model over the other. Without both NHTSA's and IIHS's ratings visible to the consumer, important differences in crashworthiness are obscured.

Adding IIHS ratings to the label would not pose an undue burden on automakers as they are aware of how we rate their products. Indeed, several already tout their IIHS *Top Safety Pick* status on the Monroney label (examples attached). We would be happy to work with NHTSA to facilitate the use of our ratings.

We recognize that requiring the use of information from outside sources such as IIHS could pose challenges for NCAP. Nevertheless, we believe that IIHS and NHTSA test results are complementary and, taken together, can have a larger influence on the future safety of vehicles. Requiring that all relevant safety information be available at the point of sale of new vehicles would be an efficient and economical way for NCAP to ensure that consumers are well-informed, and to provide a greater incentive for automakers to improve the all-around safety of their vehicles.

As NCAP, IIHS, and others endeavor to inform consumers about beneficial crash avoidance technologies, consumers are likely to be confused by the smorgasbord of unique marketing names for technologies with similar functionality. As the attachments clearly indicate, there are numerous names for systems that include some level of crash imminent braking. Many of these names, like Audi's Pre-Sense Plus or Lexus' Advanced Pre-collision System, provide no hint as to what function the named feature provides, although both systems include both FCW and CIB. A customer shopping for an Audi or Lexus with these features would have no way of knowing whether the vehicle they are considering is equipped with them.

This potential for confusion could be reduced by requiring that the Monroney label use standard nomenclature to identify safety technologies recommended by NCAP. This information could be included in the safety ratings section of the label. Because many of these technologies are optional features, it also might be helpful to include the standardized nomenclature in a parenthetical adjacent to the automaker's name for that feature or the feature package that includes it. For example:

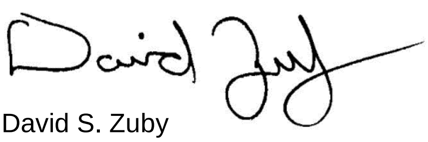
> **Distronic Plus (with Pre-Safe Brake)** (Forward Collision Warning & Collision Imminent Braking)
> **Driver Assistance Package** (Includes Forward Collision Warning)

Establishing this practice would require NHTSA to develop and maintain a list of features and their standardized names and definitions. In some cases, NHTSA could define a particular function in terms of certain performance specifications, as has been done with Forward Collision Warning and Lane Departure Warning. In any case, standard nomenclature used to identify the presence of recommended technologies on the Monroney label would help consumers choose vehicles with these features.

Conclusion

IIHS applauds NHTSA for beginning to chart the future of NCAP and involving the public in this process. We hope the agency finds the foregoing comments and the attached research papers are useful.

Sincerely,



David S. Zuby
Chief Research Officer

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Farmer, C.M. 2005. Relationships of frontal offset crash test results to real-world driver fatality rates. *Traffic Injury Prevention* 6:31-37.

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Teoh, E.R. and Lund, A.K. 2011. IIHS side crash test ratings and occupant death risk in real-world crashes. *Traffic Injury Prevention* 12:500-07.

Attachments

Highway Loss Data Institute. 2012. Volvo City Safety loss experience: an update. *Bulletin* 29(23). Arlington, VA.

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

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

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Highway Loss Data Institute. 2011. Buick collision avoidance features: initial results. *Bulletin* 28(22). Arlington, VA.

Farmer, C. M. 2011. Methods for estimating driver death rates by vehicle make and series. Arlington, VA: Insurance Institute for Highway Safety

Make/Model List Rank Ordered by Driver Death Rate Estimated for Three Population Distributions

Insurance Institute for Highway Safety. 2009. Special Issue: car size, weight, and safety. *Status Report* 44(4). Arlington, VA.

Cicchino, J.B. 2012. Survey of Volvo dealers about effects of small overlap frontal crash test results on business. Arlington, VA: Insurance Institute for Highway Safety

Examples of Monroney Labels with IIHS Ratings and *Top Safety Pick*

Automaker Names for Forward Collision Warning

Automaker Names for Forward Collision Warning with Autonomous Emergency Braking

HIGHWAY LOSS
DATA INSTITUTE

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Volvo City Safety loss experience – an update

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

Introduction

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

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

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

Methods

Insurance data

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

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

Subject vehicles

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

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

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

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

Table 1: Exposure and claims by coverage type

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

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

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

Analysis methods

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

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

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

Results

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

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

Table 3: Detailed results of linear regression analysis of property damage liability claim frequencies for Volvo XC60 vs. other midsize luxury SUVs								
Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Intercept	1	-9.4038		0.0361	-9.4746	-9.3330	67847.10	<0.0001
Calendar year								
2009	1	0.0528	5.4%	0.0182	0.0172	0.0885	8.43	0.0037
2010	1	0.0950	10.0%	0.0129	0.0696	0.1203	53.95	<0.0001
2011	1	0.1071	11.3%	0.0108	0.0858	0.1283	97.56	<0.0001
2012	0	0	0	0	0	0		
Model year								
2009	1	0.1311	14.0%	0.0212	0.0895	0.1727	38.11	<0.0001
2010	1	0.0834	8.7%	0.0204	0.0434	0.1234	16.70	<0.0001
2011	1	0.0705	7.3%	0.0207	0.0300	0.1111	11.61	0.0007
2012	0	0	0	0	0	0		
Vehicle make and series								
Acura MDX	1	0.1583	17.2%	0.0300	0.0996	0.2170	27.91	<0.0001
Acura RDX	1	0.1202	12.8%	0.0345	0.0525	0.1879	12.11	0.0005
Acura ZDX	1	0.2459	27.9%	0.0799	0.0893	0.4025	9.48	0.0021
Audi Q5 4WD	1	0.0291	3.0%	0.0338	-0.0370	0.0953	0.75	0.3880
BMW X3	1	0.0784	8.2%	0.0384	0.0031	0.1537	4.16	0.0414
BMW X5	1	0.2815	32.5%	0.0306	0.2216	0.3414	84.82	<0.0001
BMW X6	1	0.3300	39.1%	0.0457	0.2405	0.4196	52.21	<0.0001
Cadillac SRX	1	0.1474	15.9%	0.0309	0.0868	0.2080	22.75	<0.0001
Infiniti EX35	1	-0.0447	-4.4%	0.0459	-0.1346	0.0451	0.95	0.3292
Infiniti FX35	1	0.1878	20.7%	0.0364	0.1165	0.2592	26.61	<0.0001
Infiniti FX50	1	0.2131	23.8%	0.0914	0.0339	0.3923	5.43	0.0198
Land Rover LR2	1	0.2947	34.3%	0.0498	0.1970	0.3924	34.96	<0.0001
Lexus RX 350	1	0.1363	14.6%	0.0283	0.0809	0.1917	23.24	<0.0001
Lincoln MKT	1	0.0977	10.3%	0.0556	-0.0112	0.2066	3.09	0.0787
Lincoln MKX	1	0.1618	17.6%	0.0345	0.0942	0.2295	21.99	<0.0001
Mercedes-Benz GLK class	1	0.1517	16.4%	0.0324	0.0883	0.2151	21.99	<0.0001
Mercedes-Benz M class	1	0.0777	8.1%	0.0311	0.0168	0.1387	6.25	0.0124
Saab 9-4X	1	0.6464	90.9%	0.3176	0.0240	1.2688	4.14	0.0418

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

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

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

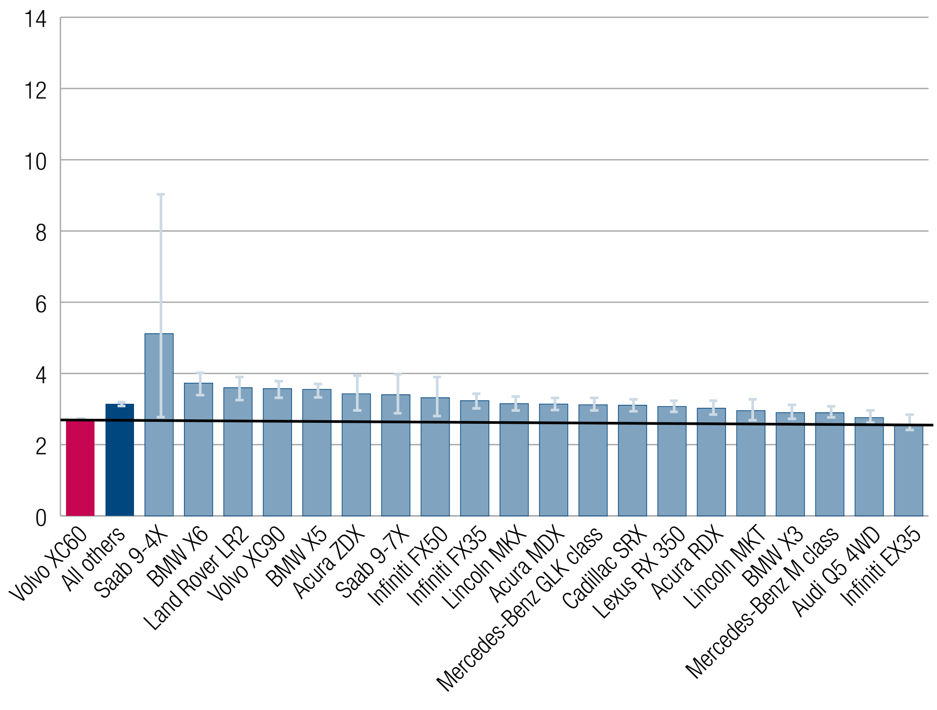
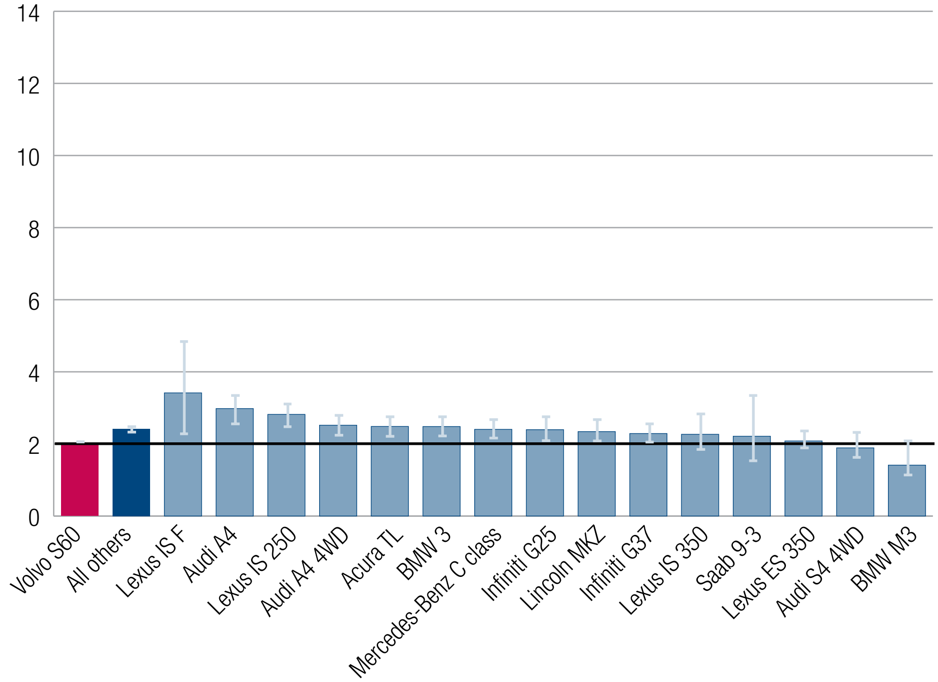


Figure 2: Property damage liability claim frequencies per 100 insured vehicle years for 2011-12 Volvo S60 with City Safety vs. other 2011-12 midsize luxury cars



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

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

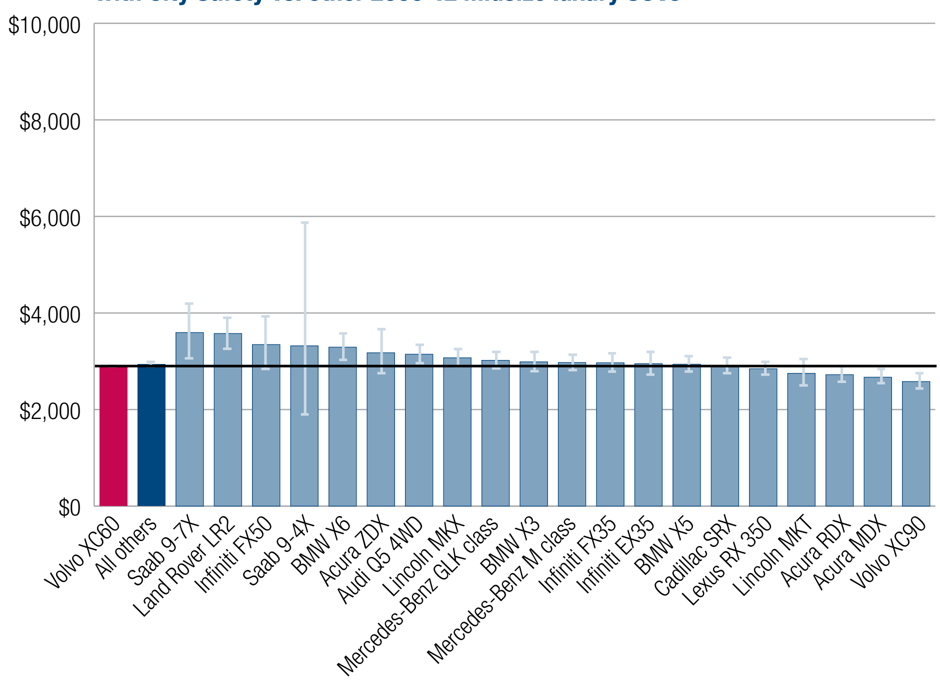
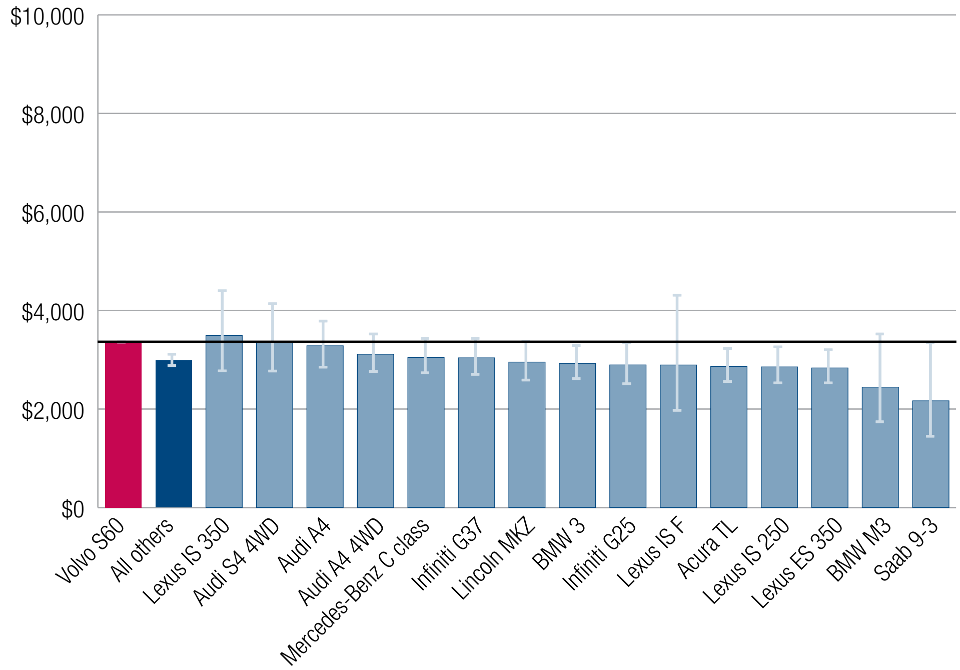


Figure 4: Property damage liability claim severities for 2011-12 Volvo S60 with City Safety vs. other 2011-12 midsize luxury cars



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

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

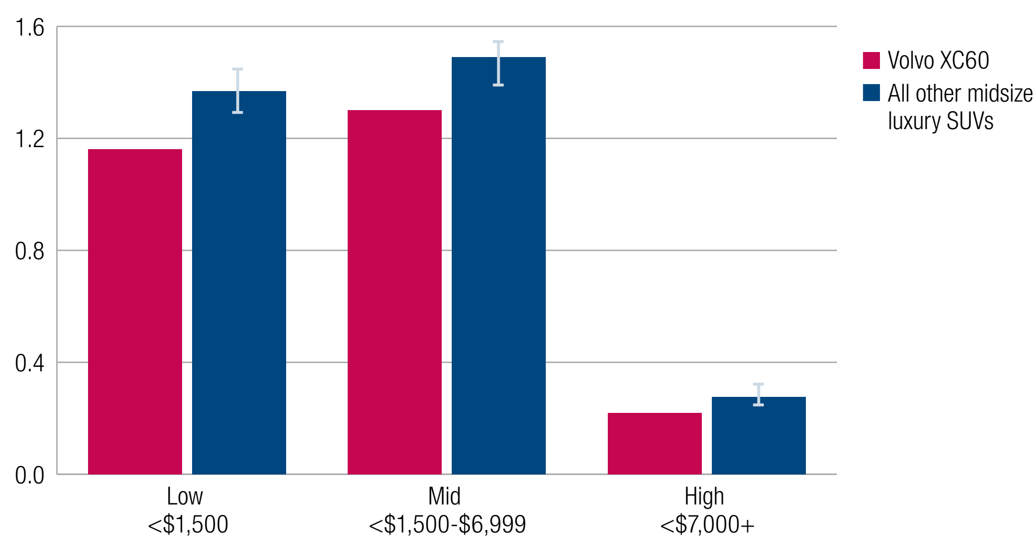
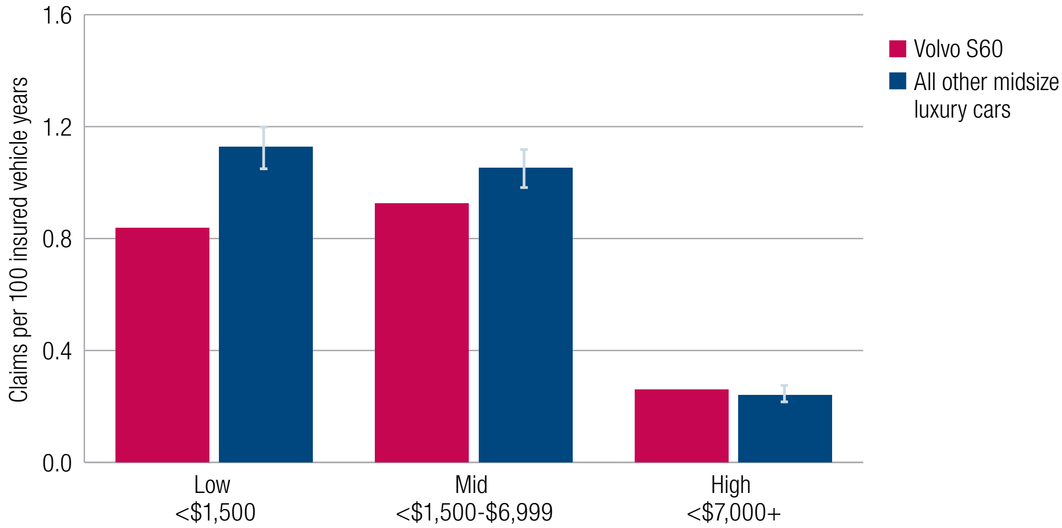


Figure 6: Property damage liability claim frequencies by claim severity range, Volvo S60 vs. other midsize luxury cars



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

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

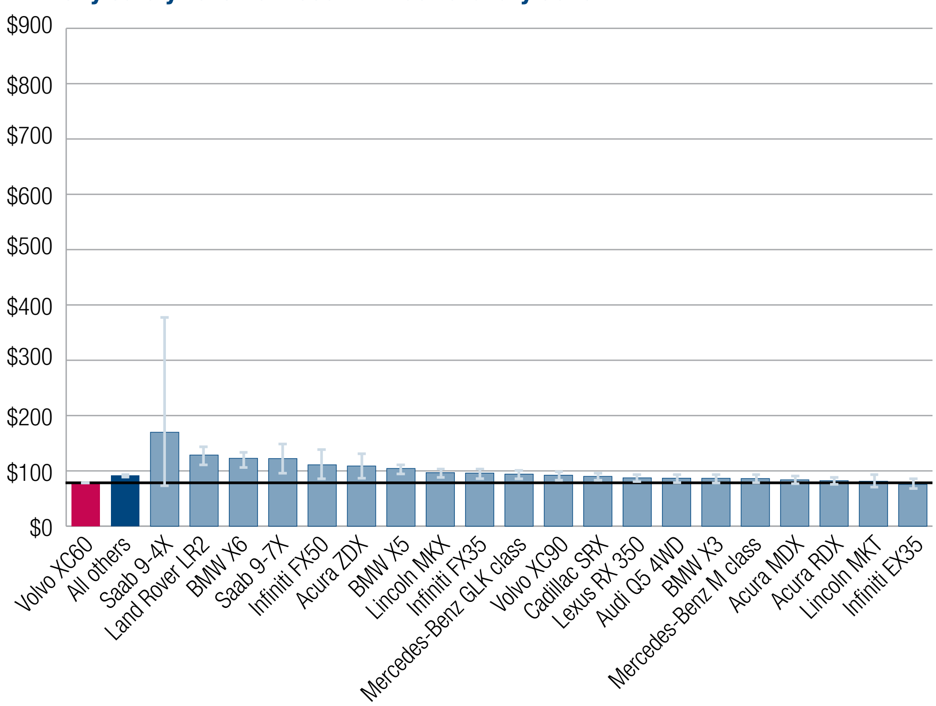


Figure 8: Property damage liability overall losses for 2011-12 Volvo S60 with City Safety vs. other 2011-12 midsize luxury cars

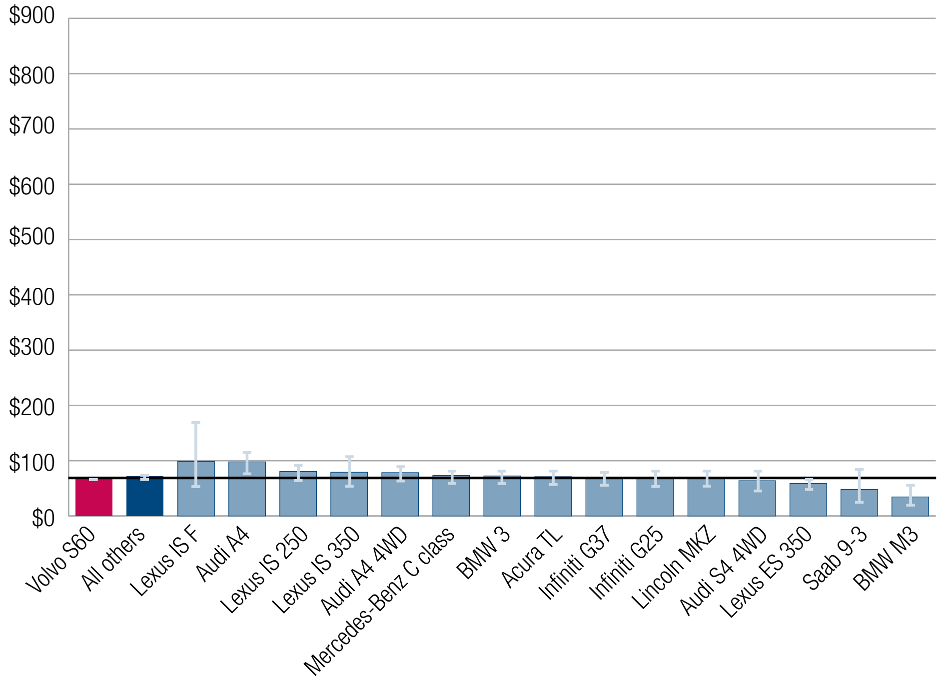


Table 4 summarizes the property damage liability results for the Volvo XC60 and S60 with City Safety. Note that the first two columns provide the weighted average estimates from the regressions and the standard error of those estimates. The third column is the effect estimate expressed as the percent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

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

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

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

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

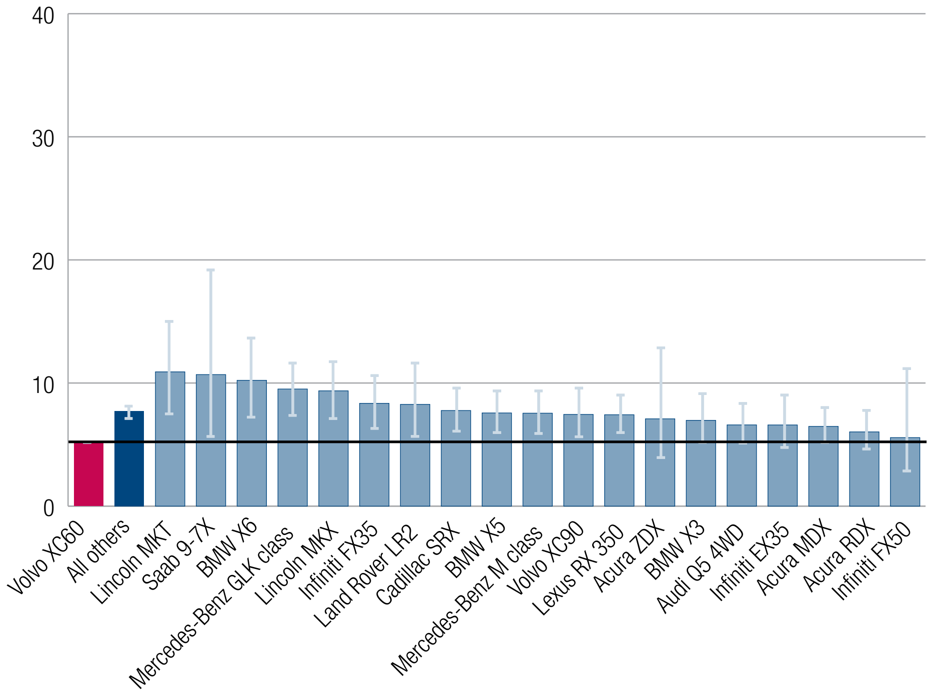


Figure 10: Bodily injury liability claim frequencies per 1,000 insured vehicle years for 2011-12 Volvo S60 with City Safety vs. other 2011-12 midsize luxury cars

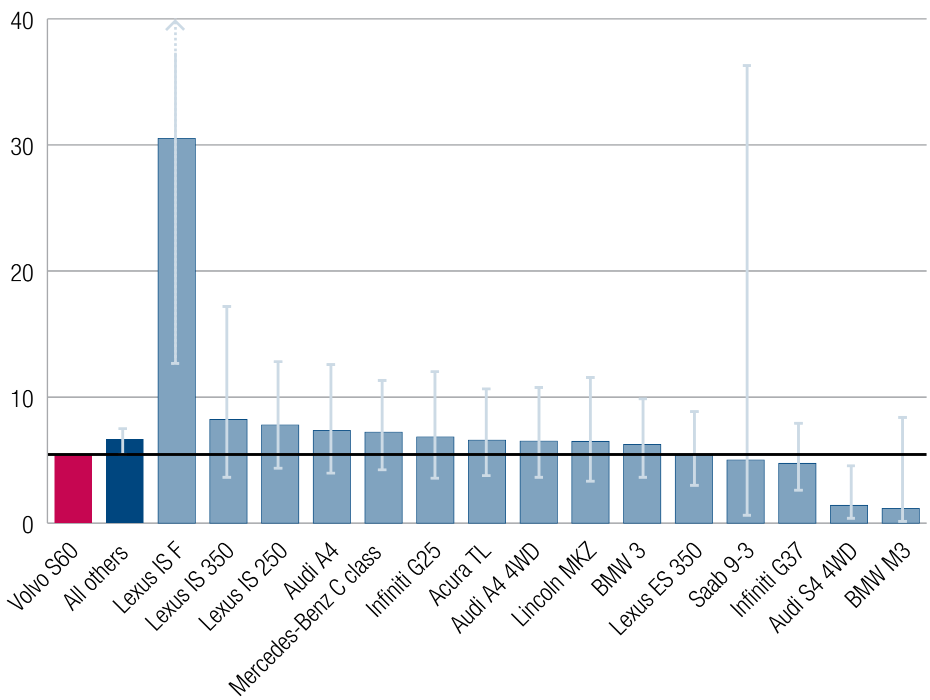


Table 5 summarizes results of the regression analysis conducted for bodily injury liability coverage. Note that analyses of claim severity were not conducted because of the relative recency of these claims and the length of time it takes for claims costs to fully develop. The layout of **Table 5** is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

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

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

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

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

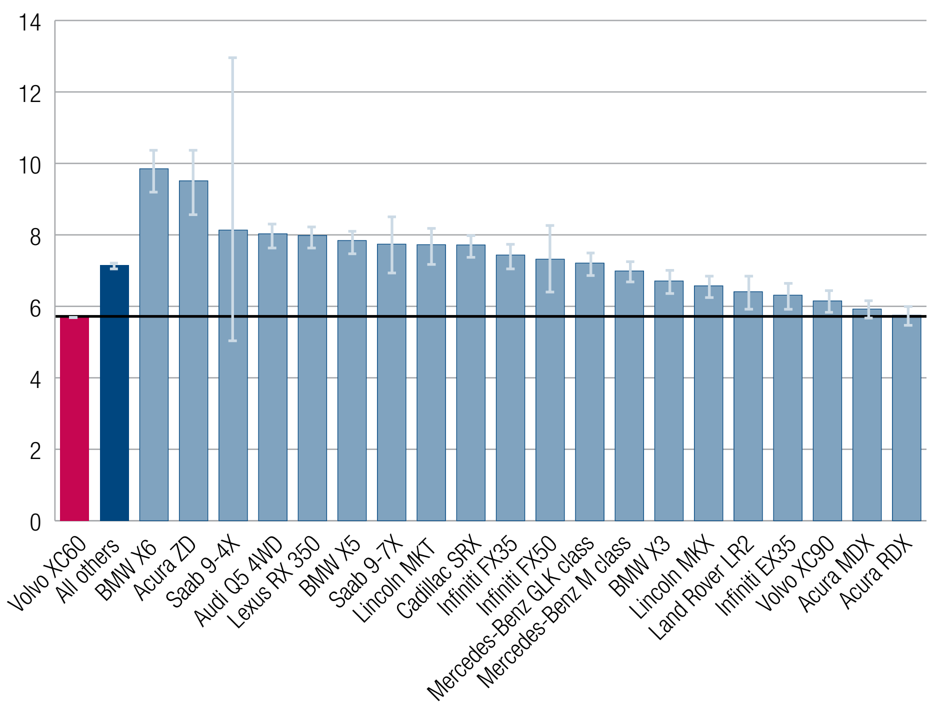


Figure 12: Collision claim frequencies per 100 insured vehicle years for 2011-12 Volvo S60 with City Safety vs. other 2011-12 midsize luxury cars

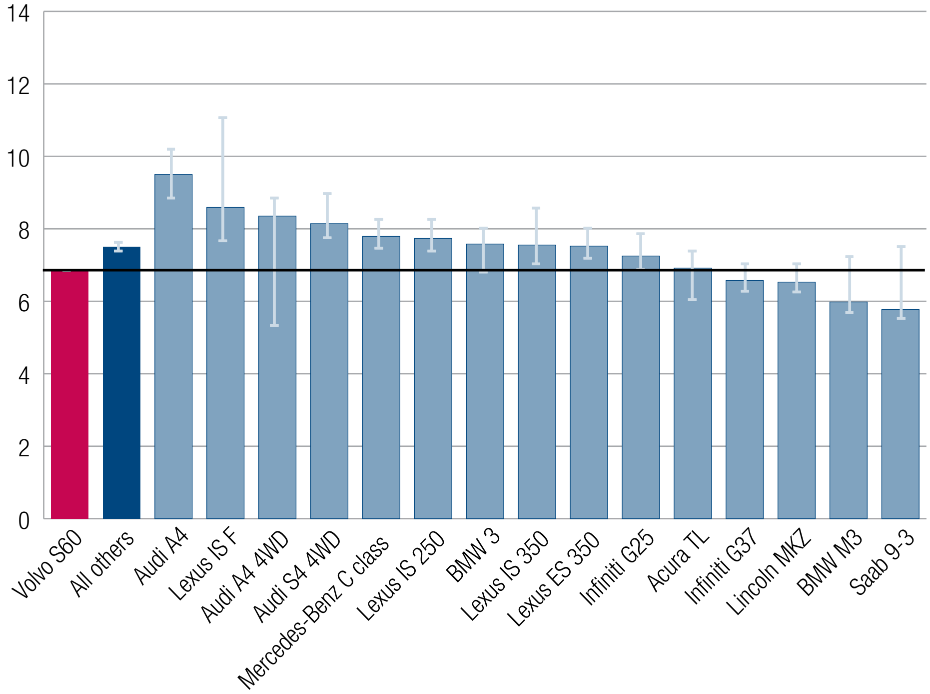


Figure 13: Collision claim severities for 2010-12 Volvo XC60 with City Safety vs. other 2009-12 midsize luxury SUVs

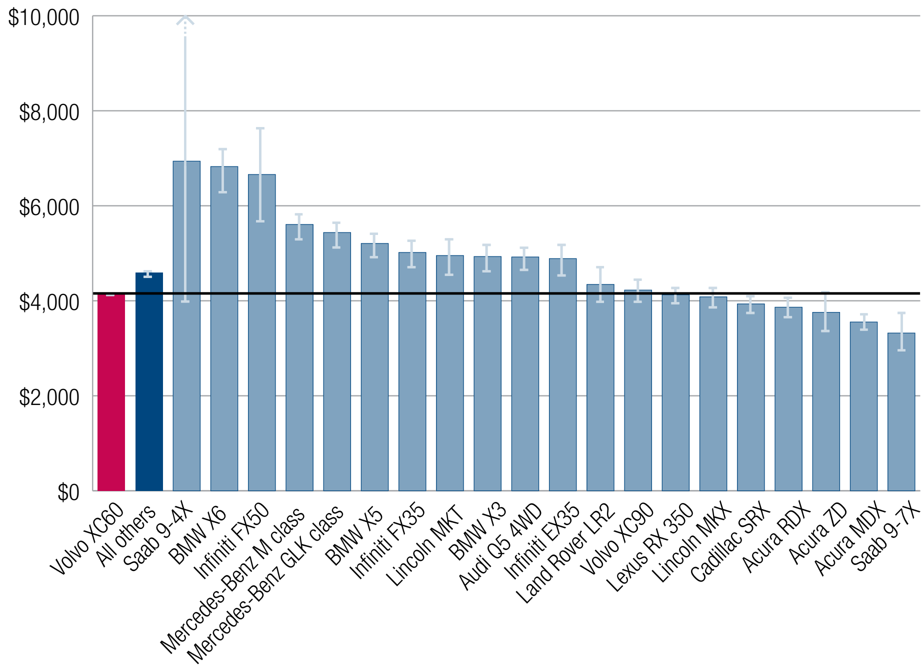


Figure 14: Collision claim severities for 2011-12 Volvo S60 with City Safety vs. other 2011-12 midsize luxury cars

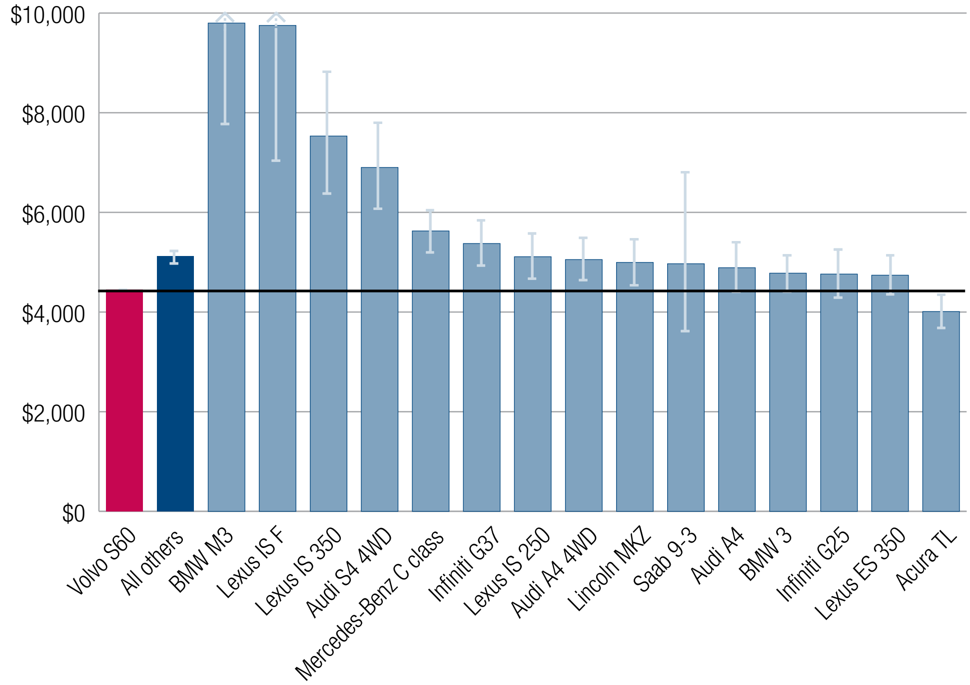


Figure 15: Collision overall losses for 2010-12 Volvo XC60 with City Safety vs. other 2009-12 midsize luxury SUVs

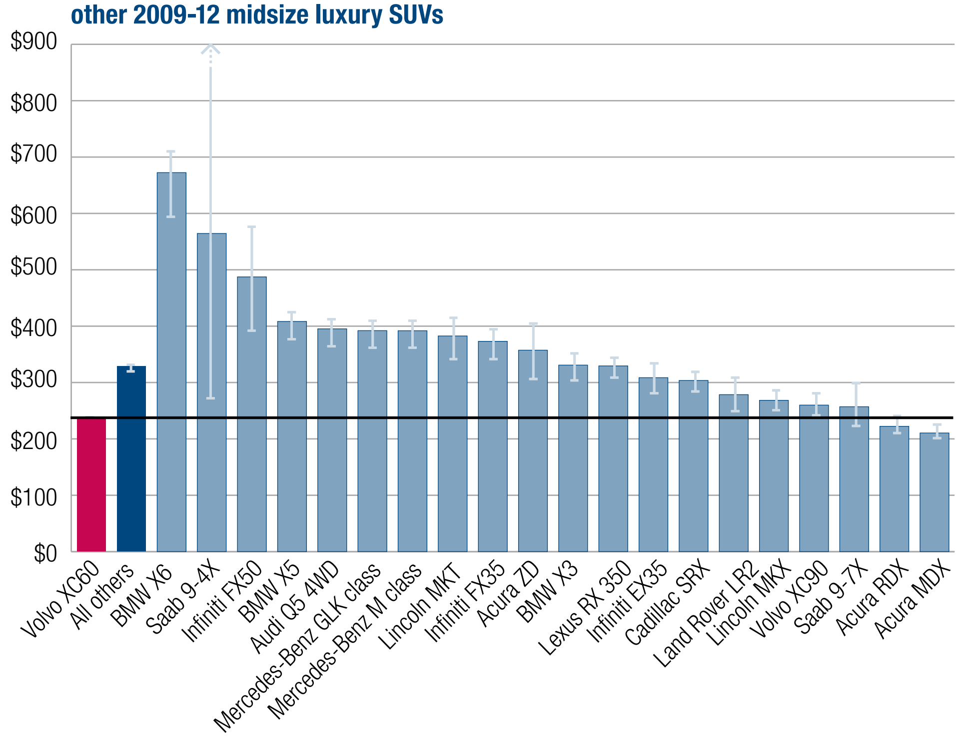


Figure 16: Collision overall losses for 2011-12 Volvo S60 with City Safety vs. other 2011-12 midsize luxury cars

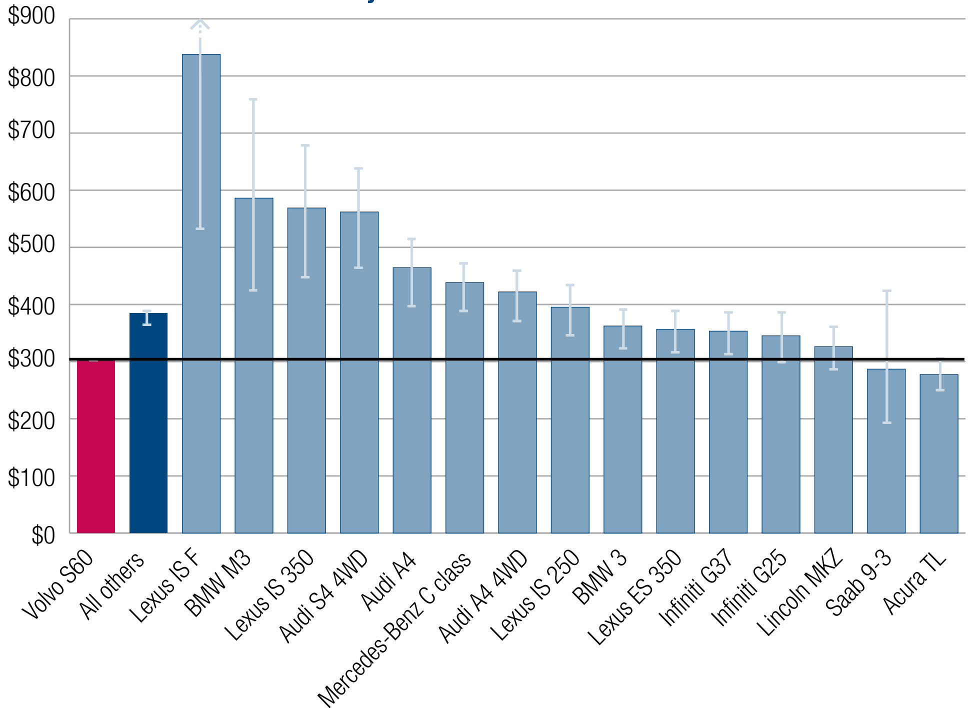


Table 6 summarizes the collision coverage results in an analogous manner to the property damage liability results. Compared to the weighted average estimate of comparison vehicles, the Volvo XC60's actual collision frequency was 20 percent lower, claim severity was 10 percent lower, and overall losses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

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

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

Discussion

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

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

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

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

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

Limitations

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

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

Appendix B: Summary loss results

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

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

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

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

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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

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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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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		

Appendix : Illustrative regression results — collision frequency

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

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Volvo collision avoidance features: initial results

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

Introduction

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

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

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

Adaptive Cruise Control is a system that uses radar sensors mounted in the front bumper to monitor traffic ahead and maintain the driver's selected following distance. As traffic conditions dictate, the system employs braking force to maintain the set following distance. Adaptive cruise control is available at speeds over 19 mph and can bring the car to a stop in traffic. Forward Collision Warning remains active even when adaptive cruise control is turned off.

Distance Alert provides information about the time interval to the vehicle ahead. Red warning lights located in the windshield glow if the vehicle is closer to the vehicle ahead than the set time interval. Distance Alert is active at speeds above 20 mph and can be deactivated.

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

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

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

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

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

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

Method

Vehicles

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

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

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

Insurance data

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

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

Statistical methods

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

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

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

Results

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

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

Table 2 : Change in insurance losses for Active Bending Lights

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-4.2%	-0.7%	2.9%	-$28	$149	$333	-$7	$8	$24
Property damage liability	-13.4%	**-9.0%**	-4.4%	-$152	-$29	$101	-$14	**-$9**	-$3

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-30.1%	**-16.8%**	-0.9%	-38.7%	-18.2%	9.2%	-43.5%	-22.7%	5.5%
Medical payments	-22.2%	-6.3%	12.8%	-52.3%	-22.9%	24.8%	-41.7%	-22.4%	3.3%
Personal injury protection	-18.3%	-6.6%	6.8%	-37.0%	-16.4%	11.0%	-12.9%	3.9%	23.9%

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

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

Table 3 : Change in insurance losses for Forward Collision Warning

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-16.5%	-6.6%	4.5%	-$125	$445	$1,093	-$36	$9	$62
Property damage liability	-21.9%	-7.1%	10.6%	-$201	$266	$821	-$18	$2	$27

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-50.3%	-9.2%	66.1%	-81.0%	-36.4%	113.4%	-50.5%	18.1%	182.1%
Medical payments	-62.5%	-27.5%	39.9%	-94.2%	-52.9%	284.2%	-82.4%	-48.7%	50.0%
Personal injury protection	-28.0%	14.0%	80.5%	-58.8%	8.2%	184.0%	-34.8%	20.1%	121.2%

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

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

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

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

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

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

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

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

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

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

Discussion

Active Bending Lights

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

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

Forward Collision Warning

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

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

Blind Spot Information System

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

Limitations

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

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

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

Reference

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

Appendix : Illustrative regression results — collision frequency

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

Appendix : Illustrative regression results — collision frequency

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

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

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

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

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Mazda collision avoidance features: initial results

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

Introduction

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

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

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

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

Method

Vehicles

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

Table 1 : Feature exposure by vehicle series

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

Insurance data

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

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

Statistical methods

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

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

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

Results

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

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

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

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

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

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

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

Table 3 : Change in insurance losses for Blind Spot Monitoring

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

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

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

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

Table 4 : Change in insurance losses for back up camera

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

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

Discussion

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

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

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

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

Limitations

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

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

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

Appendix : Illustrative regression results — collision frequency

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

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

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

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Buick collision avoidance features: initial results

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

Introduction

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

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

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

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

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

Method

Vehicles

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

Table 1 : Feature exposure by vehicle series

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

Insurance data

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

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

Statistical methods

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

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

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

Results

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

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

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

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

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

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

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

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

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

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

Discussion

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

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

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

Limitations

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

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

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

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

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

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Methods for Estimating Driver Death Rates by Vehicle Make and Series

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ABSTRACT

Driver death rates per million registered vehicles per year were calculated for 168 passenger vehicle models for sale in 2008. Rates ranged from 0 to 179 deaths per million registrations per year. Minivans and SUVs had driver death rates significantly lower than those for other vehicle types. Within vehicle type, larger vehicles generally had lower driver death rates than smaller vehicles. To account for potential differences by calendar year, driver age, gender, and driving environment, all of which can affect motor vehicle crash and injury experience, rates were standardized to a common distribution of exposure. These standardized rates ranged from 0 to 143 deaths per million registrations per year, and the relative differences among vehicle types were lessened considerably.

INTRODUCTION

Periodically since 1989 the Insurance Institute for Highway Safety (IIHS) has calculated and published driver death rates per registered vehicle. These rates provide an indication of the overall risk to drivers, including both the likelihood of being in a crash and the likelihood of being fatally injured in that crash. Assuming similar amounts and types of driving per year, comparisons can be made among the various vehicle models. Such exposure, however, may vary widely across vehicle models for a number of reasons, including vehicle cost and marketing, geography, and economic conditions. Driver characteristics, especially age and gender, affect both the likelihood of crash involvement and the likelihood of injury in a crash. For example, young drivers are overinvolved in serious crashes, and elderly drivers are more likely to be killed if they are in crashes.

To compensate for the differences in exposure, real-world crash injury rates often are standardized to a common age and gender distribution of involved drivers. For example, standardized relative injury rates per reported crash are published in Australia (Newstead et al., 2010), Sweden (Folksam, 2009), and the United States (Highway Loss Data Institute (HLDI), 2009).

Similar standardization of fatal crash rates for age and gender has not been possible. There is no national database of all reported motor vehicle crashes in the United States, so it is not possible to calculate driver death rates per crash. And, although there is a database of all fatal crashes and a corresponding database of all registered vehicles — so that it is possible to calculate driver death rates per registered vehicle for each vehicle model (IIHS, 2007) — the vehicle registration database does not include information on driver age and gender. Absent information on the exposure of each vehicle model by driver age and gender, driver death rates cannot be directly standardized to a common driver age and gender distribution.

One indirect method of lessening the effect of driver differences is to group vehicle models by size and body style. The driver population within each resulting vehicle group is likely to be much more homogeneous than the overall driver population. Therefore, comparisons among cars within a market group should be less affected by driver differences. Nevertheless, comparisons between vehicles in different market groups still are affected by driver differences.

A mathematical adjustment of death rates based on vehicle wheelbase and the proportion of occupant deaths in cars with male drivers or drivers younger than 30 was included as part of the first few IIHS (1989) evaluations. In addition to occupant death rates per 10,000 vehicle registrations, the differences between actual death rates and those predicted based on wheelbase, driver age, and gender were presented. About one-sixth of vehicles evaluated had actual death rates more than 40 percent lower or higher than those predicted by the mathematical model. These vehicles then were rated as performing much better or much worse than expected.

In 2001 a new method was introduced for adjusting the rates to differences in driver age and gender (Farmer, 2001). This adjustment made comparisons of vehicles more meaningful by standardizing each vehicle's driver death rate to a population with a common proportion of 25-64-year-old female drivers — that is, the group of drivers with the lowest fatality rate. Because the true proportion of 25-64-year-old female drivers for a given vehicle was unknown, the standardization procedure was indirect, based on an assumed mathematical relationship between overall and group-specific driver death rates.

A sharp decline in fatal crash rates beginning in 2008 necessitated further adjustments to the procedure for estimating driver death rates. Vehicle models newly designed in 2008 tended to have lower death rates than earlier models partly because their exposure period was less risky. To adjust for these differences in exposure, a statistical model was devised for estimating deaths that would have occurred if the new models had been around in earlier years. In addition, the statistical model formulated a relationship of death rates to driver age, gender, and driving environment. Rates then could be standardized to a common distribution of calendar years, age, gender, and driving environment. This paper presents the methodology for computing standardized driver death rates per million registrations per year by vehicle model for model years 2005-08 during calendar years 2006-09.

METHOD

Counts of driver deaths for each make and series of 2006-08 passenger vehicles were obtained from the U.S. Department of Transportation's Fatality Analysis Reporting System (FARS), an annual census of fatal motor vehicle crashes. A vehicle series is defined as the combination of vehicle model and body style (e.g., the two-door and four-door Honda Civic are different series).

Counts of registered vehicles for each make and series were obtained from the National Vehicle Population Profile (NVPP), a compilation of data from state registration files produced by R.L. Polk & Company. NVPP registration counts are a snapshot of vehicles registered as of July 1 of each year, so they tend to misrepresent annual registrations of the current model year. For example, registration counts on July 1, 2009 did not include any of the yet unsold 2009 models, nor did they provide information on how many months any new vehicle had been registered. In this analysis, counts of both driver deaths and vehicle registrations for each model year were restricted to calendar years later than the model year. Nearly all such vehicles registered on July 1 would have been on the road for the whole year. Also, because NVPP does not include government-owned vehicles, driver deaths in police vehicles or vehicles with government tags were excluded from the analysis.

Estimates of the proportions of drivers of each vehicle series who were younger than 25, 65 and older, male, or living in an area with at least 500 vehicles per square mile were derived using a database of automobile insurance policy information maintained by HLDI. The HLDI database covers more than 150 million individual passenger vehicles, amounting to about 80 percent of all privately insured vehicles in the United States.

Analyses were restricted to model years not significantly different in design from the 2008 model year. Design changes include changes in engineering design, such as the dimensions or weight of the vehicle, or the addition of electronic stability control (ESC) or head protection side airbags. For example, the Toyota Camry four-door car was redesigned in 2007, so only model years 2007-08 were included in this analysis. There were 25 driver deaths and 561,250 registrations for 2007 model Camrys during 2008, 19 driver deaths and 556,458 registrations for 2007 models during 2009, and 5 driver deaths and 188,347 registrations for 2008 models during 2009. Thus the totals for the 2007-08 model Camry cars were 49 driver deaths and 1,306,055 registration-years.

Data for each make, series, model year, and calendar year with at least 10,000 vehicle registrations were entered into a Poisson regression model. The model predicted the number of driver deaths based on the vehicle make and series, calendar year, vehicle age (i.e., calendar year minus model year), number of registrations, proportion of HLDI exposure for which the rated driver was younger than 25, proportion of exposure for which the rated driver was 65 or older, proportion of exposure for which the rated driver was male, and proportion of exposure for which the garaging zip code had a vehicle density of at least 500 vehicles per square mile.

By changing the values of all predictor variables other than make, series, calendar year, and vehicle age, the predicted death counts were standardized to a common exposure distribution. For example, the model parameter estimates were used to predict the number of driver deaths that would have been expected if the registrations of each vehicle series were distributed across the 10 model year/ calendar year combinations according to proportions from the overall vehicle population: 6 percent of registrations from model year 2005 in each of calendar years 2006-09, 9 percent of registrations from model year 2006 in each of calendar years 2007-09, 15 percent of registrations from model year 2007 in each of calendar years 2008-09, and 20 percent of registrations from model year 2008 in calendar year 2009. It also was supposed that each series had about 7 percent of exposure from drivers younger than 25, 13 percent from drivers 65 and older, 49 percent from male drivers, and 44 percent from drivers in areas with high vehicle density.

Standardized driver death rates were computed by dividing predicted deaths by registered vehicle-years (in millions). Approximate 95 percent confidence limits for the standardized rates were based on a Taylor series estimate of the variance of a logarithm (Snedecor and Cochran, 1980). If X represents the predicted deaths under standardized exposure, then $\mathrm{Var}\{\log X\} \approx \mathrm{Var}\{X\} / [E\{X\}]^2$. That is, $\mathrm{Var}\{X\} \approx [E\{X\}]^2\, \mathrm{Var}\{\log X\}$. For each of the 10 model year/calendar year combinations, the regression model produced estimates of $E\{X\}$ and $\mathrm{Var}\{\log X\}$, which in turn yielded estimates of $\mathrm{Var}\{X\}$. Summing the estimates of $\mathrm{Var}\{X\}$ gave an approximation to the variance of the sum of predicted deaths.

RESULTS

Table 1 summarizes the results of the regression model (except for most vehicle series parameters). Death rates were lowest in calendar year 2009. Compared with 2009, driver death rates were approximately 11 percent higher in 2006, 8 percent higher in 2007, and 5 percent higher in 2008. Death rates were highest for 4-year-old vehicles, about 7 percent lower for 3-year-old vehicles, 1 percent

Table 1
Poisson Regression of Logarithm of Driver Deaths

Parameter	Estimate	Chi-square	p-value
Intercept	-8.8178		
Make and series			
Chevrolet Cobalt 4d	-0.3393		
…			
Calendar year			
2006	0.1069	0.67	0.4142
2007	0.0732	0.67	0.4114
2008	0.0460	0.67	0.4129
2009	0		
Vehicle age			
1 year	-0.0363	0.13	0.7198
2 years	-0.0118	0.02	0.8964
3 years	-0.0755	0.69	0.4064
4 years	0		
Log(Registrations)	1		
Proportion of drivers younger than 25	0.0261	0.71	0.3997
Proportion of drivers 65 and older	0.0025	0.01	0.9078
Proportion male drivers	0.0087	0.26	0.6091
Proportion of drivers in areas with high vehicle density	-0.0121	0.58	0.4462

lower for 2-year-old vehicles, and 4 percent lower for 1-year-old vehicles. Vehicles with a higher percentage of young, old, or male drivers had higher driver death rates. Vehicles garaged in high-density areas had lower driver death rates than vehicles garaged in lower density areas.

The 2005-08 Chevrolet Cobalt had a very high proportion of young drivers (16-19 percent), an average proportion of older drivers (12-16 percent), a low proportion of male drivers (36-40 percent), and a low proportion of drivers in areas with high vehicle density (36-41 percent). So the Cobalt's 175 driver deaths and 1,128,364 registration-years gave it a relatively high rate of 155 driver deaths per million registration-years. When the registrations were redistributed (more to the later years) and the age, gender, and density distributions were standardized, the count of predicted driver deaths was reduced. For example, registrations of the 2006 Cobalt in 2007 were reduced from 129,098 to 108,235, the proportion of young drivers was reduced from 18.9 to 6.9 percent, the proportion of older drivers was increased from 12.1 to 12.7 percent, the proportion of male drivers was increased from 37.1 to 49.3 percent, and the proportion of drivers in areas with high vehicle density was increased from 37.5 to 44.0 percent. The predicted driver deaths for the 2006 Cobalt in 2007 was therefore reduced from 27 to 13.2 — that is, $\exp\{-8.8178 - 0.3393 + 0.0732 - 0.0363 + \log(108235) + 0.0261(6.914) + 0.0025(12.740) + 0.0087(49.329) - 0.0121(44.042)\}$. Overall, 132.4 driver deaths were predicted under the new exposure distribution. The estimated variance of the driver death count was 20.83.

The standardized rate for the Cobalt was 117 driver deaths per million registration-years (compared with 155 before standardization). The 95 percent confidence limits for the standardized rate were computed as $117 \pm 1.96\, \mathit{sqrt}(20.83) / 1.128364$. That is, the confidence interval includes values from 109 to 125.

Driver death rates for the Cobalt and 167 other vehicle series that had at least 100,000 registration-years of exposure were listed in an earlier publication (IIHS, 2011). Standardized rates for the other vehicle series ranged from 0 to 143 deaths per million registrations per year. Rates ranged from 0 to 179 before standardization. Vehicle series with the lowest rates mostly were minivans, SUVs, and luxury cars. The overall rate was 48 driver deaths per million registrations per year.

Table 2 lists driver death rates for passenger vehicles included in the regression model by vehicle type and size category. Columns 4-5 are based on raw counts of driver deaths, and columns 6-7 are based on standardized estimates. Death rates for small and large cars were lowered, whereas rates for midsize cars were increased, but the overall rate for cars did not change much. Death rates for minivans and SUVs tended to increase when standardized, whereas rates for pickups were decreased by quite a bit.

Table 2
Driver Death Rates per Million Registration-Years (standardized using Poisson regression), 2005-08 Models during 2006-09

			Raw		Standardized	
Vehicle style	Vehicle size	Registration-years	Driver deaths	Death rate	Driver deaths	Death rate
All	All	65,078,867	3,371	52	3,114	48
Car	Mini	1,390,941	117	84	103	74
	Small	12,295,227	911	74	829	67
	Midsize	12,333,881	538	44	596	48
	Large	8,603,132	429	50	424	49
	Very Large	1,686,396	79	47	73	43
	All	36,309,577	2,074	57	2,024	56
Minivan	All	2,835,972	54	19	70	25
SUV	Small	3,432,915	100	29	121	35
	Midsize	5,793,887	124	21	154	27
	Large	2,443,757	40	16	49	20
	Very Large	206,257	6	29	6	31
	All	11,876,816	270	23	331	28
Pickup	Small	4,236,333	346	82	233	55
	Large	6,734,169	483	72	348	52
	Very Large	1,295,307	97	75	60	46
	All	12,265,809	926	75	641	52

DISCUSSION

Standardization for driver age and gender greatly reduced the variability of driver death rates among vehicle types. Vehicle types popular with male drivers and/or young drivers, such as sports cars and pickups, had standardized death rates that were much lower than the raw rates. However, within vehicle type, size, and body style, standardization of driver death rates had less effect. With only a few exceptions, those vehicles with the highest and lowest raw driver death rates in the class also had the highest and lowest standardized rates. Vehicles similar in size and body style seem to appeal to similar types of drivers. Of course, there are driver characteristics other than age and gender that affect crash risk.

Differences in when and where vehicles are driven may lead to differences in driver death rates, even if the driver characteristics are similar. The standardization for vehicle density at the garaging location was meant to account for vehicles driven more often on rural roads, but it was an imperfect surrogate. Also, some vehicles may be driven less often at night or in poor weather conditions. The procedure described here did not address such differences in exposure.

Some vehicles are just driven less than others. Such differences in overall exposure were not accounted for directly, but may have been a factor in the adjustments for vehicle age and calendar year. National estimates of vehicle miles traveled declined in 2008 after increasing consistently for 25 years (Longthorne et al., 2010). Thus vehicles first sold in 2008 might be expected to have been driven fewer miles per year than vehicles sold earlier. Vehicles with exposure only in the later calendar years tended to have driver death rates that were increased by the standardization procedure.

In conclusion, although the standardization procedure led to a much cleaner comparison of driver death rates by vehicle make and series, other effects of driving behavior and environment still may exist. Note also that even vehicle series with millions of registration-years of exposure had rates with wide confidence intervals. So the standardized rates remain as somewhat imprecise measures of vehicle crashworthiness.

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Make/Model List Rank Ordered by Driver Death Rate Estimated for Three Population Distributions

Make/model	All ages Death rate	All ages Rank	Elderly Death rate	Elderly Rank	Nonelderly Death rate	Nonelderly Rank
Audi A6 Quattro 4d	0	1	0	1	0	1
Ford Edge 4d 4wd	0	2	0	2	0	2
Land Rover Lr3 4d	0	3	0	3	0	3
Land Rover Range Rover Sport 4d	0	4	0	4	0	4
Mercedes Benz E Class 4d 4wd	0	5	0	5	0	5
Nissan Pathfinder Armada 4d 4x4	0	6	0	6	0	6
Toyota Sienna Van 2wd	0	7	0	7	0	7
Honda Cr-V 4d 4wd	7	8	8	8	7	8
Acura Mdx 4d 4wd	11	9	11	9	11	9
Jeep Grand Cherokee 4d 4x4	11	10	11	10	11	10
Lexus Rx 400h 4d 4wd	12	11	13	12	12	11
Mercedes Benz E Class 4d 2wd	12	12	12	11	12	12
Lexus Gx 470 4d 4x4	13	13	14	13	13	13
Mercedes Benz M Class 4d 4x4	14	14	15	14	14	14
Kia Sedona Minivan Lwb	16	15	16	15	15	15
Saab 9-3 4d 2wd	16	16	16	16	16	16
Honda Odyssey Van (New)	17	17	17	17	17	17
Jeep Wrangler 4d 4x4	17	18	18	18	17	18
Honda Accord	19	19	20	19	19	19
Dodge Dakota Crew Cab Pu 4x4	20	20	21	22	20	21
Honda Pilot 4d 2wd	20	21	21	23	20	22
Honda Pilot 4d 4wd	20	22	20	20	20	23
Jeep Wrangler Swb	20	23	20	21	19	20
Acura 3.2 Tl	21	24	22	25	21	25
Acura Rl 4d 4wd	21	25	22	26	21	26
Nissan Pathfinder Armada 4d 4x2	21	26	21	24	20	24
Honda Cr-V 4d 2wd	22	27	23	28	22	27
Jeep Commander 4d 4x4	22	28	23	29	22	28
Land Rover Range Rover 4d	22	29	22	27	22	29
Nissan Frontier Cr Pu Sh 4x4	22	30	23	30	22	30
Acura Tsx 4d	23	31	24	32	23	32
Ford Fusion 4d 2wd	23	32	24	33	23	33
Toyota Tundra Pu Dbl Cab Sh 4x2	23	33	23	31	22	31
BMW X3 4d 4wd	24	34	25	34	24	34
Dodge Dakota Club 4x4	24	35	25	35	24	35
Ford Edge 4d 2wd	25	36	25	36	24	36
Hyundai Santa Fe 4d 2wd	25	37	26	37	25	37
Lexus Rx 350 4d 4wd	25	38	26	38	25	38
Dodge Nitro 4d 4wd	26	39	27	39	26	39
Toyota Tacoma Pu X Cab 4x4	26	40	27	40	26	41
Honda Ridgeline Sut 4d 4wd	27	41	28	41	26	40
Hyundai Sonata	27	42	28	42	27	42
Nissan Xterra 4d 4x4	27	43	28	43	27	43
Toyota Camry Solara Conv	27	44	28	44	27	44
Volkswagen New Jetta 4d	27	45	28	45	27	45
Audi A4 Quattro 4d 4wd (New)	28	46	29	46	28	46
Chrysler Town & Country 2wd Lwb	28	47	29	47	28	47
Pontiac Montana Sv6 Vn Lwb 2wd	28	48	29	48	28	48
Porsche Cayenne 4d 4wd	28	49	29	49	28	49
Toyota Tacoma Pu Dbl Cab Sh 4x4	28	50	29	50	28	50
Volvo Xc90 4d 4wd	28	51	29	51	28	51

Make/model	All ages Death rate	All ages Rank	Elderly Death rate	Elderly Rank	Nonelderly Death rate	Nonelderly Rank
BMW 7 series 4d	30	52	31	52	30	52
Nissan Pathfinder 4d 4x4	31	53	32	53	31	53
Lexus Es 350 4d 2wd	32	54	33	54	32	55
Mazda Cx-7 4d 2wd/4wd	32	55	33	55	32	57
Cadillac Escalade 4d 4x4	33	56	35	60	33	58
Ford Crown Victoria	33	57	34	56	32	54
Lexus Is 250 4d 2wd	33	58	34	57	32	56
Mercedes Benz Clk Class Conv	33	59	34	58	33	59
Toyota Rav4 4d 4wd	33	60	34	59	33	60
Toyota Rav4 4d 2wd	34	61	35	61	34	62
Chrysler 300 Hemi 4d 2wd	35	62	37	63	35	63
Hyundai Azera 4d	35	63	36	62	34	61
Dodge Am 1500 P/U 4x2	36	64	37	64	36	64
Toyota Camry Hybrid 4d	36	65	37	65	36	65
Cadillac Sts V6 4d 2wd/4wd	38	66	39	66	37	66
Chrysler 300 4d 2wd	38	67	39	67	38	67
Dodge Caliber 5d 2wd	39	68	40	68	39	68
Hyundai Tucson 4d 2wd	39	69	41	71	39	70
Dodge Magnum Sw 2wd	40	70	41	69	39	69
Dodge Ram 1500 Crew Pu 4x4	40	71	41	70	40	72
Ford F-150 Crew Pu 4x4	40	72	42	73	40	73
Subaru Outback 5d 4wd	40	73	42	74	40	74
Dodge Dakota Club 4x2	41	74	42	72	40	71
Kia Sportage 4wd 4d	41	75	43	76	41	76
Ford Escape 4d 2wd	42	76	43	75	41	75
Toyota Tacoma Pu X Cab 4x2	42	77	44	77	42	77
Ford F-150 Crew Pu 4x2	44	78	46	78	44	78
Dodge Avenger 4d 2wd	45	79	47	79	45	79
Subaru Forester Wagon 4wd	45	80	47	80	45	80
Hyundai Tucson 4d 4wd	46	81	48	82	46	81
Infiniti Fx35 4d 4wd	46	82	48	83	46	82
Saturn Aura 4d	46	83	48	84	46	83
Toyota Camry	46	84	47	81	46	84
Dodge Ram 2500 Crew Pu 4x4	47	85	49	85	47	85
Mercedes Benz Slk Class Conv	47	86	49	86	47	86
Toyota Avalon	47	87	49	87	47	87
Dodge Ram 1500 Crew Pu 4x2	49	88	50	88	48	88
Chevrolet Uplander Van Lwb 2wd	51	89	52	89	50	89
Dodge Charger 4d 2wd	51	90	53	90	51	90
Toyota Tacoma Pu Dbl Cab Sh 4x2	51	91	53	92	51	92
Mazda 3 4d	52	92	53	91	51	91
Toyota Prius 4d	52	93	54	93	52	93
Honda Civic Hybrid 4d	53	94	55	94	53	94
Lincoln Town Car	54	95	56	96	54	96
Toyota Matrix Sw 2wd	54	96	55	95	53	95
Dodge Dakota Crew Cab Pu 4x2	55	97	57	97	55	97
Ford F-150 Super Pu 4x4 (New)	55	98	57	98	55	98
Honda Civic	55	99	57	99	55	99
Chevrolet Colorado Pu 4x2	57	100	59	100	57	101
Mercury Grand Marquis	57	101	59	101	57	102
Chevrolet Aveo 5d	58	102	60	102	57	100
Kia Sportage 2wd 4d	58	103	60	103	58	104
Nissan Quest Wagon	58	104	60	104	57	103

Make/model	All ages Death rate	All ages Rank	Elderly Death rate	Elderly Rank	Nonelderly Death rate	Nonelderly Rank
Dodge Ram 3500 Crew Pu 4x4	59	105	61	105	59	107
Ford F-150 Super Pu 4x2 (New)	59	106	61	106	59	108
Pontiac Grand Prix	59	107	61	107	58	105
Chevrolet Colorado Cr Pu 4x2	60	108	62	108	59	106
Ford Focus	60	109	62	109	60	109
Mazda 6 4d 2wd	60	110	63	111	60	110
Nissan Pathfinder 4d 4x2	60	111	62	110	60	111
Kia Optima 4d (New)	61	112	64	114	61	112
Pontiac Vibe 5d 2wd	61	113	63	112	61	113
Toyota Tacoma Pu 4x2	61	114	63	113	61	115
Dodge Charger Hemi 4d 2wd	62	115	65	117	62	117
Ford F-150 Pickup 4x4 (New)	62	116	65	119	62	118
Subaru B9 Tribeca 4d 4wd	62	117	64	115	61	114
Suzuki Forenza 4d	62	118	65	122	62	121
BMW 3 series 4d	63	119	65	116	62	116
Cadillac Srx 4d 2wd/4wd	63	120	66	123	63	122
Dodge Grand Caravan	63	121	65	118	63	123
Honda Fit Sw	63	122	65	120	62	119
Pontiac Soltice Conv	63	123	65	121	62	120
Honda Civic Coupe	64	124	66	124	64	124
Chevrolet Impala	65	125	68	128	65	125
Ford F-150 Pickup 4x2 (New)	65	126	68	129	65	126
Nissan Sentra	65	127	67	125	65	127
Pontiac G6 4d	65	128	67	126	65	128
Toyota Yaris 4d	65	129	67	127	65	129
Dodge Magnum Hemi Sw 2wd	66	130	69	131	66	130
Toyota Corolla	66	131	69	133	66	132
Chevrolet Malibu 4d (New)	67	132	69	130	67	133
Mazda 5 Sw	67	133	69	132	66	131
Chevrolet Corvette	69	134	71	134	68	134
Hyundai Accent 4d	70	135	72	135	70	136
Nissan Altima	70	136	72	136	69	135
Nissan Frontier Pu King C 4x2	71	137	74	138	71	138
Lincoln Zephyr/Mkz 4d 2wd	72	138	74	137	71	137
Nissan Xterra 4d 4x2	72	139	75	140	72	139
Chevrolet Colorado Cr Pu 4x4	73	140	75	139	73	140
Chevrolet Hhr Sw	73	141	76	141	73	141
Ford Ranger Super Cab	75	142	77	142	74	142
Buick Lacrosse 4d	76	143	79	143	76	143
Chrysler Sebring 4d 2wd	76	144	79	144	76	144
Buick Lucerne 4d	77	145	80	145	77	145
Nissan Frontier Cr Pu Sh 4x2	77	146	80	146	77	146
Ford Ranger Super Cab 4x4	79	147	82	147	79	147
Toyota Yaris 3d	79	148	82	148	79	148
Hyundai Elantra 4d	80	149	83	149	80	149
Ford Ranger	81	150	84	150	81	150
Mitsubishi Eclipse 2wd	82	151	85	152	82	152
Mitsubishi Galant	82	152	85	153	82	153
Nissan Maxima	82	153	85	154	82	154
Mazda Mx-5/Miata Conv.	83	154	85	151	82	151
Subaru Legacy 4wd	83	155	86	155	82	155
Kia Spectra 4d (New)	87	156	90	156	87	156
Kia Rio 4d	89	157	92	157	88	157

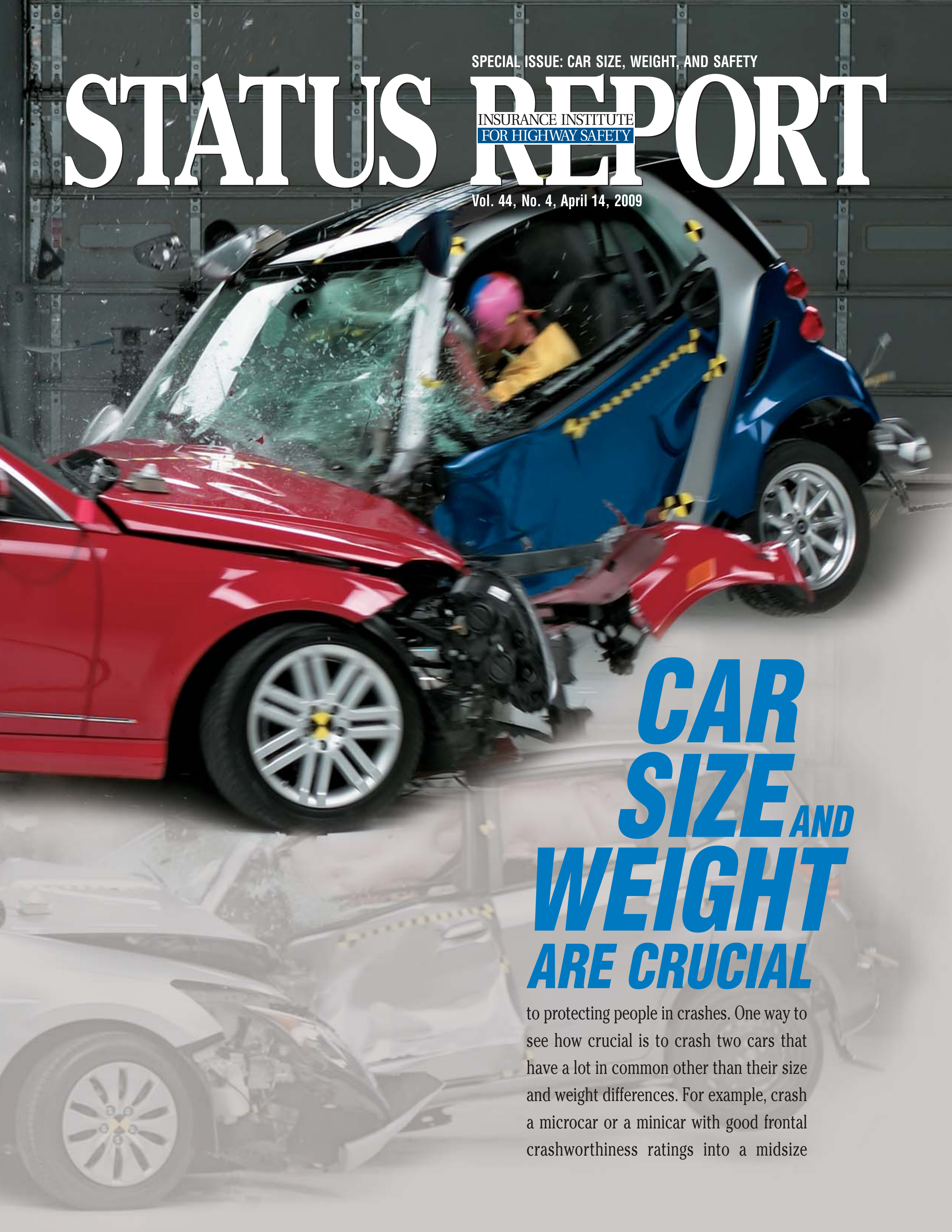
Make/model	All ages		Elderly		Nonelderly	
	Death rate	Rank	Death rate	Rank	Death rate	Rank
Nissan Titan Cr Pu Ln 4x4	92	158	95	158	92	159
Chevrolet Colorado Pu Ext 4x2	93	159	96	159	92	158
Hyundai Tiburon	96	160	99	160	95	160
Nissan Versa 5d	96	161	99	161	95	161
Chevrolet Malibu	99	162	102	162	99	162
Kia Spectra5 Sw	102	163	106	163	102	163
Nissan Titan Pu King Cab Ln 4x2	111	164	115	164	111	164
Chevrolet Cobalt 4d	117	165	121	165	117	165
Chevrolet Aveo 4d	119	166	123	166	119	166
Nissan Titan Cr Pu Ln 4x2	126	167	130	167	125	167
Nissan 350z 2d	143	168	148	168	142	168

SPECIAL ISSUE: CAR SIZE, WEIGHT, AND SAFETY

STATUS REPORT

INSURANCE INSTITUTE FOR HIGHWAY SAFETY

Vol. 44, No. 4, April 14, 2009



CAR SIZE AND WEIGHT ARE CRUCIAL

to protecting people in crashes. One way to see how crucial is to crash two cars that have a lot in common other than their size and weight differences. For example, crash a microcar or a minicar with good frontal crashworthiness ratings into a midsize model that earns the same ratings and was manufactured by the same automaker. What happens in the front-to-front collision says a lot about the safety consequences of vehicle size and weight.

The Institute recently crashed a Honda Fit into a Honda Accord, a Smart Fortwo into a Mercedes C class, and a Toyota Yaris into a Toyota Camry (these automakers have micro and minicars rated good for frontal crashworthiness, based on the Institute's 40 mph offset test into a deformable barrier). The car-to-car tests aren't about whether one minicar is more crashworthy than another. Such information is available from the comparative ratings based on the barrier tests.

The new tests of paired cars are about the physics of crashes. Reflecting Newton's laws of motion, the results confirm the lesson that bigger, heavier cars are safer (see facing page). Some minicars earn higher crashworthiness ratings than others, but as a group these cars generally can't protect people in crashes as well as bigger, heavier models.

"There are good reasons people buy minicars," says David Zuby, the Institute's senior vice president for vehicle research. "For starters, they're affordable, and they use less gas. But the safety trade-offs are clear from the results of our new tests."

ratings with those of midsize cars — or with the ratings of cars in any other class, for that matter, because of the effects of vehicle size and weight."

The Institute didn't choose SUVs or pickups, or even large cars, to pair with the minis in the new crash tests. The choice of midsize cars reveals how much influence some extra size and weight can have on crash outcomes.

Honda Accord versus Fit: The Accord came through the frontal test without significant downgrades. Measured intrusion at 8 locations in the occupant compartment was in the good range, and all *(continues on p.6)*

MIDSIZE HONDA ACCORD: GOOD

MINI HONDA FIT: POOR

The midsize Honda Accord's occupant compartment remained intact during this 40 mph frontal collision with the Fit, a minicar. In contrast, there was a lot of intrusion into the Fit's occupant compartment, which compromised the survival space around the driver dummy. Measures recorded on the dummy indicate that the risk of serious injury would be high in a real-world collision similar to this test.

As in the barrier tests the Institute conducts for consumer information, each of the cars in the frontal offset crashes involving pairs of 2009 models from Daimler, Honda, and Toyota were going 40 mph. Researchers rated each car's performance from good to poor based on measured intrusion into the occupant compartment, forces recorded on the Hybrid III driver dummy, and movement of the dummy during the impact. The main difference between these tests and those conducted for consumer information is the car-to-car versus car-into-barrier configuration.

"Sometimes the whole issue of size and weight gets obscured in the quest to buy a car with good safety ratings," Zuby says. "The ratings are important, but frontal ones can be used only to compare cars that are similar in size and weight. You can compare the ratings of the Fit and Yaris, for example, and find they both earn good overall scores. But you can't compare these cars'

SIZE

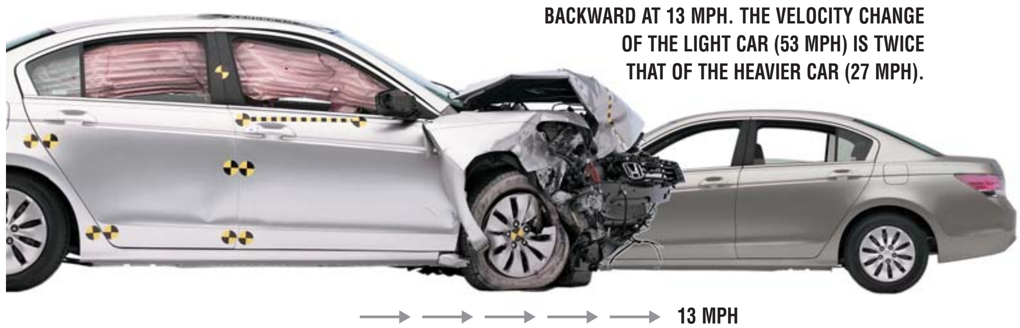
When a car crashes into a solid barrier, the outcome depends in part on the size of the front end. If one car's front end is long enough to crush twice as much as another car's in a barrier crash at the same speed, its restrained occupants will experience half as much force as the people in the smaller car because it takes them twice as long to stop.

WEIGHT

When two cars going the same speed crash front to front, the outcome depends in part on the cars' relative weights. The heavier car will push the lighter car backward during the impact, which means the velocity change of the heavier car will be much less than that of the lighter car. If the lighter car weighs half as much as the heavier car, the forces on its occupants will be twice as great.

40 MPH 40 MPH

ONE OF THESE CARS WEIGHS TWICE AS MUCH AS THE OTHER. WHEN THEY COLLIDE, EACH GOING 40 MPH, THE HEAVY CAR PUSHES THE LIGHT ONE BACKWARD AT 13 MPH. THE VELOCITY CHANGE OF THE LIGHT CAR (53 MPH) IS TWICE THAT OF THE HEAVIER CAR (27 MPH).



PHYSICS
DICTATE CRASH OUTCOMES

The poor performance of all three micro and minicars in frontal impacts with midsize cars (see p. 1) isn't surprising. It reflects the laws of the physical universe, specifically principles related to force and distance.

Although the physics of frontal car crashes usually are described in terms of what happens to the vehicles, injuries depend on the forces that act on the occupants — and these forces are affected by two key physical factors. One is the weight of a crashing vehicle, which determines how much its velocity will change during impact. The greater the change in velocity, the greater the forces on the people inside and the higher the risk of injury.

The second physical factor affecting injury likelihood is vehicle size, specifically the distance from the front of a vehicle to its occupant compartment. The longer this is, the lower the forces on the occupants, provided vehicle designers take advantage of the extra length.

These two factors, size and weight, have separate effects, but they're highly correlated. In theory the lighter weights of smaller cars could be offset by increasing the sizes of their front ends, keeping weight down by using materials like aluminum, plastic, or titanium. But this typically doesn't occur because such materials cost so much.

Characteristics including the stiffness of a vehicle's front end also influence the outcomes of crashes. However, size and weight are the basic influences.

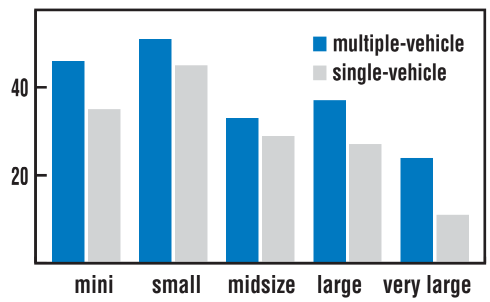
Size and weight affect injury likelihood in all kinds of crashes. In a collision involving two vehicles that differ in size and weight, the people in the smaller, lighter vehicle will be at a disadvantage. The bigger, heavier vehicle will push the smaller, lighter one backward during the impact. This means less force on the occupants of the heavier vehicle and more on the people in the lighter vehicle. Greater force means greater risk, so the people in the smaller, lighter vehicle are more likely to be injured.

Crash statistics confirm this. The death rate in 1-3-year-old minicars involved in multiple-vehicle crashes during 2007 was almost twice as high as the rate in very large cars.

"Some minicars are definitely more crashworthy than others," says David Zuby, Institute senior vice president for vehicle research. "So it pays to compare their safety ratings. But as a group minicars do a comparatively poor job of protecting people in crashes, simply because they're smaller and lighter. In collisions with bigger vehicles, the forces acting on the smaller one are higher, and there's less distance from the front of a small car to the occupant compartment to 'ride down' the impact. These and other factors increase injury likelihood."

Fatality risk in minicars is high in single- as well as multiple-vehicle crashes. The death rate per million 1-3-year-old minis in single-vehicle crashes during 2007 was 35 compared with 11 per million for very large cars. Even in midsize cars, the death rate in single-vehicle crashes was 17 percent lower than in minicars.

DRIVER DEATHS PER MILLION 1-3-YEAR-OLD CARS REGISTERED, 2007



Driver death rates decline fairly consistently as vehicle size increases. This doesn't mean drivers have to choose the heaviest vehicles on the road to reap safety benefits. New crash tests demonstrate that midsize cars afford a lot more protection than minicars from the same manufacturer (see p.1). The overall driver death rate in midsize cars is 23 percent lower than in minicars.

"The lower death rates in single-vehicle crashes of larger cars are because many objects that vehicles hit aren't solid, and big, heavy vehicles have a better chance of moving or deforming the objects they strike. This dissipates some of the energy of the impact," Zuby explains.

Insurance claims filed for injuries under personal injury protection coverage also are higher for minis than for midsize cars. Overall losses, which reflect both claim frequency and severity, are 193 for 4-door minis versus 147 for 4-door midsize cars (100 is the average for all cars).

FUEL ECONOMY AND SAFETY CAN BE ACHIEVED AT THE SAME TIME

One reason people buy smaller cars is to conserve fuel. The price of gasoline skyrocketed last year, and there's no telling what the price at the pump might be next week. Meanwhile, the gears are turning to hike federal fuel economy requirements to address environmental concerns.

The conflict is that smaller vehicles use less fuel but do a relatively poor job of protecting their occupants in crashes (see p.3). Thus, fuel conservation policies have tended to conflict with motor vehicle safety policies. But they don't have to.

"The key going forward will be for consumers and policymakers to recognize the potential conflict and make choices that serve safety as well as fuel economy. The first step is to look at the consequences of past policies and choose future ones that serve both goals instead of setting the two at odds," says Institute president Adrian Lund.

Fuel economy at the expense of safety: More than 30 years have elapsed since Congress enacted the Energy Policy and Conservation Act of 1975, which required automakers to build cars that use less fuel. The result during the first 15 or so years of this law was to improve the overall fuel economy of the US car fleet by about 75 percent.

The main way automakers achieved this was by reducing car weights. For example, Chrysler stopped making big cars altogether. By 1985 cars were an average of 500 pounds lighter than they would have been without the federal requirements.

The downside was to increase fatality risk in crashes. Multiple studies document this, including Institute research comparing deaths in Ford and General Motors cars before and after they were downsized during 1977-86 (see *Status Report*, Sept. 8, 1990; on the web at iihs.org). The finding was a 23 percent increase in deaths per 10,000 registered cars.

Subsequent research documents the continuing price in terms of lives. For example, the National Research Council concluded in 2002 that 1,300 to 2,600 additional crash deaths occurred in 1993 because of vehicle weight reductions to comply with federal standards (see *Status Report*, April 6, 2002; on the web at iihs.org).

A problem with the current structure of fuel economy standards for cars is that the target of 27.5 miles per gallon is applied to an automaker's whole fleet, no matter the mix of cars an individual automaker sells. This encourages manufacturers to sell more smaller, lighter cars to offset the fuel consumed by their bigger, heavier models. Sometimes automakers even sell the smaller — and less safe — cars at a loss to ensure compliance with fleetwide requirements.

"What's needed instead is to restructure fuel economy standards for cars the same as the government has done for other kinds of passenger vehicles," Lund advises.

In 2006 the National Highway Traffic Safety Administration adopted a fuel economy system for SUVs, pickup trucks, and vans that mandates lower fuel consumption as vehicles get smaller and lighter, thus removing the incentive for automakers to downsize their lightest vehicles to comply (see *Status Report*, April 22, 2006; on the web at iihs.org). The result is to force the auto manufacturers to use vehicle and engine technologies to improve fuel economy. By 2011 all SUVs, pickup trucks, and vans will have to comply.

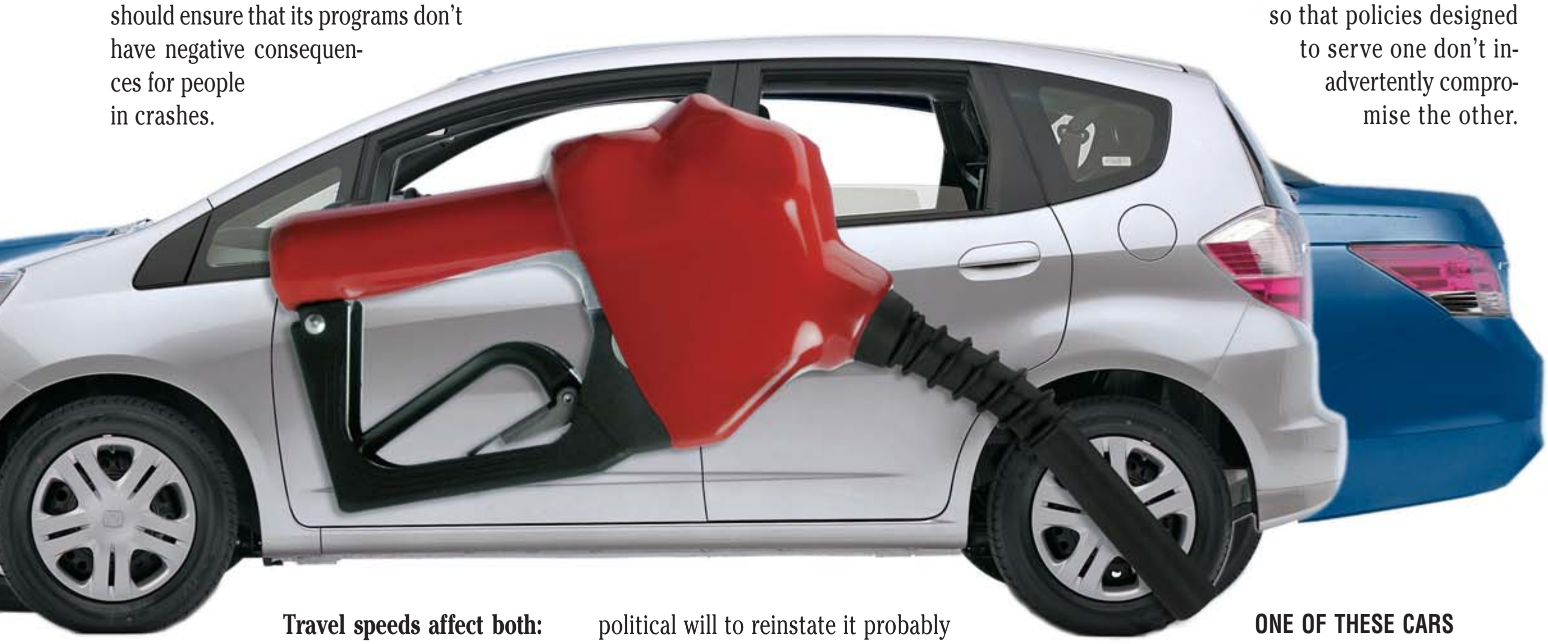
However, the same plan doesn't yet apply to cars, which still are subject to a fleetwide fuel economy standard. The Bush administration proposed a size-based standard for cars, like the other passenger vehicles, but left it to the current administration to carry through. Now the Obama administration says it's boosting the fuel economy standard for cars, beginning with 2011 models, and this will be accomplished under a size-based system.

On a separate front, California officials are trying to improve air quality by setting more stringent emissions limits than the federal government requires. The state's carbon emissions limit is structured so that vehicles of all sizes would be held to a single average, which conflicts with occupant safety goals.

A US Court of Appeals is considering whether federal fuel economy standards preempt California's emissions standard, and the Institute has filed a brief opposing the state. The problem, the Institute told the court, is that "the easiest, cheapest, and quickest way for automakers to meet a significant reduction in an overall fleet average of carbon emissions is to downsize to reduce fuel consumption," which costs lives in crashes. Lund adds that if a state does succeed in preempting federal fuel economy or emissions standards, it should ensure that its programs don't have negative consequences for people in crashes.

"Drivers don't have to wait for the government to act. They can simply choose to drive slower or choose to buy cars that aren't the smallest ones available but still earn kudos for fuel economy," Lund points out. For example, the Honda Civic Hybrid and Toyota Prius, also a hybrid, get better gas mileage than the Smart Fortwo. Even the Volkswagen Jetta with a diesel engine does almost as well.

There are other ways, both individual and societal, to serve fuel economy and safety simultaneously. For example, roundabouts serve both at intersections (see *Status Report*, June 9, 2008; on the web at iihs.org). The key going forward is to keep the potential conflict between safety and fuel conservation in mind so that policies designed to serve one don't inadvertently compromise the other.



ONE OF THESE CARS IS BIGGER THAN THE OTHER, but this doesn't mean their fuel economy necessarily varies by as much as their size difference suggests. Some models that are classified as small or even midsize get as many miles to the gallon, or almost as many, as cars classified as minis. The safety plus is that death rates are lower in the larger cars (see chart, facing page). So driving a relatively big car that's also economical on fuel is one way to serve both safety and fuel conservation. Another way is for state and local officials to set and enforce lower speed limits. Going slower uses less gas to cover the same distance, and it reduces both crash likelihood and the severity of the crashes that occur.

Travel speeds affect both: Setting higher federal fuel economy targets isn't the only way to conserve fuel. How about lowering speed limits? Going slower uses less fuel to cover the same distance. There's a big safety bonus, too, that's evident in the experience of the 1970-80s (see *Status Report*, Nov. 22, 2003; on the web at iihs.org).

Goaded by federal lawmakers, every state adopted 55 mph speed limits on interstate highways in 1974. The impetus was the 1973 oil embargo, and the idea was to conserve fuel by slowing down motorists until automakers could build cars that use less gas. The immediate effect was to save thousands of barrels of fuel per day — and thousands of lives. In fact, highway deaths declined about 20 percent the first year, from 55,511 in 1973 to 46,402 in 1974. The National Research Council estimated that most of the reduction was due to the lower speed limit, and the rest was because of reduced travel. By 1983 the national maximum 55 mph limit still was saving 2,000 to 4,000 lives annually.

With the oil crisis a thing of the past by the middle of the 1980s, Congress lifted pressure on states to retain 55. Speed limits began going up in 1987, and so did occupant deaths in crashes. Fifteen to 30 percent increases were documented.

"The national maximum speed limit was adopted to save fuel, but it turned out to be one of the most dramatic safety successes in motor vehicle history," Lund points out. "The political will to reinstate it probably is lacking, but if policymakers want a win-win approach, this is it. It saves fuel and lives at the same time."

More good choices going forward: Another way to serve both safety and fuel economy would be to curtail the horsepower race. Only a few cars used to be capable of 300 horsepower, but now many cars match this. Average horsepower is 70 percent higher than it was in the mid-1980s, and some of today's high-performance cars surpass the power of even the muscle cars of the 1960-70s. If an automaker were forced to use engine-enhancing technology to improve fuel efficiency instead of to boost performance, safety would improve, too, because vehicles with souped-up horsepower are associated with increased injury risk (see *Status Report*, April 22, 2006; on the web at iihs.org).

SMART INTO C CLASS: POOR

The space around the driver dummy in the Smart Fortwo collapsed during a 40 mph frontal offset crash test into a Mercedes C class. Multiple injuries, including to the head, would be likely for a real-world driver of a Smart in a similar collision. This outcome contrasts with the Smart's performance in the Institute's frontal offset barrier test that's run at the same 40 mph speed. In the barrier test, the Smart earned a good rating overall, while it rates poor in the collision with the C class.

(continued from p. 2) except one measure of injury likelihood recorded on the driver dummy's head, neck, chest, and both legs also were good. Only the value recorded on the left foot veered from good into the acceptable range (values are based on thresholds indicating injury likelihood).

In contrast, a number of injury measures on the dummy in the Fit were less than good. Forces on the left lower leg and right upper leg were in the marginal range, while the measure on the right tibia was poor. These indicate a high risk of leg injury in a real-world crash of similar severity. In addition, the dummy's head struck the steering wheel through the airbag.

Intrusion into the Fit's occupant compartment was extensive at 6 of 8 measured locations, warranting a marginal rating for the structure. Overall, the Fit is rated poor in this front-to-front test, despite its good crashworthiness rating based on the Institute's offset barrier test. The Accord earns good ratings for performance in both tests.

Mercedes C class versus Smart: After striking the front of the C class, the Smart went airborne and turned around 450 degrees. This contributed to excessive movement of the dummy during rebound — a dramatic indication of the Smart's poor performance but not the only one. There was extensive intrusion into the space around the dummy from head to feet. The instrument panel moved up and toward the dummy. The steering wheel was displaced upward. Multiple measures of injury likelihood, including those on the dummy's head, were poor, as were measures on both legs.

"The Smart is the smallest car we tested, so it's not surprising that its performance looked worse than the Fit's. Still both fall into the poor category, and it's hard to distinguish between poor and poorer," Zuby says. "In both the Smart and Fit, occupants would be subject to high injury risk in crashes with heavier cars."

In contrast, the C class held up well, with little to no intrusion into the occupant compartment. Nearly all measures of injury likelihood were in the good range, though the measure on the head was downgraded to acceptable because the dummy's head struck the B-pillar hard. Still, this was a good performance overall.

Toyota Camry versus Yaris: There was far more intrusion into the compartment of the Yaris than the Camry. The minicar's door was largely torn away. The driver seats in both cars tipped forward, but only in the Yaris did the steering wheel move excessively.

Similar contrasts characterize the measures of injury likelihood recorded on the dummies. The heads of both struck the cars' steering wheels through the airbags, but only the head injury measure on the dummy in the Yaris rated poor. There was extensive force on the neck and right leg plus a deep gash at the right knee of the dummy in the minicar.

Like the Smart and Fit, the Yaris earns an overall rating of poor in the car-to-car test. The Camry is acceptable, which doesn't match its good rating in the Institute's 40 mph barrier test, despite the similar speed and offset configuration (see facing page). Still the midsize car fared much better than the mini.

Laws of physics prevail: Some proponents of mini and small cars claim they're as safe as bigger, heavier cars. But the claims don't hold up. For example, there's a claim

TOYOTA CAMRY: ACCEPTABLE

TOYOTA YARIS: POOR

that the addition of safety features to the smallest cars in recent years reduces injury risk, and this is true as far as it goes. Airbags, advanced belts, electronic stability control, and other features are helping. The same features have been added to cars of all sizes, though, so the smallest cars still don't match bigger ones in terms of occupant protection.

Would hazards be reduced if all passenger vehicles were as small as the smallest ones? Yes, this would help in vehicle-to-vehicle crashes, but occupants of smaller cars are at increased risk in all kinds of crashes, not just collisions with heavier passenger vehicles. Almost half of all crash deaths in minicars occur in single-vehicle crashes, and these deaths wouldn't be reduced if all cars became smaller and lighter. In fact, the result would be to afford less occupant protection fleetwide in single-vehicle crashes.

Yet another claim is that minicars are easier to maneuver than big cars, so their drivers can avoid crashes in the first place. Insurance claims experience says otherwise. The frequency of claims filed for crash damage is higher for mini 4-door cars than for midsize ones.

There's no getting around the laws of the physical universe. The Institute's new crash tests confirm this — again.

YARIS IN BARRIER TEST: GOOD

YARIS INTO CAMRY: POOR

BARRIER TEST VS. CAR TO CAR: **Car-to-car crash tests often are more demanding than the front-into-barrier tests the Institute conducts for consumer information (go to iihs.org/ratings). A basic reason is that the barrier test mimics a frontal crash between identical cars — a Toyota Yaris into a Yaris, for example. Because the midsize Toyota Camry weighs more than the Yaris, it inflicted more force on the minicar, compared with a barrier test.**

Drivers of minicars aren't likely to confine their crash experience to other minis. As the smallest cars on the road, they're far more likely to collide with bigger, heavier vehicles. This is when the safety consequences resemble those in the crash with the Camry — or worse.

Another consideration is that, while the Institute's barrier approximates the front of another car, it can't be designed to mimic the various fronts of hundreds of different cars. This helps explain why the Camry performed worse in the test with the Yaris than in the barrier impact that approximated a crash with another Camry — something about the Yaris' front end was more difficult to manage.

STATUS REPORT

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SPECIAL ISSUE

CAR SIZE & WEIGHT, AGAIN: The new series of crashes involving mini and midsize cars isn't the Institute's first foray into testing to demonstrate vehicle size and weight effects in frontal crashes. The first time was in 1971, and the test series featured an AMC Gremlin (above left) then known as an economy car, crashing into AMC's large Ambassador model.

Survey of Volvo Dealers about Effects of Small Overlap Frontal Crash Test Results on Business

October 2012

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Abstract

Objective: On August 14, 2012, announcement of the Volvo S60 model's good performance in the Insurance Institute for Highway Safety's new small overlap frontal crash test was announced. A survey of Volvo dealerships in the United States was conducted to determine if dealers had experienced increased interest in the Volvo S60 from consumers.

Methods: Between August 28 and September 6, 2012, managers at 206 of the 314 U.S. Volvo dealerships were interviewed.

Results: Following the August 14 release of the small overlap frontal crash test results, 49 percent of dealers reported an increase in the number of customers calling or visiting the dealership because they were interested in purchasing a Volvo S60. Fifty-five percent of dealers reported an increase in the number of customers naming the safety performance of Volvo as a reason they were considering purchasing a Volvo, and 68 percent reported that any customer had mentioned the performance of Volvo in recent crash tests as a reason they were considering Volvo. The dealers that reported sales figures experienced an 18 percent increase in sales of all Volvo models from the week before the announcement to the week after and a 41 percent increase in Volvo S60 sales.

Conclusion: The Volvo S60's good performance in the Insurance Institute for Highway Safety's small overlap frontal crash test appears to have positively influenced consumer opinion soon after the results were released. As with other types of crashworthiness ratings, it is hoped that the increased consumer interest in vehicles that perform well in the small overlap frontal crash test will encourage all automakers to improve vehicle design.

Introduction

The Insurance Institute for Highway Safety (IIHS) has rated vehicles based on performance in a moderate overlap frontal crash test since 1995. In this test, 40 percent of a vehicle's front end is crashed into a deformable barrier just more than 2 feet tall at 40 mi/h. A good rating in the moderate overlap test is associated with 74 percent lower odds of a driver fatality in a head-on collision as compared with a poor rating (Farmer, 2005). Since the test was introduced, advances in vehicle design have led to marked improvements in frontal crashworthiness ratings (Lund and Nolan, 2003).

In 2012, IIHS introduced a new small overlap frontal crash test. The test is designed to replicate the vehicle damage and motion that occurs in a head-on collision where a small portion of the vehicle's front end contacts the struck object, such as when the front corner of a vehicle collides with another vehicle, or when a vehicle strikes a tree or utility pole. In the test, 25 percent of a vehicle's front end on the driver's side is crashed into a 5-foot-tall rigid barrier at 40 mi/h. Compared with the moderate overlap frontal crash test, the small overlap test puts higher stress on the outer part of the vehicle's frame, which typically is less protected by the vehicle's crush-zone structures. IIHS was the first non-automaker in the United States and Europe to use this test to provide consumer information on this aspect of vehicle occupant protection.

On August 14, 2012, IIHS released results of the performance of 11 midsize luxury and near-luxury cars in the small overlap frontal crash test. Only 2 of the 11 vehicles tested received the top rating of good. One of these, the Volvo S60, performed the best structurally. Results of this inaugural crash test received extensive media coverage, which reached an estimated audience of 204 million viewers in the U.S. through 2,550 broadcasts.

Surveys of customers and car dealerships have shown that new car purchase decisions are influenced by crashworthiness ratings (Ferguson, 1992; IIHS, 1990; McCartt and Wells, 2010), but it is unknown to what extent crash test results translate directly into increased consumer interest in top-performing vehicles. To gather information on consumer interest in the Volvo S60 shortly after release of the small overlap frontal crash test results, IIHS conducted a telephone survey of U.S. Volvo dealerships during the 2 weeks following the release.

Method

OpinionAmerica Group surveyed the 314 U.S. Volvo dealerships listed on Volvo's (2012) website as of August 21, 2012 between August 28 and September 6, 2012. The interviewer asked to speak with the dealership's sales manager or with the general manager or owner if the sales manager was unavailable. Six to eight attempts were made to contact each dealership. Interviews were completed with 206 dealerships (67 percent). Of the 108 dealerships that did not respond, 102 reported that they did not have time to complete the survey when called and two refused to participate. Additionally, four phone numbers that were called were non-working. The survey took approximately 5 minutes to complete and consisted of nine questions.

Results

As summarized in Table 1, 67 percent of those interviewed were sales managers, 15 percent were general managers or owners, and 15 percent were sales representatives. Ninety-four percent of respondents reported that they knew about the Volvo S60's performance in the small overlap frontal crash test prior to the interview.

Table 1
Job title of dealer representative that completed survey

	Percent (N=206)
Sales manager	67
General manager or owner	15
Sales representative	15
Business manager	1
Assistant sales manager	<1
Internet manager	<1
Master sales consultant	<1
New car manager	<1
Volvo manager	<1

Dealer representatives were asked if there was a change in the number of people who had contacted or visited their dealerships since the August 14 release because they were interested in purchasing a Volvo S60, and if more or fewer customers who had contacted the dealership since the release had mentioned the safety performance of Volvo as a reason for considering a Volvo (Table 2). Nearly half of dealers reported an increase in calls and visits from customers interested in purchasing a Volvo S60, and 55 percent reported that more customers had mentioned the safety performance of Volvo as a reason for considering a Volvo. Dealer representatives also were asked how many people contacted or visited the dealership because they are interested in purchasing a Volvo S60 in a typical week and in the weeks since the August 14 release. The 202 dealers that provided this information for both a typical week and since the release reported an average of 12.9 contacts and visits per week before the release and 16.5 since the release.

Table 2
Change in interest in Volvo S60 and mention of Volvo's safety since release of IIHS small overlap frontal crash test results

		Percent (N=206)
Number of customers considering purchasing a Volvo S60 contacting or visiting dealership	More	49
	Same	50
	Less	1
Number of customers who mentioned safety performance as reason for considering Volvo	More	55
	Same	44
	Less	<1
	Don't know/Refused	<1
		(N=202)
Average number of contacts or visits to dealerships per week by customers considering Volvo S60	Typical week	12.9
	Since announcement	16.5

Sixty-eight percent of dealers reported that since the release any customer had mentioned Volvo's performance in recent crash tests as a reason they are considering a Volvo (Table 3). Twenty-seven percent of dealers said that at least half of their customers who were considering buying a Volvo mentioned Volvo's recent crash test performance.

Table 3
Proportion of customers that mentioned Volvo's performance in recent crash tests since release of IIHS small overlap frontal crash test results

	Percent (N=206)
Three-quarters or more	11
Between half and three-quarters	16
Between one-quarter and half	23
Less than one quarter	18
None	30
Don't know/refused	2

Finally, respondents were asked about the dealership's sales of the Volvo S60 and of all Volvo models for four weeks in 2012: July 29 to August 4, August 5 to 11 (the week before the release), August 12 to 18 (the week of the release), and August 19 to 25 (the week after the release). Sales numbers for all Volvo models and for the Volvo S60 model for the week before the release and the week after the release were provided by 158 dealers. These dealers reported an increase of 18 percent in total sales for all Volvos (from a total of 809 the week before to a total of 956 the week after) and an increase of 41 percent in total sales for the Volvo S60 model (from a total of 267 the week before to a total of 376 the week after) (Table 4).

Table 5 presents the sales figures for all 4 weeks, based on the 156 dealers who provided information for all 4 weeks.

Table 4
Total sales of S60 and of all Volvo models the week before and after release of IIHS small overlap frontal crash test results

		(N=158)
	All Volvo models	Volvo S60 model
Week before	809	267
Week after	956	376

Table 5
Total sales of S60 and of all Volvo models July 29 to August 25

		(N=156)
	All Volvo models	Volvo S60 model
July 29-August 4	1,046	317
August 5-11 (week before release)	798	261
August 12-18 (week of release)	822	329
August 19-25 (week after release)	944	369

Discussion

This study collected information from about two-thirds of U.S. Volvo dealers on interest from customers and on sales immediately after the August 14, 2012 announcement of the Volvo S60's good performance in the IIHS new small overlap frontal crash test. After the release, more customers were interested in the S60 and mentioned Volvo's safety, and many customers mentioned Volvo's performance in crash tests. The increase in interest in the Volvo S60 model appears to have translated into an increase in sales. The sales figures cover a short span of time, and sales can vary from week to week, but the percentage increase in Volvo S60 sales surpassed the percentage increase in overall Volvo sales.

Previous surveys have demonstrated that some consumers factor vehicle safety ratings into their opinions of vehicles and purchase choices (e.g., McCartt and Wells, 2010), and the current results suggest that some consumers seem to be factoring performance in IIHS's new small overlap frontal crash test into their purchasing decisions. In turn, this may encourage vehicle manufacturers to improve vehicle design so that more models receive a good rating, as has happened in response to IIHS's moderate overlap frontal and side impact crash tests (Lund and Nolan, 2003; Teoh and Lund, 2011). In a study of vehicles with good ratings in IIHS's moderate overlap frontal crash test, small overlap crashes accounted for nearly a quarter of the frontal crashes involving serious or fatal injury to front seat occupants (Brumbelow and Zuby, 2009). Thus, improved crashworthiness in small overlap crashes has the potential to save many lives.

Acknowledgment

This research was supported by the Insurance Institute for Highway Safety.

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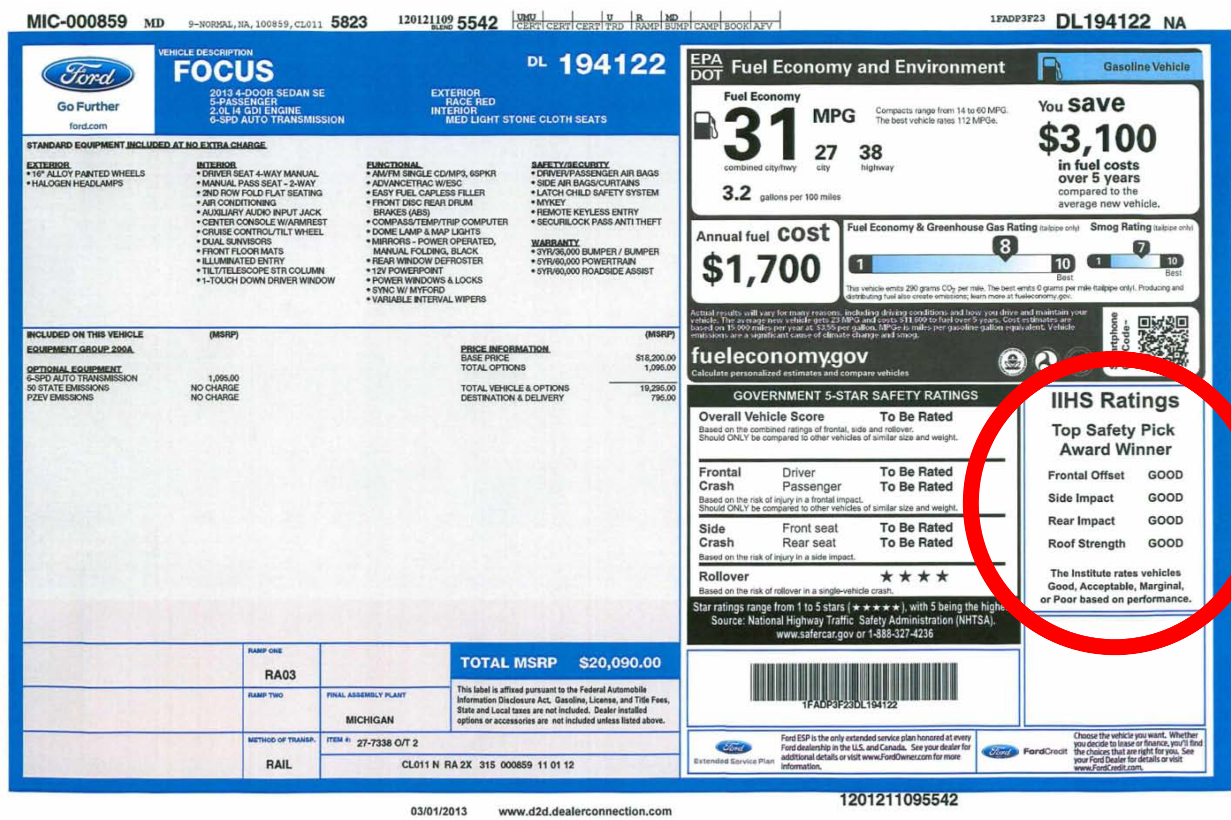
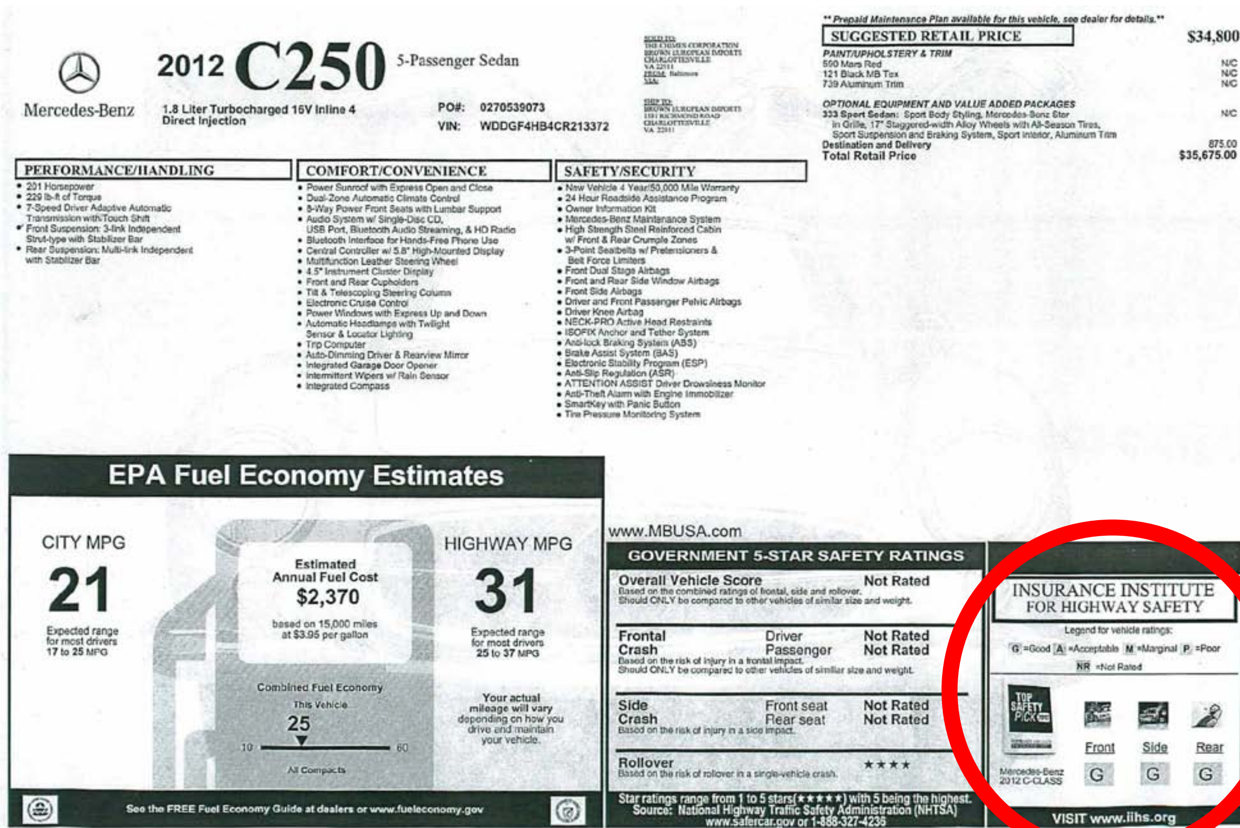
Examples of Monroney Labels with IIHS Ratings and *Top Safety Pick*





2012 DODGE AVENGER SE

THIS VEHICLE IS MANUFACTURED TO MEET SPECIFIC UNITED STATES REQUIREMENTS. THIS VEHICLE IS NOT MANUFACTURED FOR SALE OR REGISTRATION OUTSIDE OF THE UNITED STATES.

MANUFACTURER'S SUGGESTED RETAIL PRICE OF THIS MODEL INCLUDING DEALER PREPARATION

Base Price: $18,995

DODGE AVENGER SE
Exterior Color: Tungsten Metallic Clear Coat Exterior Paint
Interior Color: Black Interior Color
Interior: Premium Cloth Bucket Seats
Engine: 2.4-Liter I4 PZEV 16-Valve Dual VVT Engine
Transmission: 4-Speed Automatic VLP Transmission

STANDARD EQUIPMENT (UNLESS REPLACED BY OPTIONAL EQUIPMENT)

FUNCTIONAL/SAFETY FEATURES
Advanced Multistage Front Airbags
Supplemental Front Seat-Mounted Side Airbags
Supplemental Side-Curtain Front and Rear Airbags
Front Seat Active Head Restraints
Electronic Stability Control
Antilock 4-Wheel Disc Brakes
Traction Control
Security Alarm
Child Seat Anchor System-LATCH Ready
Height-Adjustable Front Shoulder Belts
Child Seat Upper Tether Anchorages
Front and Rear Stabilizer Bars
Speed Control
Rear Door Child Protection Locks
Tire Pressure Monitor with Warning Lamp

INTERIOR FEATURES
Air Conditioning
Air Filtering
Media Center 130 CD/MP3
Audio Jack Input for Mobile Devices
4 Speakers
Tilt / Telescope Steering Column
Steering Wheel-Mounted Audio Controls
Height-Adjustable Driver's Seat
Driver's Manually Adjustable Lumbar Support
Power Windows with Driver's One-Touch-Down Feature
60 / 40 Rear Seat with Trunk Pass-Through
Rear Armrest
Laminated Windshield and Front Door Glass
Instrument Cluster with LED Lighting
Center Console 12-Volt Power Outlet
Passenger-Side Sun Visor with Mirror
Outside Temperature Display In Odometer
Premium Front and Rear Floor Mats
Trunk Dress-Up
Trunk Lamp

EXTERIOR FEATURES
Quad LHD Optics Headlamps
LED Tail Lamps
225/55R17 BSW All Season Touring Tires
17-Inch x 6.5-Inch Steel Wheels
17-Inch Wheel Covers
Body-Color Fascias
Body-Color Door Handles
Power Mirrors
Tinted Glass Windows
Bright/Black Grille
Compact Spare Tire

OPTIONAL EQUIPMENT
Customer Preferred Package 25Y
2.4-Liter I4 PZEV 16-Valve Dual VVT Engine
18.5-Gallon Fuel Tank
Uconnect® Voice Command with Bluetooth® $360
Bluetooth® Streaming Audio
Remote USB Port
Auto-Dimming Rearview Mirror with Microphone

DESTINATION CHARGE $850

TOTAL PRICE: * $20,205

WARRANTY COVERAGE
5-year or 100,000-mile Powertrain Limited Warranty.
3-year or 36,000-mile Basic Limited Warranty.
24-hour towing assistance; certain restrictions apply.
Ask Dealer for a copy of the limited warranties or see your owner's manual for details.

5 YEAR/100,000 MILE
POWERTRAIN WARRANTY

Assembly Point/Port of Entry: STERLING HTS, MICH., U.S.A.
VIN: 1C3-CDZAB7CN-238364 L4-VON: 9625 0312

SHIPTO: 68849 21
HERITAGE CHRYSLER DODGE JEEP RAM
9219 HARFORD ROAD
BALTIMORE MD 21234-

SOLDTO: 35 68849
HERITAGE CHRYSLER DODGE JEEP RAM
9219 HARFORD ROAD
BALTIMORE MD 21234-

THIS LABEL IS ADDED TO THIS VEHICLE TO COMPLY WITH FEDERAL LAW. THE LABEL CANNOT BE REMOVED OR ALTERED PRIOR TO DELIVERY TO THE ULTIMATE PURCHASER.
* STATE AND/OR LOCAL TAXES IF ANY, LICENSE AND TITLE FEES AND DEALER SUPPLIED AND INSTALLED OPTIONS AND ACCESSORIES ARE NOT INCLUDED IN THIS PRICE. DISCOUNT, IF ANY, IS BASED ON PRICE OF OPTIONS IF PURCHASED SEPARATELY.

TOP SAFETY PICK 2012

For more information visit: www.dodge.com • or call 1-800-4ADODGE
Chrysler Group LLC

EPA Fuel Economy Estimates

These estimates reflect new EPA methods beginning with 2008 models.

CITY MPG **21**
Expected range for most drivers 17 to 25 MPG

Estimated Annual Fuel Cost **$2,314**
based on 15,000 miles at $3.70 per gallon

HIGHWAY MPG **30**
Expected range for most drivers 24 to 36 MPG

Combined Fuel Economy
This vehicle 24
10 — 99
All MIDSIZE CARS

Your actual mileage will vary depending on how you drive and maintain your vehicle.

See the FREE Fuel Economy Guide at dealers or www.fueleconomy.gov

GOVERNMENT 5-STAR SAFETY RATINGS

Overall Vehicle Score		★★★★
Based on the combined ratings of frontal, side, and rollover. Should ONLY be compared to other vehicles of similar size and weight. ⚠ Safety concern: visit www.safercar.gov or call 1-888-327-4236 for more details.		
Frontal Crash	Driver	★★★★★
	Passenger	★★★
Based on the risk of injury in a frontal impact. Should ONLY be compared to other vehicles of similar size and weight.		
Side Crash	Front seat	★★★
	Rear seat	★★★★★
Based on the risk of injury in a side impact.		
Rollover		★★★★
Based on the risk of rollover in a single-vehicle crash.		

Star ratings range from 1 to 5 stars (★★★★★) with 5 being the highest.
Source: National Highway Traffic Safety Administration (NHTSA)
www.safercar.gov or 1-888-327-4236

The safety ratings above are based on Federal Government tests of particular vehicles equipped with certain features and options. The performance of this vehicle may differ.
Bumper Performance
This vehicle is equipped with bumper systems that can withstand a frontal barrier impact speed of 2.5 miles per hour and a rear barrier impact speed of 2.5 miles per hour with no more damage than allowed by the Federal bumper standard. The Federal bumper standard allows damage to the bumpers and attaching hardware and specifies barrier tests to be conducted at 2.5 miles per hour.

PARTS CONTENT INFORMATION
FOR VEHICLES IN THIS CARLINE:
U.S./CANADIAN PARTS CONTENT: 74 %
NOTE: PARTS CONTENT DOES NOT INCLUDE FINAL ASSEMBLY, DISTRIBUTION, OR OTHER NON-PARTS COSTS.
FOR THIS VEHICLE:
FINAL ASSEMBLY POINT:
STERLING HTS, MICH., U.S.A.
COUNTRY OF ORIGIN:
ENGINE: UNITED STATES
TRANSMISSION: UNITED STATES

FIAT 500 — 2013 MODEL YEAR

THIS VEHICLE IS MANUFACTURED TO MEET SPECIFIC UNITED STATES REQUIREMENTS. THIS VEHICLE IS NOT MANUFACTURED FOR SALE OR REGISTRATION OUTSIDE OF THE UNITED STATES.

MANUFACTURER'S SUGGESTED RETAIL PRICE OF THIS MODEL INCLUDING DEALER PREPARATION

Base Price: $15,500

FIAT 500 POP HATCHBACK
Exterior Color: Argento (Silver) Exterior Paint
Interior Color: Avorio (Ivory) Interior Ambient
Interior: Cloth Bucket Seats
Engine: 1.4-Liter I4 MultiAir ® Engine
Transmission: 6-Speed Automatic Transmission

STANDARD EQUIPMENT (UNLESS REPLACED BY OPTIONAL EQUIPMENT)

FUNCTIONAL/SAFETY FEATURES
Advanced Multistage Front Airbags
Supplemental Front Seat-Mounted Side Airbags
Supplemental Side-Curtain Front and Rear Airbags
Driver Inflatable Knee-Bolster Airbag
Front Seat Reactive Head Restraints
Child Seat Anchor System-LATCH Ready
4-Wheel Anti-Lock Disc Power Brakes
Electronic Stability Control
Tire Pressure Monitoring Display
Power Windows with Front One-Touch-Down Feature
Exterior Spotter Mirror
Power Door Locks
Remote Keyless Entry
Cruise Control
Hill Start Assist
Rear Window Defroster
Variable Intermittent Windshield Wipers
Rear Window Wiper / Washer
Engine Immobilizer
12-Volt Auxiliary Power Outlet in Console
10.5-Gallon Fuel Tank

INTERIOR FEATURES
Air Conditioning with Micron Filter
Driver Seat Memory
Driver Seat Height Adjuster
Rear 50 / 50 Split Fold-Down Seat
Rear Cargo Shelf Panel
AM/FM/CD/MP3 Radio
BLUE&ME ™ Handsfree Communication with USB Port
6 Speakers
Auxiliary Audio Input Jack
Steering Wheel Mounted Audio Controls
Leather-Wrapped Steering Wheel
Tilt Steering Column
Electronic Vehicle Information Center
Sun Visors with Vanity Mirror
Tachometer
Rearview Day / Night Mirror
Front Floor Mats

EXTERIOR FEATURES
15-Inch x 6.0-Inch Steel Wheels
185/55 R15 All Season Tires
15-Inch Wheel Covers
Bi-Function Halogen Projector Headlamps
Tinted Glass Windows
Chrome Exhaust Tip
Chrome Door Handles
Body-Color Power Heated Mirrors
Tire Service Kit

OPTIONAL EQUIPMENT
Customer Preferred Package 22A
Rosso (Red) Seats
6-Speed Automatic Transmission $1,250
Body-Color Power Heated Mirrors

DESTINATION CHARGE $700

TOTAL PRICE: * $17,450

WARRANTY COVERAGE
Basic Warranty: 4 Year / 50,000 Miles.
Powertrain Warranty: 4 Year / 50,000 Miles.
Roadside assistance; certain restrictions apply.

Assembly Point/Port of Entry: TOLUCA, MEXICO
VIN: 3C3-CFFARXDT-514382 L4-VON: 2809 0823

SHIPTO: 67068 47
SAFFORD FIAT OF TYSONS CORNER
8448 LEESBURG PIKE
VIENNA VA 22182-2403

SOLDTO: 35 69068
SAFFORD FIAT OF TYSONS CORNER
8448 LEESBURG PIKE
VIENNA VA 22182-2403

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* STATE AND/OR LOCAL TAXES IF ANY, LICENSE AND TITLE FEES AND DEALER SUPPLIED AND INSTALLED OPTIONS AND ACCESSORIES ARE NOT INCLUDED IN THIS PRICE. DISCOUNT, IF ANY, IS BASED ON PRICE OF OPTIONS IF PURCHASED SEPARATELY.

TOP SAFETY PICK 2012

For more information visit: www.fiatusa.com or call 1-888-CIAOFIAT
Chrysler Group LLC

EPA ...el Economy and Environment

Gasoline Vehicle

Fuel Economy
30 MPG combined city/hwy
27 city 34 highway
3.3 gallons per 100 miles

Minicompact cars range from 13 to 37 MPG. The best vehicle rates 112 MPGe.

You **save** **$2,100** in fuel costs over 5 years compared to the average new vehicle.

Annual fuel **cost** **$1,900**

Fuel Economy & Greenhouse Gas Rating (tailpipe only): 8 (1 to 10 Best)
Smog Rating (tailpipe only): 5 (1 to 10 Best)

This vehicle emits 295 grams CO2 per mile. The best emits 0 grams per mile (tailpipe only). Producing and distributing fuel also creates emissions; learn more at fueleconomy.gov

Actual results will vary for many reasons, including driving conditions and how you drive and maintain your vehicle. The average new vehicle gets 23 MPG and cost $11,600 to fuel over 5 years. Cost estimates are based on 15,000 miles per year at $3.55 per gallon. MPGe is miles per gasoline gallon equivalent. Vehicle emissions are a significant cause of climate change and smog.

fueleconomy.gov
Calculate personalized estimates and compare vehicles

Smartphone QR Code™

GOVERNMENT 5-STAR SAFETY RATINGS

Overall Vehicle Score		Not Rated
Based on the combined ratings of frontal, side, and rollover. Should ONLY be compared to other vehicles of similar size and weight. ⚠ Safety concern: visit www.safercar.gov or call 1-888-327-4236 for more details.		
Frontal Crash	Driver	★★★★
	Passenger	★★★
Based on the risk of injury in a frontal impact. Should ONLY be compared to other vehicles of similar size and weight.		
Side Crash	Front seat	Not Rated
	Rear seat	Not Rated
Based on the risk of injury in a side impact.		
Rollover		★★★★
Based on the risk of rollover in a single-vehicle crash.		

Star ratings range from 1 to 5 stars (★★★★★) with 5 being the highest.
Source: National Highway Traffic Safety Administration (NHTSA)
www.safercar.gov or 1-888-327-4236

The safety ratings above are based on Federal Government tests of particular vehicles equipped with certain features and options. The performance of this vehicle may differ.
Bumper Performance
This vehicle is equipped with bumper systems that can withstand a frontal barrier impact speed of 2.5 miles per hour and a rear barrier impact speed of 2.5 miles per hour with no more damage than allowed by the Federal bumper standard. The Federal bumper standard allows damage to the bumpers and attaching hardware and specifies barrier tests to be conducted at 2.5 miles per hour.

PARTS CONTENT INFORMATION
FOR VEHICLES IN THIS CARLINE:
U.S./CANADIAN PARTS CONTENT: 21 %
MAJOR SOURCES OF FOREIGN PARTS CONTENT:
MEXICO: 49 %
NOTE: PARTS CONTENT DOES NOT INCLUDE FINAL ASSEMBLY, DISTRIBUTION, OR OTHER NON-PARTS COSTS.
FOR THIS VEHICLE:
FINAL ASSEMBLY POINT:
TOLUCA, MEXICO
COUNTRY OF ORIGIN:
ENGINE: UNITED STATES
TRANSMISSION: JAPAN

HYUNDAI 2013 ELANTRA GLS

[illegible] North Ame[illegible] Car of the Year

IIHS Top Safety Pick

Hyundai Assurance

Hyundai Hope On Wheels

SOLD TO: VA011
PRICE HYUNDAI CORPORATION
2150 SEMINOLE TRAIL
CHARLOTTESVILLE VA 22901

SHIPPED TO: VA011

VIN: 5NPDH4AE9DH251507
MODEL: 45422F45
ENGINE: G4NBCK079900
PORT OF ENTRY: MA
EXTERIOR COLOR: SPARKLING RUBY
INTERIOR/SEAT COLOR: BEIGE(YD)/BEIGE(YD)
MODE OF TRANSPORT: TRUCK
ACCESSORY WEIGHT: 12 lbs.
EMISSIONS: This vehicle is certified to meet emission requirements in all 50 states.

Manufacturer's suggested retail price includes manufacturer's recommended pre-delivery service. Gasoline license and title fees, state and local taxes and dealer installed options and accessories are not included in the manufacturer's suggested retail price.

This label has been affixed to this vehicle by Hyundai Motor America, pursuant to the requirements of 15 U.S.C. 1231 et seq. which prohibits its removal or alteration prior to delivery to the ultimate purchaser.

PART CONTENT INFORMATION

FOR VEHICLES IN THIS CARLINE: U.S./CANADIAN PARTS CONTENT: 36 %
MAJOR SOURCES OF FOREIGN PARTS CONTENT: Korea 63 %

Note: Parts content does not include final assembly, distribution, or other non-parts costs.
FOR THIS VEHICLE: FINAL ASSEMBLY POINT: Montgomery, Alabama U.S.
COUNTRY OF ORIGIN: ENGINE: U.S.A. TRANSMISSION: U.S.A.

STANDARD FEATURES:	
AMERICA'S BEST WARRANTY	
5-year/60,000-mile New Vehicle Warranty	INCLUDED
10-year/100,000-mile Powertrain Warranty	INCLUDED
7-year/Unlimited-mile Anti-perforation Warranty	INCLUDED
*5-year/Unlimited-mile Roadside Assistance	INCLUDED
*Limited warranties, see dealer for details	
ADVANCED SAFETY TECHNOLOGY	
*Electronic Stability Control (ESC) w/ Traction Control	INCLUDED
*ABS w/ Electronic Brake Force Distribution & Brake Assist	INCLUDED
*4-Wheel Disc Brakes	INCLUDED
*Front, Front Side Impact & Side Curtain Airbags	INCLUDED
*Front Seatbelt Pre-Tensioners	INCLUDED
*Tire Pressure Monitoring System	INCLUDED
*Daytime Running Lights	INCLUDED
POWERTRAIN TECHNOLOGY	
*1.8L, 148 HP, 131 lbs-ft Torque, DOHC 4-Cylinder	INCLUDED
*Dual Continuous Variable Valve Timing	INCLUDED
*6-Speed Automatic Transmission w/ SHIFTRONIC®	INCLUDED
COMFORT & CONVENIENCE	
*16" Alloy Wheels w/ P205/55R16 Tires	INCLUDED
*Solar Glass w/ Windshield Shade Band	INCLUDED
*Bodycolor Door Handles & Mirrors	INCLUDED
*Map Lights w/ Sunglass Holder	INCLUDED
*Air Conditioning w/ Cabin Air Filter	INCLUDED
*AM/FM/SiriusXM/CD/MP3 Audio System w/ 6 Speakers	INCLUDED
*Satellite Radio w/90 Day Trial; Not Available in AK & HI	INCLUDED
*iPod®/USB & Auxiliary Input Jacks	INCLUDED
*Remote Keyless Entry w/ Alarm	INCLUDED
*Power Heated Outside Mirrors	INCLUDED
*Power Windows and Door Locks	INCLUDED
*Trip Computer	INCLUDED
*External Temperature Display	INCLUDED
*Steering Wheel Mounted Cruise Control	INCLUDED
*Tilt-and-Telescopic Steering Column	INCLUDED
*Driver Seat Height Adjustment	INCLUDED
*Front Armrest Storage Box	INCLUDED
*Front Passenger Seatback Pocket	INCLUDED
*60/40 Split-Folding Rear Seat	INCLUDED
*Rear Center Armrest w/ Cupholders	INCLUDED
*Front and Rear Door Map Pockets	INCLUDED
***Full Tank of Gas**	INCLUDED

Manufacturer's Suggested Retail Price:	$17,815.00
ADDED FEATURES:	
*Preferred Package:	$650.00
Heated Front Seats	
Steering Wheel Audio Controls	
Bluetooth® Hands-Free Phone System with Voice Recognition	
Cloth Insert Door Trim	
Sliding Center Armrest	
Illuminated Vanity Mirrors with Extensions	
Illuminated Ignition	
Front Foglights	
*Carpeted Floor Mats	$95.00
*First Aid Kit	$25.00
*Auto-Dimming Rearview Mirror with HomeLink® and Compass	$250.00
Inland Freight & Handling :	$775.00
Total Price :	**$19,610.00**

303 A 1

EPA DOT Fuel Economy and Environment — Gasoline Vehicle

Fuel Economy
32 MPG combined city/hwy — 28 city, 38 highway
Midsize Cars range from 13 to 99 MPG. The best vehicle rates 112 MPGe.
3.1 gallons per 100 miles

You **save $3,350** in fuel costs over 5 years compared to the average new vehicle.

Annual fuel **cost $ 1,650**

Fuel Economy & Greenhouse Gas Rating (tailpipe only): 8 (1 – 10 Best)
Smog Rating (tailpipe only): 5 (1 – 10 Best)

This vehicle emits 277 grams CO_2 per mile. The best emits 0 grams per mile (tailpipe only). Producing and distributing fuel also create emissions; learn more at fueleconomy.gov.

Actual results will vary for many reasons, including driving conditions and how you drive and maintain your vehicle. The average new vehicle gets 23 MPG and costs $11,600 to fuel over 5 years. Cost estimates are based on 15,000 miles per year at $ 3.55 per gallon. MPGe is miles per gasoline gallon equivalent. Vehicle emissions are a significant cause of climate change and smog.

fueleconomy.gov
Calculate personalized estimates and compare vehicles

Smartphone QR Code™

GOVERNMENT 5-STAR SAFETY RATINGS

Overall Vehicle Score ★★★★★
Based on the combined ratings of frontal, side and rollover. Should ONLY be compared to other vehicles of similar size and weight.

Frontal Crash — Driver ★★★★★; Passenger ★★★★
Based on the risk of injury in a frontal impact. Should ONLY be compared to other vehicles of similar size and weight.

Side Crash — Front seat ★★★★; Rear seat ★★★★★
Based on the risk of injury in a side impact.

Rollover ★★★★
Based on the risk of rollover in a single-vehicle crash.

Star ratings range from 1 to 5 stars (★★★★★) with 5 being the highest.
Source: National Highway Traffic Safety Administration (NHTSA).
www.safercar.gov or 1-888-327-4236

Environmental Performance

Protect the Environment, choose vehicles with **higher scores:**

Global Warming Score: 8 (1 – Average new vehicle – 10 Cleanest)
Smog Score: 5 (1 – Average new vehicle – 10 Cleanest)

Using alternate fuels may improve scores. See www.DriveClean.ca.gov

Vehicle emissions are a primary contributor to global warming and smog. Scores are determined by the California Air Resources Board based on this vehicle's measured emissions. Please visit www.DriveClean.ca.gov for more information.
California Environmental Protection Agency AIR RESOURCES BOARD

HYUNDAI 2013 TUCSON GLS AWD PZEV

IIHS Top Safety Pick

Kelley Blue Book [illegible] Resale Val[illegible]ward: Top 10 Winner

Hyundai Hope On Wheels

SOLD TO: VA011
PRICE HYUNDAI CORPORATION
2150 SEMINOLE TRAIL
CHARLOTTESVILLE VA 22901

SHIPPED TO: VA011

VIN: KM8JUCAC1DU604802
MODEL: 83422A4P
ENGINE: G4KECU873204
PORT OF ENTRY: BR
EXTERIOR COLOR: CHAI BRONZE
INTERIOR/SEAT COLOR: BLACK(9P)/BLACK(9P)
MODE OF TRANSPORT: TRUCK
ACCESSORY WEIGHT: 21 lbs.
EMISSIONS: This vehicle meets California Emissions regulations and is Certified as a Partial Zero Emission Vehicle (PZEV)

Manufacturer's suggested retail price includes manufacturer's recommended pre-delivery service. Gasoline license and title fees, state and local taxes and dealer installed options and accessories are not included in the manufacturer's suggested retail price.

This label has been affixed to this vehicle by Hyundai Motor America, pursuant to the requirements of 15 U.S.C. 1231 et seq. which prohibits its removal or alteration prior to delivery to the ultimate purchaser.

PART CONTENT INFORMATION

FOR VEHICLES IN THIS CARLINE: U.S./CANADIAN PARTS CONTENT: 1 %
MAJOR SOURCES OF FOREIGN PARTS CONTENT: Korea 96 %

Note: Parts content does not include final assembly, distribution, or other non-parts costs.
FOR THIS VEHICLE: FINAL ASSEMBLY POINT: Ulsan, Korea
COUNTRY OF ORIGIN: ENGINE: Korea TRANSMISSION: Korea

STANDARD FEATURES:	
AMERICA'S BEST WARRANTY	
5-year/60,000-mile New Vehicle Warranty	INCLUDED
10-year/100,000-mile Powertrain Warranty	INCLUDED
7-year/Unlimited-mile Anti-perforation Warranty	INCLUDED
*5-year/Unlimited-mile Roadside Assistance	INCLUDED
*Limited warranties, see dealer for details	
ADVANCED SAFETY TECHNOLOGY	
*Electronic Stability Control (ESC) w/ Traction Control	INCLUDED
*ABS w/ Electronic Brake-force Distribution & Brake Assist	INCLUDED
*4-Wheel Disc Brakes	INCLUDED
*Downhill Brake Control & Hillstart Assist Control	INCLUDED
*Front, Front Side & Side Curtain Airbags w/ Rollover Sensors	INCLUDED
*Front Active Head Restraints & Front Seatbelt Pre-Tensioners	INCLUDED
*Tire Pressure Monitoring System (TPMS)	INCLUDED
POWERTRAIN TECHNOLOGY	
*2.4L DOHC 16 Valve 4-Cylinder Engine w/ Dual CVVT	INCLUDED
*170 Horsepower @6,000 rpm/ 163 lb-ft torque @4,000 rpm	INCLUDED
*6-Speed Auto Transmission w/ SHIFTRONIC®	INCLUDED
*Active ECO System	INCLUDED
***COMFORT & CONVENIENCE**	INCLUDED
*SACHS Premium Shock Absorbers	INCLUDED
*17-inch Alloy Wheels and P225/60HR17 Tires	INCLUDED
*Automatic Headlight Control w/ Front Fog Lights	INCLUDED
*Power Heated Side Mirrors w/ Turn Signal Indicators	INCLUDED
*Roof Side Rails & Lower Bodyside Cladding	INCLUDED
*Front Solar Glass & Rear Privacy Glass	INCLUDED
*Rear Wiper w/ Washer	INCLUDED
*Bodycolor Rear Spoiler w/ LED Stop Lights	INCLUDED
*Power Door & Liftgate Locks	INCLUDED
*Keyless Entry System with Alarm	INCLUDED
*Leatherette Bolster w/ Cloth Insert Seats	INCLUDED
*Heated Front Seats	INCLUDED
*60/40 Split Folding Rear Seat	INCLUDED
*Leather Wrapped Steering Wheel and Gear Shift Knob	INCLUDED
*Steering Wheel-Mounted Cruise, Audio & Phone Controls	INCLUDED
*Illuminated Vanity Mirrors & Glove Box	INCLUDED
*Air Conditioning with Cabin Air Filter	INCLUDED
*AM/FM/SiriusXM®/CD/MP3 w/ iPod®/USB/Aux Input Jacks	INCLUDED
*SiriusXM® w/ 90 Day Trial; Not Available in AK & HI	INCLUDED
*Bluetooth® Hands-Free Phone System	INCLUDED
***Full Tank of Gas**	INCLUDED

Manufacturer's Suggested Retail Price:	$24,095.00
ADDED FEATURES:	
*Carpeted Floor Mats	$100.00
*Cargo Net	$50.00
*Auto-Dimming Mirror w/ HomeLink® & Compass	$250.00
*Mudguards	$85.00
*Roof Rack Cross Rails	$205.00
Inland Freight & Handling :	$825.00
Total Price :	**$25,610.00**

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EPA DOT Fuel Economy and Environment — Gasoline Vehicle

Fuel Economy
23 MPG combined city/hwy — 21 city, 28 highway
Small SUVs range from 16 to 32 MPG. The best vehicle rates 112 MPGe.
4.3 gallons per 100 miles

You **save $100** in fuel costs over 5 years compared to the average new vehicle.

Annual fuel **cost $ 2,300**

Fuel Economy & Greenhouse Gas Rating (tailpipe only): 6 (1 – 10 Best)
Smog Rating (tailpipe only): 9 (1 – 10 Best)

This vehicle emits 381 grams CO_2 per mile. The best emits 0 grams per mile (tailpipe only). Producing and distributing fuel also create emissions; learn more at fueleconomy.gov.

Actual results will vary for many reasons, including driving conditions and how you drive and maintain your vehicle. The average new vehicle gets 23 MPG and costs $11,600 to fuel over 5 years. Cost estimates are based on 15,000 miles per year at $ 3.55 per gallon. MPGe is miles per gasoline gallon equivalent. Vehicle emissions are a significant cause of climate change and smog.

fueleconomy.gov
Calculate personalized estimates and compare vehicles

Smartphone QR Code™

GOVERNMENT 5-STAR SAFETY RATINGS

Overall Vehicle Score ★★★★
Based on the combined ratings of frontal, side and rollover. Should ONLY be compared to other vehicles of similar size and weight.

Frontal Crash — Driver ★★★★; Passenger ★★★★
Based on the risk of injury in a frontal impact. Should ONLY be compared to other vehicles of similar size and weight.

Side Crash — Front seat ★★★★★; Rear seat ★★★★★
Based on the risk of injury in a side impact.

Rollover ★★★★
Based on the risk of rollover in a single-vehicle crash.

Star ratings range from 1 to 5 stars (★★★★★) with 5 being the highest.
Source: National Highway Traffic Safety Administration (NHTSA).
www.safercar.gov or 1-888-327-4236

Environmental Performance

Protect the Environment, choose vehicles with **higher scores:**

Global Warming Score: 9 (1 – Average new vehicle – 10 Cleanest)
Smog Score: 7 (1 – Average new vehicle – 10 Cleanest)

Using alternate fuels may improve scores. See www.DriveClean.ca.gov

Vehicle emissions are a primary contributor to global warming and smog. Scores are determined by the California Air Resources Board based on this vehicle's measured emissions. Please visit www.DriveClean.ca.gov for more information.
California Environmental Protection Agency AIR RESOURCES BOARD

Automaker Names for Forward Collision Warning

Automaker	Website name	Window sticker name
Acura	Forward collision warning	Forward collision warning
Honda	Forward collision warning	Forward collision warning
BMW	Lane departure warning with forward collision warning	Lane departure warning
Buick	Forward collision alert	Forward collision alert
Cadillac	Forward collision alert	Forward collision alert
Chevrolet	Forward collision alert	Forward collision alert
GMC	Forward collision alert	Forward collision alert
Chrysler	Forward collision warning	Forward collision warning
Dodge	Forward collision warning	Forward collision warning
Jeep	Forward collision warning	Forward collision warning
Ford	Collision warning and brake support	Adaptive cruise/collision warning
Hyundai	Smart cruise control	Smart cruise control
Infiniti	Forward collision warning	Forward collision warning
Jaguar	Forward alert	Adaptive cruise ctrl w/Adv EBA
Lexus	Pre-collision system	Pre-collision system
Lexus	Pre-collision system with dynamic radar control	Pre-collision system with dynamic radar control
Toyota	Pre-collision system	Pre-collision system

Automaker Names for Forward Collision Warning with Autonomous Emergency Braking

Automaker	Website name	Window sticker name
Acura	Collision mitigation braking system (CMBS)	Collision mitigation braking system (CMBS)
Audi	Pre-sense Plus with adaptive cruise control with Stop & Go	Pre-sense Plus
BMW	Active cruise control with Stop & Go	Active cruise control
Cadillac	Front and rear automatic braking	Front and rear automatic braking
Infiniti	Intelligent brake assist with forward collision warning	Intelligent brake assist with forward collision warning
Land Rover	Intelligent emergency braking (IEB) incorporates advanced emergency braking assist (AEBA)	Adaptive Cruise Ctrl w/Queue Assist & IEB
Lexus	Advanced pre-collision system	Advanced pre-collision system
Toyota	Advanced pre-collision system	Advanced pre-collision system
Lincoln	Collision warning with brake support	Adaptive cruise control and collision warning with brake support
Mercedes-Benz	Distronic Plus with Pre-safe Brake	Distronic Plus with Pre-safe Brake
Mercedes-Benz	Collision prevention assist	Collision prevention assist
Porsche	Adaptive cruise control with Porsche Active Safe	Adaptive cruise control with Porsche Active Safe
Subaru	Eyesight	Eyesight driver-assist system (pre-collision braking system, adaptive cruise control, lane departure warning and lane sway warning, pre-collision throttle management system)
Volvo	Collision warning with full auto brake	Collision warning with full auto brake