



Mazda collision avoidance features

This is the second report examining collision avoidance features offered by Mazda. In 2011, the Highway Loss Data Institute (HLDI, 2011) performed an initial look at three collision avoidance features — Adaptive Front Lighting System, Blind Spot Monitoring, and a back-up camera — offered by Mazda on model year 2007–10 vehicles. This study updates and expands the loss results for these features and examines several new features introduced on model year 2014 vehicles. These features include front crash prevention technologies such as Adaptive Cruise Control, Forward Obstruction Warning, and Mazda’s Smart City Brake Support as well as Lane Departure Warning and Rear Cross Traffic Alert.

The updated results for Adaptive Front Lighting System, Blind Spot Monitoring, and the back-up camera indicate significant reductions for property damage liability claim frequencies and some injury coverage frequencies. Results for the new systems indicate strong potential for Mazda’s Smart City Brake Support with significant reductions in property damage liability claim frequency. Bodily injury liability claim frequency was also reduced, but the result was not significant. Results for the remaining features were inconclusive, as limited loss data are available for vehicles equipped with these systems. The table below summarizes the estimated changes in claim frequency for Mazda’s collision avoidance features. Statistically significant estimates are bolded.

Summary of estimated changes in claim frequency for Mazda’s collision avoidance systems

| Vehicle damage coverage type | Adaptive Front Lighting System | Blind Spot Monitoring | Back-up camera | Smart City Brake Support | Combined front crash prevention systems | Lane Departure Warning | Rear Cross Traffic Alert |
|------------------------------|--------------------------------|-----------------------|----------------|--------------------------|---|------------------------|--------------------------|
| Collision | -1.7% | -3.1% | 0.6% | -3.4% | 1.9% | -3.7% | 1.5% |
| Property damage liability | -4.6% | -11.1% | -4.2% | -13.4% | -15.2% | -4.5% | -2.3% |
| Injury coverage type | | | | | | | |
| Bodily injury liability | -3.6% | -17.7% | -4.4% | -11.5% | | | -5.2% |
| Medical payment | -10.1% | -15.4% | -8.2% | 12.0% | | | -4.4% |
| Personal injury protection | -7.7% | -11.1% | -8.2% | -5.2% | | | 11.6% |

► Introduction

This Highway Loss Data Institute (HLDI) bulletin updates loss results for three collision avoidance features examined in an earlier HLDI (2011) report to include additional vehicle series, model years, and exposure. These features are:

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 and at vehicle speeds above 1 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 blind spot detection 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 above 6.3 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 camera is active when the transmission is in reverse.

New features available on model year 2014 vehicles include:

Adaptive Cruise Control (Mazda Radar Cruise Control) is a system that uses radar sensors mounted in the front grille 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 between 19 and 90 mph. Forward Obstruction Warning remains active even when Adaptive Cruise Control is turned off. Adaptive Cruise Control is always present on vehicles with Forward Obstruction Warning and therefore the analysis cannot separate out the individual effects of these features.

Forward Obstruction Warning uses radar to assess the risk of a rear-end collision with an obstacle in front, and warns the driver with a visual alert and a continuous warning sound. This system is functional at speeds of 6 mph and above, and when the relative speed between the driver's vehicle and the obstruction is between 6 and 90 mph. The system may be deactivated under the multi-information display settings menu, but the default setting is on. Forward Obstruction Warning is always present on vehicles with Adaptive Cruise Control, and therefore the analysis cannot separate out the individual effects of these features.

Smart City Brake Support operates the brakes if the laser sensor determines that a collision with a vehicle ahead is unavoidable. It may also be possible to avoid a collision if the relative speed between the driver's vehicle and the vehicle ahead is less than about 9.3 mph. In addition, when the driver depresses the brake pedal while the system is in the operation range at about 2–18 mph, additional brake assistance is applied. The system may be deactivated under the multi-information display settings menu, but the default setting is on.

Lane Departure Warning uses a forward facing camera mounted by the interior rearview mirror to determine if the driver's vehicle is unintentionally leaving its lane. A steady green indicator light shows when lane lines are recognizable and the vehicle speed is 40 mph or greater. The indicator light turns yellow, meaning the system is not operational, when the lane lines are not recognizable or the vehicle speed is less than 40 mph. The system indicates a flashing green indicator light and a continuous warning sound when lane lines are recognizable, the vehicle speed is 40 mph or greater, and the vehicle deviates from its lane. The system may be deactivated by using a switch to the left of the steering wheel in the dashboard area. At the next ignition cycle, it will be in the previous on/off setting.

Rear Cross Traffic Alert is a system that alerts drivers to vehicles that are adjacent to them when the vehicle is in reverse. The system uses radar sensors mounted inside the rear bumper to scan a range behind and to the sides of the vehicle. If a vehicle has been detected, a warning light on the appropriate side mirror is illuminated, and an auditory warning is given. Vehicles with a rearview monitor also receive a warning indication in the rearview monitor. The system is functional at speeds under 6 mph and can be deactivated by the driver, but will reactivate at the next ignition cycle.

► Method

Vehicles

Although some features are available as standard equipment for certain model years and trim levels, other features are offered as optional equipment. The presence or absence of these optional 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 2010 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, were also 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

| Series | Model year range | Adaptive Cruise Control | Forward Obstruction Warning | Smart City Brake Support | Blind Spot Monitoring | Lane Departure Warning | Adaptive Front Lighting | Rear Cross Traffic Alert | Back-up camera | Total exposure |
|------------------------|------------------|-------------------------|-----------------------------|--------------------------|-----------------------|------------------------|-------------------------|--------------------------|----------------|----------------|
| Mazda 3 4dr | 2010–14 | < 1% | < 1% | < 1% | 8% | < 1% | 10% | 4% | 3% | 650,051 |
| Mazda 3 station wagon | 2010–13 | | | | 8% | | 18% | | | 304,010 |
| Mazda 3 5dr | 2014 | 5% | 5% | 6% | 83% | 6% | 20% | 83% | 61% | 27,286 |
| Mazda 6 4dr | 2009–14 | 2% | 2% | 6% | 41% | < 1% | 4% | 10% | 15% | 542,363 |
| Mazda CX-5 4dr | 2013–14 | | | 11% | 75% | | 23% | | 75% | 121,274 |
| Mazda CX-5 4dr 4WD | 2013–14 | | | 23% | 89% | | 41% | | 89% | 115,241 |
| Mazda CX-7 4dr | 2010–12 | | | | 4% | | | | 42% | 241,643 |
| Mazda CX-7 4dr 2WD/4WD | 2007–09 | | | | | | | | 19% | 521,643 |
| Mazda CX-7 4dr 4WD | 2010–12 | | | | 37% | | | | 63% | 35,202 |
| Mazda CX-9 4dr | 2007–14 | | | | 34% | | | 1% | 44% | 317,778 |
| Mazda CX-9 4WD | 2007–14 | | | | 40% | | | 2% | 58% | 357,401 |
| Mazda Tribute 4dr | 2010–11 | | | | | | | | 43% | 17,590 |
| Mazda Tribute 4dr 4WD | 2010–11 | | | | | | | | 63% | 7,019 |

Insurance data

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

Because different crash avoidance features may affect different types of insurance coverage, it 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 (PIP coverage) that pay up to a specified amount for injuries to occupants of involved-insured vehicles, regardless of who is at fault in a collision. The District of Columbia has a hybrid insurance system for injuries and is excluded from the injury analysis.

Statistical methods

Regression analysis was used to quantify the effect of each vehicle feature while controlling for 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. Based on the model year and vehicle series, a single variable called SERIESMY was created for inclusion in the regression model. Effectively, this variable controlled for the variation caused by vehicle design changes that occur from model year to model year.

For each safety feature supplied by the manufacturer, a binary variable was included to indicate the presence of that feature. With the exception of Adaptive Cruise Control and Forward Obstruction Warning, separate estimates for each individual feature were possible. Since those two features were always bundled together, the analysis cannot separate out the individual effects of those features. In addition, while Smart City Brake Support was available on vehicles without Adaptive Cruise Control and Forward Obstruction Warning, all vehicles with Adaptive Cruise Control and Forward Obstruction Warning also had Smart City Brake Support. Since all three features could potentially prevent or mitigate similar crash types, the effectiveness of the three features combined was estimated. The effect of Smart City Brake Support, without Adaptive Cruise Control and Forward Obstruction Warning, was still estimated separately.

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: 75.6 percent for PIP, 70 percent for BI, and 61.3 percent for MedPay. The low severity range was <\$1,000 for PIP and MedPay, <\$5,000 for BI; high severity covered all loss payments greater than that.

A separate regression was performed for each insurance loss measure for a total of 15 regressions (5 coverages x 3 loss measures each). For space reasons, only the estimates for the individual crash avoidance features are shown on the following pages. To illustrate the analyses, however, **Appendix A** contains full model results for collision claim frequencies. To further simplify the presentation here, the exponent of the parameter estimate was calculated, 1 was subtracted, and the resultant multiplied by 100. The resulting number corresponds to the effect of the feature on that loss measure. For example, the estimate of the effect of Smart City Brake Support on collision claim frequency was -0.0349; thus, vehicles with the feature had 3.4 percent fewer collision claims than without Smart City Brake Support ($(\exp(-0.0349)-1)*100=-3.4$).

► Results

Results for Mazda's collision avoidance features are summarized in the following tables. **Tables 2–4** present the updated loss results for the three features examined in the 2011 report. **Table 5** compares the updated frequency estimates with the prior estimates. **Tables 6–9** summarize the loss results for the new features introduced on model year 2014 vehicles. For all tables, the lower and upper bounds represent the 95 percent confidence limits for the estimates. Estimates that are statistically significant at the 95 percent confidence level are bolded.

Table 2 summarizes the results for Mazda's Adaptive Front Lighting System. For vehicle damage losses, collision claim frequency was down 1.7 percent and property damage liability claim frequency was down 4.6 percent. Only the PDL estimate was statistically significant. Collision claim severity was up \$167 while property damage liability severity was down \$146. Both results were statistically significant. This resulted in an increase to collision overall losses of \$7 and a statistically significant reduction to property damage liability overall losses of \$11.

For injury losses, the overall frequency of claims (paid plus reserve) decreased for all coverages, with the decreases for medical payment and personal injury protection being significant. 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 | -3.7% | -1.7% | 0.4% | \$72 | \$167 | \$265 | -\$3 | \$7 | \$17 |
| Property damage liability | -7.4% | -4.6% | -1.6% | -\$224 | -\$146 | -\$66 | -\$15 | -\$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 | -11.8% | -3.6% | 5.4% | -30.3% | -18.5% | -4.7% | -15.3% | -1.2% | 15.3% |
| Medical payment | -18.5% | -10.1% | -0.7% | -47.2% | -30.0% | -7.1% | -20.9% | -8.5% | 5.7% |
| Personal injury protection | -14.1% | -7.7% | -0.8% | -20.4% | -7.3% | 8.0% | -18.7% | -10.3% | -0.9% |

Results for Mazda's Blind Spot Monitoring are summarized in **Table 3**. Claim frequencies for all coverage types, both vehicle damage and injury, are down and statistically significant. Collision and PDL severities are also down but not significant.

Table 3: Change in insurance losses for Blind Spot Monitoring System

| Vehicle damage coverage type | Lower bound | FREQUENCY | Upper bound | Lower bound | SEVERITY | Upper bound | Lower bound | OVERALL LOSSES | Upper bound |
|------------------------------|-------------|---------------|-------------|-------------|------------------------|-------------|-------------|-------------------------|-------------|
| Collision | -4.4% | -3.1% | -1.7% | -\$72 | -\$9 | \$55 | -\$17 | -\$10 | -\$4 |
| Property damage liability | -12.8% | -11.1% | -9.4% | -\$64 | -\$12 | \$41 | -\$16 | -\$14 | -\$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 | -22.4% | -17.7% | -12.6% | -25.0% | -17.1% | -8.5% | -30.6% | -23.1% | -14.8% |
| Medical payment | -20.7% | -15.4% | -9.7% | -30.9% | -17.7% | -1.9% | -26.1% | -18.7% | -10.6% |
| Personal injury protection | -15.1% | -11.1% | -6.9% | -26.2% | -18.2% | -9.4% | -14.2% | -8.7% | -2.9% |

Table 4 summarizes results for Mazda’s back-up camera. For vehicle damage losses, claim frequency is down 4.2 percent for property damage liability and significant. The frequency for collision coverage is up slightly but not significant. Claim severities for collision coverage are up \$84 and significant. This results in a statistically significant increase to overall losses for collision of \$8. Claim severities for property damage liability are down \$21 although not significant. Consequently, overall losses for property damage liability were down \$6 and significant.

For injury losses, the overall frequency of claims (both paid and reserved) is lower for all coverage types, with medical payment and personal injury protection being statistically significant. Frequencies were also down among paid claims for both low and high severity claims. However, only the high severity personal injury protection frequency was 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 | -0.8% | 0.6% | 1.9% | \$23 | \$84 | \$145 | \$2 | \$8 | \$14 |
| Property damage liability | -5.9% | -4.2% | -2.5% | -\$70 | -\$21 | \$28 | -\$9 | -\$6 | -\$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 | -9.6% | -4.4% | 1.1% | -14.1% | -5.6% | 3.6% | -12.4% | -3.7% | 5.9% |
| Medical payment | -13.7% | -8.2% | -2.3% | -22.4% | -8.3% | 8.5% | -13.3% | -5.2% | 3.6% |
| Personal injury protection | -12.0% | -8.2% | -4.3% | -6.7% | 2.6% | 12.8% | -14.3% | -9.4% | -4.2% |

Table 5 compares the estimated changes in claim frequency published in December 2011 for Mazda’s Adaptive Front Lighting System, Blind Spot Monitoring, and back-up camera with the updated results included in this report. It is important to note that the updated results include new model years and vehicles not included in the original study. For example, in the original study, the Adaptive Front Lighting System was only available on the 2010 Mazda 3. In this study, the Adaptive Front Lighting System is also available on the 2011–2014 Mazda 3, the 2014 Mazda 6, and the 2013–14 Mazda CX-5.

The updated results show smaller benefits for the Adaptive Front Lighting System than previously estimated. Collision claim frequency went from a statistically significant 6.4 percent reduction to a non-significant 1.7 percent reduction. Similarly, property damage liability claim frequency went from a 10.1 percent reduction to a 4.6 percent reduction, although this result remained statistically significant. The injury benefits for all three coverages are also smaller now than previously estimated.

Vehicle damage coverages show larger benefits for Blind Spot Monitoring than previously estimated. Collision claim frequency now shows a statistically significant 3.1 percent reduction compared to no benefit from the initial results. The property damage liability benefit also increased from a 7.5 percent reduction to an 11.1 percent reduction. Injury coverages for Blind Spot monitoring show slightly smaller benefits than previously estimated, although all results are still statistically significant.

The updated results for Mazda’s back-up camera show increased claim frequency benefits for all coverages. Collision claim frequency originally showed a statistically significant 3.1 percent disbenefit. The updated results show only a 0.6 percent disbenefit that is not significant. The benefit for property damage claim frequency increased from a 2.3 percent reduction to a significant 4.2 percent reduction. Injury coverages also show larger reductions in claim frequency, with medical payment and personal injury protection being statistically significant.

Table 5: Change in claim frequencies by collision avoidance feature, initial vs. updated results

| Vehicle damage coverage type | Adaptive Front Lighting System | | Blind Spot Monitoring | | back-up camera | |
|------------------------------|--------------------------------|-----------------|-----------------------|-----------------|-----------------|-----------------|
| | Initial results | Updated results | Initial results | Updated results | Initial results | Updated results |
| Collision | -6.4% | -1.7% | 0.0% | -3.1% | 3.1% | 0.6% |
| Property damage liability | -10.1% | -4.6% | -7.5% | -11.1% | -2.3% | -4.2% |

| Injury coverage type | Adaptive Front Lighting System | | Blind Spot Monitoring | | back-up camera | |
|----------------------------|--------------------------------|-----------------|-----------------------|-----------------|-----------------|-----------------|
| | Initial results | Updated results | Initial results | Updated results | Initial results | Updated results |
| Bodily injury liability | -12.5% | -3.6% | -20.9% | -17.7% | -3.1% | -4.4% |
| Medical payment | -28.9% | -10.1% | -23.9% | -15.4% | 0.6% | -8.2% |
| Personal injury protection | -28.8% | -7.7% | -14.5% | -11.1% | -2.1% | -8.2% |

The remaining features evaluated in this study were introduced on model year 2014 vehicles. Consequently, claims data for vehicles equipped with some of these features are sparse. This is especially true for injury claims. In such instances, the estimates for these features can vary wildly with extremely large confidence bounds. As a result of sparse data, injury estimates for vehicles with Mazda’s Lane Departure Warning as well as vehicles equipped with the combination of Forward Obstruction Warning, Adaptive Cruise Control, and Smart City Brake Support are not presented here. The effect of these features was still controlled for when computing injury estimates for the other features.

Table 6 summarizes the loss results for Mazda’s Smart City Brake Support. Collision claim frequencies are down 3.4 percent, though this result is not significant. Property damage claim frequencies are down a significant 13.4 percent. Collision claim severity remained essentially unchanged while property damage claim severity rose \$237. This results in slightly lower overall losses for both collision and property damage liability coverages, though neither result is significant.

Under injury coverages, the overall frequency of claims (paid plus reserved) decreases for bodily injury liability and personal injury protection but increases for medical payment. Among paid claims, the high severity frequency was lower for all three coverages. The low severity frequency was higher for medical payment and personal injury protection but lower for bodily injury liability.

Table 6: Change in Insurance losses for Smart City Brake Support

| Vehicle damage coverage type | Lower bound | FREQUENCY | Upper bound | Lower bound | SEVERITY | Upper bound | Lower bound | OVERALL LOSSES | Upper bound |
|------------------------------|-------------|---------------|-------------|-------------|--------------|-------------|-------------|----------------|-------------|
| | Collision | -7.3% | -3.4% | 0.6% | -\$196 | -\$14 | \$176 | -\$29 | -\$12 |
| Property damage liability | -19.0% | -13.4% | -7.3% | \$45 | \$237 | \$442 | -\$17 | -\$7 | \$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 | -28.5% | -11.5% | 9.5% | -40.6% | -11.9% | 30.7% | -40.3% | -10.3% |
| Medical payment | -8.7% | 12.0% | 37.4% | -9.0% | 55.8% | 166.7% | -29.4% | -3.5% | 31.8% |
| Personal injury protection | -18.6% | -5.2% | 10.4% | -18.1% | 14.3% | 59.4% | -27.4% | -10.4% | 10.6% |

Results for the combined front crash prevention systems — Adaptive Cruise Control, Forward Obstruction Warning, and Smart City Brake Support — are summarized in **Table 7**. These estimates indicate the change in insurance losses for vehicles equipped with all three features, compared with vehicles without any of the three features. Collision coverage shows a slight increase in claim frequency of 1.9 percent with severity down \$89. This results in a \$1 decline in overall losses. None of the collision results were significant. Property damage claim frequency was down 15.2 percent with severity up \$725. Both results were statistically significant. This results in a nonsignificant increase to overall losses of \$7. Injury results are not shown due to the small number of injury claims and exposure for vehicles equipped with these features.

**Table 7: Change in insurance losses for combined front crash prevention systems
(Adaptive Cruise Control, Forward Obstruction Warning, and Smart City Brake Support)**

| Vehicle damage coverage type | Lower bound | FREQUENCY | Upper bound | Lower bound | SEVERITY | Upper bound | Lower bound | OVERALL LOSSES | Upper bound |
|------------------------------|-------------|---------------|-------------|-------------|--------------|-------------|-------------|----------------|-------------|
| Collision | -5.8% | 1.9% | 10.2% | -\$416 | -\$89 | \$267 | -\$34 | -\$1 | \$37 |
| Property damage liability | -26.4% | -15.2% | -2.3% | \$261 | \$725 | \$1,257 | -\$15 | \$7 | \$33 |

| 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 | | | | | | | | | |
| Medical payment | Injury results not shown due to insufficient data | | | | | | | | |
| Personal injury protection | | | | | | | | | |

Table 8 summarizes the results for Lane Departure Warning. Vehicle damage coverages show reductions to collision and property damage claim frequencies but increases in severities. As a result, overall losses increase for both coverages as well. None of the results were statistically significant. Injury results are not shown due to insufficient data.

Table 8: Change in insurance losses for Lane Departure Warning

| Vehicle damage coverage type | Lower bound | FREQUENCY | Upper bound | Lower bound | SEVERITY | Upper bound | Lower bound | OVERALL LOSSES | Upper bound |
|------------------------------|-------------|-----------|-------------|-------------|----------|-------------|-------------|----------------|-------------|
| Collision | -13.1% | -3.7% | 6.8% | -\$118 | \$351 | \$875 | -\$32 | \$14 | \$66 |
| Property damage liability | -21.2% | -4.5% | 15.9% | -\$276 | \$263 | \$913 | -\$23 | \$5 | \$41 |

| 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 | | | | | | | | | |
| Medical payment | Injury results not shown due to insufficient data | | | | | | | | |
| Personal injury protection | | | | | | | | | |

Table 9 summarizes the results for Rear Cross Traffic Alert. No clear pattern emerges with no estimates being statistically significant. Collision coverage shows a slight increase to claim frequency but reduced severity. Property damage claim frequencies are slightly reduced but severity is higher. For the injury coverages, overall frequency of claims (paid plus reserved) is down for bodily injury and medical payment but up for personal injury protection. Among paid claims, frequencies are up for both low and high severities with the exception of high-severity bodily injury claims.

Table 9: Change in insurance losses for Rear Cross Traffic Alert

| Vehicle damage coverage type | Lower bound | FREQUENCY | Upper bound | Lower bound | SEVERITY | Upper bound | Lower bound | OVERALL LOSSES | Upper bound |
|------------------------------|-------------|-----------|-------------|-------------|----------|-------------|-------------|----------------|-------------|
| Collision | -2.8% | 1.5% | 6.0% | -\$297 | -\$110 | \$86 | -\$22 | -\$4 | \$17 |
| Property damage liability | -8.6% | -2.3% | 4.5% | -\$71 | \$114 | \$311 | -\$8 | \$2 | \$13 |

| 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 | -24.3% | -5.2% | 18.9% | -15.0% | 35.5% | 115.8% | -55.9% | -30.2% | 10.6% |
| Medical payment | -24.2% | -4.4% | 20.4% | -45.0% | 10.0% | 120.2% | -13.9% | 25.6% | 83.1% |
| Personal injury protection | -5.1% | 11.6% | 31.2% | -28.0% | 5.1% | 53.3% | -1.6% | 22.7% | 53.0% |

Discussion

Although the inclusion of additional model years and vehicles series have changed the point estimates for Mazda's Adaptive Front Lighting System, Blind Spot Monitoring, and back-up camera, loss results for these features continue to be favorable. The benefits for Mazda's Adaptive Front Lighting system are reduced compared with the initial estimates. However, the new, reduced estimates are consistent with results from other manufacturers. It is still unclear why, to the extent that adaptive lighting is effective, there are greater reductions to property damage claims than collision claims. However, this trend is consistent with other manufacturers' adaptive lighting systems.

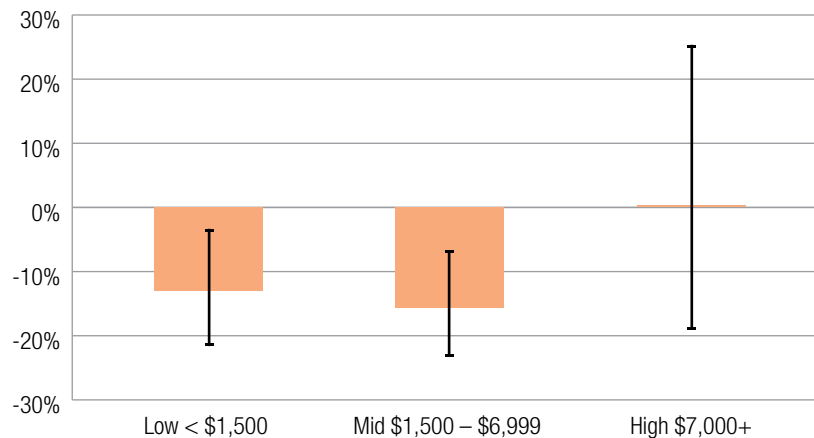
Claim frequency benefits for Mazda's Blind Spot Monitoring are improved for the vehicle damage coverages and reduced for the injury coverages. However, the new estimates are within the confidence bounds of the original study. These results are generally consistent with expectations. Incursion into occupied adjacent lanes would be expected to result in two-vehicle crashes that lead to property damage claims against the encroaching driver. The estimated reduction in property damage claims is 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 that typically occur on multi-lane roads, many of which are higher speed roads, it is expected that the system would help prevent high-speed crashes and the injuries involved. All of the injury coverages have statistically significant reductions in claim frequency.

Mazda's back-up cameras show improved results compared with initial estimates. 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 expectations, collision claims show no real change in frequency for vehicles with Mazda's back-up camera, although property damage claims did decrease significantly. There was a reduction to bodily injury claims as well, although this was not statistically significant but it could be an indication that cameras are reducing some nonoccupant crashes. Surprisingly, there were significant reductions to medical payment and personal injury protection claims.

The new collision avoidance features introduced on some 2014 Mazda vehicles include front crash prevention systems that are designed to prevent front-to-rear crashes, which are the type of crashes that result in property damage and bodily injury claims. Mazda's Smart City Brake Support, which is a low-speed braking system similar to Volvo's City Safety system, appears to be effective at reducing these types of claims. The reduction to property damage claims was statistically significant and consistent with other manufacturers, including the estimate for Volvo's City Safety. The estimated reduction in bodily injury claims was not significant. However, the system is still new and more loss data are needed to be confident in the injury coverage results.

Property damage liability claim severity was also higher for Mazda's Smart City Brake Support. An examination of PDL claim frequency by claim size explains this result. The figure below shows the estimated change in PDL claim frequency for vehicles equipped with Smart City Brake Support by size of claim. The estimated effects indicate that the frequency of low-and mid-severity claims was much lower for vehicles with Smart City Brake Support. However, the frequency of high-severity claims was about the same. This finding is consistent with the expectations for a low-speed autonomous emergency braking system. It is designed to eliminate, or at least mitigate, low-speed and low-severity front-to-rear crashes. By removing many of the lowest cost claims, Smart City Brake Support shifted the distribution of claim severity to a higher mean.

Changes to property damage liability claim frequencies by claim severity range for Smart City Brake Support



The addition of Adaptive Cruise Control and Forward Obstruction Warning to vehicles equipped with Smart City Brake Support do not appear to substantively affect claim frequency results compared with vehicles with just Smart City Brake Support. This could be an indication that most of the benefit from these front crash prevention systems comes at low speeds. Similar to the vehicles equipped with just Smart City Brake Support, property damage liability claim severity was also higher for vehicles equipped with all three of these systems. However, an analysis of PDL claim frequency by claim size was inconclusive as the data are still very limited for vehicles equipped with all three of these features. More data are needed before drawing any conclusions.

Although physical damage coverages show a reduction in claim frequencies for Mazda's Lane Departure Warning system, a lack of data prevents drawing a meaningful conclusion as to the effectiveness of this system.

Rear Cross Traffic Alert is designed to detect vehicles that might be crossing your rearward path, such as when you are backing out of a parking space. Similar to the back-up camera, this system operates when the vehicle is in reverse. This would be expected to yield reductions in property damage and bodily injury claims. While frequencies are down for both of these coverage types, the estimates are not significant and have wide confidence bounds.

Overall, Mazda's Adaptive Front Lighting System, Blind Spot Monitoring System, and back-up camera are reducing insurance losses. Initial results for Mazda's Smart City Brake Support are also promising. However, conclusions regarding Mazda's Adaptive Cruise Control, Forward Obstruction Warning, Lane Departure Warning, and Rear Cross Traffic Alert systems must wait for additional data.

► Limitations

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

Additionally, the data supplied to HLDI does not include detailed crash information. Information on point of impact and the vehicle's transmission status is not available. The technologies in this report target certain crash types. For example, the back-up camera is designed to prevent collisions when a vehicle is backing up. 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 or tied to higher trim levels and associated with increased costs. The type of person who selects these options or trim levels may be different from the person who declines. While the analysis controls for several driver characteristics, there may be other uncontrolled attributes with people who select these features.

References

Highway Loss Data Institute. 2011. Mazda collision avoidance features: initial results. *Loss Bulletin*. Vol. 28, No 13. Arlington, VA.

► Appendix A

| Appendix A: Illustrative regression results — collision frequency | | | | | | | | |
|---|-------------------------|--------------------|----------|--------|----------------|----------------------------|------------|---------|
| Parameter | | Degrees of freedom | Estimate | Effect | Standard error | Wald 95% confidence limits | Chi-square | P-value |
| Intercept | | 1 | -9.1296 | | 0.0982 | -9.3220 -8.9372 | 8652.02 | <0.0001 |
| Calendar year | 2006 | 1 | 0.0653 | 6.7% | 0.0643 | -0.0608 0.1914 | 1.03 | 0.3101 |
| | 2007 | 1 | 0.1665 | 18.1% | 0.0207 | 0.1259 0.2072 | 64.52 | <0.0001 |
| | 2008 | 1 | 0.1042 | 11.0% | 0.0153 | 0.0742 0.1342 | 46.21 | <0.0001 |
| | 2009 | 1 | 0.0669 | 6.9% | 0.0128 | 0.0419 0.0919 | 27.49 | <0.0001 |
| | 2010 | 1 | 0.0477 | 4.9% | 0.0109 | 0.0264 0.0690 | 19.32 | <0.0001 |
| | 2011 | 1 | 0.0377 | 3.8% | 0.0096 | 0.0189 0.0564 | 15.53 | <0.0001 |
| | 2012 | 1 | -0.0131 | -1.3% | 0.0088 | -0.0303 0.0041 | 2.22 | 0.1358 |
| | 2013 | 1 | 0.0027 | 0.3% | 0.0081 | -0.0132 0.0186 | 0.11 | 0.7354 |
| | 2014 | 1 | 0.0165 | 1.7% | 0.0077 | 0.0015 0.0315 | 4.66 | 0.0308 |
| | 2015 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Vehicle model year and series | 2010 3 4dr | 1 | 0.3822 | 46.6% | 0.0860 | 0.2138 0.5507 | 19.77 | <0.0001 |
| | 2011 3 4dr | 1 | 0.4730 | 60.5% | 0.0854 | 0.3056 0.6405 | 30.65 | <0.0001 |
| | 2012 3 4dr | 1 | 0.4574 | 58.0% | 0.0855 | 0.2899 0.6250 | 28.64 | <0.0001 |
| | 2013 3 4dr | 1 | 0.4969 | 64.4% | 0.0861 | 0.3282 0.6656 | 33.34 | <0.0001 |
| | 2014 3 4dr | 1 | 0.6284 | 87.5% | 0.0877 | 0.4565 0.8002 | 51.36 | <0.0001 |
| | 2010 3 station wagon | 1 | 0.2806 | 32.4% | 0.0859 | 0.1123 0.4489 | 10.68 | 0.0011 |
| | 2011 3 station wagon | 1 | 0.3762 | 45.7% | 0.0865 | 0.2066 0.5459 | 18.90 | <0.0001 |
| | 2012 3 station wagon | 1 | 0.3121 | 36.6% | 0.0862 | 0.1432 0.4810 | 13.12 | 0.0003 |
| | 2013 3 station wagon | 1 | 0.3504 | 42.0% | 0.0874 | 0.1791 0.5217 | 16.08 | <0.0001 |
| | 2014 Mazda 3 5dr | 1 | 0.5904 | 80.5% | 0.0892 | 0.4156 0.7651 | 43.85 | <0.0001 |
| | 2009 6 4dr | 1 | 0.3581 | 43.1% | 0.0858 | 0.1900 0.5262 | 17.43 | <0.0001 |
| | 2010 6 4dr | 1 | 0.3817 | 46.5% | 0.0857 | 0.2137 0.5497 | 19.83 | <0.0001 |
| | 2011 6 4dr | 1 | 0.4416 | 55.5% | 0.0863 | 0.2724 0.6107 | 26.18 | <0.0001 |
| | 2012 6 4dr | 1 | 0.5403 | 71.7% | 0.0862 | 0.3713 0.7094 | 39.25 | <0.0001 |
| | 2013 6 4dr | 1 | 0.4857 | 62.5% | 0.0889 | 0.3114 0.6600 | 29.83 | <0.0001 |
| | 2014 6 4dr | 1 | 0.6537 | 92.3% | 0.0876 | 0.4821 0.8253 | 55.74 | <0.0001 |
| | 2013 Mazda CX-5 4dr | 1 | 0.3543 | 42.5% | 0.0866 | 0.1846 0.5240 | 16.74 | <0.0001 |
| | 2014 Mazda CX-5 4dr | 1 | 0.3395 | 40.4% | 0.0867 | 0.1697 0.5094 | 15.35 | <0.0001 |
| | 2013 Mazda CX-5 4dr 4WD | 1 | 0.3464 | 41.4% | 0.0868 | 0.1762 0.5165 | 15.92 | <0.0001 |
| | 2014 Mazda CX-5 4dr 4WD | 1 | 0.3739 | 45.3% | 0.0868 | 0.2038 0.5439 | 18.57 | <0.0001 |
| | 2010 Mazda CX-7 4dr | 1 | 0.4141 | 51.3% | 0.0856 | 0.2463 0.5819 | 23.40 | <0.0001 |
| | 2011 Mazda CX-7 4dr | 1 | 0.4569 | 57.9% | 0.0857 | 0.2888 0.6250 | 28.39 | <0.0001 |
| | 2012 Mazda CX-7 4dr | 1 | 0.4898 | 63.2% | 0.0892 | 0.3149 0.6648 | 30.13 | <0.0001 |
| 2007 Mazda CX-7 4dr 2WD/4WD | 1 | 0.3794 | 46.1% | 0.0854 | 0.2121 0.5467 | 19.75 | <0.0001 | |

Appendix A: Illustrative regression results — collision frequency

| Parameter | Degrees of freedom | Estimate | Effect | Standard error | Wald 95% confidence limits | | Chi-square | P-value |
|-------------------------------|--------------------|----------|--------|----------------|----------------------------|---------|------------|---------|
| 2008 Mazda CX-7 4dr 2WD/4WD | 1 | 0.3827 | 46.6% | 0.0856 | 0.2150 | 0.5504 | 20.00 | <0.0001 |
| 2009 Mazda CX-7 4dr 2WD/4WD | 1 | 0.4016 | 49.4% | 0.0864 | 0.2322 | 0.5710 | 21.60 | <0.0001 |
| 2010 Mazda CX-7 4dr 4WD | 1 | 0.5015 | 65.1% | 0.0878 | 0.3295 | 0.6736 | 32.64 | <0.0001 |
| 2011 Mazda CX-7 4dr 4WD | 1 | 0.5627 | 75.5% | 0.0916 | 0.3831 | 0.7423 | 37.72 | <0.0001 |
| 2012 Mazda CX-7 4dr 4WD | 1 | 0.6349 | 88.7% | 0.1851 | 0.2722 | 0.9977 | 11.77 | 0.0006 |
| 2007 Mazda CX-9 4dr | 1 | 0.2867 | 33.2% | 0.0869 | 0.1164 | 0.4569 | 10.89 | 0.0010 |
| 2008 Mazda CX-9 4dr | 1 | 0.2660 | 30.5% | 0.0862 | 0.0970 | 0.4350 | 9.52 | 0.0020 |
| 2009 Mazda CX-9 4dr | 1 | 0.2668 | 30.6% | 0.0886 | 0.0930 | 0.4405 | 9.06 | 0.0026 |
| 2010 Mazda CX-9 4dr | 1 | 0.3565 | 42.8% | 0.0866 | 0.1868 | 0.5262 | 16.95 | <0.0001 |
| 2011 Mazda CX-9 4dr | 1 | 0.4028 | 49.6% | 0.0874 | 0.2314 | 0.5742 | 21.22 | <0.0001 |
| 2012 Mazda CX-9 4dr | 1 | 0.3892 | 47.6% | 0.0878 | 0.2171 | 0.5613 | 19.64 | <0.0001 |
| 2013 Mazda CX-9 4dr | 1 | 0.4829 | 62.1% | 0.0913 | 0.3040 | 0.6617 | 27.99 | <0.0001 |
| 2014 Mazda CX-9 4dr | 1 | 0.5725 | 77.3% | 0.0999 | 0.3766 | 0.7683 | 32.81 | <0.0001 |
| 2007 Mazda CX-9 4dr 4WD | 1 | 0.3827 | 46.6% | 0.0868 | 0.2126 | 0.5528 | 19.44 | <0.0001 |
| 2008 Mazda CX-9 4dr 4WD | 1 | 0.3885 | 47.5% | 0.0859 | 0.2201 | 0.5569 | 20.45 | <0.0001 |
| 2009 Mazda CX-9 4dr 4WD | 1 | 0.3940 | 48.3% | 0.0874 | 0.2226 | 0.5653 | 20.31 | <0.0001 |
| 2010 Mazda CX-9 4dr 4WD | 1 | 0.4974 | 64.4% | 0.0860 | 0.3288 | 0.6660 | 33.44 | <0.0001 |
| 2011 Mazda CX-9 4dr 4WD | 1 | 0.5073 | 66.1% | 0.0864 | 0.3379 | 0.6767 | 34.45 | <0.0001 |
| 2012 Mazda CX-9 4dr 4WD | 1 | 0.5488 | 73.1% | 0.0867 | 0.3788 | 0.7188 | 40.04 | <0.0001 |
| 2013 Mazda CX-9 4dr 4WD | 1 | 0.6303 | 87.8% | 0.0897 | 0.4545 | 0.8060 | 49.41 | <0.0001 |
| 2014 Mazda CX-9 4dr 4WD | 1 | 0.5567 | 74.5% | 0.0969 | 0.3667 | 0.7467 | 32.98 | <0.0001 |
| 2010 Mazda Tribute 4dr | 1 | 0.1578 | 17.1% | 0.0939 | -0.0263 | 0.3419 | 2.82 | 0.0930 |
| 2011 Mazda Tribute 4dr | 1 | 0.0594 | 6.1% | 0.1022 | -0.1410 | 0.2597 | 0.34 | 0.5616 |
| 2010 Mazda Tribute 4dr 4WD | 1 | -0.0418 | -4.1% | 0.1106 | -0.2587 | 0.1750 | 0.14 | 0.7053 |
| 2011 Mazda Tribute 4dr 4WD | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Rated driver age group | | | | | | | | |
| 14–24 | 1 | 0.2739 | 31.5% | 0.0083 | 0.2576 | 0.2901 | 1089.18 | <0.0001 |
| 25–29 | 1 | 0.0873 | 9.1% | 0.0076 | 0.0724 | 0.1023 | 131.03 | <0.0001 |
| 30–39 | 1 | 0.0135 | 1.4% | 0.0064 | 0.0010 | 0.0260 | 4.49 | 0.0341 |
| 50–59 | 1 | -0.0337 | -3.3% | 0.0070 | -0.0474 | -0.0200 | 23.37 | <0.0001 |
| 60–64 | 1 | -0.0344 | -3.4% | 0.0103 | -0.0546 | -0.0142 | 11.12 | 0.0009 |
| 65–69 | 1 | 0.0057 | 0.6% | 0.0120 | -0.0178 | 0.0293 | 0.23 | 0.6330 |
| 70+ | 1 | 0.1189 | 12.6% | 0.0116 | 0.0961 | 0.1417 | 104.58 | <0.0001 |
| Unknown | 1 | 0.0910 | 9.5% | 0.0112 | 0.0690 | 0.1130 | 65.88 | <0.0001 |
| 40–49 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Rated driver gender | | | | | | | | |
| Male | 1 | -0.0519 | -5.1% | 0.0049 | -0.0615 | -0.0424 | 113.95 | <0.0001 |
| Unknown | 1 | -0.2147 | -19.3% | 0.0140 | -0.2421 | -0.1874 | 236.86 | <0.0001 |
| Female | 0 | 0 | 0 | 0 | 0 | 0 | | |

Appendix A: Illustrative regression results — collision frequency

| Parameter | | Degrees of freedom | Estimate | Effect | Standard error | Wald 95% confidence limits | | Chi-square | P-value |
|-----------------------------|------------------|--------------------|----------|--------|----------------|----------------------------|---------|------------|---------|
| Rated driver marital status | Single | 1 | 0.1786 | 19.6% | 0.0055 | 0.1679 | 0.1893 | 1073.39 | <0.0001 |
| | Unknown | 1 | 0.1855 | 20.4% | 0.0138 | 0.1584 | 0.2127 | 179.83 | <0.0001 |
| | Married | 0 | 0 | | 0 | 0 | 0 | | |
| Risk | Nonstandard | 1 | 0.1529 | 16.5% | 0.0068 | 0.1396 | 0.1662 | 507.61 | <0.0001 |
| | Standard | 0 | 0 | 0 | 0 | 0 | 0 | | |
| State | Alabama | 1 | -0.1345 | -12.6% | 0.0518 | -0.2360 | -0.0330 | 6.74 | 0.0094 |
| | Arizona | 1 | -0.1825 | -16.7% | 0.0502 | -0.2808 | -0.0841 | 13.23 | 0.0003 |
| | Arkansas | 1 | -0.1279 | -12.0% | 0.0568 | -0.2392 | -0.0166 | 5.07 | 0.0244 |
| | California | 1 | 0.0378 | 3.9% | 0.0482 | -0.0567 | 0.1323 | 0.61 | 0.4330 |
| | Colorado | 1 | -0.0954 | -9.1% | 0.0500 | -0.1934 | 0.0025 | 3.65 | 0.0561 |
| | Connecticut | 1 | -0.1290 | -12.1% | 0.0503 | -0.2276 | -0.0304 | 6.58 | 0.0103 |
| | Delaware | 1 | -0.0894 | -8.6% | 0.0546 | -0.1964 | 0.0175 | 2.69 | 0.1011 |
| | Dist of Columbia | 1 | 0.2212 | 24.8% | 0.0613 | 0.1011 | 0.3413 | 13.03 | 0.0003 |
| | Florida | 1 | -0.3249 | -27.7% | 0.0484 | -0.4197 | -0.2301 | 45.14 | <0.0001 |
| | Georgia | 1 | -0.2148 | -19.3% | 0.0497 | -0.3122 | -0.1173 | 18.65 | <0.0001 |
| | Idaho | 1 | -0.3043 | -26.2% | 0.0644 | -0.4305 | -0.1782 | 22.36 | <0.0001 |
| | Illinois | 1 | -0.1058 | -10.0% | 0.0488 | -0.2014 | -0.0102 | 4.70 | 0.0301 |
| | Indiana | 1 | -0.1925 | -17.5% | 0.0511 | -0.2926 | -0.0923 | 14.20 | 0.0002 |
| | Iowa | 1 | -0.2107 | -19.0% | 0.0561 | -0.3206 | -0.1007 | 14.10 | 0.0002 |
| | Kansas | 1 | -0.2139 | -19.3% | 0.0528 | -0.3174 | -0.1104 | 16.41 | <0.0001 |
| | Kentucky | 1 | -0.2758 | -24.1% | 0.0518 | -0.3773 | -0.1742 | 28.34 | <0.0001 |
| | Louisiana | 1 | 0.0409 | 4.2% | 0.0500 | -0.0572 | 0.1389 | 0.67 | 0.4143 |
| | Maine | 1 | -0.0934 | -8.9% | 0.0636 | -0.2180 | 0.0312 | 2.16 | 0.1418 |
| | Maryland | 1 | -0.0585 | -5.7% | 0.0491 | -0.1548 | 0.0378 | 1.42 | 0.2337 |
| | Massachusetts | 1 | -0.0880 | -8.4% | 0.0503 | -0.1865 | 0.0106 | 3.06 | 0.0803 |
| | Michigan | 1 | 0.2217 | 24.8% | 0.0498 | 0.1240 | 0.3193 | 19.80 | <0.0001 |
| | Minnesota | 1 | -0.2068 | -18.7% | 0.0502 | -0.3051 | -0.1084 | 16.99 | <0.0001 |
| | Mississippi | 1 | -0.0406 | -4.0% | 0.0581 | -0.1545 | 0.0732 | 0.49 | 0.4844 |
| | Missouri | 1 | -0.2311 | -20.6% | 0.0504 | -0.3299 | -0.1323 | 21.02 | <0.0001 |
| | Montana | 1 | -0.1151 | -10.9% | 0.0847 | -0.2810 | 0.0509 | 1.85 | 0.1741 |
| | Nebraska | 1 | -0.2918 | -25.3% | 0.0553 | -0.4002 | -0.1833 | 27.80 | <0.0001 |
| | Nevada | 1 | -0.1889 | -17.2% | 0.0546 | -0.2959 | -0.0819 | 11.98 | 0.0005 |
| | New Hampshire | 1 | 0.0276 | 2.8% | 0.0549 | -0.0799 | 0.1351 | 0.25 | 0.6146 |
| | New Jersey | 1 | -0.1422 | -13.3% | 0.0486 | -0.2376 | -0.0469 | 8.55 | 0.0035 |
| | New Mexico | 1 | -0.1570 | -14.5% | 0.0562 | -0.2671 | -0.0470 | 7.82 | 0.0052 |
| | New York | 1 | 0.0078 | 0.8% | 0.0483 | -0.0869 | 0.1026 | 0.03 | 0.8716 |
| | North Carolina | 1 | -0.3360 | -28.5% | 0.0497 | -0.4334 | -0.2387 | 45.77 | <0.0001 |
| North Dakota | 1 | 0.0266 | 2.7% | 0.0772 | -0.1246 | 0.1778 | 0.12 | 0.7303 | |
| Ohio | 1 | -0.2426 | -21.5% | 0.0490 | -0.3386 | -0.1466 | 24.55 | <0.0001 | |
| Oklahoma | 1 | -0.2084 | -18.8% | 0.0529 | -0.3121 | -0.1048 | 15.53 | <0.0001 | |
| Oregon | 1 | -0.2862 | -24.9% | 0.0515 | -0.3871 | -0.1853 | 30.90 | <0.0001 | |
| Pennsylvania | 1 | 0.0167 | 1.7% | 0.0484 | -0.0781 | 0.1116 | 0.12 | 0.7294 | |
| Rhode Island | 1 | -0.0144 | -1.4% | 0.0559 | -0.1239 | 0.0951 | 0.07 | 0.7965 | |

Appendix A: Illustrative regression results — collision frequency

| Parameter | Degrees of freedom | Estimate | Effect | Standard error | Wald 95% confidence limits | | Chi-square | P-value |
|--|--------------------|----------|--------|----------------|----------------------------|---------|------------|---------|
| South Carolina | 1 | -0.2555 | -22.5% | 0.0527 | -0.3588 | -0.1522 | 23.52 | <0.0001 |
| South Dakota | 1 | -0.1884 | -17.2% | 0.0794 | -0.3440 | -0.0328 | 5.63 | 0.0176 |
| Tennessee | 1 | -0.1663 | -15.3% | 0.0505 | -0.2652 | -0.0673 | 10.84 | 0.0010 |
| Texas | 1 | -0.1347 | -12.6% | 0.0482 | -0.2292 | -0.0402 | 7.80 | 0.0052 |
| Utah | 1 | -0.2784 | -24.3% | 0.0524 | -0.3812 | -0.1756 | 28.18 | <0.0001 |
| Vermont | 1 | -0.1058 | -10.0% | 0.0761 | -0.2549 | 0.0434 | 1.93 | 0.1646 |
| Virginia | 1 | -0.1215 | -11.4% | 0.0490 | -0.2175 | -0.0255 | 6.15 | 0.0131 |
| Washington | 1 | -0.1681 | -15.5% | 0.0494 | -0.2649 | -0.0712 | 11.56 | 0.0007 |
| West Virginia | 1 | -0.2332 | -20.8% | 0.0619 | -0.3546 | -0.1118 | 14.18 | 0.0002 |
| Wisconsin | 1 | -0.1713 | -15.7% | 0.0509 | -0.2711 | -0.0714 | 11.3 | 0.0008 |
| Wyoming | 1 | -0.0158 | -1.6% | 0.0889 | -0.1901 | 0.1585 | 0.03 | 0.8593 |
| Hawaii | 1 | 0.0185 | 1.9% | 0.0540 | -0.0873 | 0.1244 | 0.12 | 0.7312 |
| Alaska | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Deductible range | | | | | | | | |
| 0–250 | 1 | 0.4963 | 64.3% | 0.0078 | 0.4810 | 0.5115 | 4065.97 | <0.0001 |
| 1,001+ | 1 | -0.3997 | -32.9% | 0.0403 | -0.4787 | -0.3208 | 98.45 | <0.0001 |
| 251–500 | 1 | 0.2966 | 34.5% | 0.0066 | 0.2836 | 0.3096 | 2002.65 | <0.0001 |
| 501–1,000 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Registered vehicle density | | | | | | | | |
| 0–99 | 1 | -0.1872 | -17.1% | 0.0078 | -0.2025 | -0.1719 | 575.21 | <0.0001 |
| 100–499 | 1 | -0.1316 | -12.3% | 0.0050 | -0.1414 | -0.1217 | 683.44 | <0.0001 |
| 500+ | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Adaptive Cruise Control, Forward Obstruction Warning and Smart City Brake Support | 1 | 0.0186 | 1.9% | 0.0399 | -0.0597 | 0.0969 | 0.22 | 0.6413 |
| Smart City Brake Support | 1 | -0.0349 | -3.4% | 0.0211 | -0.0762 | 0.0064 | 2.75 | 0.0973 |
| Blind Spot Monitoring | 1 | -0.0313 | -3.1% | 0.0071 | -0.0453 | -0.0173 | 19.33 | <0.0001 |
| Lane Departure Warning | 1 | -0.0374 | -3.7% | 0.0524 | -0.1402 | 0.0654 | 0.51 | 0.4756 |
| Adaptive Front Lighting System | 1 | -0.0172 | -1.7% | 0.0106 | -0.0379 | 0.0036 | 2.63 | 0.1045 |
| Rear Cross Traffic Alert | 1 | 0.0152 | 1.5% | 0.0222 | -0.0283 | 0.0586 | 0.47 | 0.4940 |
| Back-up camera | 1 | 0.0055 | 0.6% | 0.0067 | -0.0075 | 0.0185 | 0.68 | 0.4086 |



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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. DW201509 NB Runs 244 & 245

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