HLDI
Highway Loss Data Institute

Bulletin | Vol. 38, No. 1: April 2021

Advanced Driver Assistance Systems on the 2017–19 Nissan Rogue

Summary

This is the second study to estimate changes in insurance losses associated with Nissan's ProPILOT Assist, a Level 2 driving automation technology, as equipped on the Nissan Rogue. In 2019, the Highway Loss Data Institute (HLDI, 2019a) published its first look at ProPILOT Assist on the 2017-18 Nissan Rogue. The current report updates the 2019 analysis with new collision avoidance features (Rear Automatic Braking and Rear Sonar System), one additional model year (2019), and nearly twice the exposure.

ProPILOT Assist combines steering support with Nissan's adaptive cruise control system (called Intelligent Cruise Control) to keep the vehicle in the center of the lane while controlling speed and following distance. Numerous studies by the Highway Loss Data Institute (HLDI) have found that various advanced driver assistance systems (ADAS) significantly reduce claim frequency under different vehicle damage and injury coverage types. However, it has been challenging to analyze how the technology that automates part of the driving task (driving automation technology) affects insurance losses, due to the confounding effects of associated ADAS features.

Claim frequency results for the 2017–19 Nissan Rogue are shown in the following table. Statistically significant results are bolded. Consistent with previous HLDI research on ADAS, the ADAS available on the 2017–19 Nissan Rogue were associated with reductions in claim frequency under the different coverage types; many of the reductions were statistically significant.

Nissan's Rear Automatic Braking and Rear Sonar System were associated with large, statistically significant reductions to collision (13.5 percent) and property damage liability (PDL) (31 percent) claim frequencies. These results are consistent with other HLDI research on rear automatic braking systems and provide further evidence of the potential for these systems to reduce insurance losses.

The addition of Intelligent Cruise Control and ProPILOT Assist to vehicles already equipped with Forward Emergency Braking (FEB) do not appear to provide significant additional benefits to claim frequency beyond those provided by FEB. In fact, the collision, PDL, and bodily injury liability claim frequency benefits with these systems included were all lower compared with FEB alone.

Change in claim frequencies by collision avoidance feature, results summary

Vehicle damage coverage type	Forward Emergency Braking (FEB)	Intelligent Cruise Control (ICC) + FEB	ProPILOT Assist + ICC and FEB	Blind Spot Warning / Rear Cross-Traffic Alert	Around View Monitor / Moving Object Detection	Rear Automatic Braking / Rear Sonar System
Collision	-2.2%	-1.9%	1.1%	**-4.7%**	-1.7%	**-13.5%**
Property damage liability	**-7.8%**	-4.1%	-5.6%	**-11.6%**	**-6.5%**	**-31.0%**
Injury coverage type						
Bodily injury liability	-14.2%	-5.1%	-13.1%	-8.9%	**-17.9%**	-21.5%
Medical payment	4.0%	-4.5%	-19.1%	**-13.1%**	**-13.6%**	14.5%
Personal injury protection	0.1%	6.9%	5.0%	-3.4%	**-14.8%**	0.6%

Introduction

Advanced Driver Assistance Systems (ADAS) inform the driver of a potential collision and may apply steering or braking input to mitigate or prevent a crash. Numerous studies by HLDI have found that the presence of different ADAS features is associated with a significant reduction in claim frequency under different vehicle damage and injury coverage types (HLDI, 2020b). ADAS are foundational elements of driving automation technology that continuously support the driver by providing sustained steering, throttle, or braking input. For instance, adaptive cruise control (ACC) maintains a set speed and also modulates vehicle speed to maintain a set following distance to a vehicle ahead; it is a Level 1 driving automation technology based on the definitions established by SAE International (2018). By continuously supporting the driver, driving automation technology like ACC helps maintain or increase safety margins (Kessler et al., 2012) and may prevent safety-critical events from developing into near crashes or crashes that are not addressed by current ADAS.

Previous HLDI research on the real-world benefits of driving automation technology relative to the underlying ADAS features has been mixed. A 2009 HLDI study examined an ACC system equipped to 2008 and 2009 model year Mercedes vehicles called Distronic that also included a forward collision warning (FCW) feature (HLDI, 2009). The presence of Distronic was associated with a 5 percent reduction in collision claim frequency and an 8 percent reduction in property damage liability (PDL) claim frequency, but the independent contribution of the ACC and FCW functions of the Distronic system to these reductions could not be determined. Subsequent HLDI research on ADAS (HLDI, 2020b) suggests that FCW contributed to most of the effect observed in this 2009 HLDI study on ADAS.

A 2017 HLDI study examined the effects of various ADAS features on 2012–16 Tesla Model S vehicles that became available through over-the-air software updates. One feature that was added in a software update was Tesla Autopilot, a Level 2 driving automation technology. Autopilot supports the driver with multiple aspects of the driving task by providing sustained steering, throttle, and braking control. The actual software version present on individual Tesla Model S vehicles could not be determined, so this study compared periods when a feature was available with periods when it was not. Collision claim frequency during a period following the introduction of Autopilot and other features via software update (e.g., automated lane change, side-collision avoidance) was significantly reduced by 13 percent relative to an earlier period where Autopilot was not available but other ADAS features were. Estimates for the other coverages were not significant and had large confidence bounds.

A study of 2013–17 BMW vehicles (HLDI, 2019b) found significant reductions in collision claim frequency (7 percent), PDL claim frequency (26 percent) and bodily injury (BI) liability claim frequency (29 percent) for vehicles equipped with BMW's Driving Assistant Plus package, a package of systems capable of Level 2 driving automation. However, these reductions were on par with reductions for vehicles equipped with the less advanced Driver Assistant package, implying that the increased automation provided by the Plus package did not confer additional benefits towards reducing insurance losses.

In 2020, HLDI (2020a) examined the changes in insurance losses associated with another Level 2 driving automation technology, Audi's Traffic Jam Assist on the 2017 Q7 and A4. Audi's Traffic Jam Assist can assist the driver by controlling the vehicle's speed, using the adaptive cruise control system as well as the steering. This system reduced collision claim frequency by 4 percent, PDL claim frequency by 20 percent, BI liability claim frequency by 15 percent, medical payment (MedPay) claim frequency by 28 percent, and personal injury protection (PIP) claim frequency by 14 percent. The results for PDL and MedPay were statistically significant.

In the 2018 model year, Nissan introduced a Level 2 driving automation technology called ProPILOT Assist as an optional feature on certain Rogue and Leaf vehicles. ProPILOT Assist adds steering support to an available ACC system called Intelligent Cruise Control to keep the vehicle centered in the lane in addition to maintaining a set speed and following distance to the vehicle ahead. Both driving automation technologies are available on Nissan Rogue vehicles that are equipped with other standard or optional ADAS features. The staggered introduction of Intelligent Cruise Control followed by ProPILOT Assist as a stand-alone optional feature on the Nissan Rogue across model years provides a unique opportunity to examine the effects of Level 1 and Level 2 driving automation technology on insurance losses independent of other ADAS features. Both driving automation technologies were expected to strengthen the reductions in insurance losses associated with different ADAS features that have been observed in past HLDI studies, by reducing the severity of crash imminent situations that ADAS features typically act on and by preventing crash imminent situations from developing altogether.

The following Nissan ADAS and driving automation technologies were examined in this study.

Advanced Driver Assistance Systems

Forward Emergency Braking (FEB) uses a front radar sensor to measure the distance to the vehicle ahead. A visual and auditory warning is provided to the driver if a risk of a forward collision is detected. If the driver does not brake following the warning, then the system applies partial braking if a forward collision risk is still detected. The system applies harder braking if a collision is imminent. The system functions at speeds above 3 mph and will not detect stationary vehicles when the vehicle is traveling over 50 mph. Some FEB systems also include pedestrian detection, which provides a visual and auditory warning and automatic braking if a collision risk with a pedestrian is detected. The pedestrian detection function is available at speeds between 6 and 37 mph.

Blind Spot Warning (BSW) uses radar sensors mounted near the rear bumper to detect other vehicles in adjacent lanes. An indicator light near the A-pillar is illuminated when a vehicle is detected by the system. An audible warning is provided and the A-pillar light flashes if the turn signal is used in the direction of an adjacent vehicle detected by the system. The system detects vehicles up to 10 feet behind the rear bumper that are within 10 feet of either side of the vehicle. The system is available at speeds above 20 mph.

Rear Cross-Traffic Alert (RCTA) uses the same radar sensors as the BSW system to detect vehicles approaching from the side when the vehicle is reversing at less than 5 mph. If the system detects an approaching vehicle, then an indicator light near the A-pillar on the side the vehicle is approaching from flashes and an audible warning is presented. The system can detect approaching vehicles from about 66 feet away.

Around View Monitor uses cameras located in the front grille, on the side mirrors, and above the vehicle license plate to display a bird's-eye view of the vehicle, 150-degree-front view, 150-degree-rear view, or a front-passenger-side view. Predicted course lines based on steering wheel position are displayed in the front view and rear view with distance indicators at 1.5, 3, 7, and 10 feet. The different camera views are available when the vehicle transmission is in reverse. The front view is only available at speeds below 6 mph.

Moving Object Detection uses image processing technology on the camera images to detect moving objects around the vehicle. A yellow frame is displayed on the camera image and an auditory warning is provided when a moving object is detected.

High Beam Assist is available at speeds above 25 mph. The system will automatically switch from the high-beam setting to the low-beam setting when the ambient-image sensor near the rearview mirror detects an oncoming vehicle or vehicle ahead.

RearView Monitor uses a camera located above the vehicle's license plate to show an image of the area directly behind the vehicle when it is in reverse. Guidelines showing the approximate distance to objects in the camera image are provided at 1.5, 3, 7, and 10 feet behind the vehicle. Every 2017–19 Nissan Rogue was equipped with this technology.

Intelligent Lane Intervention uses a front-facing camera behind the rearview mirror to monitor the travel lane at speeds above 37 mph. A visual and auditory warning is provided when the vehicle approaches a lane marking. The system applies braking to the left or right wheels to assist the driver in returning the vehicle to the center of the lane.

Rear Automatic Braking detects objects behind the vehicle using the parking sensors located on the rear bumper. A visual and auditory warning is provided to the driver if a risk of a collision with an object is detected when the vehicle is backing up. The system will then automatically apply the brakes. After the automatic brake application, the driver must apply the brakes to maintain brake pressure. The system operates at speeds less than 9 mph.

Rear Sonar System uses sonar sensors mounted in the rear bumpers to detect nearby objects and vehicles when the vehicle is traveling at a low speed. A visual and audible warning is provided when an object is detected behind the vehicle when the transmission is in the reverse position. The system is available at speeds of 6 mph and lower.

Driving automation technologies

Intelligent Cruise Control is an ACC system that uses a radar sensor mounted on the front bumper to monitor the traffic ahead. The system maintains the driver's selected speed and automatically reduces it to maintain a driver-selected following distance when it detects a slower moving vehicle ahead. The system is available at speeds between 20 and 90 mph and can bring the vehicle to a complete stop. The system can apply up to 40 percent of the vehicle's total braking power when slowing for the traffic ahead. Intelligent Cruise Control is an SAE Level 1 driving automation technology (SAE International, 2018).

ProPILOT Assist combines steering assist with Intelligent Cruise Control and uses a front-facing camera located behind the rearview mirror to provide steering input to assist in keeping the vehicle centered in the lane. Steering assist is only available when lane markings are detected, a vehicle ahead is detected (only necessary when traveling under 37 mph), the driver's hands are detected on the steering wheel, and the windshield wiper is not operating at a low or high speed. The steering assist is placed into a temporary standby mode when a turn signal is used or lane markings on both sides of the lane are not detected. If the system detects that the steering wheel is not being operated or the driver's hands are off of the steering wheel, then a cascade of warnings will be presented, followed by a quick brake application, and finally, the vehicle will slow to a stop with the hazard flashers turned on. Additionally, the ProPILOT Assist system is not available when the driver seat belt is unbuckled. ProPILOT Assist is a Level 2 driving automation technology.

Method

Feature dependencies

Many sensor systems enable more than one ADAS or driving automation feature and, consequently, some features are only available with other features. For example, BSW and RCTA both use radar sensors in the rear bumper to detect vehicles approaching from the side either in adjacent lanes (BSW) or approaching the path of a reversing vehicle (RCTA). BSW and RCTA are often bundled together, and the effect cannot be separated. Similarly, multiple features may be available as standard equipment on specific models but optional or not available on others. The insurance data provided to HLDI do not contain information on the type of crash that led to a claim, so it is not possible to separate the effect of individual features in a bundle on insurance losses. Due to these feature dependencies, we combined BSW with RCTA for the statistical analysis and also Around View Monitor with Moving Object Detection and Rear Automatic Braking with Rear Sonar System. The presence of additional features related to other feature dependencies are noted in the *Results*.

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 Number (VIN), and must be determined from build information maintained by the manufacturer. Nissan provided HLDI with VINs for 2015–19 model year Nissan Rogue vehicles and information about the presence or absence of the ADAS and driving automation technologies listed previously for each VIN. However, this study only included 2017–19 Nissan Rogues for the following reasons:

- The 2015 Nissan Rogue was excluded from the study because the sensors that enabled certain functions differed from the sensors that enabled the same functions in the 2016–19 Nissan Rogues. Specifically, the BSW system in the 2015 Nissan Rogue used image processing of a rear-facing camera to detect approaching vehicles in adjacent lanes instead of radars mounted in the rear bumper like the 2016–19 Nissan Rogues. Image processing of the rear-facing camera image also was used to support detection of lane markings to enable a lane departure warning system; a similar function was enabled using a front-facing camera in 2017–19 Nissan Rogues.
- The 2016 Nissan Rogue was excluded from the study because the feature dependencies of the optional ADAS were different from subsequent model years and did not permit the effect of Around View Monitor with Moving Object Detection and BSW with RCTA on insurance loss to be computed.

Table 1 shows the model years and total collision exposure in insured vehicle years for the 2017–19 Nissan Rogues included in this study. **Table 2** lists the percentage of collision exposure by feature.

Table 1: Feature exposure by vehicle series

Make	Series	Model year range	Total collision exposure
Nissan	Rogue 4D 2WD	2017–19	282,951
Nissan	Rogue 4D 4WD	2017–19	415,960
Total collision exposure			**698,911**

Table 2: Percent of collision exposure with feature

Feature	Collision exposure with feature
Forward Emergency Braking	52%
Intelligent Cruise Control	18%
ProPILOT Assist	6%
Blind Spot Warning / Rear Cross-Traffic Alert	80%
Around View Monitor / Moving Object Detection	36%
Rear Automatic Braking / Rear Sonar System	8%

Insurance data

Automobile insurance covers damage to vehicles and property in crashes plus injuries to people involved in the 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 collision, PDL, BI liability, PIP, and MedPay coverages. Exposure is measured in insured vehicle years. An insured vehicle year is one vehicle insured for one year, two vehicles insured for six months, etc.

Different crash avoidance features may affect insurance coverage types differently. Hence, 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 another vehicle; this coverage is common to all 50 states. PDL coverage insures against vehicle damage that at-fault drivers cause to other people's vehicles and property in crashes. This coverage exists in all states except Michigan, where vehicle damage is covered on a no-fault basis where each insured vehicle pays for its own damage in a crash regardless of who is at fault.

Coverage of injuries is more complex. BI liability coverage insures against medical, hospital, and other expenses for injuries that at-fault drivers inflict on occupants of other vehicles or other road users. Although motorists in most states may have BI liability coverage, this information is analyzed using information from 33 states with traditional tort insurance systems where the at-fault driver has first obligation to pay for injuries. MedPay coverage also is sold in the 33 states with traditional tort insurance systems and covers injuries to insured drivers and passengers in their vehicles but not injuries to people in other vehicles involved in the crash. Seventeen states employ no-fault injury systems. In these systems, PIP coverage pays 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 was excluded from the injury analyses.

Statistical methods

Regression analysis was used to quantify the effect of each vehicle feature or groups of features while controlling for the other features and covariates. The covariates included calendar year, model year, garaging state, the number of registered vehicles per square mile (vehicle density), rated driver age group, rated driver gender, rated driver marital status, deductible range (collision coverage only), and risk. A single variable called SERIESMY was created using the model year and vehicle series to control for the variation caused by vehicle design changes across model years. A binary variable for Forward Emergency Braking (FEB), Intelligent Cruise Control combined with FEB, ProPILOT Assist combined with Intelligent Cruise Control and FEB, BSW and RCTA, Around View Monitor and Moving Object Detection, and Rear Automatic Braking and Rear Sonar System was included to indicate when each feature or feature group was present or absent.

Claim frequency was modeled using a Poisson distribution, whereas the average loss payment per claim, or 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. Estimates for frequency, severity, and overall losses are presented for collision and property damage liability coverages. Three frequency estimates are presented for PIP, BI liability, and MedPay. The first is the frequency for all claims including those that already have been paid and 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 percent for PIP, 69 percent for BI liability, and 62 percent for MedPay. The low-severity range was less than $1,000 for PIP and MedPay, and less than $5,000 for BI liability coverage. The high-severity range covered all loss payments that exceeded the low-severity range.

For space reasons, only the estimates for the individual ADAS and driving automation technology features are shown on the following pages. The effect associated with the presence of a feature on each insurance loss measure was expressed as a percentage change to simplify the presentation of results. The effect was computed by exponentiating the parameter estimate, subtracting 1, and then multiplying the resultant by 100. For example, the parameter estimate for the effect of FEB on collision claim frequency was −0.0220; thus, vehicles with this feature had 2 percent fewer collision claims than vehicles without the feature ((exp(−0.0220)−1) × 100=−2). The **Appendix** contains full model results for collision claim frequencies to illustrate the regression analyses.

Results

Results for the various ADAS and driving automation technology features are summarized in **Tables 3–8**. In each table, the lower and upper bounds represent the 95 percent confidence limits for each estimate. Estimates that are statistically significant at the 95 percent confidence level are bolded.

Forward Emergency Braking

The effects of Forward Emergency Braking (FEB) on insurance losses are summarized in **Table 3**. The presence of FEB was associated with a 2 percent reduction in collision claim frequency and a significant 8 percent reduction in PDL claim frequency. Collision claim severity was significantly increased by 5 percent for Rogues with FEB compared with Rogues without the feature. PDL claim severity was increased by 2 percent for vehicles with FEB, but this effect was not statistically significant. Overall losses under collision coverage for vehicles with FEB increased by 2 percent but decreased by 6 percent under PDL coverage; neither change was statistically significant.

The effect of FEB on insurance losses under the different injury coverages was mixed. FEB was associated with a 14 percent reduction in BI liability claim frequency, a 4 percent increase in MedPay claim frequency, and a 0.1 percent increase in PIP claim frequency. None of these changes in claim frequency were statistically significant. The presence of FEB was associated with a significant 30 percent decrease in the frequency of low-severity BI claims (<$5,000) and a significant 32 percent increase in the frequency of low-severity PIP claims (<$1,000). None of the other results were statistically significant.

Table 3: Change in insurance losses for Forward Emergency Braking									
Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-5.4%	-2.2%	1.2%	0.9%	**4.7%**	8.5%	-2.6%	2.4%	7.6%
Property damage liability	-12.5%	**-7.8%**	-2.8%	-2.6%	2.3%	7.5%	-12.2%	-5.6%	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	-26.9%	-14.2%	0.7%	-48.9%	**-29.9%**	-3.7%	-31.8%	-10.8%	16.7%
Medical payment	-10.6%	4.0%	21.1%	-49.8%	-19.4%	29.3%	-3.9%	18.2%	45.3%
Personal injury protection	-9.2%	0.1%	10.4%	4.7%	**32.2%**	66.9%	-19.2%	-8.3%	4.0%

Intelligent Cruise Control and Forward Emergency Braking

Intelligent Cruise Control was not available as a stand-alone option on the 2017–19 Nissan Rogue. Intelligent Cruise Control on the 2017 Nissan Rogue was packaged with Intelligent Lane Intervention and Forward Emergency Braking (FEB) with pedestrian detection. The system was packaged with Around View Monitor and Moving Object Detection on some 2018–19 Nissan Rogues and was a standard feature along with other ADAS features (e.g., Forward Emergency Braking with pedestrian detection, Intelligent Lane Intervention, High Beam Assist) on other 2018–19 Nissan Rogues.

Table 4 summarizes the effects of Intelligent Cruise Control and Forward Emergency Braking (FEB) on insurance losses after controlling for other vehicle features and variables included in the model. Intelligent Cruise Control, in combination with FEB, was associated with a 2 percent decrease in collision claim frequency, a significant 8 percent increase in collision claim severity, and an almost 6 percent increase in overall losses under collision coverage. PDL claim frequency decreased by 4 percent, PDL claim severity increased by 3 percent, and overall losses under PDL coverage decreased by 1 percent for Rogues with Intelligent Cruise Control and FEB relative to Rogues without the features.

The effect of Intelligent Cruise Control with FEB on insurance losses under injury coverage types was mixed. The presence of Intelligent Cruise Control and FEB was associated with a 5 percent decrease in BI liability claim frequency, a 5 percent decrease in MedPay claim frequency, and a 7 percent increase in PIP claim frequency. None of the changes in insurance losses under the different injury coverage types were statistically significant.

Table 4: Change in insurance losses for Intelligent Cruise Control and Forward Emergency Braking									
Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-6.7%	-1.9%	3.2%	2.1%	**7.8%**	13.8%	-1.8%	5.8%	13.9%
Property damage liability	-11.3%	-4.1%	3.7%	-4.1%	3.2%	11.0%	-11.0%	-1.0%	10.1%
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	-24.7%	-5.1%	19.6%	-47.0%	-17.1%	29.6%	-44.7%	-17.6%	22.8%
Medical payment	-23.9%	-4.5%	20.0%	-53.4%	-8.2%	81.1%	-17.5%	12.3%	53.0%
Personal injury protection	-7.4%	6.9%	23.5%	-10.5%	28.0%	83.0%	-18.9%	-2.5%	17.2%

ProPILOT Assist, Intelligent Cruise Control, and Forward Emergency Braking

The effect of ProPILOT Assist, in combination with Intelligent Cruise Control and FEB on insurance losses under different coverage types after controlling for the effects of other ADAS features and other variables on insurance losses is summarized in **Table 5**. ProPILOT Assist, Intelligent Cruise Control, and FEB, altogether, were associated with a 1 percent increase in collision claim frequency, a significant 11 percent increase in collision claim severity, and a significant 13 percent increase in overall losses under collision coverage. The presence of ProPILOT Assist, Intelligent Cruise Control, and FEB was associated with a 6 percent reduction in PDL claim frequency. PDL claim severity was increased by 2 percent and overall losses were decreased by 4 percent for Rogues with these features. The changes in insurance losses under PDL coverage were not statistically significant.

The effect of ProPilot Assist, Intelligent Cruise Control, and FEB on insurance losses under the injury coverage types was mixed. The presence of these features was associated with a 13 percent reduction in BI claim frequency, a 19 percent reduction in MedPay claim frequency, and a 5 percent increase in PIP claim frequency; none of the effects were statistically significant. ProPILOT Assist, in combination with Intelligent Cruise Control and FEB also was associated with a significant 70 percent increase in the frequency of low-severity PIP claims. None of the other results were statistically significant.

Table 5: Change in insurance losses for ProPILOT Assist, Forward Emergency Braking, and Intelligent Cruise Control

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-5.4%	1.1%	8.1%	3.6%	**11.2%**	19.4%	2.1%	**12.5%**	23.9%
Property damage liability	-15.0%	-5.6%	4.9%	-7.6%	2.0%	12.5%	-16.6%	-3.7%	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	-36.4%	-13.1%	18.8%	-60.6%	-27.2%	34.5%	-60.3%	-30.3%	22.6%
Medical payment	-40.8%	-19.1%	10.4%	-81.3%	-48.7%	40.8%	-38.8%	-5.3%	46.7%
Personal injury protection	-12.9%	5.0%	26.5%	7.0%	**70.0%**	169.6%	-30.3%	-11.6%	12.3%

Blind Spot Warning and Rear Cross-Traffic Alert

Blind Spot Warning (BSW) and Rear Cross-Traffic Alert (RCTA) were always present together on the 2017–19 Nissan Rogue. **Table 6** summarizes the results for the combination of BSW and RCTA on the Nissan Rogue. The presence of BSW and RCTA was associated with significant reductions in collision claim frequency (–5 percent) and PDL claim frequency (–12 percent). Collision claim severity was slightly increased by 2 percent for Rogues with BSW and RCTA, and PDL claim severity was increased by 4 percent; neither effect was statistically significant. Despite increased claim severity under vehicle damage coverage types, BSW and RCTA were associated with 2 and 9 percent reductions in overall losses under collision and PDL coverages, respectively, though only the benefit for PDL is significant.

The presence of BSW and RCTA was associated with a 9 percent reduction in BI claim frequency. The frequency of high-severity BI claims was significantly reduced by 18 percent for Rogues with these features. BSW and RCTA also were associated with reductions in MedPay claim frequency (–13 percent) and PIP claim frequency (–3 percent), but only the reduction in MedPay claim frequency was statistically significant.

Table 6: Change in insurance losses for Blind Spot Warning and 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	-7.1%	**-4.7%**	-2.2%	-0.4%	2.4%	5.2%	-6.0%	-2.4%	1.3%
Property damage liability	-14.9%	**-11.6%**	-8.2%	-0.1%	3.5%	7.1%	-13.2%	**-8.6%**	-3.7%

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	-17.7%	-8.9%	0.8%	-17.2%	-0.5%	19.6%	-30.8%	**-18.3%**	-3.6%
Medical payment	-22.3%	**-13.1%**	-2.7%	-37.9%	-14.4%	17.9%	-24.1%	-11.1%	4.1%
Personal injury protection	-10.0%	-3.4%	3.7%	-9.6%	9.1%	31.6%	-12.0%	-3.8%	5.2%

Around View Monitor and Moving Object Detection

Around View Monitor and Moving Object Detection were part of an optional package on the 2017–19 Nissan Rogue; the optional package on the 2018–19 Nissan Rogue also included Intelligent Cruise Control. The combination of Around View Monitor and Moving Object Detection was associated with a 2 percent reduction in collision claim frequency and a significant 7 percent reduction in PDL claim frequency. The severity of collision claims was reduced by 1 percent with the presence of this combination, and PDL claim severity was reduced by 4 percent for Rogues with the feature relative to Rogues without it. Overall, Around View Monitor and Moving Object Detection were associated with a 3 percent reduction in overall losses under collision coverage and a significant 10 percent reduction in overall losses under PDL coverage.

The combination of Around View Monitor and Moving Object Detection was associated with significant reductions in claim frequency under the different injury coverage types. BI liability claim frequency was reduced by 18 percent, MedPay claim frequency was reduced by 14 percent, and PIP claim frequency was reduced by 15 percent for vehicles with this combination.

Table 7: Change in insurance losses for Around View Monitor and Moving Object Detection

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-4.5%	-1.7%	1.2%	-4.2%	-1.2%	1.9%	-6.9%	-2.9%	1.3%
Property damage liability	-10.5%	**-6.5%**	-2.3%	-7.5%	-3.6%	0.4%	-15.1%	**-9.9%**	-4.3%

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	-27.8%	**-17.9%**	-6.7%	-41.8%	**-26.1%**	-6.2%	-31.9%	-15.6%	4.6%
Medical payment	-24.2%	**-13.6%**	-1.5%	-45.3%	-19.6%	18.1%	-31.4%	**-17.6%**	-1.1%
Personal injury protection	-21.4%	**-14.8%**	-7.7%	-32.5%	-17.2%	1.6%	-22.0%	**-13.6%**	-4.3%

Rear Automatic Braking and Rear Sonar System

Rear Automatic Braking and Rear Sonar System were part of an optional package on the 2019 Nissan Rogue. **Table 8** summarizes the results for this combination on the Nissan Rogue. Their presence was associated with a 14 percent reduction in collision claim frequency and a 31 percent reduction in PDL claim frequency. Both effects were statistically significant. Collision claim severity was significantly increased by 7 percent for Rogues with the feature relative to Rogues without it, and PDL claim severity was significantly increased by 23 percent. Overall, Rear Automatic Braking and Rear Sonar System were associated with a 7 percent reduction in overall losses under collision coverage and a significant 15 percent reduction in overall losses under PDL coverage.

Table 8: Change in insurance losses for Rear Automatic Braking and Rear Sonar System

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-18.9%	**-13.5%**	-7.8%	0.3%	**7.4%**	15.0%	-15.4%	-7.1%	2.0%
Property damage liability	-37.5%	**-31.0%**	-23.7%	12.4%	**23.3%**	35.3%	-25.7%	**-14.9%**	-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	-39.9%	-21.5%	2.7%	-41.2%	5.7%	90.0%	-47.8%	-14.9%	38.7%
Medical payment	-15.0%	14.5%	54.1%	-66.2%	-7.9%	151.3%	-25.6%	14.4%	75.8%
Personal injury protection	-15.0%	0.6%	19.2%	-26.4%	18.3%	90.3%	-17.8%	1.8%	26.1%

The purpose of Rear Automatic Braking and Rear Sonar System is to assist drivers while performing backing maneuvers. Because backing is typically done at low speeds, the expectation is that these systems would be more likely to prevent low-severity collisions and PDL claims as opposed to high-severity claims. As shown in Figures 1 and 2 below, the benefits to collision and PDL claim frequency were lessened as the claim severity range increased. Collision claim frequency was reduced by 17 percent with the presence of Rear Automatic Braking and Rear Sonar System for low-severity (<$2,000) claims, 16 percent for mid-low severity ($2,000–$4,999) claims, 8 percent for mid-high severity ($5,000–$11,999) claims, and 7 percent for high severity ($12,000+) claims. The results for low- and mid-low severity claims were statistically significant. For PDL, a similar pattern emerged, showing claim frequency reductions of 44 percent for low-severity (<$1,500) claims, 30 percent for mid-severity ($1,500–$6,999) claims, and 7 percent for high severity ($7,000+) claims. Both changes in the low- and mid-severity ranges were statistically significant. The large confidence bounds for effects in the high- and mid-high severity range under collision and the high-severity range under PDL highlights the limited amount of data, so the results should be interpreted with caution. Consequently, the observed increases in both collision and PDL claim severity are likely attributable to a greater reduction in lower severity claims, resulting in the claim severity distribution shifting towards a higher mean.

Figure 1: Change in collision claim frequency by severity range for Rear Automatic Braking and Rear Sonar System

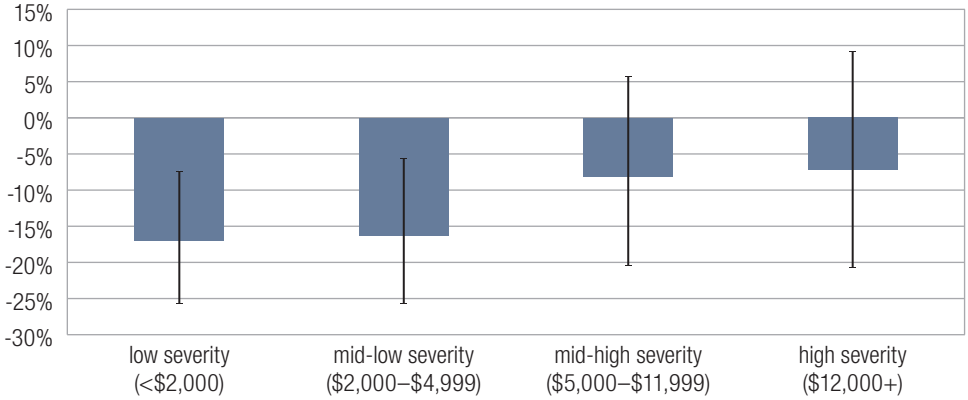
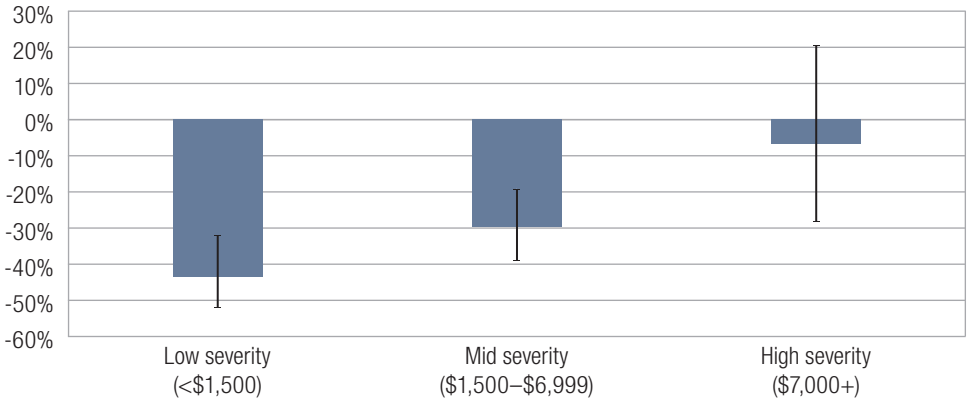


Figure 2: Change in PDL claim frequency by severity range for Rear Automatic Braking and Rear Sonar System



The effect of Rear Automatic Braking and Rear Sonar System on insurance losses under injury coverage types was mixed. This combination was associated with a 22 percent reduction in BI liability claim frequency, a 15 percent increase in MedPay claim frequency, and a 1 percent increase in PIP claim frequency. None of these changes was statistically significant.

Discussion

Consistent with previous HLDI research (HLDI, 2020b), most ADAS features on the 2017–19 Nissan Rogue were associated with reductions in collision claim frequency and PDL claim frequency; most of the effects were statistically significant. The driving automation technologies available on the 2017–19 Nissan Rogues were expected to further reduce insurance losses, but results were mixed.

Intelligent Cruise Control, a Level 1 driving automation technology that assists with speed control and maintains following distance, did not further reduce collision claim frequency or PDL claim frequency compared with Forward Emergency Braking (FEB) alone. In fact, the presence of Intelligent Cruise Control, in combination with FEB, was associated with a decrease, but not statistically significant, in the collision and PDL claim frequency reductions compared with FEB alone. On the other hand, ProPILOT Assist, a Level 2 driving automation technology that adds sustained steering support to Intelligent Cruise Control, was associated with an increase in collision claim frequency but a reduction in PDL claim frequency in combination with Intelligent Cruise Control and FEB. Neither result was statistically significant, but the reduction for PDL claim frequency was larger compared with Intelligent Cruise Control and FEB together.

The insurance loss results for Intelligent Cruise Control were unexpected. Previous research has found that using ACC increases following distance (Kessler et al., 2012), which would be expected to reduce front-to-rear crash risk, but the presence of an ACC system on the 2017–19 Nissan Rogue lessened the reductions of insurance losses under vehicle damage coverage types compared with FEB only. However, the estimate for the Nissan Rogue Intelligent Cruise Control did not reflect the effect of this feature alone, as it was often available in combination with Intelligent Lane Intervention and FEB with pedestrian detection. Pedestrian detection would not be expected to influence collision and PDL claim frequency. On the other hand, lane departure warning and prevention systems like Intelligent Lane Intervention have been shown to reduce relevant police-reported crash rates (Cicchino, 2018) even if the effect of these systems on insurance losses is indiscernible (HLDI, 2018b). A companion HLDI analysis of Intelligent Cruise Control and other ADAS features on the 2016–19 Nissan Sentra, Murano, and Altima better isolated the effects of Intelligent Cruise Control from other ADAS features. This analysis found that the system with FEB significantly reduced collision claim frequency and PDL claim frequency by 8 percent and 24 percent, respectively, and was associated with large and significant reductions in claim frequency for each injury coverage type (HLDI, 2021). Hence, the dependency between Intelligent Cruise Control and Intelligent Lane Intervention may have obscured the benefits of the Nissan Rogue's Intelligent Cruise Control on insurance losses in the current analysis.

As noted previously, the ProPILOT Assist system added lane centering to Intelligent Cruise Control and was a standalone option on the most expensive 2018–19 Nissan Rogue model that was already equipped with Intelligent Cruise Control and a host of other ADAS features. A field operational test of vehicles with ACC and Level 2 driving automation technology found that people who drove a 2017 Volvo S90 used the vehicle's Level 2 driving automation technology 3 times more than the ACC system alone (Reagan, Hu, Cicchino, Seppelt, Fridman, & Glazer, 2019). Hence, it is plausible that the estimated benefit of ProPILOT Assist may be due to the increased use of Intelligent Cruise Control and not the lane-centering feature alone. Future HLDI research should examine the point-of-impact distribution of all collision claims alone and with matching PDL claims for Nissan Rogues with and without ProPILOT Assist, to help identify the crash types that the feature is preventing and the mechanism through which it is reducing insurance losses.

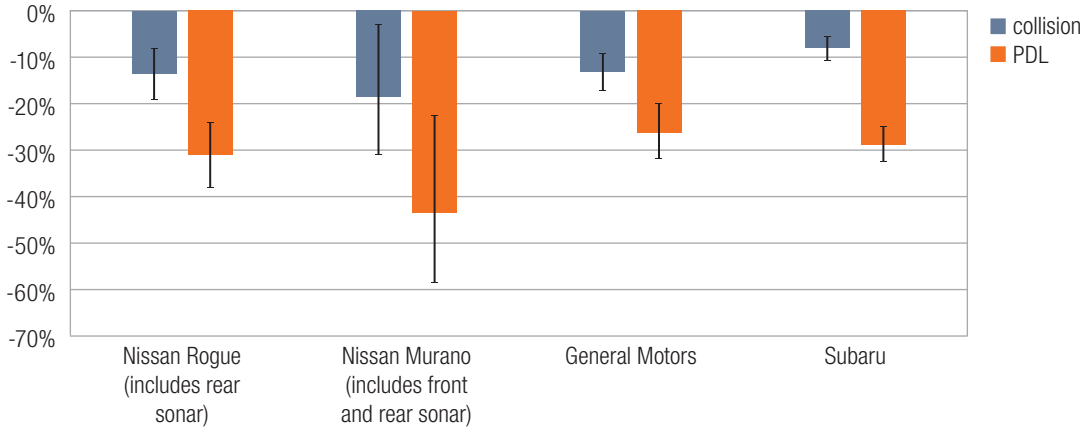
The average severity of collision claims by claim size is shown in **Table 9** for Rogues with FEB; FEB and Intelligent Cruise Control; FEB, Intelligent Cruise Control, and ProPILOT Assist; or Rogues without any of these technologies. Collision claim severity was similar in each claim size range, except for claims of $12,000 or more. The average size of high-severity collision claims of $12,000 or more was 10 percent higher for vehicles with FEB; 17 percent higher for vehicles with FEB and Intelligent Cruise Control; and 26 percent higher for vehicles with FEB, Intelligent Cruise Control, and ProPILOT Assist relative to vehicles without these technologies. The ADAS and driving automation technologies available on the 2017–19 Nissan Rogue were first introduced on the most expensive models before becoming available on less expensive models in a subsequent model year. Consequently, the cost of repairing Nissan Rogues with ADAS or driving automation technology that were either severely damaged in a crash or declared a total loss would be more expensive, on average, due to differences in base price and would be reflected by the increased collision claim severity associated with these features.

Table 9: Average severity for 2017–19 Nissan Rogue collision claims by claim size and features					
Features	Low severity (<$2,000)	Mid-low severity ($2,000–$4,999)	Mid-high severity ($5,000–$11,999)	High severity ($12,000+)	Overall severity
No FEB, Intelligent Cruise Control, or ProPILOT Assist	$1,035	$3,236	$7,496	$18,436	$5,393
FEB only	$1,044	$3,247	$7,590	$20,211	$5,825
FEB and Intelligent Cruise Control	$1,048	$3,248	$7,562	$21,494	$5,651
FEB, Intelligent Cruise Control, and ProPILOT Assist	$1,092	$3,203	$7,624	$23,201	$6,582

As found in previous HLDI studies of ADAS, BSW with RCTA and AVM with MOD significantly reduced claim frequency under different coverage types. The 5 percent and 12 percent reductions in collision and PDL claim frequency associated with the Nissan Rogue's BSW with RCTA systems were larger than the 3 percent and 7 percent reductions observed for these coverage types observed in previous HLDI studies (2020b) of ADAS. The 7 percent reduction in PDL claim frequency observed for AVM with MOD was similar to the 7 percent reduction in PDL claim frequency observed for Audi's surround view camera (HLDI, 2018). AVM with MOD significantly reduced claim frequency under each injury coverage, but the confidence bounds for these effects were large so these effects may change as the data mature.

The combination of Rear Automatic Braking and Rear Sonar System significantly reduced claim frequency under collision and PDL coverages. The 14 percent reduction in collision claim frequency and 31 percent reduction in PDL claim frequency were consistent with other estimates of rear automatic braking systems as shown in **Figure 3** below (HLDI, 2020b, 2021). These results support the growing evidence of the significant impact that rear automatic braking systems have on reducing insurance losses.

Figure 3: Change in claim frequency for Rear AEB by coverage type



Limitations

ADAS and driving automation technology can only affect insurance losses if the technology is used by drivers. Many ADAS systems, like FCW and automatic emergency braking, are enabled at ignition or are left on by drivers (Reagan, Cicchino, Kerfoot, & Weast, 2018). In contrast, the use of driving automation technologies like Intelligent Cruise Control and ProPILOT Assist is discretionary, and drivers mostly use Level 1 and Level 2 driving automation technology on limited-access freeways and highways (Reagan et al., 2019). Hence, driving automation technology like the ones examined in this study may only act on a limited population of crashes that result in insurance losses, which suggests that the actual effect of Intelligent Cruise Control and ProPILOT Assist on insurance losses may be much greater than the effect observed in this study.

The data supplied to HLDI do not include detailed crash information. Information on point of impact is limited and information on the vehicle's transmission status and the status of ADAS or driving automation technology at the time of loss is not available. The technologies in this study target specific crash types. For example, FEB is designed

to prevent front-to-rear crashes while AVM is designed to prevent low-speed collisions that typically occur during backing. All collisions, regardless of the ability of a feature to mitigate or prevent a crash and a subsequent insurance claim, were included in the analysis and may have obscured the effects that a given feature had on the relevant crash population and associated insurance loss.

Finally, data were relatively sparse for vehicles with Intelligent Cruise Control or ProPILOT Assist. Consequently, the confidence bounds were large for many of the effects (e.g., ProPILOT Assist and BI liability claim frequency). This analysis will be repeated and expanded as the data mature to better understand how these systems are affecting insurance losses.

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Appendix

Appendix: Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Intercept		1	-8.5071		0.0337	-8.5731	-8.4410	63719.20	
Calendar year	2016	1	-1.3906	-75.1%	0.2042	-1.7909	-0.9903	46.35	<0.0001
	2017	1	0.0280	2.8%	0.0138	0.0008	0.0552	4.10	0.0429
	2019	1	0.0006	0.1%	0.0096	-0.0182	0.0195	0.00	0.9458
	2018	0							
Vehicle model year and series	2017 Rogue 4D 2WD	1	0.0509	5.2%	0.0256	0.0006	0.1013	3.94	0.0473
	2017 Rogue 4D 4WD	1	0.0157	1.6%	0.0204	-0.0244	0.0558	0.59	0.4429
	2018 Rogue 4D 2WD	1	0.0106	1.1%	0.0207	-0.0300	0.0513	0.26	0.6085
	2019 Rogue 4D 2WD	1	0.0193	1.9%	0.0351	-0.0495	0.0883	0.30	0.5815
	2019 Rogue 4D 4WD	1	0.0068	0.7%	0.0312	-0.0545	0.0681	0.05	0.8273
	2018 Rogue 4D 4WD	0							
Rated driver age group	14–24	1	0.1112	11.8%	0.0210	0.0699	0.1525	27.83	<0.0001
	25–29	1	0.0897	9.4%	0.0177	0.0550	0.1245	25.67	<0.0001
	30–39	1	0.0145	1.5%	0.0146	-0.0141	0.0432	0.99	0.3191
	50–59	1	-0.0402	-3.9%	0.0147	-0.0691	-0.0112	7.39	0.0066
	60–64	1	-0.0317	-3.1%	0.0181	-0.0673	0.0038	3.05	0.0806
	65–69	1	0.0235	2.4%	0.0190	-0.0137	0.0608	1.53	0.2157
	70+	1	0.1219	13.0%	0.0168	0.0888	0.1550	52.14	<0.0001
	Unknown	1	-0.0426	-4.2%	0.0357	-0.1127	0.0274	1.42	0.2335
	40–49	0							
Rated driver gender	Male	1	-0.0312	-3.1%	0.0093	-0.0495	-0.0128	11.15	0.0008
	Unknown	1	-0.1634	-15.1%	0.0415	-0.2449	-0.0820	15.48	<0.0001
	Female	0							
Rated driver marital status	Single	1	0.1890	20.8%	0.0094	0.1704	0.2075	400.07	<0.0001
	Unknown	1	0.2184	24.4%	0.0389	0.1420	0.2948	31.43	<0.0001
	Married	0							
Risk	Nonstandard	1	0.2608	29.8%	0.0205	0.2205	0.3012	160.72	<0.0001
	Standard	0							
State	Alabama	1	0.1214	12.9%	0.0417	0.0396	0.2032	8.47	0.0036
	Alaska	1	0.3317	39.3%	0.1331	0.0707	0.5927	6.20	0.0127
	Arizona	1	0.1813	19.9%	0.0380	0.1066	0.2559	22.67	<0.0001
	Arkansas	1	0.1092	11.5%	0.0598	-0.0079	0.2264	3.34	0.0677
	California	1	0.3603	43.4%	0.0217	0.3176	0.4030	273.75	<0.0001
	Colorado	1	0.2649	30.3%	0.0411	0.1843	0.3456	41.49	<0.0001
	Connecticut	1	0.0219	2.2%	0.0365	-0.0495	0.0935	0.36	0.5476
	Delaware	1	0.0991	10.4%	0.0715	-0.0412	0.2394	1.92	0.1663
	District of Columbia	1	0.7313	107.8%	0.0974	0.5404	0.9222	56.37	<0.0001
	Florida	1	-0.0702	-6.8%	0.0211	-0.1116	-0.0287	11.02	0.0009
	Georgia	1	0.0804	8.4%	0.0298	0.0219	0.1390	7.25	0.0071
	Hawaii	1	0.1494	16.1%	0.0729	0.0065	0.2923	4.20	0.0404
	Idaho	1	0.0296	3.0%	0.0982	-0.1628	0.2221	0.09	0.7626
	Illinois	1	0.1340	14.3%	0.0296	0.0759	0.1921	20.42	<0.0001

Appendix: Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	Indiana	1	0.1634	17.8%	0.0467	0.0718	0.2550	12.23	0.0005
	Iowa	1	0.0785	8.2%	0.0605	-0.0401	0.1971	1.68	0.1947
	Kansas	1	-0.0416	-4.1%	0.0742	-0.1871	0.1039	0.31	0.5751
	Kentucky	1	-0.0846	-8.1%	0.0521	-0.1868	0.0176	2.63	0.1049
	Louisiana	1	0.2413	27.3%	0.0379	0.1669	0.3156	40.50	<0.0001
	Maine	1	0.1174	12.5%	0.0649	-0.0097	0.2446	3.27	0.0704
	Maryland	1	0.3669	44.3%	0.0347	0.2989	0.4350	111.76	<0.0001
	Massachusetts	1	0.6450	90.6%	0.0336	0.5790	0.7110	367.11	<0.0001
	Michigan	1	0.3932	48.2%	0.0401	0.3145	0.4719	95.83	<0.0001
	Minnesota	1	0.0649	6.7%	0.0433	-0.0200	0.1499	2.24	0.1343
	Mississippi	1	0.2309	26.0%	0.0563	0.1204	0.3413	16.80	<0.0001
	Missouri	1	0.0206	2.1%	0.0441	-0.0659	0.1071	0.22	0.6402
	Montana	1	-0.0015	-0.1%	0.1278	-0.2521	0.2490	0.00	0.9904
	Nebraska	1	0.0221	2.2%	0.0661	-0.1073	0.1517	0.11	0.7372
	Nevada	1	0.2206	24.7%	0.0509	0.1207	0.3204	18.76	<0.0001
	New Hampshire	1	0.2663	30.5%	0.0524	0.1636	0.3690	25.82	<0.0001
	New Jersey	1	0.0606	6.2%	0.0270	0.0076	0.1137	5.02	0.0250
	New Mexico	1	0.2452	27.8%	0.0698	0.1083	0.3820	12.34	0.0004
	New York	1	0.2386	26.9%	0.0238	0.1918	0.2854	99.81	<0.0001
	North Carolina	1	-0.0640	-6.2%	0.0340	-0.1308	0.0027	3.54	0.0600
	North Dakota	1	0.3640	43.9%	0.1125	0.1434	0.5846	10.46	0.0012
	Ohio	1	-0.0315	-3.1%	0.0317	-0.0937	0.0306	0.99	0.3200
	Oklahoma	1	0.0365	3.7%	0.0537	-0.0688	0.1418	0.46	0.4966
	Oregon	1	0.1153	12.2%	0.0556	0.0061	0.2244	4.29	0.0384
	Pennsylvania	1	0.2629	30.1%	0.0269	0.2101	0.3157	95.16	<0.0001
	Rhode Island	1	0.1405	15.1%	0.0689	0.0054	0.2756	4.16	0.0415
	South Carolina	1	-0.0140	-1.4%	0.0417	-0.0957	0.0677	0.11	0.7366
	South Dakota	1	0.0278	2.8%	0.1541	-0.2743	0.3299	0.03	0.8567
	Tennessee	1	0.1643	17.9%	0.0315	0.1024	0.2263	27.09	<0.0001
	Utah	1	-0.0158	-1.6%	0.0582	-0.1300	0.0984	0.07	0.7861
	Vermont	1	0.0421	4.3%	0.1068	-0.1672	0.2515	0.16	0.6930
	Virginia	1	0.1533	16.6%	0.0316	0.0913	0.2153	23.49	<0.0001
	Washington	1	0.1699	18.5%	0.0417	0.0881	0.2517	16.59	<0.0001
	West Virginia	1	0.0611	6.3%	0.0716	-0.0792	0.2015	0.73	0.3932
	Wisconsin	1	0.0267	2.7%	0.0487	-0.0688	0.1223	0.30	0.5833
	Wyoming	1	-0.0501	-4.9%	0.1620	-0.3677	0.2674	0.10	0.7569
	Texas	0							
Deductible range	0–250	1	0.1005	10.6%	0.0113	0.0782	0.1228	77.81	<0.0001
	1001+	1	-0.1590	-14.7%	0.0119	-0.1825	-0.1356	176.39	<0.0001
	501–1000	1	-0.4774	-38.0%	0.0593	-0.5938	-0.3610	64.63	<0.0001
	251–500	0							
Registered vehicle density	0–99	1	-0.3008	-26.0%	0.0156	-0.3315	-0.2701	368.39	<0.0001
	100–499	1	-0.1726	-15.9%	0.0106	-0.1934	-0.1518	264.30	<0.0001
	500+	0							

Appendix: Illustrative regression results — collision frequency								
Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Around View Monitor / Moving Object Detection	1	-0.0171	-1.7%	0.0146	-0.0459	0.0116	1.36	0.2428
Blind Spot Warning / Rear Cross-Traffic Alert	1	-0.0482	-4.7%	0.0131	-0.0740	-0.0223	13.38	0.0003
Forward Emergency Braking	1	-0.0220	-2.2%	0.0173	-0.0560	0.0119	1.62	0.2033
Intelligent Cruise Control and Forward Emergency Braking	1	-0.0189	-1.9%	0.0257	-0.0693	0.0314	0.54	0.4618
ProPilot Assist, Intelligent Cruise Control, and Forward Emergency Braking	1	0.0112	1.1%	0.0339	-0.0552	0.0776	0.11	0.7405
Rear Automatic Braking / Rear Sonar System	1	-0.1448	-13.5%	0.0327	-0.2089	-0.0806	19.60	<0.0001

HLDI
Highway Loss Data Institute

4121 Wilson Boulevard, 6th floor
Arlington, VA 22203
+1 703 247 1500
iihs-hldi.org

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