HLDI
Highway Loss Data Institute

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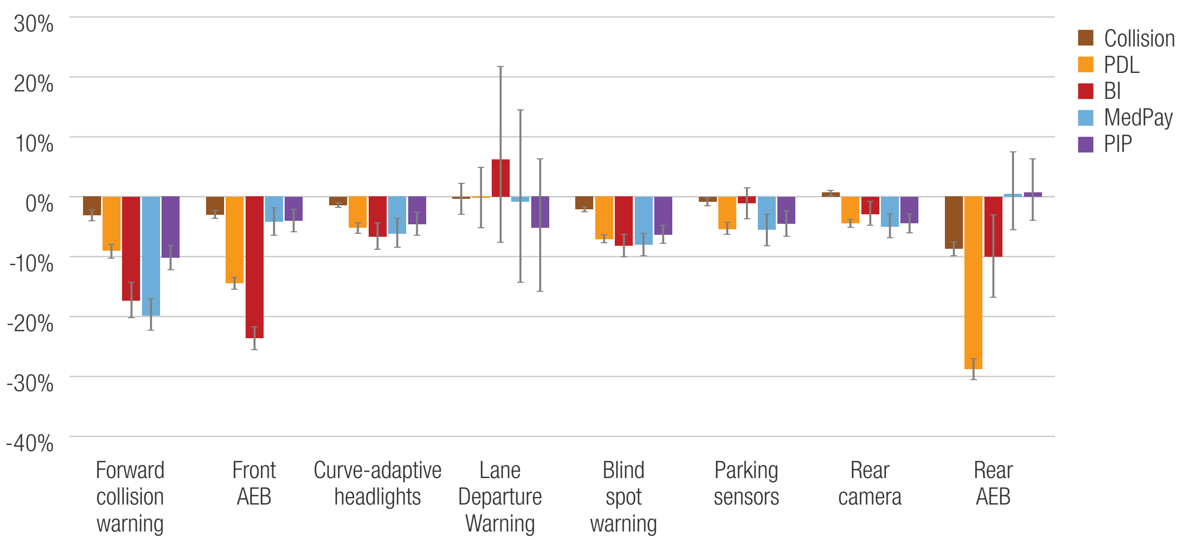
Compendium of HLDI collision avoidance research

Summary

The Highway Loss Data Institute (HLDI) has evaluated collision avoidance technologies since 2009, publishing more than 95 reports on the topic.

This compendium synthesizes HLDI's most recent findings for individual manufacturers to estimate the combined effect of each technology. With the exception of lane departure warning, rear cameras and rear automatic emergency braking, almost all the technologies are associated with statistically significant reductions in claim frequencies. The only statistically significant increase in claim frequency was the small increase under collision coverage for rear cameras. Both front and rear automatic emergency braking, which take action for the driver in a crash-imminent situation, are associated with larger frequency reductions than technologies that rely on the driver to respond to warnings. Curve-adaptive headlights and forward collision warning, both of which are enabled by front-mounted equipment vulnerable to crash damage, are associated with significant increases in collision claim severity.

Change in claim frequency associated with collision avoidance technologies by coverage type



Introduction

Collision avoidance technologies have the potential to reduce crashes and related injuries and deaths. An Insurance Institute for Highway Safety (IIHS) analysis of police-reported crashes between 2004 and 2008 indicated that, together, forward collision warning, lane departure warning, blind spot monitoring, and curve-adaptive headlights could prevent or mitigate nearly one-third of crashes reported to police each year (Jermakian, 2011). In 2009, the Highway Loss Data Institute (HLDI) was the first group to document the effects of a collision avoidance technology on motor vehicle crashes when it evaluated the Mercedes-Benz Distronic system (HLDI, 2009). Since then, HLDI has published more than 95 research reports documenting the efficacy of various collision avoidance technologies for reducing claim frequency and insurance losses. This report summarizes HLDI's most recent evaluations for eight collision avoidance technologies: forward collision warning, front automatic emergency braking (AEB), curve-adaptive headlights, lane departure warning, blind spot warning, parking sensors, rear camera, and rear AEB (HLDI, 2017, 2018a–h, 2019, 2021a, 2021c-f, 2022e). Results are combined to estimate the collective effect of each technology on claim frequencies across the manufacturers and vehicle models examined to date. Results for collision claim severity and overall losses are combined across manufacturers and vehicle models only for those technologies mounted on the front of the vehicle and most susceptible to damage in a crash.

Methods

Vehicles

HLDI examined the effect of collision avoidance technologies on insurance claim frequency, severity, and overall losses for 11 makes: Acura, Audi, BMW, Buick, General Motors (GM), Honda, Mazda, Mercedes-Benz, Nissan, Subaru, and Volvo. Many collision avoidance technologies offered by these manufacturers were available only as optional equipment. Consequently, HLDI had to determine which vehicles were equipped with each technology in order to evaluate its effect.

HLDI used the following three methods to determine the presence or absence of collision avoidance technologies for vehicles in a study population:

- A manufacturer supplied HLDI with Vehicle Identification Numbers (VINs) and the presence or absence of collision avoidance technologies for each VIN. This approach was used to analyze the effects of collision avoidance and technologies for makes including Acura, Audi, BMW, GM, Mazda, Mercedes-Benz, Nissan, and Volvo vehicles.
- Some collision avoidance technologies are standard on certain vehicle trim levels. On vehicles from certain manufacturers, the trim level can be identified in the first 10 positions of the VIN, allowing the presence of an associated collision avoidance technology to be determined. This approach was used to analyze collision avoidance technologies on the Honda Accord, Honda Odyssey, and Honda Pilot.
- Some manufacturers explicitly code the presence of collision avoidance technologies in the first 10 positions of the VIN. This approach was used to analyze collision avoidance technologies for Subaru vehicles and some Honda vehicles.

Collision avoidance technologies

The collision avoidance technologies included in this report are defined as follows:

Forward collision warning (FCW) mitigates frontal crashes by using sensors like cameras or radar to detect when the vehicle is getting too close to the one in front of it and alerts the driver using an audible, visual, and/or haptic warning. Some systems also are capable of detecting pedestrians.

Front automatic emergency braking (AEB) uses the same kinds of sensors as forward collision warning to alert drivers of emergency situations and automatically applies the vehicle brakes if the driver does not respond to a warning or a crash-imminent situation.

Curve-adaptive headlights pivot in the direction of travel based on steering wheel movement and sometimes the vehicle's speed to better illuminate curved roads at night.

Lane departure warning (LDW) uses cameras to track the vehicle's position in the lane and alerts the driver if the vehicle inadvertently strays across the lane markings when the turn signal is not activated. Some vehicles include lane-keeping assist, which keeps the vehicle within the lane using light braking or minor steering adjustments.

Blind spot warning (BSW) uses sensors to monitor areas beside the vehicle and alerts the driver when a vehicle is detected in one of the blind spots in an adjacent lane or when a vehicle is swiftly approaching a blind spot.

Parking sensors use radar or ultrasonic sensors to detect nearby objects or objects in the vehicle's path to help drivers park and back up. The system audibly indicates when objects are in close proximity at very low speeds. Rear cameras enhance rear visibility by providing a view of the area directly behind the vehicle in an interior display.

Rear cameras visually display surroundings directly to the rear of the vehicle at very low speeds when the vehicle is traveling in reverse.

Rear AEB automatically applies the brakes to keep the vehicle from reversing into an object detected by sensors.

Other technologies

Some collision avoidance features are only available with other collision avoidance or advanced driver assistance features.

Adaptive cruise control (ACC) maintains a set speed and following distance from the vehicle ahead using information from a camera or radar sensor. Frequently, it is present on vehicles equipped with FCW or front AEB.

Rear cross-traffic alert (RCTA) issues a warning when the vehicle is reversing, and another vehicle is detected approaching from either side and may cross its path. RCTA often is enabled by the same radar sensor that enables BSW.

Distance alert uses information from a camera or radar to inform the driver about the time interval to the vehicle in front and alerts the driver when the vehicle is closer than a set time interval. This function is sometimes combined with FCW or front AEB.

Fatigue warning alerts the driver if signs of drowsiness are detected based on steering input and other driver behaviors.

Surround-view cameras integrate views from multiple cameras including a rear camera to provide the driver with a 360-degree, top-down view of the vehicle and its surroundings to assist the driver with parking and other low-speed maneuvers.

High-beam assist uses a camera to detect headlights and taillights from other vehicles and automatically switches between low and high beams to better illuminate the road ahead without blinding other drivers.

Manufacturers have adopted different names for the technologies listed above. For simplicity, this report uses the terms above when discussing the results for each manufacturer. Some manufacturers offer multiple versions of the same collision avoidance technology. The marketing name of the collision avoidance technology is included in these instances.

Insurance data

Automobile insurance covers damage to vehicles and property and injuries to people that result from crashes. Different insurance coverages pay for vehicle damage versus injuries, and different coverages may apply depending on who is at fault. This report discusses results for property damage liability (PDL), collision, bodily injury (BI) liability, personal injury protection (PIP), and medical payment (MedPay) coverages. Exposure was measured in insured vehicle years. An insured vehicle year is one vehicle insured for 1 year, two vehicles insured for 6 months, etc.

Collision avoidance technologies may affect different insurance coverage types differently, so 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. PDL coverage insures against physical 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 with each vehicle's insurance paying for that vehicle's damage in a crash, regardless of who is at fault.

Insurance coverage for injuries is more complicated. 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 was only analyzed for the 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 the passengers in their vehicles, but not injuries to people in other vehicles involved in the crash. The 17 other states without traditional tort insurance systems employ no-fault injury systems where 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.

Statistical methods

The HLDI research discussed in this report used regression analysis to quantify the effect of each collision avoidance technology on claim frequency by comparing vehicles equipped with a collision avoidance technology with vehicles without the technology. All regression models included a variable that indicated the presence or absence of a collision avoidance technology for a specific model year, make, and series. Other covariates included were calendar year; model year; garaging state; vehicle density, defined as the number of registered vehicles per square mile; rated driver age group; rated driver gender; rated driver marital status; deductible range for collision coverage; and rated risk. Additional variables indicating the presence of other collision avoidance technologies were included to better isolate the effect of the collision avoidance technology of interest. Finally, a variable that combined model year and vehicle series was included to control for vehicle design changes that occurred across model years.

Claim frequency, defined as the number of claims per 100 or 1,000 insured vehicle years, was modeled using a Poisson distribution, and claim severity, defined as the average loss payment per claim, was modeled using a Gamma distribution. Both variables were modeled using a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models. Estimates for claim frequency are presented for collision, PDL, BI liability, PIP, and MedPay coverage types. BI liability, PIP, and MedPay claim frequencies are for all claims, including those that have been paid and those for which money has been set aside for possible payment in the future, known as claims with reserves. Collision claim severity and overall losses under collision coverage are only reported for forward collision warning, front AEB, and curve-adaptive headlights because these technologies are enabled by equipment mounted on the front of the vehicle and more vulnerable to damage in a crash (e.g., HLDI 2016; 2021a).

The estimated effect of a crash avoidance technology is presented as a percent change. The percent change in an outcome measure was calculated by subtracting 1 from the exponent of the parameter estimate for the crash avoidance technology indicator variable and multiplying the resultant by 100. A percent change less than 0 indicated that the crash avoidance technology was associated with a reduction in the outcome measure, and a value above 0 indicated the technology was associated with an increase in the outcome measure. The percent change can be considered statistically significant when the 95 percent confidence interval does not include 0.

Combined analysis loss results

A weighted average was calculated to estimate the combined effect of each crash avoidance technology on claim frequency under each coverage type across manufacturers and vehicle models and the combined effect of curve adaptive headlights, forward collision warning, and front AEB on collision claim severity and overall losses. The weights in the average were proportional to the inverse variance of the respective estimates. Estimates with high variance as indicated by large confidence intervals contributed less than estimates with low variance as indicated by small confidence intervals. Wider confidence intervals typically reflected cases with less exposure and/or fewer claims. The weighted average is presented as a percent change. The weighted average only included estimates for manufacturers or vehicle models where HLDI was reasonably certain that the model estimates were due to the collision avoidance technology of interest. Some manufacturers offered multiple versions of the same collision avoidance technology. For example, two front AEB systems offered by Mazda were included: Smart City Brake and Smart City Brake and Forward Obstruction Warning (or FCW). Each version of a technology was included in the weighted average. The marketing names were used to differentiate the versions.

Linked features

Some collision avoidance technologies are only available with other technologies, and the effects of each technology on insurance claim frequency cannot be separated. However, in some circumstances it is reasonable to assume that one technology contributes more to a model estimate than another. FCW addresses front-to-rear crashes, which make up a much larger proportion of the crash population than crashes addressed by LDW. Jermakian (2011) estimated that FCW was relevant to about 20 percent of crashes reported to police each year, and LDW was only relevant to 3 percent. Likewise, in separate analyses of FCW and LDW involving different but comparable passenger vehicle populations, the proportion of police-reported crashes relevant to FCW was twice the size of the proportion that was relevant to LDW (Cicchino, 2017a; 2018a). Thus, estimates for FCW that include LDW are assumed to mostly reflect the effect of FCW.

FCW, front AEB, and ACC are often enabled by the same radar and available together, but while FCW and front AEB are typically always on (Reagan et al., 2018), ACC is used at the driver's discretion. Hence, estimates of FCW or front AEB that also included ACC were assumed to mostly reflect the effect of FCW and/or front AEB.

BSW systems enabled by radar sensors are often only available with RCTA. Backing crashes like those that occur in parking lots make up a small proportion of police-reported crashes (Cicchino, 2017c), but these low-severity events are estimated to contribute to around one-fifth of collision and PDL claims (Wells et al., 1991). Hence, it is likely that RCTA, when combined with BSW, would result in larger reductions to insurance claim frequencies than BSW alone. Future analyses will reconsider whether the weighted estimate for BSW should include systems where BSW is paired with RCTA. Throughout this report the presence of additional technologies is noted when an estimate includes a technology other than the one of interest.

Predicted prevalence of safety features

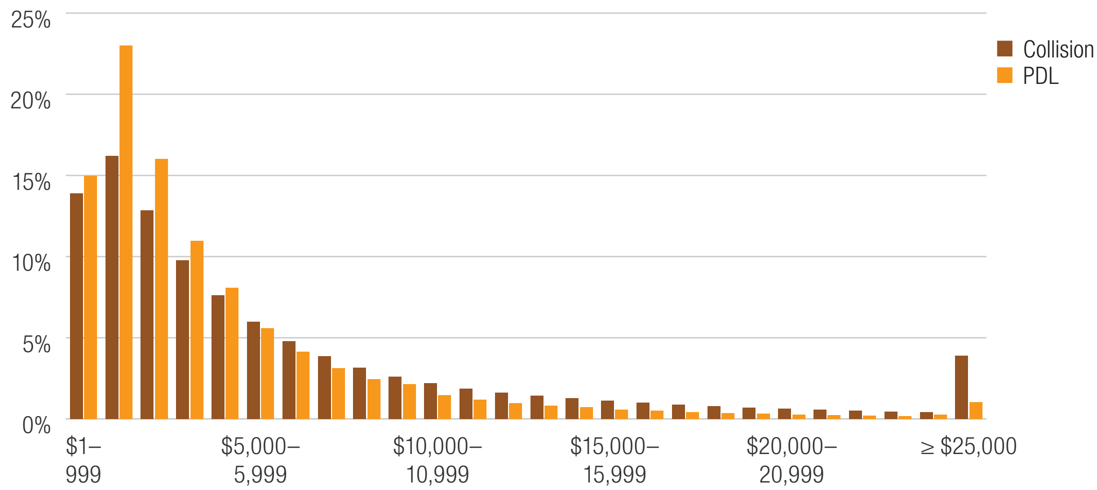
Vehicle feature information from HLDI was combined with vehicle registration data from IHS Markit to estimate the prevalence of each collision avoidance technology in the registered vehicle fleet for calendar years 2021 and 2026. For calendar year 2021, each model year, make, and series with an available collision avoidance technology was weighted by the number of registered vehicles to compute the proportion of all registered vehicles with a collision avoidance technology. A technology was considered available if it was standard or optional equipment. Thirty-year trends in new vehicle registrations and attrition rates were used to estimate the number of vehicle registrations for the 2022 calendar year and each subsequent calendar year. On average, new vehicle registrations would increase 0.5 percent each calendar year, and attrition rates would decline 0.12 percent each model year. Availability of collision avoidance technology in the 2021 calendar year and each subsequent calendar year was estimated several different ways as described in HLDI 2022d.

Claim size

A crash can result in damage for any dollar value up to the full price of the vehicle. Crash avoidance technologies prevent or mitigate different crashes differently. For example, rear AEB systems are designed to prevent low-speed backing crashes, which typically result in low-severity claims. The distribution of claim size under collision and PDL coverages may better illuminate the effects of different crash avoidance technologies.

The figure below is based on collision and PDL coverage results for 1981-2022 model year vehicles incurred under private passenger automobile policies in calendar year 2021. As shown in **Figure 1**, most claims under collision and PDL coverages are for relatively low dollar amounts. Nearly 50 percent of automobile collision claims cost less than $3,000. The largest percentage of collision and PDL claims occurs in the $1,000–1,999 range.

Figure 1: Distribution of collision and PDL claims, 2021 calendar year by claim size, 1981–2022 model years



Results

Figure 2 summarizes the effects of collision avoidance technologies on claim frequency under five coverage types combined across manufacturers and vehicle models. The numerical values of the point estimates and the associated confidence intervals are shown in the **Appendix**. Many collision avoidance technologies were associated with claim frequency reductions under each coverage type, and more than two-thirds of the reductions were statistically significant. There were three technologies associated with increased claim frequencies: lane departure warning under BI liability coverage, rear cameras under collision coverage, and rear AEB under MedPay and PIP. The increase of less than 1 percent associated with the rear cameras was the only statistically significant increase.

Figure 2: Change in claim frequency associated with various collision avoidance technologies by coverage type

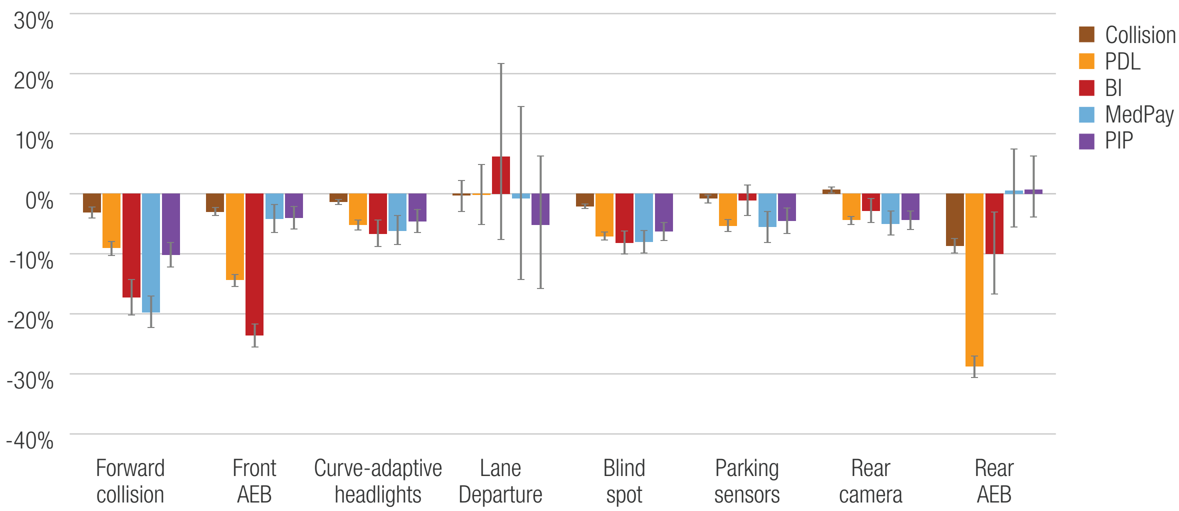
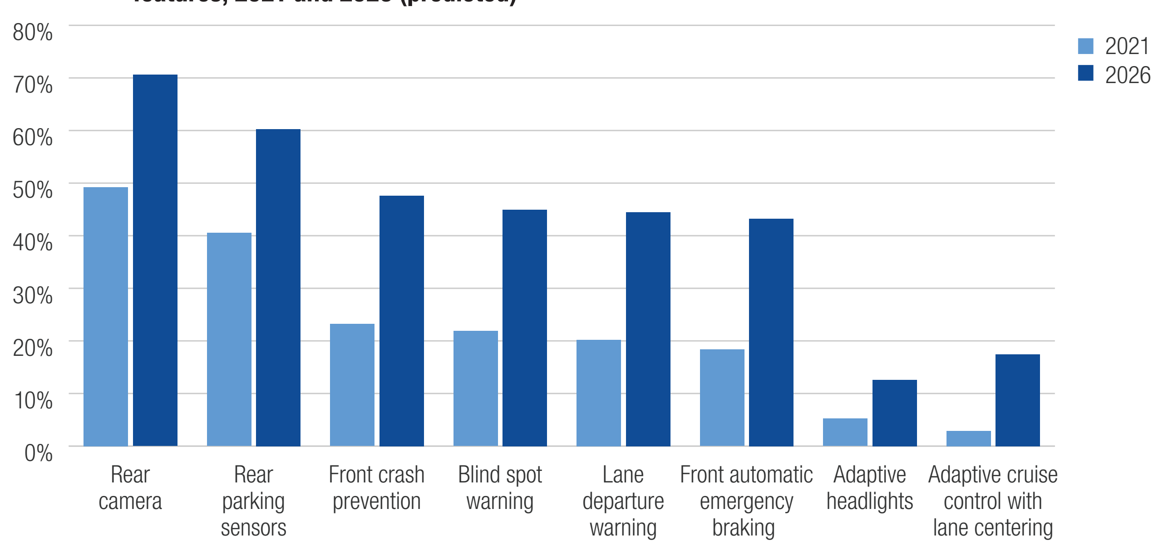


Figure 3 shows the proportion of registered vehicles in the U.S. with various collision avoidance technologies in 2021 and the estimated proportion of registered vehicles with the technologies in 2026. Most systems are estimated to see increases of over 20 percentage points by 2026. However, curve adaptive headlights and adaptive cruise control with lane centering are only estimated to increase 7 percent and 15 percent, respectively. More than 70 percent of the registered vehicle population is expected to be equipped with rear cameras by 2026. Rear parking sensors are estimated to approach 60 percent fleet penetration by 2026. Front AEB is estimated to increase from 18 percent of the registered vehicle population in 2021 to 43 percent in 2026. This increase is associated with a voluntary manufacturer commitment brokered by IIHS and the National Highway Traffic Safety Administration to equip at least 95 percent of their vehicles with the feature by the current production year.

Figure 3: Percentage of registered vehicles equipped with collision avoidance features, 2021 and 2026 (predicted)

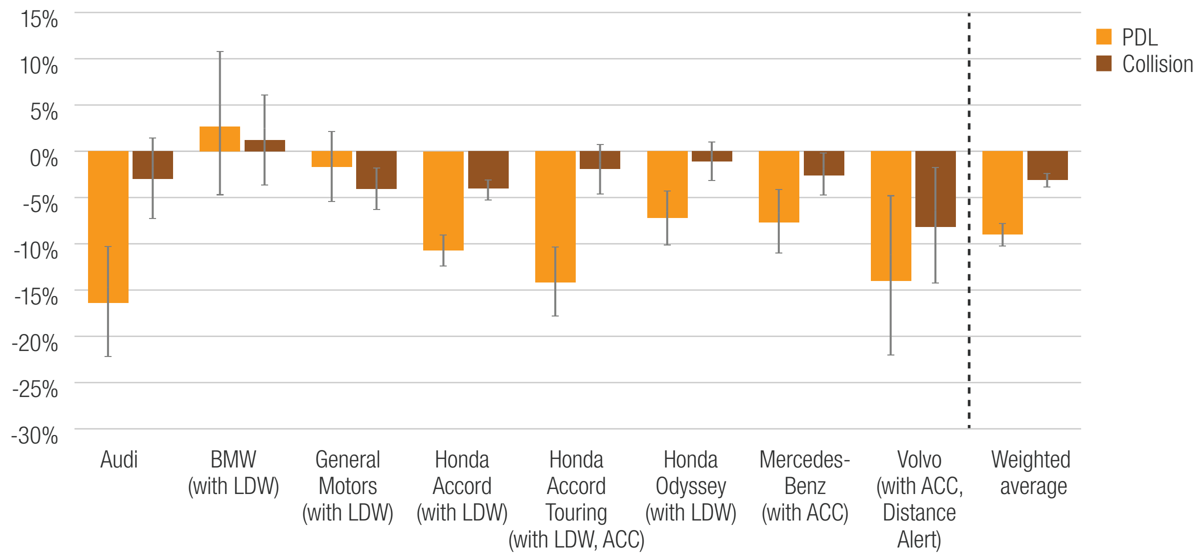


Forward collision warning (FCW)

Claim frequency

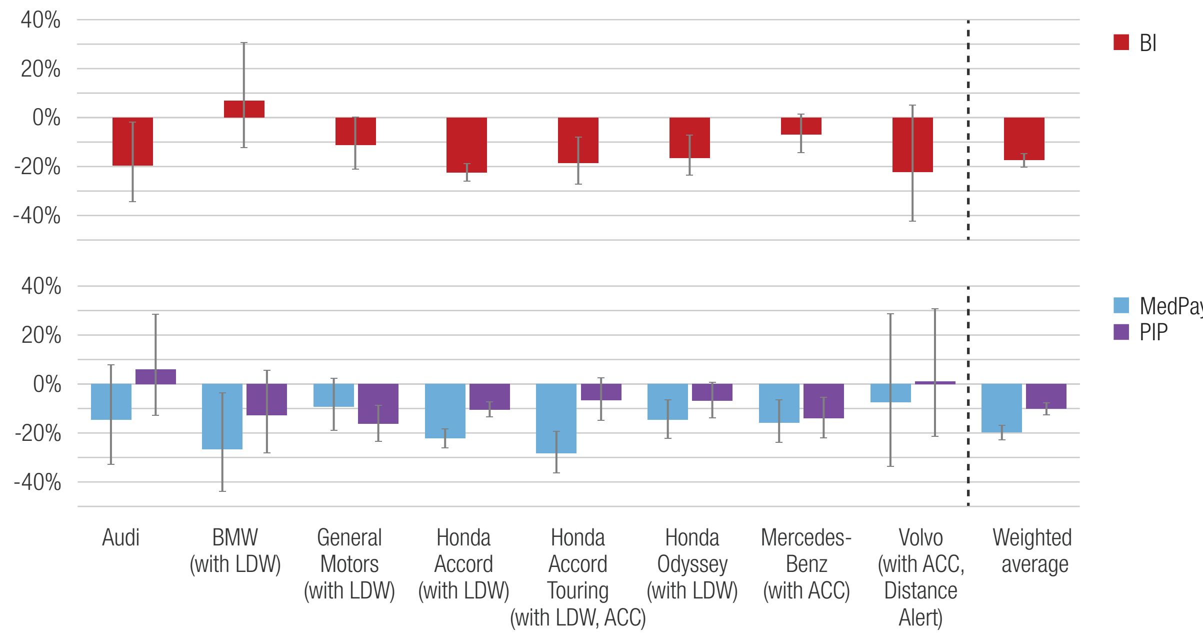
HLDI examined FCW systems offered on Audi, BMW, GM, Honda Accord, Honda Odyssey, Mercedes-Benz, and Volvo vehicles. Some of the FCW systems were available in combination with LDW and/or ACC. FCW reduced the PDL and collision claim frequencies for every manufacturer except BMW (**Figure 4**). Neither result for BMW was statistically significant. Combined across manufacturers, FCW was associated with a significant 9.0 percent reduction in PDL claim freqeuncy and a significant 3.1 percent reduction in collision claim frequency.

Figure 4: Change in PDL and collision claim frequency associated with FCW



FCW reduced MedPay claim frequency for each manufacturer and reduced BI liability and PIP claim frequencies for most of the manufacturers or models studied (**Figure 5**). Across manufacturers, the technology was associated with a significant 17.3 percent reduction in BI liability claim frequency, a significant 19.8 percent reduction in MedPay claim frequency, and a significant 10.2 percent reduction in PIP claim frequency.

Figure 5: Change in BI liability, MedPay, and PIP claim frequency associated with FCW



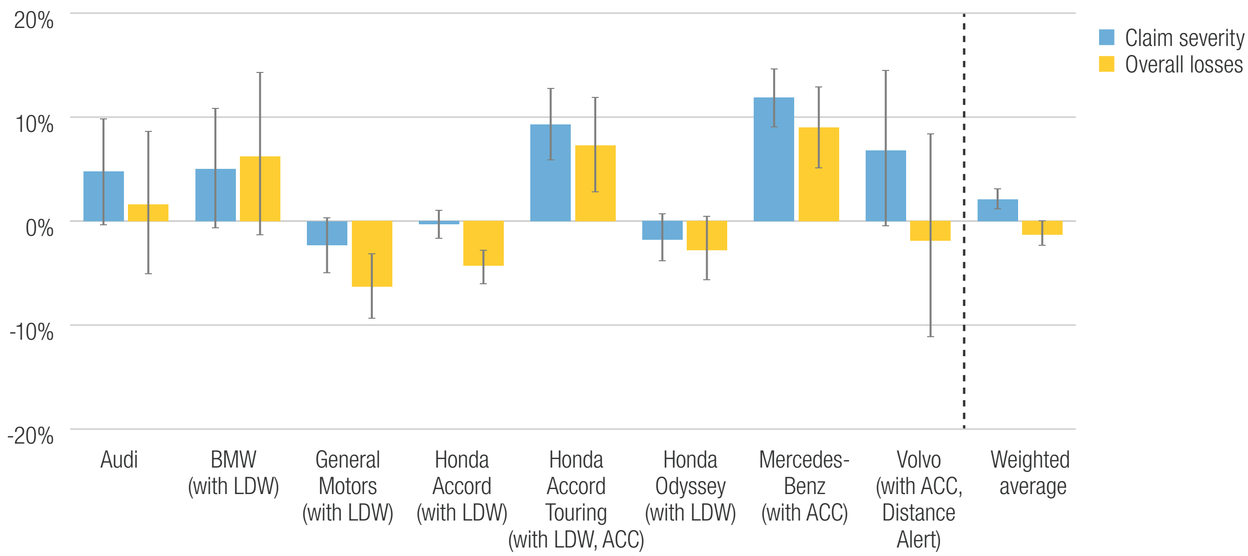
Collision claim severity and overall losses

FCW was associated with a reduction in vehicle damage claim frequencies but not always a reduction in claim severity. As illustrated in **Figure 6**, the collision claim severity for vehicles with FCW increased for some manufacturers and vehicle models but not for others.

The difference in claim severity changes for the two Honda Accords merits comment. The system described as "Honda Accord (with LDW)" is enabled by a camera-based sensor mounted behind the windshield, while the system described as "Honda Accord Touring (with LDW, ACC)" is enabled by a radar-based sensor mounted in the front grill. The camera-based sensor, due to its location, is much less likely to be damaged than the radar-based sensor, and, because the camera-based sensor is mounted to the windshield, it would likely be covered under comprehensive coverage and not collision.

Across manufacturers, FCW was associated with a significant 2.1 percent increase in collision claim severity. Overall losses under collision coverage decreased by a significant 1.3 percent for vehicles equipped with FCW.

Figure 6: Change in collision claim severity and overall losses associated with FCW

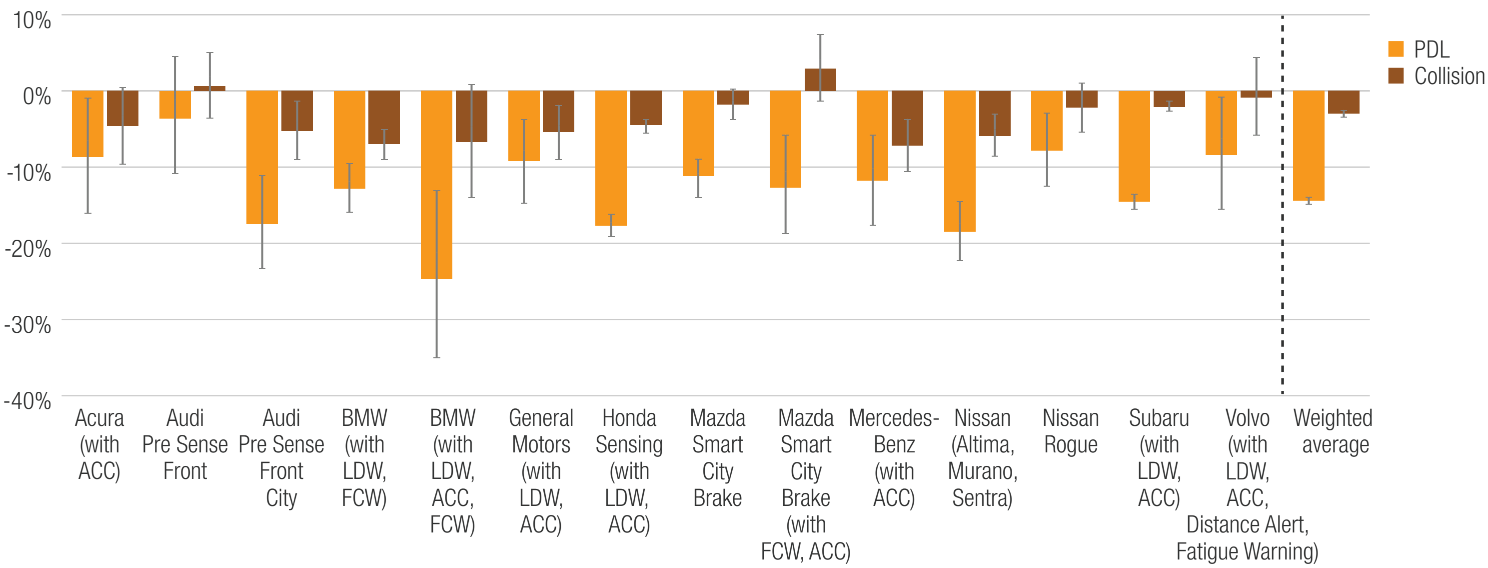


Front automatic emergency braking (AEB)

Claim frequency

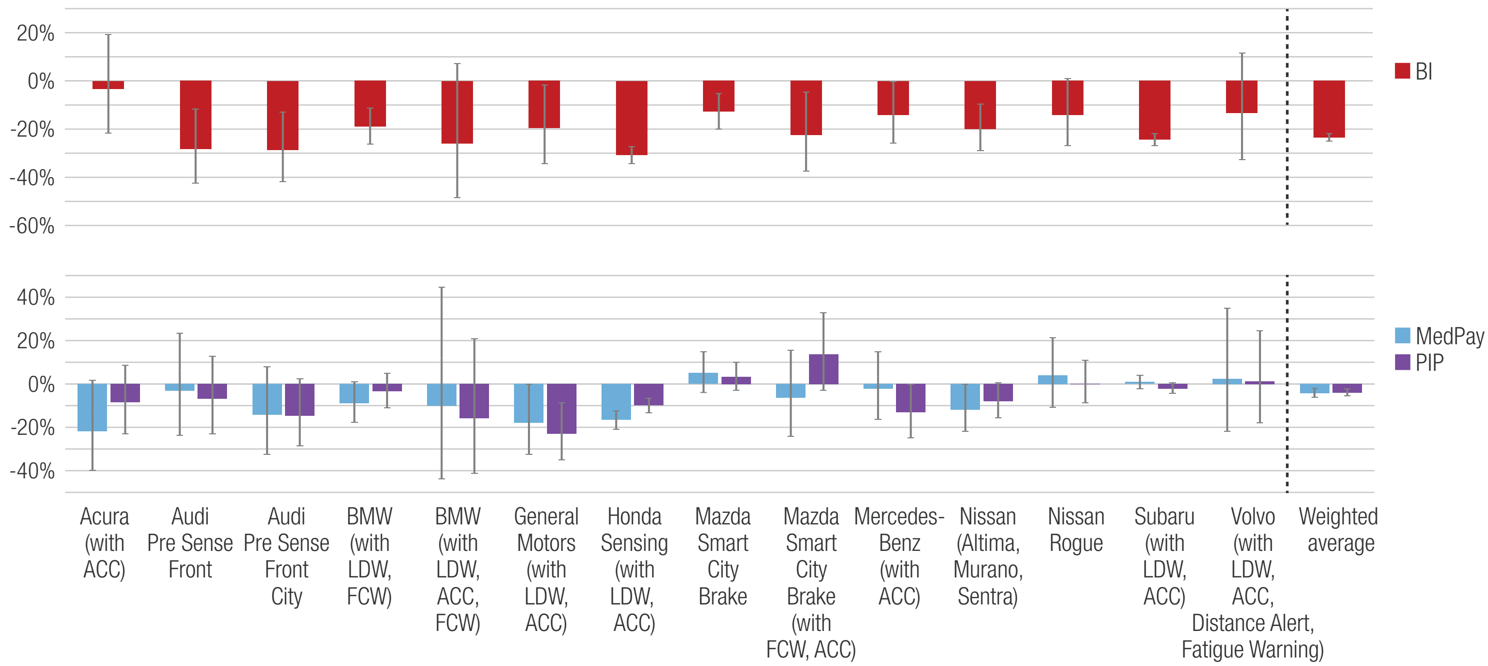
HLDI examined front AEB systems offered on Acura, Audi, BMW, GM, Honda, Mazda, Mercedes-Benz, Nissan, Subaru, and Volvo vehicles. Some front AEB systems were available with LDW, ACC, fatigue warning, and/or distance alert. Front AEB significantly reduced collision claim frequency for Audi vehicles with Pre-Sense Front City, BMW vehicles with LDW and FCW, GM vehicles, Honda vehicles with the Sensing package, Mercedes-Benz vehicles, one group of Nissan vehicles, and Subaru vehicles (**Figure 7**). Across manufacturers, front AEB was associated with a significant 3.0 percent reduction in collision claim frequency. Front AEB was also associated with a significant 14.4 percent reduction in PDL claim frequency. Among manufacturers, PDL frequency reductions ranged from 3.6 (Audi Pre Sense Front) to 24.7 (BMW with LDW, ACC, and FCW).

Figure 7: Change in PDL and collision claim frequency associated with front AEB



The presence of front AEB was associated with BI claim frequency reductions between 3.3 and 30.7 percent for each manufacturer or vehicle model (**Figure 8**). MedPay and PIP claim frequency reductions were also observed for most manufacturers. When manufacturers were combined, front AEB was associated with a significant 23.6 percent reduction in BI liability claim frequency, a significant 4.2 percent reduction in MedPay claim frequency, and a significant 4.0 percent reduction in PIP claim frequency.

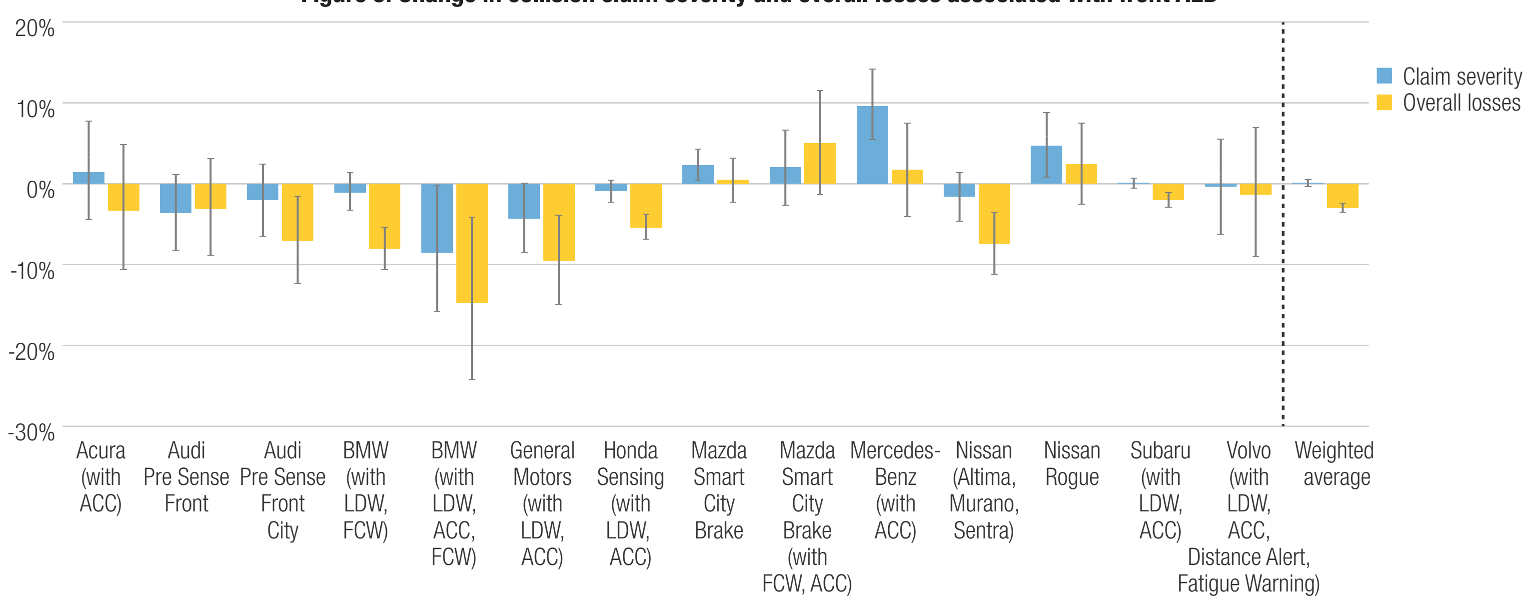
Figure 8: Change in BI liability, MedPay, and PIP claim frequency associated with front AEB



Collision claim severity and overall losses

Front AEB had inconsistent effects on collision claim severity and overall losses among manufacturers (**Figure 9**). On average, front AEB did not have a significant effect on collision claim severity. Front AEB reduced overall losses under collision coverage by a significant 3.0 percent.

Figure 9: Change in collision claim severity and overall losses associated with front AEB

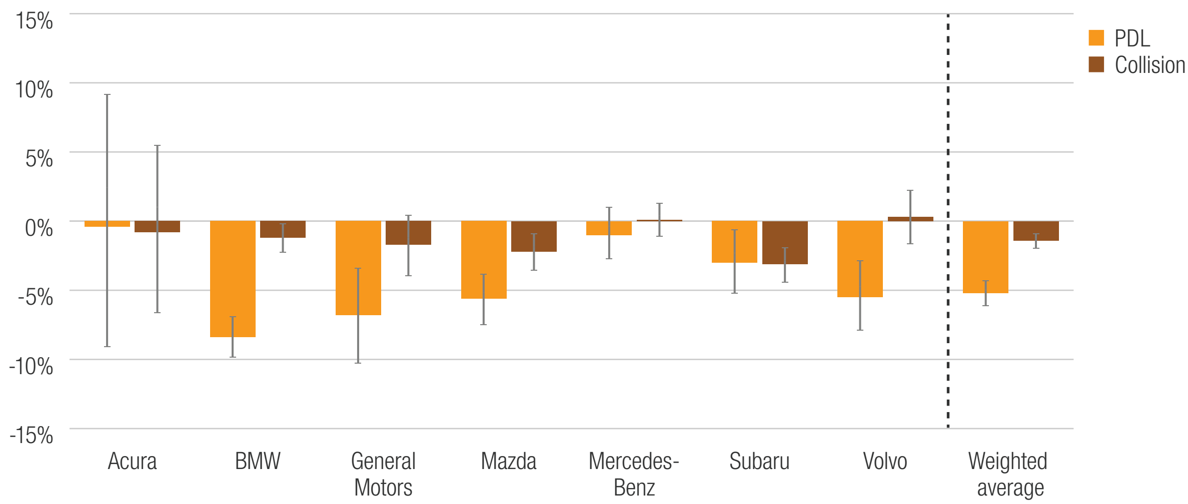


Curve-adaptive headlights

Claim frequency

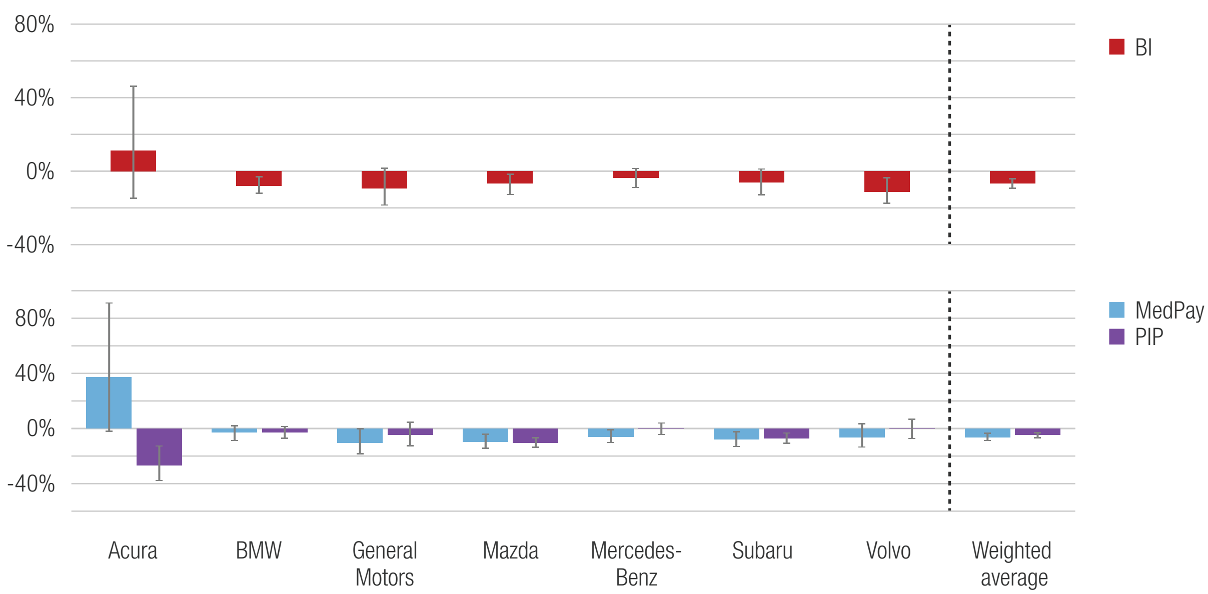
Figure 10 shows the changes in PDL and collision claim frequencies associated with the presence of curve-adaptive headlights for Acura, BMW, GM, Mazda, Mercedes-Benz, Subaru, and Volvo vehicles. Curve-adaptive headlights were associated with significant reductions in PDL claim frequency for BMW, GM, Mazda, Subaru, and Volvo vehicles and significant reductions in collision claim frequency for BMW, Mazda, and Subaru vehicles. Across manufacturers, curve-adaptive headlights were associated with a significant 5.2 percent reduction in PDL claim frequency and a significant 1.4 percent reduction in collision claim frequency.

Figure 10: Change in PDL and collision claim frequency associated with curve-adaptive headlights



Curve-adaptive headlights were associated with reduced claim frequency under BI liability and MedPay for every manufacturer except Acura. Curve-adaptive headlights also were associated with frequency reductions under PIP coverage for every manufacturer (**Figure 11**). Across manufacturers, the presence of curve-adaptive headlights was associated with a significant 6.7 percent reduction in BI claim frequency, a significant 6.2 percent reduction in MedPay claim frequency, and a significant 4.6 percent reduction in PIP claim frequency.

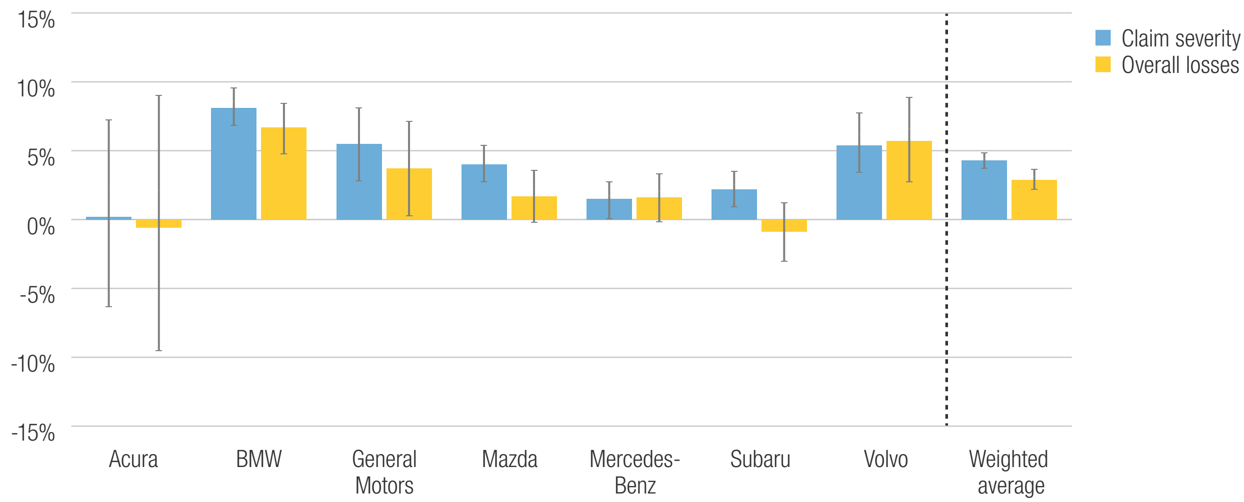
Figure 11: Change in BI liability, MedPay, and PIP claim frequency associated with curve-adaptive headlights



Collision claim severity and overall losses

Collision claim severity for vehicles equipped with curve-adaptive headlights increased for each manufacturer, and overall losses for collision coverage increased for every manufacturer except Acura and Subaru (**Figure 12**). Both Acura and Subaru results were not statistically significant. On average, curve-adaptive headlights were associated with a significant 4.3 percent increase in collision claim severity and a significant 2.9 percent increase in overall losses under collision coverage.

Figure 12: Change in collision claim severity and overall losses associated with curve-adaptive headlights



Lane departure warning (LDW)

Claim frequency

LDW alerts the driver if the vehicle is straying across a lane marking when the turn signal is not activated. **Figure 13** shows the change in PDL and collision claim frequency associated with LDW for Audi, Mercedes-Benz, and Mazda vehicles. Mazda vehicles with LDW were also equipped with high-beam assist. The changes in PDL claim frequency and collision claim frequency associated with LDW were inconsistent among manufacturers. On average, LDW was associated with a 0.2 percent reduction in PDL claim frequency and a 0.3 percent reduction in collision claim frequency; neither change was statistically significant.

Figure 13: Change in PDL and collision claim frequency associated with LDW

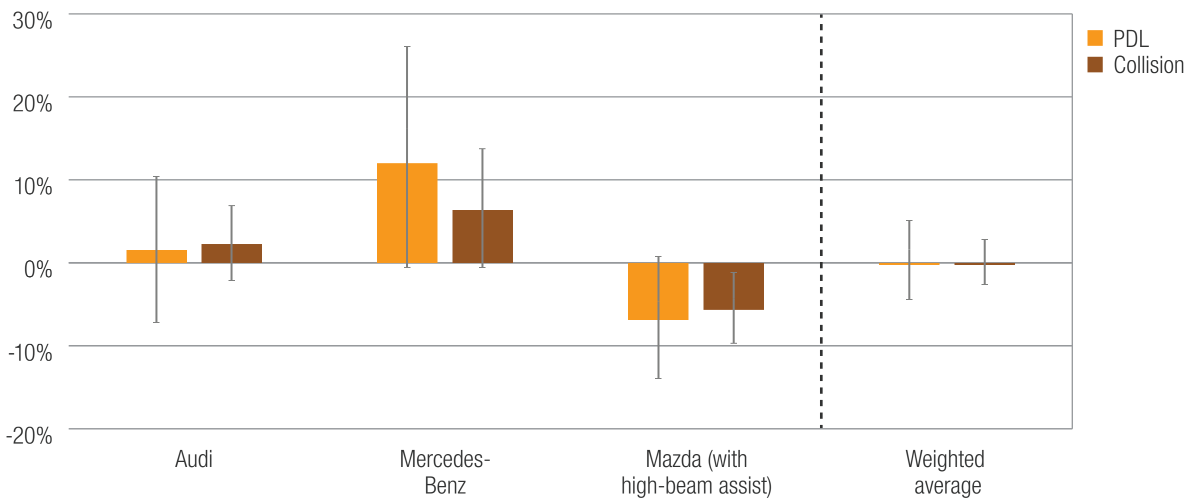
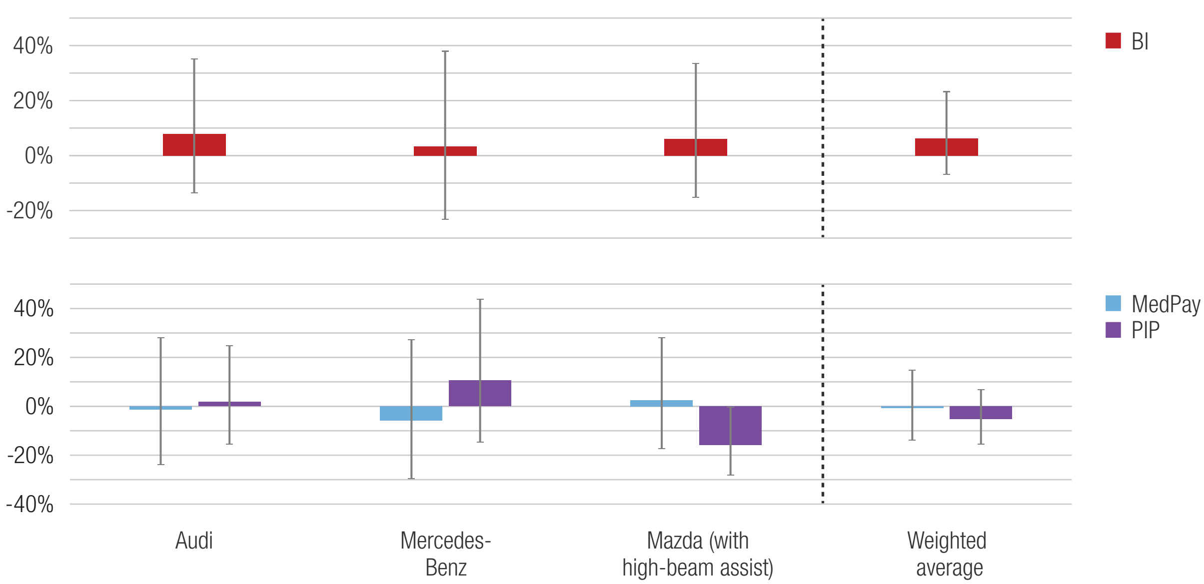


Figure 14 shows the percent change in BI liability, MedPay, and PIP claim frequencies associated with LDW for Audi, Mercedes-Benz, and Mazda. The presence of LDW was associated with inconsistent changes in MedPay and PIP claim frequencies across manufacturers. Combined, the MedPay claim frequency decreased 0.8 percent, and the PIP claim frequency decreased 5.2 percent for vehicles with LDW. In contrast, LDW was associated with BI liability claim frequency increases for each manufacturer and a 6.2 percent increase in the weighted average. The percent changes in BI liability, MedPay, and PIP claim frequencies were not statistically significant.

Figure 14: Change in BI liability, MedPay, and PIP claim frequency associated with LDW

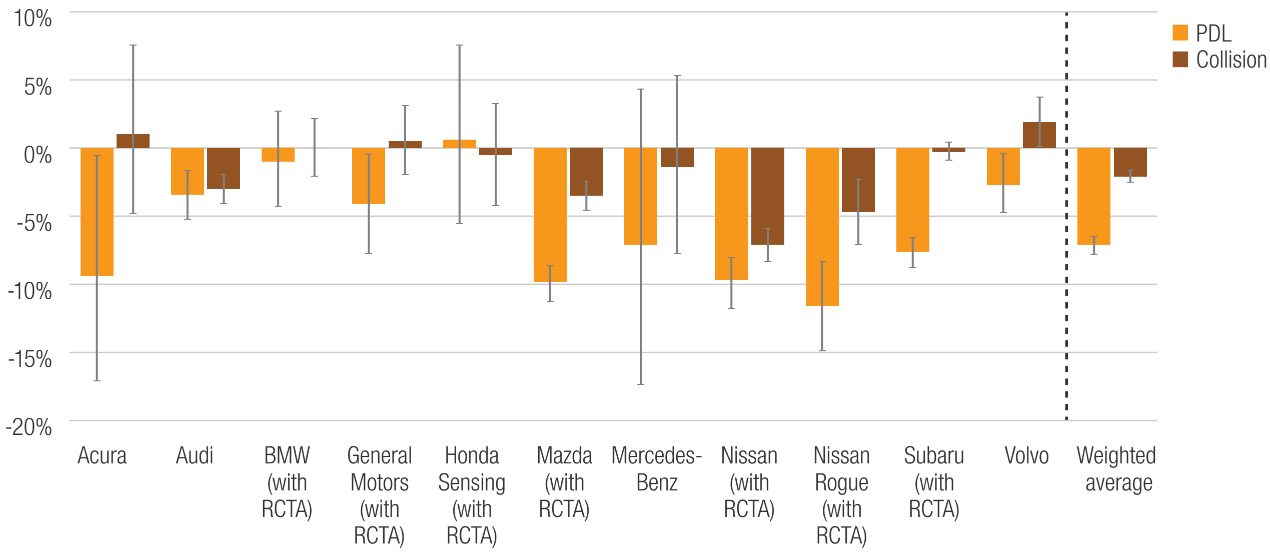


Blind spot warning (BSW)

Claim frequency

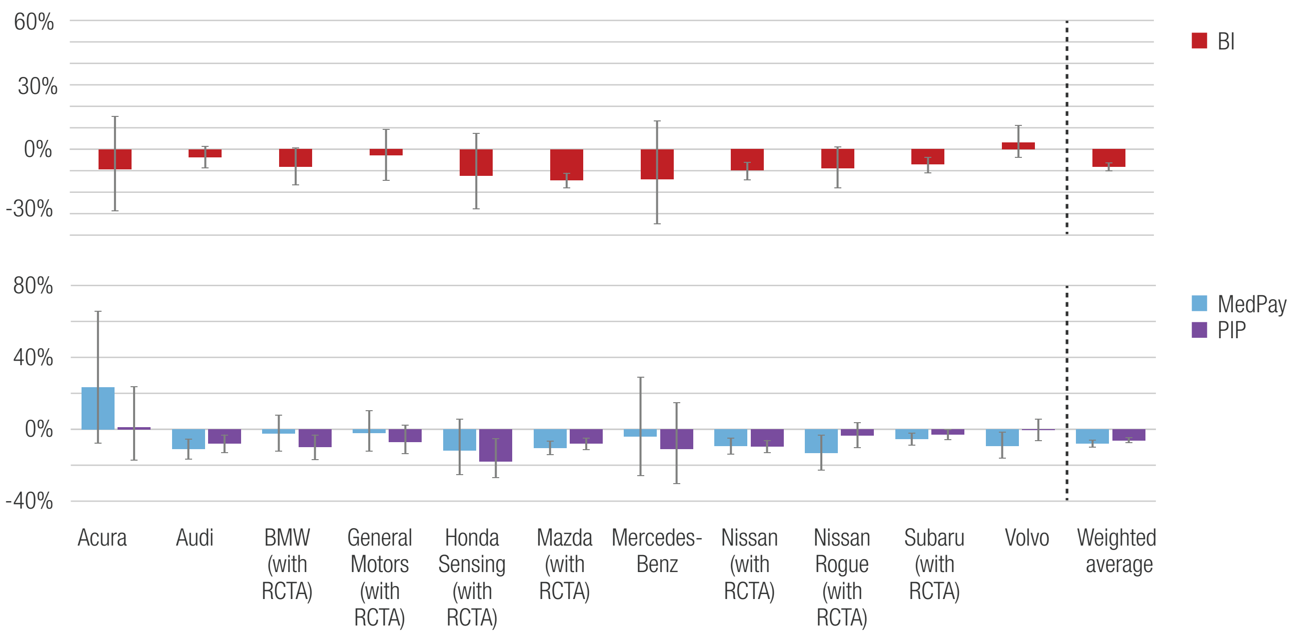
Figure 15 shows the changes in PDL and collision claim frequencies associated with BSW for Acura, Audi, BMW, GM, Honda (Sensing), Mazda, Mercedes-Benz, Nissan, Subaru, and Volvo vehicles. Equipped vehicles from all these manufacturers except for Acura, Audi, Mercedes-Benz and Volvo are also equipped with RCTA. BSW was associated with PDL claim frequency reductions for every manufacturer except for Honda, and across manufacturers the technology was associated with a significant 7.1 percent reduction in PDL claim frequency. BSW was associated with claim frequency reductions under collision coverage for some manufacturers but not for others. Across manufacturers, BSW was associated with a significant 2.1 percent reduction in collision claim frequency.

Figure 15: Change in PDL and collision claim frequency associated with BSW



The presence of BSW was associated with significant reductions in injury claim frequencies (**Figure 16**). Collectively, BSW significantly decreased BI liability, MedPay, and PIP claim frequencies by 8.2, 8.0, and 6.3 percent, respectively. At the manufacturer level, BSW reduced the BI liability claim frequency for every manufacturer but Volvo. The effects of BSW on MedPay and PIP claim frequencies were mostly beneficial for specific manufacturers and vehicle models.

Figure 16: Change in BI liability, MedPay, and PIP claim frequency associated with BSW

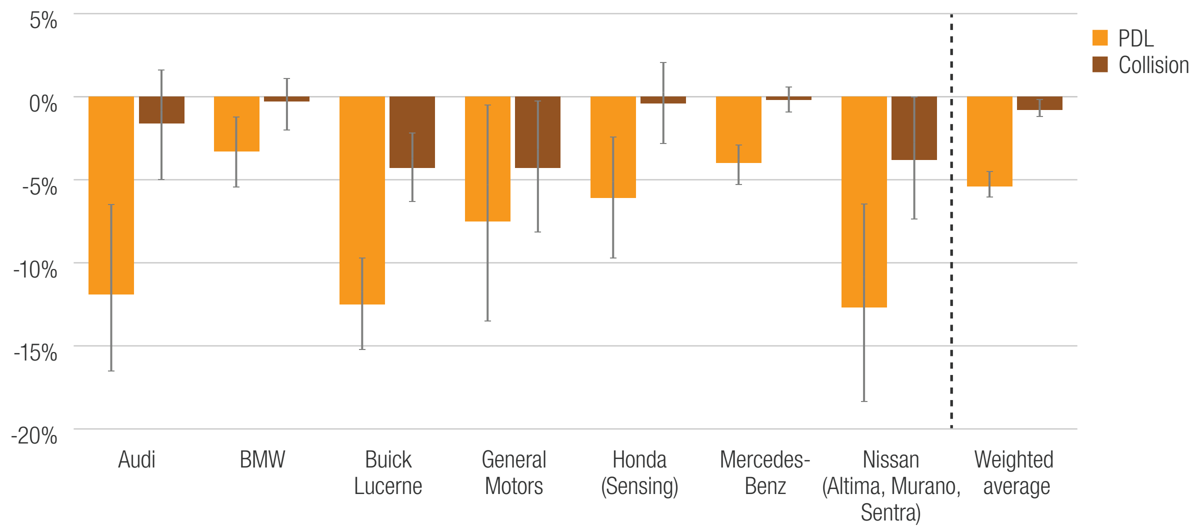


Parking sensors

Claim frequency

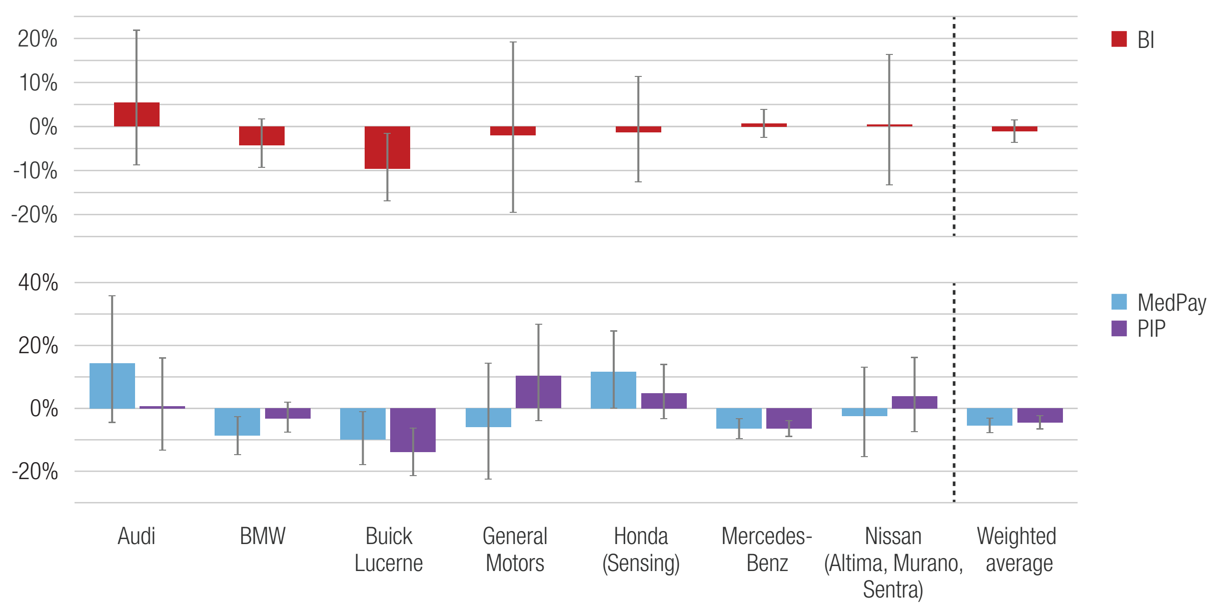
Figure 17 shows changes in PDL and collision claim frequencies associated with the presence of parking sensors for Audi, BMW, Buick, GM, Honda (Sensing), Mercedes-Benz, and Nissan vehicles. Parking sensors reduced PDL claim frequency across manufacturers and were associated with a significant 5.4 percent reduction in PDL claim frequency. Parking sensors were associated with reduced collision claim frequencies for every manufacturer. When manufacturers were combined, parking sensors were associated with a significant 0.8 percent reduction in collision claim frequency.

Figure 17: Change in PDL and collision claim frequency associated with parking sensors



Parking sensors had an inconsistent effect on injury coverage claim frequencies for different manufacturers and vehicles (**Figure 18**). When manufacturers were combined, the presence of parking sensors was associated with a 1.1 percent reduction in BI liability claim frequency; this effect was not statistically significant. The effect of parking sensors on MedPay and PIP claim frequencies also was inconsistent; however, on average across manufacturers the presence of parking sensors was associated with a significant 5.5 percent reduction in MedPay claim frequency and a significant 4.5 percent reduction in PIP claim frequency.

Figure 18: Change in BI liability, MedPay, and PIP claim frequency associated with parking sensors

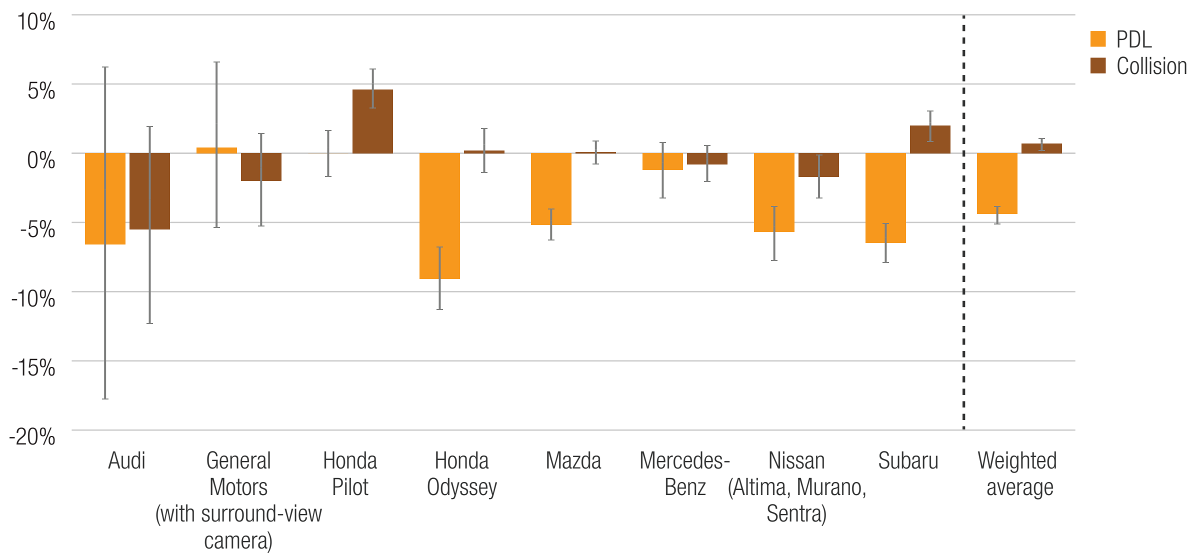


Rear camera

Claim frequency

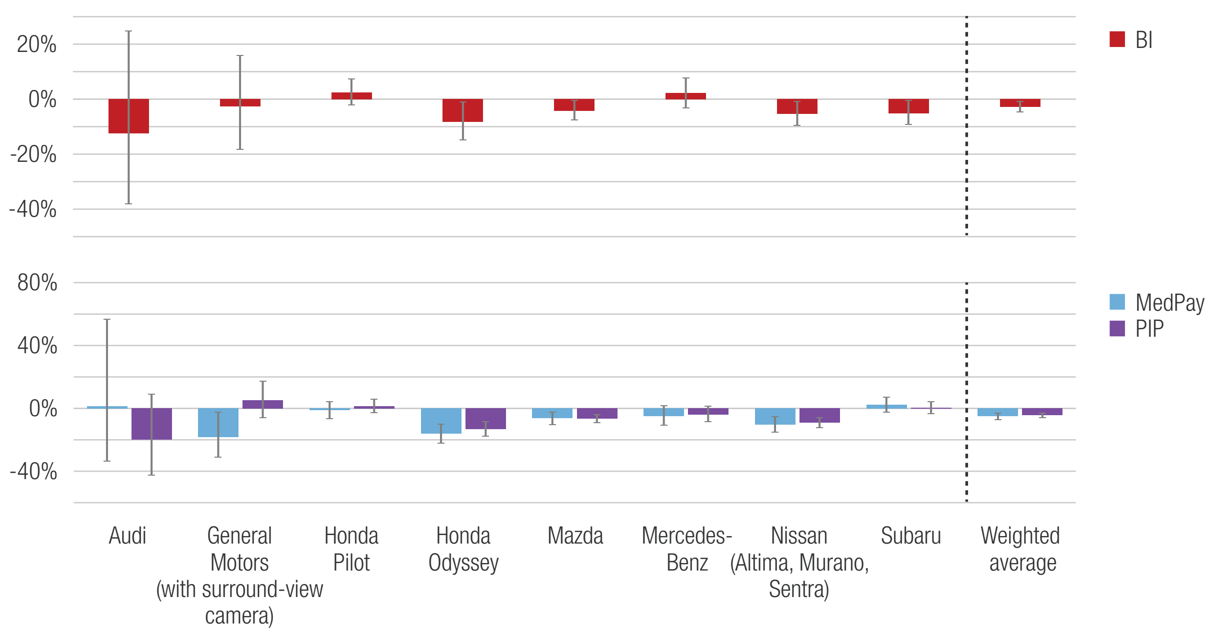
Figure 19 shows the association between a rear camera and PDL and collision claim frequencies for Audi, GM, Honda (Pilot and Odyssey), Mazda, Mercedes-Benz, Nissan (Altima, Murano, and Sentra), and Subaru vehicles. The presence of a rear camera was associated with a reduction in PDL claim frequency for six of the eight manufacturers and vehicle models. When combined, the presence of a rear camera was associated with a significant 4.4 percent reduction in PDL claim frequency. Rear cameras had an inconsistent effect on collision claim frequencies for specific manufacturers and vehicle models. When combined, the presence of a rear camera was associated with a significant 0.7 percent increase in collision claim frequency.

Figure 19: Change in PDL and collision claim frequency associated with rear cameras



The changes in injury claim frequencies associated with rear cameras were not consistent for the injury coverage types across manufacturers and vehicle models (**Figure 20**). When combined, the presence of a rear camera was associated with a significant 5.0 reduction in MedPay claim frequency, a significant 4.4 percent reduction in PIP claim frequency and a significant 2.9 percent reduction in BI liability claim frequency.

Figure 20: Change in BI liability, MedPay, and PIP claim frequency associated with rear cameras

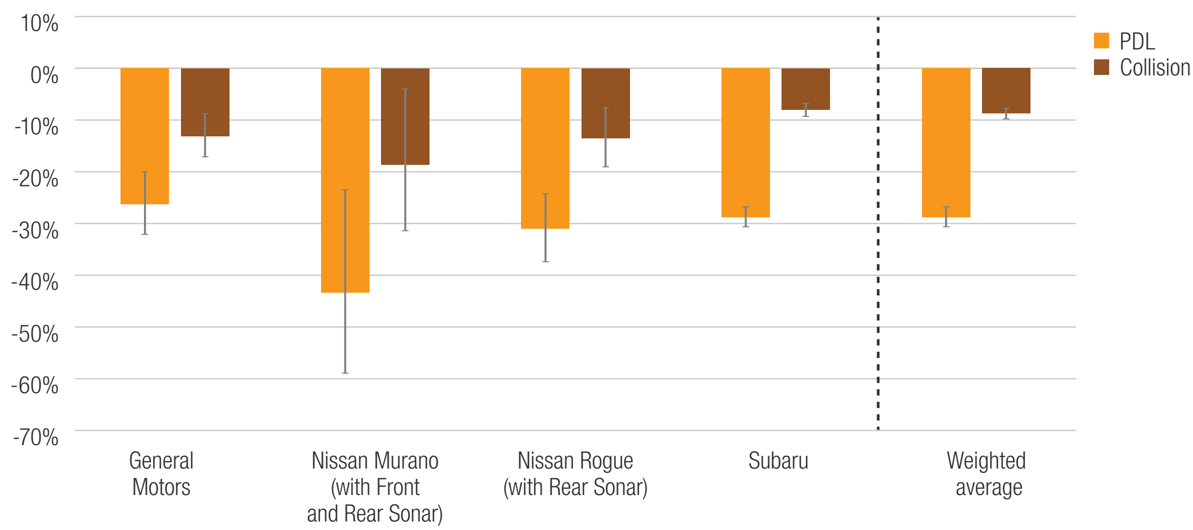


Rear AEB

Claim frequency

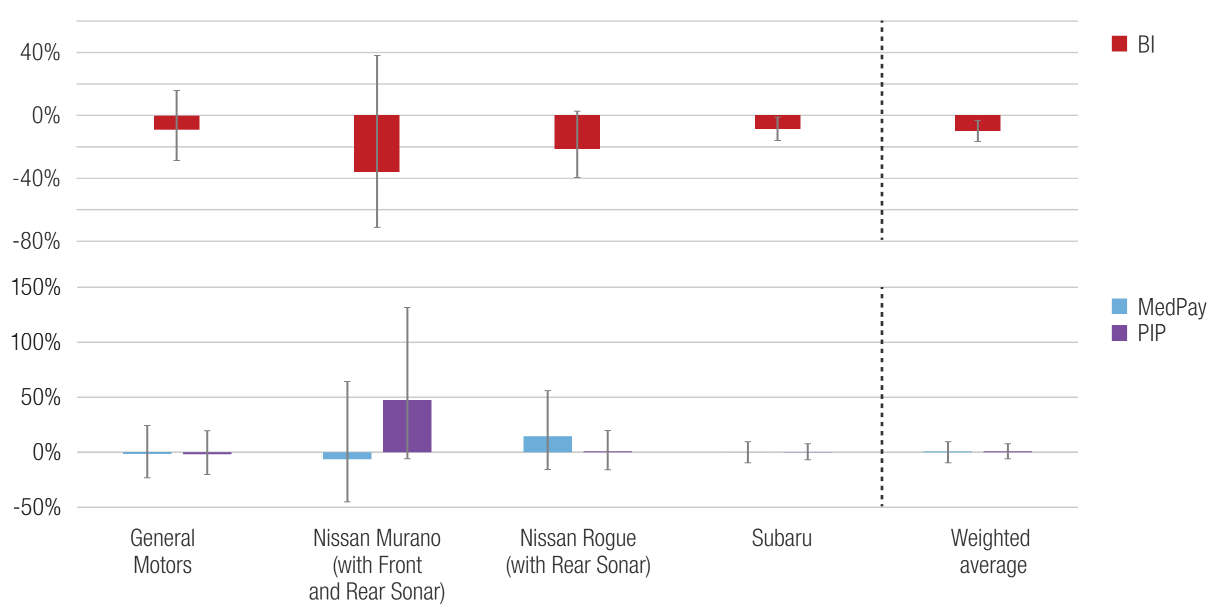
Figure 21 shows the effects of rear AEB on PDL and collision claim frequencies for GM vehicles, the Nissan Murano, the Nissan Rogue, and Subaru vehicles. Rear AEB was associated with significant reductions in PDL and collision claim frequencies for manufacturers and vehicle models. Collectively, the presence of rear AEB was associated with a significant 28.8 percent reduction in PDL claim frequency and a significant 8.7 percent reduction in collision claim frequency.

Figure 21: Change in PDL and collision claim frequency associated with rear AEB



The presence of rear AEB was associated with reductions in BI liability claim frequency across manufacturers and vehicle models. When combined, the presence of a rear camera was associated with a significant 10 percent reduction in BI claim frequency. Rear cameras had an inconsistent effect on MedPay and PIP claim frequencies across manufacturers and vehicle models (Figure 22). Rear AEB increased the MedPay claim frequency by 0.5 percent, and the PIP claim frequency by 0.7 percent. Neither change was statistically significant.

Figure 22: Change in BI liability, MedPay, and PIP claim frequency associated with rear AEB



Discussion

HLDI has conducted more than 95 studies analyzing the association between collision avoidance technologies and changes in claim frequency, severity, and overall losses. Most collision avoidance technologies are associated with reductions in vehicle damage and injury claim frequencies under various coverage types. FCW, front AEB, curve-adaptive headlights, BSW, and parking sensors have been shown to reduce collision, PDL, BI liability, MedPay, and PIP claim frequencies; most of these reductions are statistically significant. LDW, rear cameras, and rear AEB reduce claim frequencies under most coverage types. Curve-adaptive headlights and FCW without AEB, both of which rely on equipment mounted to the front of the vehicle, were associated with increased collision claim severity, though front AEB was not. As a result of the higher claim severity, curve-adaptive headlights were associated with higher overall losses, despite lower collision claim frequency.

Claim frequency

Most collision avoidance technologies affected claim frequency as expected. FCW, front AEB, and BSW are designed to mitigate or prevent collisions with other vehicles, and the findings suggest that the technologies have been successful in this regard. FCW, front AEB, and BSW significantly reduced PDL and BI liability claim frequencies that cover third-party property damage and injury. These technologies also significantly reduced collision claim frequency. Parking sensors, rear cameras, and rear AEB also appeared to help drivers avoid objects and other vehicles when reversing or parking. Each of these technologies significantly reduced PDL claim frequency, parking sensors and rear AEB significantly reduced collision claim frequency too.

Collision avoidance technologies that automatically respond in a crash-imminent situation were more effective for reducing third-party vehicle damage and third-party injury claim frequencies than technologies that only inform or warn drivers. FCW reduced PDL claim frequency by 9.0 percent and BI liability claim frequency by 17.3 percent, but front AEB reduced PDL claim frequency by 14.4 percent and BI liability claim frequency by 23.6 percent. Similarly, rear AEB reduced PDL claim frequency by 28.8 percent, which was more than 5 times the reduction associated with parking sensors and rear cameras.

Some collision avoidance technologies influenced claim frequency in an unexpected way. Curve-adaptive headlights can help prevent single-vehicle crashes that occur at night by providing more light on curved roads; however, this technology did not greatly reduce collision claim frequency. Curve-adaptive headlights were associated with larger significant reductions in PDL and BI claim frequencies, which suggests the technology prevented multivehicle crashes or possibly crashes with pedestrians or other vulnerable road users. One possible explanation is that the additional light from curve-adaptive headlights helps oncoming drivers detect equipped vehicles earlier on curved roads. Similarly, LDW, which should help prevent single-vehicle run-off-road crashes, was not associated with a significant reduction in collision claim frequency. Additionally, unlike the other collision avoidance technologies examined, the changes in claim frequency associated with LDW were inconsistent across coverage types. It is possible that any benefit of LDW is not detectable. The technology is estimated to be relevant to only 3 percent of crashes reported to police each year (Jermakian, 2011) and likely an even smaller proportion of collision claims, which are dominated by low-severity events. Lane-keeping assist may prove more effective for reducing claim frequency than LDW systems that only inform the driver that the vehicle is leaving or has left the lane.

Collision claim severity and overall losses

Curve-adaptive headlights tend to be more expensive than conventional halogen headlights. For instance, the 2017 Subaru Outback's steering-responsive xenon headlamp assembly ($657) costs nearly twice as much as the regular halogen headlight assembly ($355) (Audatex Estimating, 2018). Unfortunately, the front of the vehicle, where headlights are located, is a common point of impact in crashes (e.g., HLDI, 2022c). Consequently, curve-adaptive headlights elevate repair costs for many collision claims as evidenced by the associated increases in collision claim severity across manufacturers.

Locating forward-looking sensors that support FCW and front AEB in the front bumper may make vehicles with those technologies more susceptible to increased repair costs as well. HLDI analyses of FCW found that collision claim severity increased for Honda Accord vehicles equipped with a radar unit mounted in the front bumper, but severity was essentially unchanged for Honda Accord vehicles with a camera mounted in a more protected location behind the windshield. This finding suggests the radar unit may have been responsible for the increase in claim severity, though Honda Accord vehicles equipped with a radar unit also had LED headlights. A HLDI (2016) analysis of vehicle parts data from front impact collision damage estimates for the 2013–14 Honda Accord indicated that the LED headlights contributed to a larger percentage increase in repair estimate dollars than the radar unit. Reductions in collision claim frequency also may offset some of the additional expense of radar or other forward-looking sensors that enable FCW and front AEB. For example, FCW significantly increased collision claim severity across manufacturers but significantly reduced the collision claim frequency and was associated with a very small reduction in overall losses under collision coverage.

Converging evidence

HLDI analyses of insurance claims provided the first estimates of the real-world effect of different collision avoidance technologies on crash outcomes. Subsequent research by IIHS has used police-reported crash data to examine the effectiveness of these technologies for preventing the types of crashes they were designed to address. Most of the IIHS findings are consistent with the HLDI findings. For example, IIHS found that FCW and front AEB reduced rear-end crash involvement rates (Cicchino, 2017a), BSW reduced lane-change crash involvement rates (Cicchino, 2017b), and rear cameras, rear parking sensors, and GM's rear AEB system all reduced backing-crash involvement rates (Cicchino, 2017c; 2018b). In contrast with HLDI findings, IIHS found that LDW reduced the involvement rates for relevant police-reported crash types — single-vehicle run-off-road, side-swipe, and head-on collisions (Cicchino, 2018a). As discussed above, these types of crashes are relatively rare, so even large reductions may be hard to detect in insurance claims, which are dominated by claims for lower-severity crashes (e.g., HLDI, 2022a and 2022b). The reductions in the MedPay and PIP claim frequencies, while not significant, were consistent with Cicchino's findings.

Claim severity is typically interpreted as a measure of damageability and repair costs, but changes in severity also may provide valuable insights into the types of crashes a given technology is preventing or mitigating. A HLDI (2017) study of GM vehicles found that parking sensors with a rearview camera or combined with rear AEB significantly reduced the frequency of lower-severity claims indicative of a parking lot crash but not the higher-severity claims that result from higher-speed collisions. Other HLDI studies have noted shifts in average claim severity for other collision avoidance technologies that may reflect the absence of crashes that the technology is designed to mitigate or prevent (HLDI, 2018f).

Other nuanced analyses provide additional evidence that technologies are having the anticipated effects on crash outcomes in the real world. For example, a HLDI (2021c) study found that the presence of FCW and LDW decreased PDL claim frequency by 17 percent for rated drivers 24 and younger, 12 percent for rated drivers 25-64 years old, and 3 percent for rated drivers 65 and older. These differences are in line with what we know about rated driver age and PDL claim frequency, which is higher for drivers 24 years and younger than for drivers 25-64 years old (HLDI, 2014). Another study that looked at Subaru vehicles and the Honda Accord by registered vehicle density found that front crash prevention systems help mitigate some of the increased crash risk associated with driving in high-density areas (HLDI, 2021b)

Looking ahead

While collision avoidance technologies are offered on many new vehicles, these features are far less prevalent among all passenger vehicles in the U.S. fleet. For instance, a rear camera was either standard or optional equipment on 100 percent of new 2021 model year vehicles, but only 59 percent of registered vehicles in the 2021 calendar year (HLDI, 2022d). Front crash prevention was standard or optional on 89 percent of 2021 model year vehicles but only 36 percent of registered vehicles in the 2021 calendar year. Reductions in claim frequencies observed for many collision avoidance technologies, although sizeable, have only minimal impact on the population of passenger vehicle crashes that occur annually. Crashes and the associated insurance claims and losses experienced by the entire population of passenger vehicles will decrease over time as collision avoidance become more common among registered vehicles in the U.S. fleet.

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Appendix A

Appendix A				
Collision avoidance technology	Coverage type	Percent change	Lower 95% confidence limit	Upper 95% confidence limit
FCW	Collision	-3.1	-3.9	-2.4
	PDL	-9.0	-10.2	-7.9
	BI liability	-17.3	-20.1	-14.5
	MedPay	-19.8	-22.5	-16.9
	PIP	-10.2	-12.6	-7.7
Front AEB	Collision	-3.0	-3.5	-2.6
	PDL	-14.4	-15.1	-13.7
	BI liability	-23.6	-25.4	-21.7
	MedPay	-4.2	-6.4	-2.0
	PIP	-4.0	-5.7	-2.3
Curve-adaptive headlights	Collision	-1.4	-1.9	-0.9
	PDL	-5.2	-6.0	-4.4
	BI liability	-6.7	-8.9	-4.5
	MedPay	-6.2	-8.5	-3.7
	PIP	-4.6	-6.5	-2.7
LDW	Collision	-0.3	-3.1	2.5
	PDL	-0.2	-5.2	5.1
	BI liability	6.2	-7.7	22.0
	MedPay	-0.8	-14.2	14.8
	PIP	-5.2	-15.6	6.4
BSW	Collision	-2.1	-2.5	-1.6
	PDL	-7.1	-7.8	-6.5
	BI liability	-8.2	-10.0	-6.4
	MedPay	-8.0	-9.9	-6.0
	PIP	-6.3	-7.7	-4.8
Parking sensors	Collision	-0.8	-1.4	-0.2
	PDL	-5.4	-6.3	-4.5
	BI liability	-1.1	-3.6	1.3
	MedPay	-5.5	-8.1	-2.9
	PIP	-4.5	-6.6	-2.4
Rear camera	Collision	0.7	0.2	1.2
	PDL	-4.4	-5.1	-3.8
	BI liability	-2.9	-4.8	-1.0
	MedPay	-5.0	-7.0	-2.9
	PIP	-4.4	-6.0	-2.9
Rear AEB	Collision	-8.7	-9.9	-7.5
	PDL	-28.8	-30.5	-27.1
	BI liability	-10.0	-16.5	-3.0
	MedPay	0.5	-5.7	7.1
	PIP	0.7	-4.2	5.9

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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. DH