



2015–23 Mazda advanced driver assistance systems

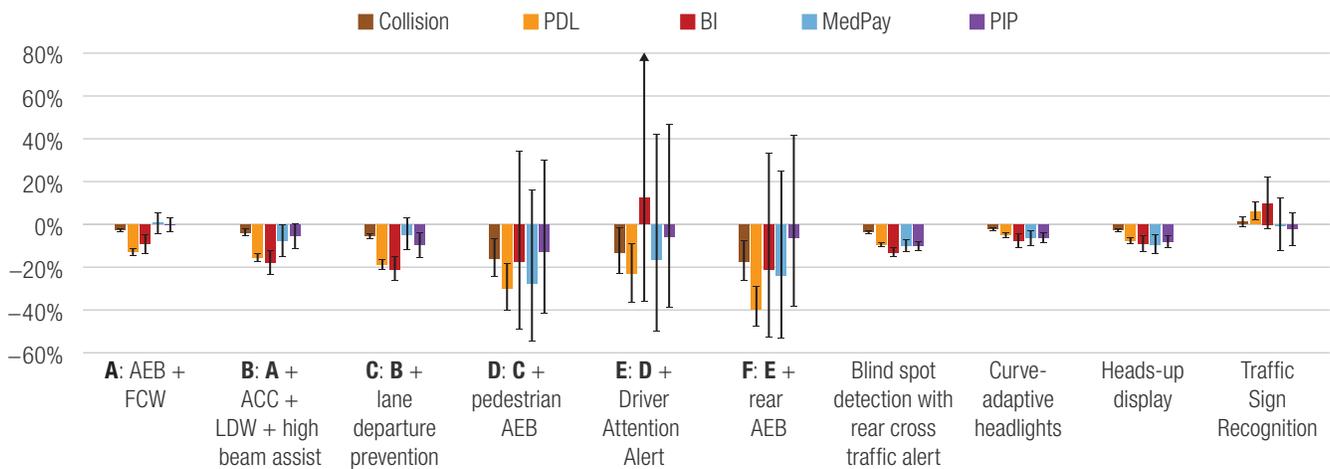
► Summary

The Highway Loss Data Institute (HLDI) has been analyzing Mazda’s advanced driver assistance systems since 2011, assessing new model years and expanded feature sets with each subsequent report. This bulletin presents the latest findings on advanced driver assistance systems available on 2015–23 Mazda vehicles, including effect estimates for six mutually exclusive feature bundles (*Bundles A–F*) that incorporate Mazda’s front crash prevention systems and four stand-alone features. Two of those features, a heads-up display and Traffic Sign Recognition, are analyzed here for the first time.

As shown in the figure below, each of Mazda’s driver assistance feature bundles, all of which include front automatic emergency braking (AEB) and forward collision warning (FCW), was associated with reductions in insurance claim frequencies under most or all coverages. The more comprehensive bundles yielded larger benefits, with the exception of *Bundle E*, which did not demonstrate additional improvements over *Bundle D*. *Bundle E* included all features from *Bundle D* plus Driver Attention Alert, which is designed to detect signs of driver fatigue or distraction. The added feature may not have yielded further reductions in claim frequency because it operates only under limited conditions.

Several stand-alone systems also showed reduced claim frequencies. Blind spot detection with rear cross traffic alert, curve-adaptive headlights, and the heads-up display were associated with statistically significant claim frequency reductions across all coverage types. However, Traffic Sign Recognition was not associated with statistically significant benefits under any coverage type.

Changes in claim frequency associated with Mazda advanced driver assistance systems



The progression from *Bundle A* to *Bundle F* reflects both the addition of more features and the evolution of technologies introduced earlier. For example, while all the bundles had AEB system, *Bundles D, E, and F* contain more advanced versions than that in *Bundles A, B, and C*, offering additional capabilities such as pedestrian detection. As a result, the more comprehensive bundles were expected to deliver enhanced performance, particularly in preventing crashes at higher speeds. A supplemental analysis examining the impact of Mazda’s advanced driver assistance systems on collision and property damage liability claim frequencies by severity range found that bundles with more advanced features were generally associated with greater reductions in claim frequency across all severity ranges.

► Introduction

The Highway Loss Data Institute (HLDI) has been evaluating and reporting on Mazda's driver assistance technologies since 2011. Prior studies have consistently found that many of Mazda's advanced driver assistance systems were associated with benefits in reducing insurance losses. See **Appendix A** for a list of these studies.

HLDI's initial analysis examined the only three collision avoidance features that were available on Mazda's 2007–10 model year vehicles: curve-adaptive headlights, blind spot detection, and a rear parking camera. Since then, Mazda has steadily introduced more driver assistance technologies across its vehicle lineup. This bulletin examines the effectiveness of Mazda's advanced driver assistance systems on insurance losses for 2015–23 model year vehicles.

Mazda uses its own terminology for driver assistance features, and the features that offer the same or similar functionalities may be labeled differently across vehicle series or trims. To ensure consistency in the analysis, this bulletin applies standardized feature names across all vehicle series. Only these uniform feature names are used in the following analysis. **Appendix B** provides a detailed mapping of the standardized names to Mazda's original feature labels.

The functionality of the Mazda features included in this study is detailed below.

Front crash prevention systems

Front automatic emergency braking (AEB) and forward collision warning (FCW), available on model year 2015–18 vehicles, are integrated systems designed to prevent or mitigate frontal collisions. Mazda's system uses a radar or laser sensor (and a forward-sensing camera in some models) to monitor the distance to the vehicle ahead. If a potential collision is detected, the system issues a visual and audible warning via the instrument cluster. If the sensors determine that a collision is imminent, the system automatically applies the brakes to help reduce the severity of the impact. In addition, when the driver depresses the brake pedal while the system is in a certain operating speed range, enhanced brake assistance is provided to support rapid deceleration. Note that some early model years may include only AEB, only FCW, or both features.

Front AEB with pedestrian detection and FCW, introduced in model year 2018, are designed to alert the driver of a potential collision with either a vehicle or a pedestrian ahead. When the forward-sensing camera detects an object ahead and determines that a collision is likely, the system issues a visual alert on the display along with an audible warning. If the system determines that a collision is unavoidable, it automatically activates brake control to help reduce the severity of the impact. Additionally, if the driver depresses the brake pedal while the system is operating within its functional range, the brakes are applied more firmly and quickly to assist in avoiding the collision. The operating speed range of these functions may vary depending on the vehicle series and system generation.

Adaptive cruise control (ACC) is designed to automatically maintain a preset vehicle speed and following distance between the driver's vehicle and the vehicle ahead, without requiring manual use of the accelerator or brake pedals. Using a front radar sensor, the system continuously monitors the distance to the vehicle ahead and adjusts the equipped vehicle's speed to maintain the preset following distance. If the gap begins to close rapidly, such as when the leading vehicle brakes suddenly, ACC activates a visual warning on the display along with an audible alert to prompt the driver to maintain a safe distance. In some later model year vehicles, ACC also includes stop-hold control, allowing the vehicle to come to a complete stop and remain stationary if the vehicle ahead stops. When the traffic starts moving, the system resumes the same preset speed and following distance at a cue from the driver.

Side-assist systems

Lane departure warning (LDW) uses the forward-sensing camera to detect white or yellow lane markings on the road. If the system determines that the vehicle may be unintentionally deviating from its lane, it alerts the driver by activating a lane departure warning sound, vibrating the steering wheel, and indicating an alert in the display.

Lane departure prevention (LDP) is designed to help the driver stay within the travel lane by providing both alerts and steering assistance. Using the forward-sensing camera, the system detects white and yellow lane markings on the road. If it determines that the vehicle may be unintentionally drifting out of its lane, LDP operates the electric power steering to assist the driver's steering operation. In addition to steering support, the system alerts the driver through a lane departure warning sound, steering wheel vibration, and a visual indicator in the display.

Blind spot detection monitors whether vehicles are approaching from the rear in an adjacent lane while the vehicle is traveling in the forward direction at a speed of 6.3 mph (10 km/h) or higher. When a vehicle is detected, the feature alerts the driver by turning on a warning light and displaying the vehicle detection screen (for vehicles with multi-information display and active driving display). If the turn signal lever is operated to signal a turn in the direction from which the vehicle in the adjacent lane is approaching, the system notifies the driver of possible danger with an audible alert and enhanced visual indicators. The detection area on this system covers the driving lanes on both sides of the vehicle and from the rear part of the front doors to about 164 feet (50 meters) behind the vehicle.

Night-assist systems

High beam assist uses the forward-sensing camera to monitor road conditions ahead while driving in darkness. It automatically switches the headlights between high and low beams based on the surrounding environment. When the vehicle is traveling at approximately 19 mph (30 km/h) or faster and no vehicles are detected ahead or approaching from the opposite direction, the system activates the high beams. Conversely, it switches to low beams when it detects a vehicle ahead or oncoming headlights, when the area is well lit, or when the vehicle is traveling less than about 12 mph (20 km/h).

Curve-adaptive headlights automatically adjust the direction of the headlight beams to the left or right in conjunction with the operation of the steering wheel after the headlights have been turned on.

Parking-assist systems

Rear cross traffic alert is designed to assist the driver in monitoring the area behind while the vehicle is reversing. The system detects vehicles approaching from the rear left, rear right, and directly to the rear of the vehicle while the vehicle is being reversed. If a potential hazard is detected, rear cross traffic alert notifies the driver using the blind spot detection lights and an audible tone.

Rear AEB, first introduced in the 2021 model year, operates when the vehicle is moving backward at a speed of approximately 2–4 mph (2–8 km/h). If the system's ultrasonic sensors detect that a collision is imminent with an obstruction behind the vehicle, rear AEB automatically applies the brakes to prevent or mitigate the impact.

Other driver assistance systems

Driver Attention Alert, introduced in model year 2021, is designed to detect signs of driver fatigue and reduced attentiveness and to encourage the driver to take a break when necessary. The feature operates on laned roads at travel speeds of 41–86 mph (65–140 km/h). It estimates the driver's accumulated fatigue and decreased attentiveness based on the information from the forward-sensing camera and other vehicle information. If the system detects signs of reduced attentiveness, it prompts the driver to take a rest through a visual alert on the multi-information display and an audible warning.

The **heads-up display** projects essential driving information, such as speed, navigation guidance, and safety alerts, directly onto the windshield. This allows the driver to stay focused on the road without needing to glance down at the instrument cluster or center display.

Traffic Sign Recognition, available on model year 2021–23 vehicles, uses the forward-sensing camera or recorded information in the navigation system to identify and display recognized traffic signs (such as speed limit, do not enter, and traffic stop signs) on the active driving display. If the vehicle speed exceeds the speed limit sign indicated in the active driving display, the system alerts the driver with a visual warning and an audible alert.

Feature dependencies

As driver assistance technology has evolved, many of the sensor and camera systems provide functionality for more than one collision avoidance feature. For example, the radar sensors used for blind spot detection are also used for rear cross traffic alert. Similarly, the forward-sensing camera that is used for front AEB and FCW is used to identify lane markings for the lane departure warning and lane departure prevention systems and also supports high beam assist. As a result, many of the vehicles equipped with front AEB and FCW also have these other systems.

Mazda also has multiple systems that provide similar functionality with different levels of sophistication and capabilities. For instance, both lane departure warning and lane departure prevention provide warnings if the vehicle appears to be unintentionally departing its lane. However, the more advanced lane departure prevention expands on that functionality by actively assisting with steering through electric power steering to help prevent an unintended lane departure.

In addition, Mazda provides several versions of front crash prevention packages. All packages include at least front AEB and FCW. On some vehicles with front AEB and FCW, an optional upgrade added lane departure warning, adaptive cruise control, and high beam assist, but it was not possible to get these systems without already having front AEB and FCW. Vehicles equipped with lane departure prevention, which Mazda introduced in model year 2016, also include the aforementioned systems.

Furthermore, even when different sensor systems are used, Mazda chooses to bundle certain technologies together. As a result, some driver assistance features are never available independently from other features. For example, rear AEB was introduced in model year 2021 as an optional feature on selected Mazda vehicles, but it is only available in conjunction with the front crash prevention systems mentioned previously.

Because the insurance data provided to HLDI do not contain information on the type of crash that led to a claim, it is not always possible to separate out the individual effect on insurance losses for driver assistance features that are only available with other features. In these circumstances, HLDI evaluates the effect of the combined group of features. The *Method* section contains additional details about how systems were chosen to be grouped and evaluated.

► Method

Vehicles

Although some driver assistance systems are offered as standard equipment for specific model years and trim levels, others are available only as optional equipment. The presence or absence of these optional features is not discernible from the information encoded in the Vehicle Identification Numbers (VINs). Instead, feature information associated with an individual VIN were obtained from the manufacturer.

Mazda supplied HLDI with VINs for vehicles from model years 2015 to 2023 that were equipped with at least one of the advanced driver assistance systems listed previously. Vehicles not identified by Mazda were assumed not to have any of these features and thus served as the control vehicles in the analysis. Feature information for hybrid and electric vehicles were not provided by Mazda and thus those vehicles were excluded from the analysis.

Table 1A presents the collision exposure for the vehicle series and model years included in the analysis. The percentage of overall exposure for each feature, along with the model years in which the features were available, are shown in **Table 1B**.

Table 1A: Exposure by vehicle series		
Mazda series	Model year range	Collision exposure
3 4dr 2WD	2015–23	1,406,553
3 4dr 4WD	2019–23	70,854
3 5dr 2WD	2015–23	859,193
3 5dr 4WD	2019–23	77,939
6 4dr 2WD	2015–21	1,363,463
CX-3 4dr 2WD	2016–18	65,461
CX-3 4dr 2WD/4WD	2016	94,502
CX-3 4dr 4WD	2016–18	156,116
CX-30 4dr 2WD	2020–21	76,910
CX-30 4dr 4WD	2020–23	389,522
CX-5 4dr 2WD	2015–21	1,935,986
CX-5 4dr 4WD	2015–23	3,787,844
CX-50 4dr 4WD	2023	77,396
CX-9 4dr 2WD	2015–21	294,812
CX-9 4dr 4WD	2015–23	615,660
Total		11,272,212

Table 1B: Percent of collision exposure with feature		
Feature name	Exposure proportion	Available model years
Front automatic emergency braking and forward collision warning	21%	2015–18
Front automatic emergency braking with pedestrian detection and forward collision warning	40%	2018–23
Adaptive cruise control	48%	2015–23
Lane departure warning	48%	2015–23
Lane departure prevention	45%	2016–23
Blind spot detection	86%	2015–23
Rear cross traffic alert	86%	2015–23
High beam assist	48%	2015–23
Curve-adaptive headlights	34%	2015–23
Heads-up display	20%	2015–23
Rear automatic emergency braking	2%	2021–23
Driver Attention Alert	7%	2021–23
Traffic Sign Recognition	3%	2021–23

Insurance data

Automobile insurance covers damage to vehicles and property resulting from crashes, plus injuries to people involved in the crashes. Vehicle damage and injuries are paid for by different types of insurance coverage, and different coverages may apply depending on who is at fault. The current study is based on collision, property damage liability (PDL), bodily injury liability (BI), medical payment (MedPay), and personal injury protection (PIP) coverages. Exposure is measured in insured vehicle years. An insured vehicle year is equivalent to one vehicle insured for 1 year, two vehicles insured for 6 months, and so forth.

Because different advanced driver assistance systems may affect different types of insurance coverage, it is important to understand how coverages vary among the states and how this affects inclusion in the analysis. Collision coverage insures against damage to an at-fault driver's vehicle sustained in a crash with an object or other vehicle; this coverage exists in 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. In a no-fault state, each owner's insurance policy pays for crash damage to the owner's vehicle, regardless of who is at fault.

Coverage of injuries is more complex. BI coverage insures against medical, hospital, and other expenses for injuries that at-fault drivers inflict on occupants of other vehicles or others on the road. Although motorists in most states may have BI coverage, this information is analyzed only in states where the at-fault driver has the first obligation to pay for injuries (33 states with traditional tort insurance systems). MedPay coverage, also sold in the 33 states with traditional tort insurance systems, covers injuries to insured drivers and the passengers in their vehicles, but not injuries to people in other vehicles involved in the crash. Seventeen other states employ no-fault injury systems (PIP) that pay up to a specified amount for injuries to occupants of involved insured vehicles, regardless of who is at fault in a collision. The District of Columbia has a hybrid insurance system for injuries and is excluded from the injury analysis.

Driver assistance system groupings

The primary purpose of the study was to better understand how driver assistance technologies affect insurance losses. To that end, when possible and sensible, the analysis aimed to isolate the effects of individual systems. However, due to the way Mazda and other manufacturers bundle systems and the fact that a single sensor can provide functionality for several different driver assistance technologies, estimating the impact of a single system is not always feasible.

For example, the majority of vehicles equipped with adaptive cruise control also had high beam assist and lane departure warning. There is very limited data available for vehicles equipped with only one or two, but not all, of these systems, making it difficult to evaluate them independently. To improve reliability of the results, any vehicles equipped with only one or two of these systems were excluded in the analysis.

Similarly, nearly all of the vehicles with front AEB with pedestrian detection and FCW were also equipped with adaptive cruise control, high beam assist, lane departure warning, and lane departure prevention. The few vehicles that had only front AEB with pedestrian detection and FCW but not the other systems were excluded from the analysis. The single Mazda model equipped with blind spot detection and not rear cross traffic alert was also excluded.

In some cases, the statistical model can derive separate estimates for systems that are always bundled together. In other cases, evaluating the combined effect of the systems is more appropriate.

Table 2 outlines how systems were grouped and evaluated in this study. While some features may appear in multiple bundles, the bundles themselves are mutually exclusive, which means that the same vehicle cannot be equipped with more than one bundle.

Table 2: Grouping of driver assistance systems

Bundled systems	Bundle A: Front AEB and FCW	13%
	Bundle B: Front AEB, FCW, ACC, LDW, and high beam assist	3%
	Bundle C: Front AEB, FCW, ACC, LDW, high beam assist, and lane departure prevention	5%
	Bundle D: Front AEB with pedestrian detection, FCW, ACC, LDW, high beam assist, and lane departure prevention	32%
	Bundle E: Front AEB with pedestrian detection, FCW, ACC, LDW, high beam assist, lane departure prevention, and Driver Attention Alert	5%
	Bundle F: Front AEB with pedestrian detection, FCW, ACC, LDW, high beam assist, lane departure prevention, Driver Attention Alert, and rear AEB	2%
Independent systems	Blind spot detection with rear cross traffic alert	86%
	Curve-adaptive headlights	34%
	Heads-up display	20%
	Traffic Sign Recognition	3%

Statistical methods

Regression analysis was used to quantify the effect of each vehicle feature or feature bundle while controlling for the other covariates. The covariates included vehicle model year and series; calendar year; garaging state; vehicle density (number of registered vehicles per square mile); rated driver age group, gender, and marital status; deductible range (collision coverage only); and risk. For each safety feature or bundle studied, a binary variable was included.

Claim frequency was modeled using a Poisson distribution, whereas claim severity (average loss payment per claim) was modeled using a Gamma distribution. Both models used a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models. Estimates for claim frequency, claim severity, and overall losses are presented for collision and PDL coverages. For BI, MedPay, and PIP, only frequency estimates for all claims (those that have already been paid and those for which money has been set aside for possible payment in the future) are presented.

For space reasons, only the estimates for the driver assistance features or bundles are shown on the following pages. To illustrate the analysis, however, **Appendix C** contains full model results for collision claim frequency. To further simplify the presentation here, the exponent of the parameter estimate was calculated, 1 was subtracted, and the result was multiplied by 100. The resulting number corresponds to the effect of the feature or feature bundle on that loss measure. For example, the estimate of the effect of *Bundle A* on collision claim frequency was -0.0265 ; thus, vehicles with this feature bundle had 2.6% fewer collision claims than vehicles without *Bundle A* ($[\exp(-0.0265) - 1] \times 100 = -2.6$).

► Results

Results for each driver assistance feature or feature bundle are presented in the following figures. Standard practice has been to use the same y-axis range in figures when comparing results. To aid in the visualization of these results, two distinct y-axis ranges were utilized. **Figures 1–6** show the results for the bundles described in the *Method* section, and **Figures 7–10** show the results for the stand-alone features. The estimates in each figure indicate the changes in insurance losses for vehicles equipped with the feature or feature bundle compared with unequipped vehicles. For all figures, the vertical I-bars represent the 95% confidence intervals for each estimate.

Figure 1 shows the estimated differences in insurance losses associated with *Bundle A*, which includes front AEB and FCW. For vehicle damage losses, collision and PDL claim frequencies declined by 3% and 13%, respectively, while claim severity increased by approximately 4% for both. All results were statistically significant. This resulted in nearly no change in collision overall losses and a significant 10% reduction in PDL overall losses.

For injury-related losses, claim frequency decreased significantly for BI (9%) but not for MedPay or PIP.

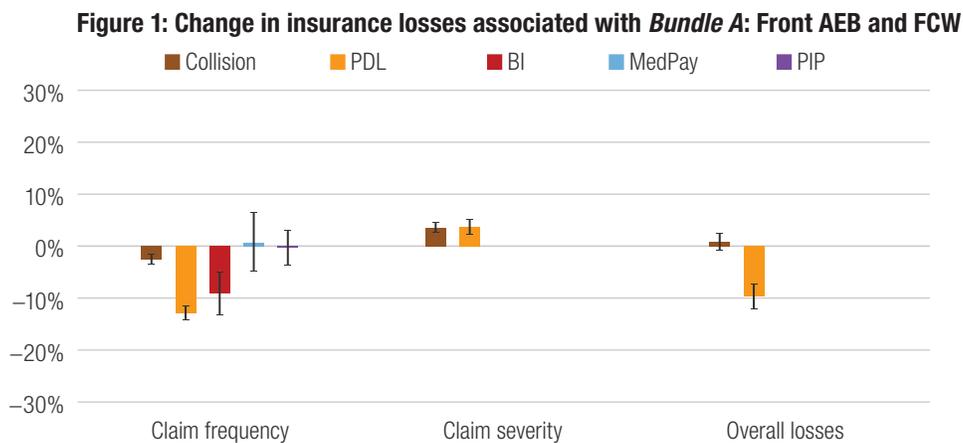
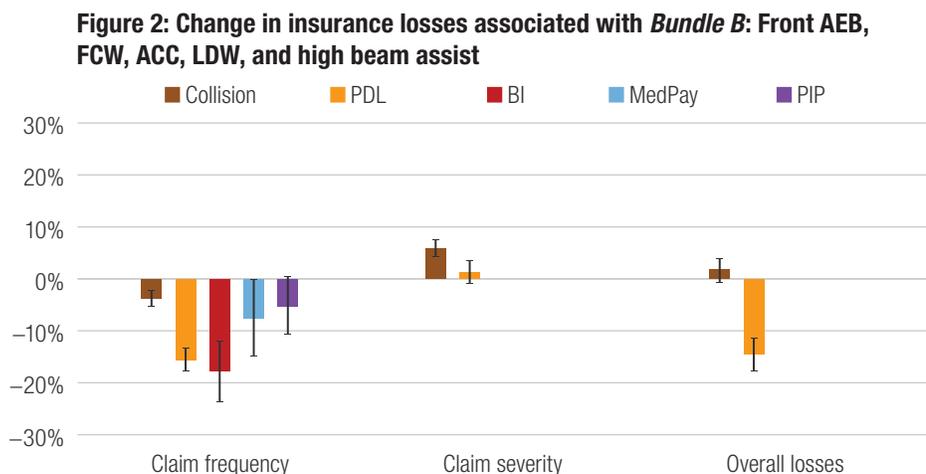


Figure 2 summarizes the estimated differences in insurance losses associated with *Bundle B*, which includes front AEB, FCW, adaptive cruise control, lane departure warning, and high beam assist. Reductions in claim frequency were observed across all five coverages. The results were statistically significant for all coverages except PIP. The largest reduction was seen in BI at 18%, followed by PDL at 16%.

In contrast, claim severity increased by 6% for collision and 1% for PDL, though only the increase in collision claim severity was statistically significant. As a result, collision overall losses showed a nonsignificant increase of 2%, while PDL overall losses showed a significant decrease of 14%.



The estimated differences in insurance losses associated with *Bundle C* are summarized in **Figure 3**. This bundle includes all the features in *Bundle B* and also lane departure prevention. For vehicle damage coverages, claim frequency declined significantly for both collision and PDL (5% and 19%, respectively). Collision claim severity increased by a statistically significant 3%, while PDL severity decreased by a nonsignificant 2%. These changes led to significant reductions in overall losses for both collision (3%) and PDL (21%).

Under injury-related coverages, claim frequency decreased for all coverage types, with significant reductions for BI and PIP. The largest reduction in claim frequency was observed for BI at 21%.

Figure 3: Change in insurance losses associated with *Bundle C*: Front AEB, FCW, ACC, LDW, high beam assist, and lane departure prevention

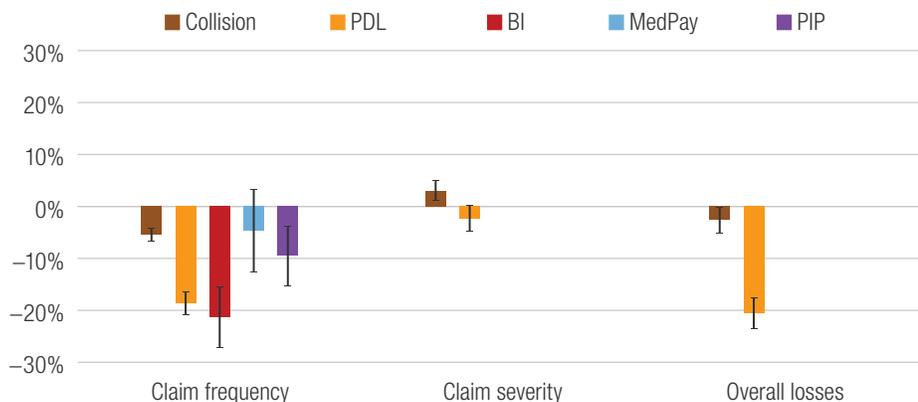
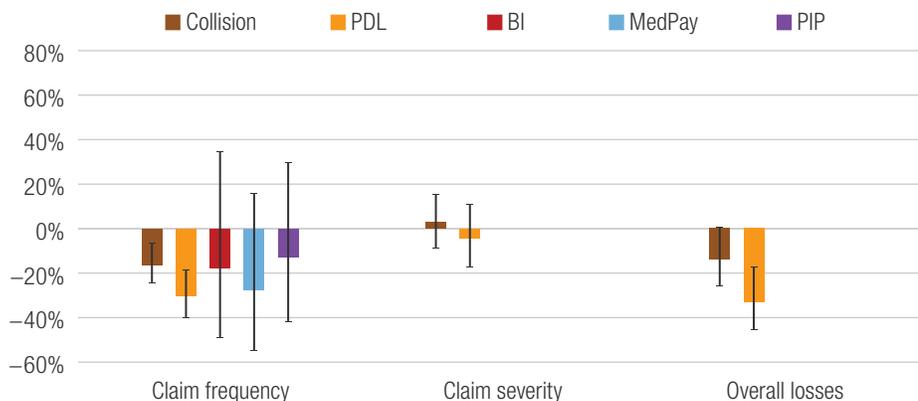


Figure 4 summarizes the estimated differences in insurance losses associated with *Bundle D* (front AEB with pedestrian detection, FCW, adaptive cruise control, lane departure warning, high beam assist, and lane departure prevention). Claim frequency reductions were observed across all studied coverages, but only the results for collision and PDL were statistically significant. The reductions in claim frequency for *Bundle D* ranged from 13% for PIP to 30% for PDL.

The bundle was also associated with an increased claim severity for collision and a decreased severity for PDL; however, neither result was statistically significant. As a consequence, overall losses declined by 14% for collision and 33% for PDL, with the result for PDL being significant.

Figure 4: Change in insurance losses associated with *Bundle D*: Front AEB with pedestrian detection, FCW, ACC, LDW, high beam assist, and lane departure prevention



The estimated differences in insurance losses associated with *Bundle E* are shown in **Figure 5**. *Bundle E* includes all features from *Bundle D* plus Driver Attention Alert. For vehicle damage losses, claim frequency decreased significantly by 13% for collision and 23% for PDL. Claim severity showed small and nonsignificant reductions of 1% for collision and 5% for PDL, resulting in a nonsignificant 14% reduction in collision overall losses and a significant 27% reduction in PDL overall losses.

For injury losses, claim frequency decreased for MedPay and PIP but not for BI. However, none of the results were statistically significant.

Figure 5: Change in insurance losses associated with *Bundle E*: Front AEB with pedestrian detection, FCW, ACC, LDW, high beam assist, lane departure prevention, and Driver Attention Alert

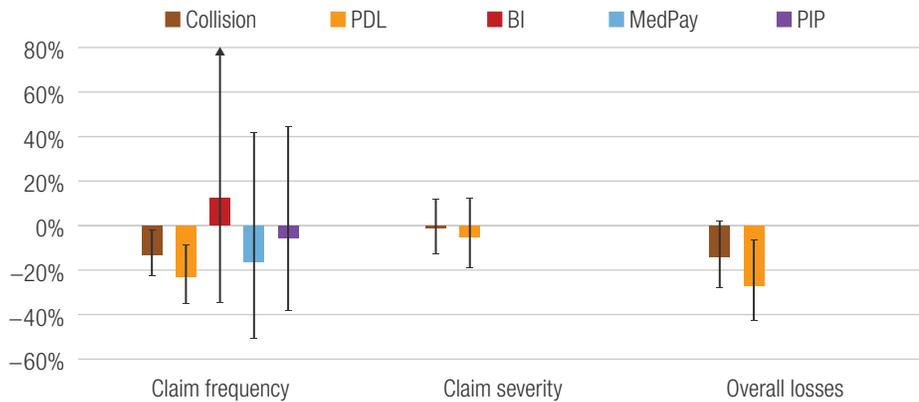


Figure 6 summarizes the estimated differences in insurance losses associated with *Bundle F*, which includes the features in *Bundle E* as well as rear AEB. For collision coverage, *Bundle F* was associated with a statistically significant 17% reduction in claim frequency and a nonsignificant 7% increase in claim severity, resulting in a nonsignificant 11% decrease in overall losses. For PDL, claim frequency declined by 39%, while claim severity increased by 3%, leading to a 37% reduction in overall losses, and only the result for claim severity was not statistically significant.

Under injury related coverages, claim frequency decreased by 21% for BI, 24% for MedPay, and 6% for PIP. However, none of these reductions were statistically significant.

Figure 6: Change in insurance losses associated with *Bundle F*: Front AEB with pedestrian detection, FCW, ACC, LDW, high beam assist, lane departure prevention, Driver Attention Alert, and rear AEB

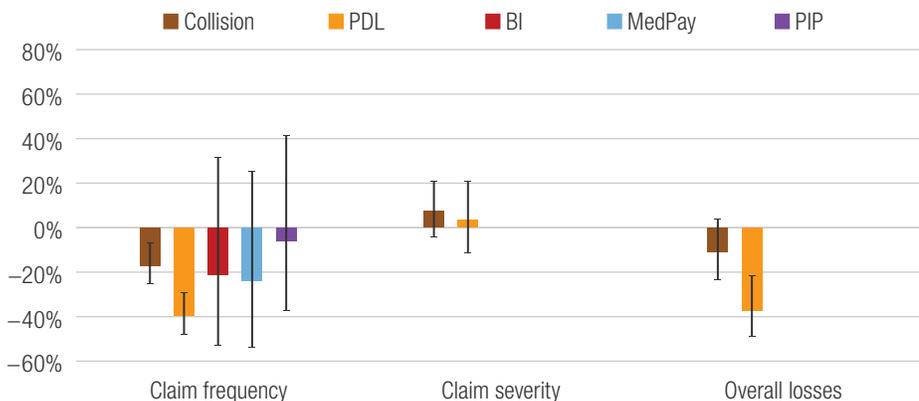
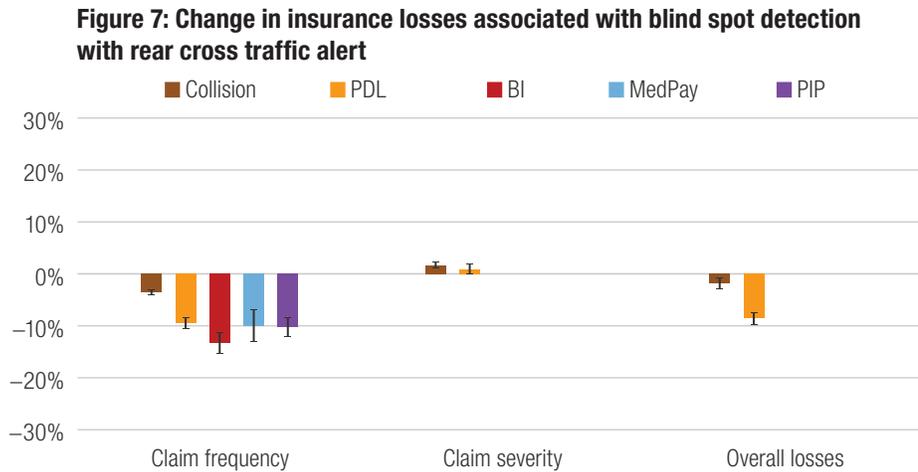


Figure 7 displays the estimated differences in insurance losses associated with blind spot detection with rear cross traffic alert. Statistically significant reductions in claim frequency were observed across all coverages, ranging from 4% for collision to 13% for BI. Claim severity increased by 2% for collision and 1% for PDL, with a statistically significant result for collision. As a result, there were significant reductions of 2% and 9% in overall losses for collision and PDL, respectively.



The estimated differences in insurance losses associated with curve-adaptive headlights are summarized in **Figure 8**. For vehicle damage losses, claim frequency showed statistically significant reductions for both collision and PDL (2% and 5%, respectively). Collision claim severity increased significantly by 3%, while PDL severity remained essentially unchanged. This resulted in no meaningful change in collision overall losses and a statistically significant 5% reduction in PDL overall losses.

For injury-related losses, claim frequency decreased significantly across all coverages, with reductions of 6% for MedPay and PIP, and 8% for BI.

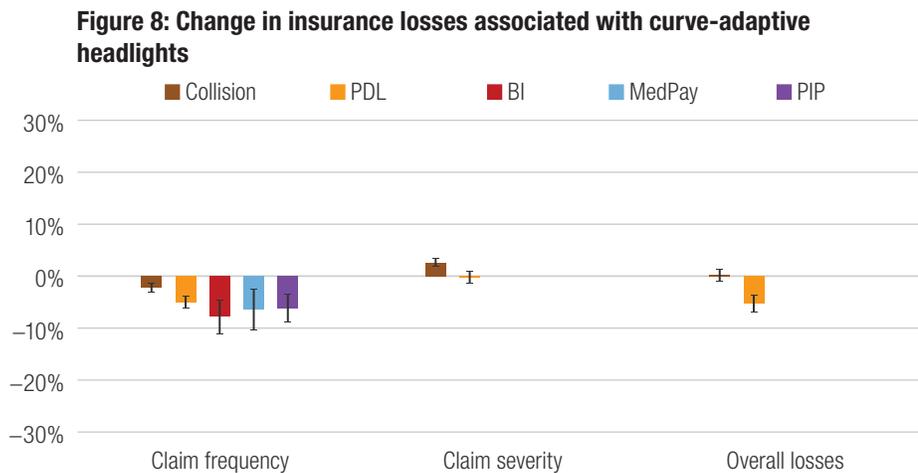


Figure 9 shows the estimated differences in insurance losses associated with the heads-up display. Statistically significant reductions in claim frequency were observed across all five coverages, ranging from 3% for collision to 9% for BI and MedPay. Collision claim severity remained essentially unchanged, resulting in a 2% reduction in collision overall losses. In contrast, PDL claim severity showed a slight significant increase of 2%. Despite this increase, the substantial reduction in claim frequency led to a statistically significant 6% decrease in PDL overall losses.

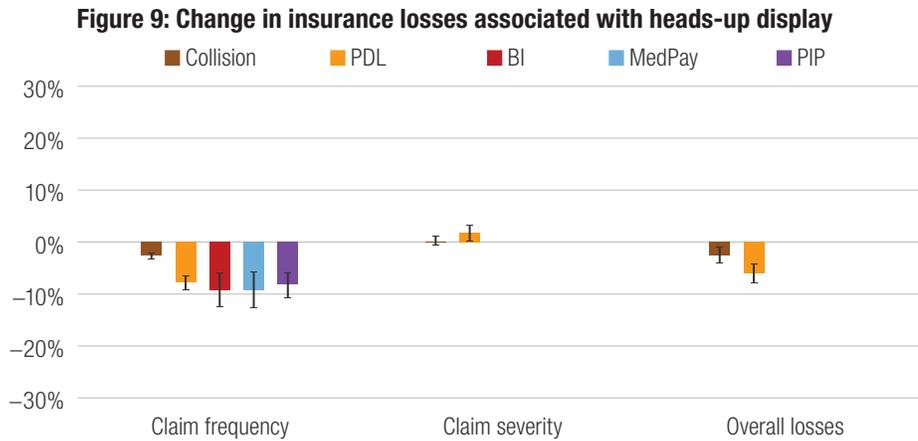
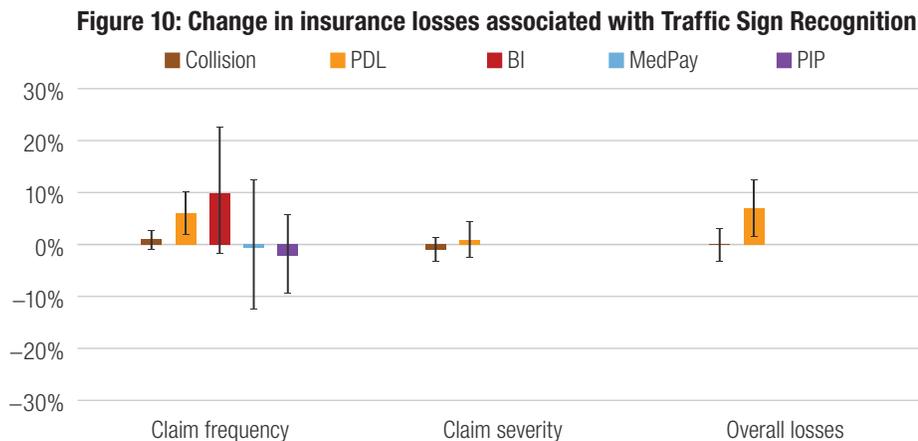


Figure 10 displays the estimated differences in insurance losses associated with Traffic Sign Recognition. For vehicle damage losses, claim frequency increased for both collision and PDL (1% and 6%, respectively). Collision claim severity decreased by 1%, while PDL severity increased by 1%. As a result, collision overall losses remained unchanged, whereas PDL overall losses increased by 7%. Only the results for PDL claim frequency and overall losses were statistically significant.

For injury-related coverages, this system was associated with a 10% increase in BI claim frequency and decreases of 1% and 2% for MedPay and PIP, respectively. However, none of these results were statistically significant.

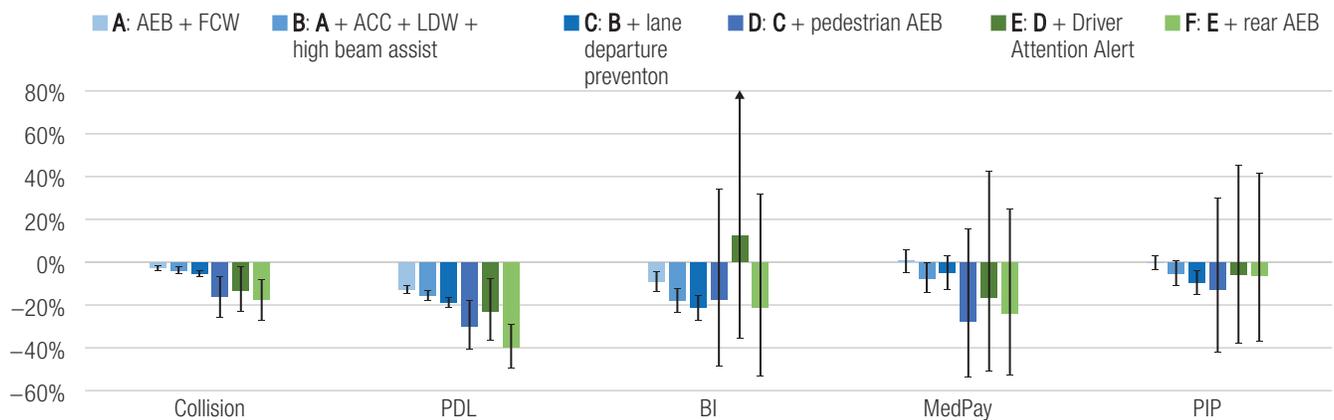


► Discussion

Most of Mazda’s advanced driver assistance systems have demonstrated promising benefits on reducing insurance losses, particularly when offered as bundled packages that include, at minimum, front automatic emergency braking (AEB) and forward collision warning (FCW).

This bulletin examined six distinct feature bundles based on the availability and interdependence of Mazda’s advanced driver assistance systems. These bundles were structured as mutually exclusive tiers, with each successive bundle incorporating one or more additional features. **Figure 11** summarizes the estimated differences in claim frequency associated with these stacked bundles. In general, bundles with more features were associated with greater reductions in claim frequency.

Figure 11: Change in claim frequency associated with Mazda driver assistance bundles



Starting with the 2014 model year, Mazda introduced two types of front crash prevention systems (HLDI, 2018). These systems are designed to primarily prevent front-to-rear crashes, which typically result in PDL and BI claims. Vehicles equipped with the basic configuration—referred to as *Bundle A*, which includes only front automatic emergency braking (AEB) and forward collision warning (FCW) — showed statistically significant reductions in claim frequencies for collision, PDL, and BI coverages compared with vehicles without these systems.

Some other vehicles were equipped with a more advanced configuration, *Bundle B*, which added adaptive cruise control (ACC), lane departure warning (LDW), and high beam assist to the basic bundle. These vehicles exhibited greater reductions in claim frequency across all coverage types than those with *Bundle A*.

In the 2016 model year, Mazda introduced lane departure prevention on select vehicles that were already equipped with lane departure warning. Vehicles with those features also included front AEB, FCW, adaptive cruise control, and high beam assist. The combination of these systems was categorized as *Bundle C*. Compared with *Bundle B*, *Bundle C* was associated with further reductions in claim frequency.

In model year 2018, Mazda enhanced its front AEB system by adding pedestrian detection capability, which became a standard feature beginning in model year 2019. *Bundle D* mirrored *Bundle C* but incorporated the upgraded pedestrian AEB. Compared with the prior *Bundle C*, *Bundle D* was associated with substantially greater benefits. Collision claim frequency reductions increased from 5% to 16%, and PDL reductions rose from 19% to 30%. However, because a large proportion of newer vehicles were equipped with pedestrian AEB and other advanced systems, there were limited numbers of unequipped vehicles in the comparison group, resulting in wide confidence intervals for injury-related coverages. While reductions in MedPay and PIP were greater than those observed for *Bundle C*, their confidence bounds overlapped.

Driver Attention Alert became available on select vehicles in model year 2021. This system detects driver fatigue and decreased attentiveness based on the information from the forward-sensing camera, which is also used for other systems such as front AEB, FCW, and lane departure warning. Thus, all vehicles with Driver Attention Alert were also equipped with systems included in *Bundle D*, forming *Bundle E*. However, *Bundle E* did not yield additional benefits

beyond those observed in *Bundle D*. In fact, it showed reduced benefits across most coverages and an increase in BI claim frequency, although only the results for collision and PDL were statistically significant. Driver Attention Alert operates under specific conditions, activating after approximately 20 minutes of driving between 41 mph and 86 mph (65 km/h and 140 km/h), and may not operate normally when lane markings are unclear or during lane changes, which may explain why there was no significant benefit associated with this system.

Bundle F includes all features in *Bundle E* and rear AEB. Compared with *Bundle E*, *Bundle F* demonstrated improved reductions in claim frequency across all coverage types, especially for PDL and BI. These findings are consistent with other HLDI research showing that rear AEB, both as a stand-alone feature and within bundles, is associated with large and significant reductions in claim frequencies (HLDI, 2022, 2023).

Across all bundles examined, collision claim severities generally increased, while PDL severities showed mixed results, as illustrated in **Figure 12**. Consequently, the overall losses for collision and PDL followed patterns similar to those observed for claim frequency, as shown in **Figure 13**.

Figure 12: Change in claim severity associated with Mazda driver assistance bundles

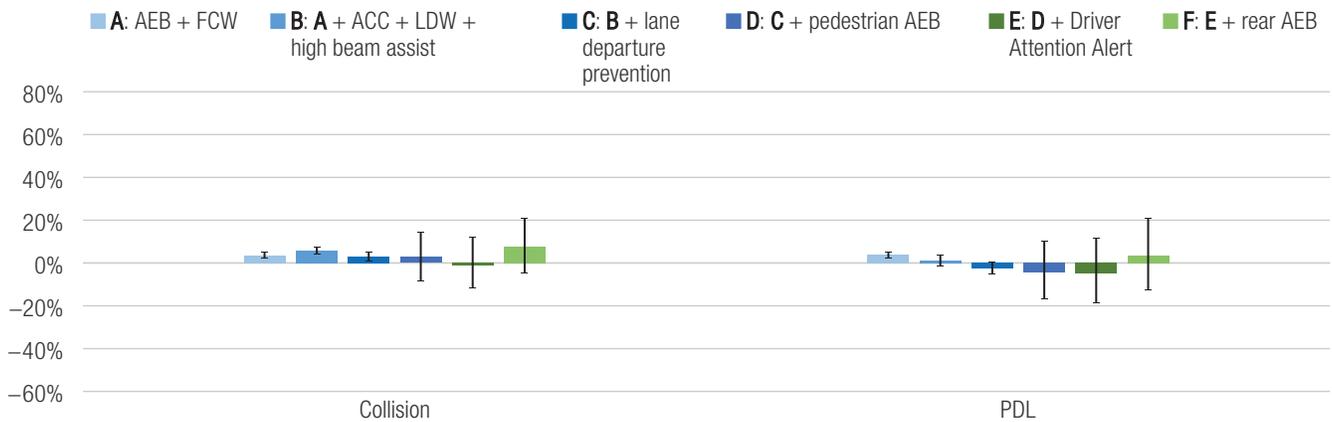
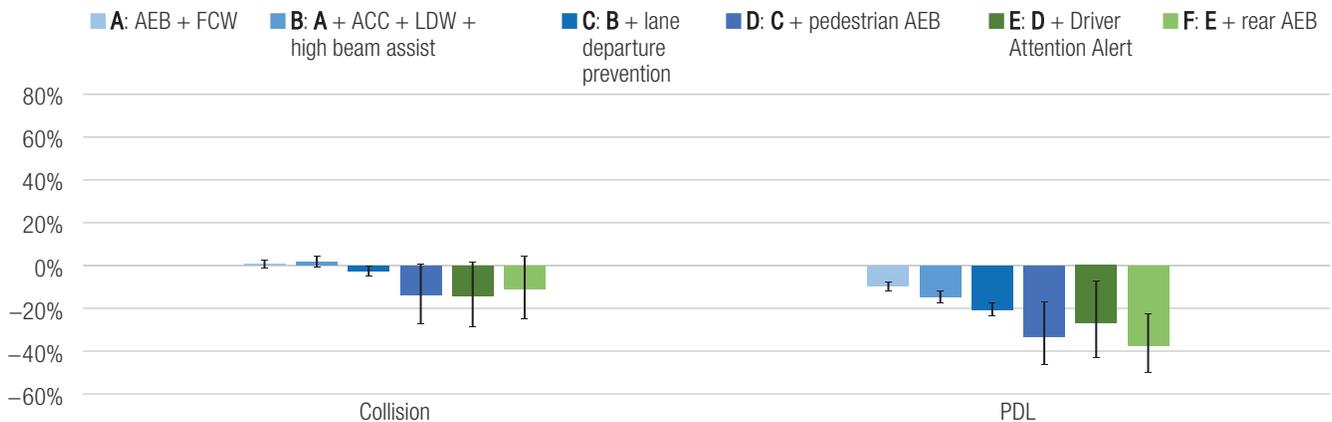


Figure 13: Change in overall losses associated with Mazda driver assistance bundles



In addition to the bundles, Mazda offers several driver assistance technologies that can be evaluated independently. Most of these systems were also associated with promising benefits in reducing insurance losses.

Mazda's blind spot detection and rear cross traffic alert systems utilize the same radar sensors mounted inside the rear bumper and, therefore, could not be assessed separately. Consistent with prior HLDI studies, vehicles equipped with these two features showed significantly lower claim frequency across all coverage types than vehicles without them (HLDI, 2018, 2023). However, the two features were also associated with slight increases in both collision and PDL claim severities.

Curve-adaptive headlights were associated with reductions in claim frequency for all coverages, which is consistent with the findings from other manufacturers (HLDI, 2023). A prior HLDI study examining this feature on the 2010 Mazda 3 by time of day found significant reductions in nighttime collision and PDL claim frequencies, while differences during the day were not statistically significant (HLDI, 2016).

The heads-up display, evaluated by HLDI for the first time, also demonstrated promising reductions in claim frequency. This may indicate that there are safety benefits in presenting critical driving information directly in the driver's line of sight and thereby reducing the need to glance away at the instrument cluster or center display.

In contrast, Traffic Sign Recognition, another system being evaluated for the first time, was the only system that did not show a significant reduction in claim frequency for any coverage. This lack of benefits may be due to various factors such as environmental conditions or obstructed signage. Moreover, a recent study from the Insurance Institute for Highway Safety (IIHS) found that a large majority of Mazda drivers with this feature tended to disable the audible warning for exceeding the posted speed limit (Cox et al., 2025), which may further explain the absence of measurable benefits.

Different collision avoidance technologies are designed to prevent different types of crashes and may operate effectively at different speed ranges. For example, previous studies (HLDI, 2022, 2025a) have shown that parking-assist systems like rear AEB and night-assist systems like curve-adaptive headlights are more likely to prevent low-speed crashes, which would typically result in low-severity collision and PDL claims rather than high-severity claims.

On the other hand, the systems installed on newer vehicles may be able to help prevent higher-severity claims. Newer vehicles are more likely to be equipped with not only a greater number of driver assistance systems but also next-generation technologies with enhanced capabilities. Some of these technologies are designed to function at a broader range of speeds than earlier versions and are expected to help prevent crashes that result in higher-dollar claims. To better understand these systems, an additional analysis was conducted to evaluate the effect of Mazda's driver assistance features and feature bundles on collision and PDL claim frequencies by severity range.

Claim severity for both collision and PDL has steadily increased over time (HLDI, 2025b, 2025c). As shown in **Table 3**, the median (50th percentile) payment of collision claims for Mazda vehicles rose more than 1½ times from \$1,767 in 2014 to \$4,750 in 2024. For PDL claims, the increase was less pronounced, but still more than 80%, rising from \$1,980 in 2014 to \$3,675 in 2024.

Table 3: Mazda collision and PDL claim size by calendar year

Calendar year	Collision		PDL	
	50th percentile	90th percentile	50th percentile	90th percentile
2014	\$1,767	\$10,481	\$1,980	\$7,557
2015	\$1,980	\$11,333	\$1,962	\$7,593
2016	\$2,155	\$12,000	\$2,030	\$7,945
2017	\$2,317	\$13,035	\$2,144	\$8,188
2018	\$2,521	\$13,620	\$2,268	\$8,551
2019	\$2,790	\$14,134	\$2,418	\$8,773
2020	\$3,040	\$14,411	\$2,605	\$9,445
2021	\$3,297	\$16,951	\$2,934	\$10,957
2022	\$3,855	\$20,053	\$3,346	\$12,576
2023	\$4,373	\$19,686	\$3,707	\$12,724
2024	\$4,750	\$18,541	\$3,675	\$11,611

To account for these claim severity changes, the severity ranges used in this bulletin vary by calendar year. For both collision and PDL coverages, a claim is defined as low-severity if its payment falls below the 50th percentile for that year. Claims with payments at or above the 90th percentile are classified as high-severity, while those between the 50th and 90th percentiles are considered mid-severity. For example, in calendar year 2024, a collision claim with a payment less than \$4,750 would be categorized as a low-severity claim; a claim with a payment of \$18,541 or more would be considered a high-severity claim; and any claim falling between \$4,750 and \$18,541 would be classified as a mid-severity claim.

Figure 14 shows the estimated change in collision claim frequency by severity range for Mazda’s driver assistance feature bundles and individual features. Overall, the systems generally demonstrated performance consistent with their intended functions.

For example, the first three driver assistance feature bundles (*Bundles A, B, and C*) were available only on the 2015–18 model year vehicles. These bundles showed relatively small reductions in low- and mid-severity collision claim frequencies. However, they were associated with increased frequency for high-severity collision claims. This pattern may reflect the limitations of early-generation systems, which were generally less effective at preventing high-speed crashes. When such crashes occurred, the presence of advanced driver assistance technologies could lead to higher repair or replacement costs, resulting in high-severity claims compared with vehicles without those systems.

Bundles D, E, and F became available in model years 2018, 2021, and 2021, respectively. These bundles demonstrated greater reductions in low- and mid-severity claim frequencies than the earlier bundles (*Bundles A, B, and C*). Notably, they also showed benefits in reducing high-severity claim frequency. These findings align with expectations that vehicles equipped with more advanced and better-performing systems can mitigate both low-speed and higher-speed crashes.

Figure 14: Change in collision claim frequency associated with Mazda driver assistance systems by severity range

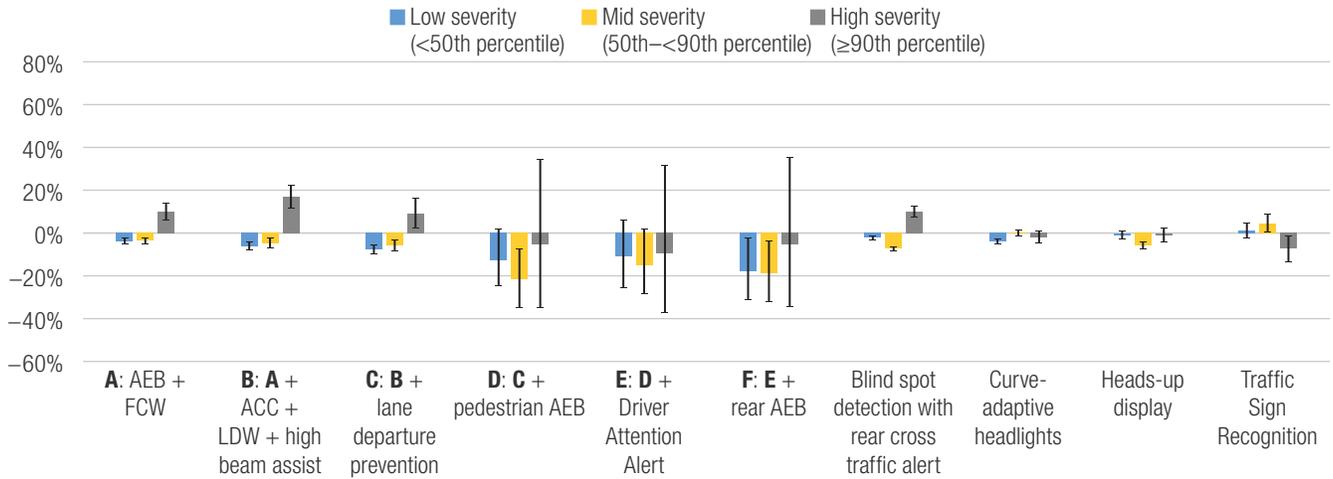
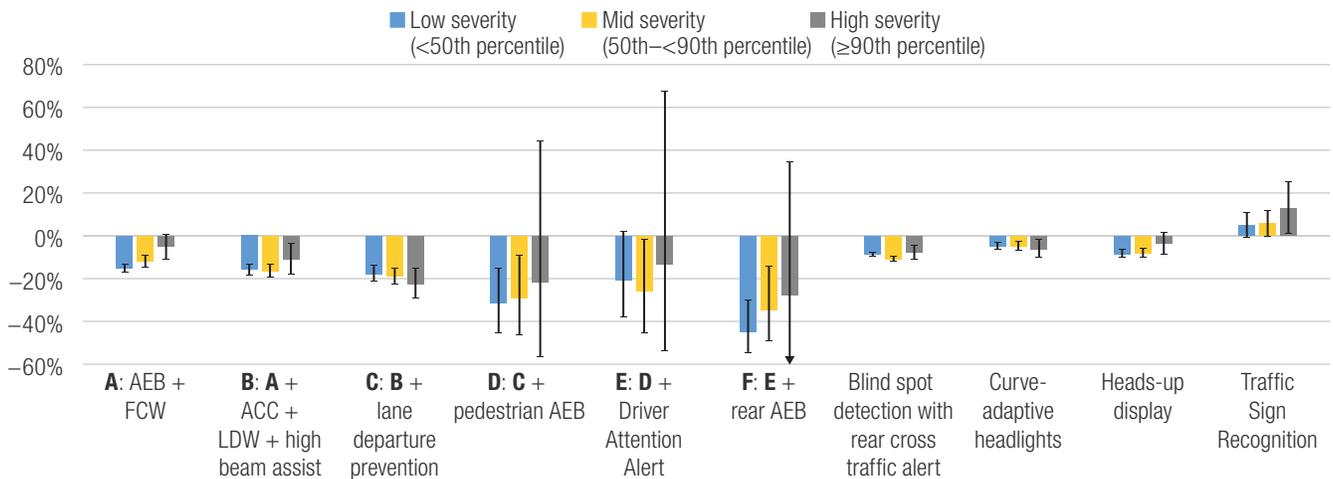


Figure 15 summarizes the estimated changes in PDL claim frequency by severity range for Mazda’s driver assistance features and feature bundles. As with collision claims, most systems demonstrated performance consistent with their intended design. From *Bundle A* through *Bundle F*, reductions in PDL claim frequency were observed across all severity ranges. Moreover, the benefits generally increased as the bundles became more comprehensive and technologically advanced, reflecting the enhanced capability of newer systems to prevent a broader range of crashes.

Figure 15: Change in PDL claim frequency associated with Mazda driver assistance systems by severity range



The results by severity range also help explain why some systems were associated with increased claim severities in collision and PDL coverages. While higher repair or replacement costs for the sensors and components that support these technologies are a likely contributor to elevated claim severity, another important factor may be a shift in the distribution of claim costs. In other words, as certain systems become more effective at preventing low-severity crashes, the remaining claims may disproportionately consist of higher-cost incidents, thereby raising the average payment per claim.

► Limitations

There are several limitations to the data used in this analysis. One key constraint is that there is no way of knowing if a feature is switched on at the time of a crash. Many of the systems included in this study can be manually deactivated by the driver, and there is no available data indicating how many were turned off prior to a crash. However, surveys conducted by IIHS suggest that the vast majority of drivers tend to leave these systems activated (Reagan et al., 2018). If a significant number of drivers do choose to disable these features, the observed reductions in claim frequency may actually be underestimates of the true effectiveness of the technologies.

Additionally, the data provided to HLDI do not include detailed crash information, which limits the ability to isolate specific crash types addressed by each technology. As a result, all collisions, regardless of whether a particular feature could have mitigated or prevented the crash, are included in the analysis.

Another consideration is that many of these features are optional and come with additional costs. The individuals who choose to purchase vehicles equipped with these technologies may differ in meaningful ways from those who do not. Although the analysis controls for several driver characteristics, there may be other unmeasured attributes associated with the people who select these features.

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► Appendix

Appendix A: Prior HLDI studies of Mazda collision avoidance features	
Publication year	HLDI <i>Loss Bulletin</i> issue
2011	Vol. 28, No. 13
2015	Vol. 32, No. 22
2016	Vol. 33, No. 3
2016	Vol. 33 No. 26
2017	Vol. 34, No. 8
2018	Vol. 35, No. 30

Appendix B: Mazda feature name mapping

HLDI feature name	Mazda feature name
Front automatic emergency braking and forward collision warning	Smart Brake Support
	Advanced Smart City Brake Support
	Smart Brake Support System (SBS) with Collision Warning
Front automatic emergency braking with pedestrian detection and forward collision warning	Smart Brake Support
	Smart Brake Support (SBS) with Collision Warning
	Smart Brake Support with Pedestrian Detection
	Advanced Smart Brake Support with Pedestrian Detection
	Advanced Smart City Brake Support
	Advanced Smart City Brake Support with Pedestrian Detection
	Advanced Smart City Brake Support (Advanced SCBS) with Pedestrian Detection
	Automatic Emergency Braking (AEB) with Night-time Pedestrian Detection
Advanced Smart City Brake Support with Pedestrian Detection (includes night-time pedestrian detection)	
Adaptive cruise control	Mazda Radar Cruise Control
	Mazda Radar Cruise Control with Stop & Go
Lane departure warning	Lane Departure Warning System
Lane departure prevention	Lane Keep Assist
Blind spot detection	Blind Spot Monitoring
Rear cross traffic alert	Rear Cross Traffic Alert
High beam assist	High Beam Control
Curve-adaptive headlights	Adaptive Front Lighting System
	Curve Adaptive Headlights
Heads-up display	Heads-Up Display
	Active Driving Display
	Active Driving Display (windshield type)
	Active Driving Display (full-color, windshield type)
	Active Driving Display with Traffic Sign Recognition
Rear automatic emergency braking	Smart Brake Support - Rear
	Smart Brake Support - Rear Crossing (Rear Cross Traffic Braking)
	Smart City Brake Support Reverse (SCBS R)
	Rear Cross Traffic Braking
	Rear Cross Traffic with Braking
	Rear Smart City Brake Support
Driver Attention Alert	Driver Attention Alert
Traffic Sign Recognition	Traffic Sign Recognition

Appendix C: Illustrative regression results — collision claim frequency

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	p value
Intercept		1	-8.3307		0.0554	-8.4393	-8.2221	22614.40	<0.0001
Calendar year	2014	1	0.3054	35.7%	0.0211	0.2640	0.3467	209.67	<0.0001
	2015	1	0.3794	46.1%	0.0085	0.3626	0.3961	1971.16	<0.0001
	2016	1	0.3384	40.3%	0.0064	0.3258	0.3509	2789.78	<0.0001
	2017	1	0.2853	33.0%	0.0056	0.2743	0.2962	2601.76	<0.0001
	2018	1	0.2529	28.8%	0.0051	0.2428	0.2630	2423.68	<0.0001
	2019	1	0.2195	24.5%	0.0049	0.2100	0.2291	2030.89	<0.0001
	2020	1	-0.1341	-12.5%	0.0051	-0.1440	-0.1241	699.21	<0.0001
	2021	1	0.0592	6.1%	0.0045	0.0503	0.0680	172.04	<0.0001
	2022	1	0.0653	6.7%	0.0043	0.0569	0.0737	233.65	<0.0001
	2024	1	-0.1185	-11.2%	0.0043	-0.1269	-0.1101	759.87	<0.0001
	2023	0	0	0	0	0	0		
Vehicle model year and series	2015 3 4dr 2WD	1	-0.1323	-12.4%	0.0554	-0.2409	-0.0237	5.70	0.0170
	2016 3 4dr 2WD	1	-0.0715	-6.9%	0.0554	-0.1800	0.0370	1.67	0.1966
	2017 3 4dr 2WD	1	-0.0463	-4.5%	0.0557	-0.1554	0.0628	0.69	0.4053
	2018 3 4dr 2WD	1	-0.0465	-4.5%	0.0569	-0.1580	0.0649	0.67	0.4130
	2019 3 4dr 2WD	1	0.1467	15.8%	0.0179	0.1117	0.1817	67.54	<0.0001
	2020 3 4dr 2WD	1	0.2399	27.1%	0.0194	0.2018	0.2780	152.38	<0.0001
	2021 3 4dr 2WD	1	0.2306	25.9%	0.0298	0.1722	0.2890	59.95	<0.0001
	2023 3 4dr 2WD	1	0.2961	34.5%	0.0400	0.2176	0.3745	54.70	<0.0001
	2022 3 4dr 2WD	1	0.2154	24.0%	0.0356	0.1457	0.2852	36.64	<0.0001
	2019 3 4dr 4WD	1	0.1374	14.7%	0.0301	0.0784	0.1963	20.84	<0.0001
	2020 3 4dr 4WD	1	0.1929	21.3%	0.0270	0.1400	0.2458	51.10	<0.0001
	2021 3 4dr 4WD	1	0.2266	25.4%	0.0315	0.1649	0.2883	51.86	<0.0001
	2023 3 4dr 4WD	1	0.3131	36.8%	0.0587	0.1980	0.4282	28.41	<0.0001
	2022 3 4dr 4WD	1	0.3053	35.7%	0.0486	0.2102	0.4005	39.54	<0.0001
	2015 3 5dr 2WD	1	-0.2091	-18.9%	0.0556	-0.3180	-0.1001	14.14	0.0002
	2016 3 5dr 2WD	1	-0.1714	-15.8%	0.0556	-0.2805	-0.0624	9.49	0.0021
	2017 3 5dr 2WD	1	-0.1874	-17.1%	0.0561	-0.2974	-0.0773	11.14	0.0008
	2018 3 5dr 2WD	1	-0.1090	-10.3%	0.0572	-0.2211	0.0032	3.63	0.0568
	2019 3 5dr 2WD	1	0.1288	13.7%	0.0242	0.0814	0.1762	28.35	<0.0001
	2020 3 5dr 2WD	1	0.1979	21.9%	0.0274	0.1442	0.2515	52.24	<0.0001
	2021 3 5dr 2WD	1	0.2002	22.2%	0.0346	0.1323	0.2681	33.43	<0.0001
	2023 3 5dr 2WD	1	0.2727	31.4%	0.0437	0.1871	0.3583	38.97	<0.0001
	2022 3 5dr 2WD	1	0.1821	20.0%	0.0364	0.1107	0.2534	25.02	<0.0001
	2019 3 5dr 4WD	1	0.1129	12.0%	0.0291	0.0560	0.1699	15.10	0.0001
	2020 3 5dr 4WD	1	0.2404	27.2%	0.0284	0.1847	0.2960	71.66	<0.0001
	2021 3 5dr 4WD	1	0.2381	26.9%	0.0290	0.1814	0.2949	67.63	<0.0001
	2023 3 5dr 4WD	1	0.2578	29.4%	0.0473	0.1652	0.3505	29.74	<0.0001
	2022 3 5dr 4WD	1	0.2388	27.0%	0.0475	0.1457	0.3319	25.27	<0.0001
	2015 6 4dr 2WD	1	-0.1075	-10.2%	0.0554	-0.2161	0.0011	3.76	0.0525
	2016 6 4dr 2WD	1	-0.0573	-5.6%	0.0554	-0.1659	0.0512	1.07	0.3007
	2017 6 4dr 2WD	1	0.0056	0.6%	0.0557	-0.1036	0.1148	0.01	0.9203
	2018 6 4dr 2WD	1	0.1521	16.4%	0.0135	0.1256	0.1785	126.70	<0.0001

Appendix C: Illustrative regression results — collision claim frequency

Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	p value
2019 6 4dr 2WD	1	0.1617	17.6%	0.0208	0.1209	0.2025	60.45	<0.0001
2020 6 4dr 2WD	1	0.2219	24.8%	0.0184	0.1859	0.2580	145.58	<0.0001
2021 6 4dr 2WD	1	0.2532	28.8%	0.0188	0.2163	0.2901	181.01	<0.0001
2016 CX-3 4dr 2WD	1	-0.2496	-22.1%	0.0650	-0.3770	-0.1222	14.74	0.0001
2017 CX-3 4dr 2WD	1	-0.3422	-29.0%	0.0604	-0.4605	-0.2239	32.14	<0.0001
2018 CX-3 4dr 2WD	1	-0.3055	-26.3%	0.0617	-0.4264	-0.1846	24.53	<0.0001
2016 CX-3 4dr 2WD/4WD	1	-0.3002	-25.9%	0.0567	-0.4113	-0.1891	28.05	<0.0001
2016 CX-3 4dr 4WD	1	-0.3735	-31.2%	0.0585	-0.4881	-0.2588	40.75	<0.0001
2017 CX-3 4dr 4WD	1	-0.3220	-27.5%	0.0572	-0.4341	-0.2099	31.67	<0.0001
2018 CX-3 4dr 4WD	1	-0.3148	-27.0%	0.0586	-0.4296	-0.1999	28.84	<0.0001
2020 CX-30 4dr 2WD	1	-0.1634	-15.1%	0.0238	-0.2100	-0.1168	47.19	<0.0001
2021 CX-30 4dr 2WD	1	-0.1478	-13.7%	0.0334	-0.2132	-0.0825	19.65	<0.0001
2020 CX-30 4dr 4WD	1	-0.1756	-16.1%	0.0187	-0.2122	-0.1389	88.23	<0.0001
2021 CX-30 4dr 4WD	1	-0.1274	-12.0%	0.0267	-0.1798	-0.0750	22.68	<0.0001
2023 CX-30 4dr 4WD	1	-0.0792	-7.6%	0.0284	-0.1348	-0.0235	7.78	0.0053
2022 CX-30 4dr 4WD	1	-0.0912	-8.7%	0.0275	-0.1450	-0.0373	11.02	0.0009
2015 CX-5 4dr 2WD	1	-0.4395	-35.6%	0.0556	-0.5485	-0.3305	62.42	<0.0001
2016 CX-5 4dr 2WD	1	-0.4233	-34.5%	0.0554	-0.5319	-0.3148	58.45	<0.0001
2017 CX-5 4dr 2WD	1	-0.2315	-20.7%	0.0562	-0.3415	-0.1214	16.99	<0.0001
2018 CX-5 4dr 2WD	1	-0.1089	-10.3%	0.0121	-0.1325	-0.0852	81.36	<0.0001
2019 CX-5 4dr 2WD	1	-0.0900	-8.6%	0.0128	-0.1150	-0.0650	49.70	<0.0001
2020 CX-5 4dr 2WD	1	-0.0433	-4.2%	0.0134	-0.0696	-0.0171	10.46	0.0012
2021 CX-5 4dr 2WD	1	-0.0158	-1.6%	0.0145	-0.0442	0.0125	1.20	0.2739
2023 CX-50 4dr 4WD	1	-0.1387	-13.0%	0.0278	-0.1931	-0.0843	24.98	<0.0001
2015 CX-9 4dr 2WD	1	-0.2253	-20.2%	0.0571	-0.3372	-0.1134	15.56	<0.0001
2016 CX-9 4dr 2WD	1	-0.0110	-1.1%	0.0577	-0.1241	0.1021	0.04	0.8487
2017 CX-9 4dr 2WD	1	-0.0416	-4.1%	0.0626	-0.1642	0.0811	0.44	0.5065
2018 CX-9 4dr 2WD	1	0.1039	10.9%	0.0184	0.0679	0.1400	31.94	<0.0001
2019 CX-9 4dr 2WD	1	0.1371	14.7%	0.0208	0.0964	0.1778	43.59	<0.0001
2020 CX-9 4dr 2WD	1	0.2045	22.7%	0.0250	0.1556	0.2534	67.15	<0.0001
2021 CX-9 4dr 2WD	1	0.0948	9.9%	0.0267	0.0425	0.1471	12.62	0.0004
2015 CX-9 4dr 4WD	1	-0.1887	-17.2%	0.0572	-0.3007	-0.0767	10.90	0.0010
2016 CX-9 4dr 4WD	1	0.0241	2.4%	0.0566	-0.0869	0.1351	0.18	0.6707
2017 CX-9 4dr 4WD	1	0.0569	5.9%	0.0578	-0.0564	0.1702	0.97	0.3248
2018 CX-9 4dr 4WD	1	0.1742	19.0%	0.0144	0.1460	0.2025	146.04	<0.0001
2019 CX-9 4dr 4WD	1	0.1812	19.9%	0.0155	0.1509	0.2115	137.16	<0.0001
2020 CX-9 4dr 4WD	1	0.2316	26.1%	0.0190	0.1944	0.2689	148.73	<0.0001
2021 CX-9 4dr 4WD	1	0.2317	26.1%	0.0172	0.1979	0.2654	181.02	<0.0001
2023 CX-9 4dr 4WD	1	0.2021	22.4%	0.0239	0.1554	0.2489	71.79	<0.0001
2022 CX-9 4dr 4WD	1	0.2521	28.7%	0.0193	0.2142	0.2901	169.87	<0.0001
2015 CX-5 4dr 4WD	1	-0.4457	-36.0%	0.0555	-0.5545	-0.3369	64.46	<0.0001
2016 CX-5 4dr 4WD	1	-0.4142	-33.9%	0.0553	-0.5225	-0.3059	56.16	<0.0001
2017 CX-5 4dr 4WD	1	-0.2125	-19.1%	0.0558	-0.3219	-0.1032	14.51	0.0001
2018 CX-5 4dr 4WD	1	-0.0769	-7.4%	0.0107	-0.0979	-0.0559	51.46	<0.0001

Appendix C: Illustrative regression results — collision claim frequency

Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	p value
2019 CX-5 4dr 4WD	1	-0.0686	-6.6%	0.0108	-0.0897	-0.0474	40.40	<0.0001
2020 CX-5 4dr 4WD	1	-0.0136	-1.4%	0.0114	-0.0360	0.0088	1.42	0.2338
2021 CX-5 4dr 4WD	1	0.0280	2.8%	0.0105	0.0073	0.0486	7.06	0.0079
2023 CX-5 4dr 4WD	1	0.0328	3.3%	0.0123	0.0087	0.0570	7.09	0.0077
2022 CX-5 4dr 4WD	0	0	0.0%	0	0	0		
Rated driver age group								
14–24	1	0.2654	30.4%	0.0046	0.2564	0.2744	3335.12	<0.0001
25–29	1	0.0991	10.4%	0.0042	0.0908	0.1074	551.65	<0.0001
40–49	1	0.0420	4.3%	0.0040	0.0342	0.0499	109.45	<0.0001
50–59	1	0.0338	3.4%	0.0040	0.0260	0.0417	71.06	<0.0001
60–64	1	0.0021	0.2%	0.0054	-0.0085	0.0126	0.15	0.7019
65–69	1	0.0249	2.5%	0.0059	0.0132	0.0365	17.59	<0.0001
70+	1	0.1529	16.5%	0.0051	0.1429	0.1629	898.09	<0.0001
Unknown	1	0.0721	7.5%	0.0099	0.0528	0.0915	53.31	<0.0001
30–39	0	0	0	0	0	0		
Rated driver gender								
Male	1	-0.0448	-4.4%	0.0025	-0.0497	-0.0399	322.68	<0.0001
Unknown	1	-0.0821	-7.9%	0.0109	-0.1033	-0.0608	57.14	<0.0001
Female	0	0	0	0	0	0		
Rated driver marital status								
Single	1	0.1812	19.9%	0.0027	0.1759	0.1866	4372.77	<0.0001
Unknown	1	0.0943	9.9%	0.0114	0.0721	0.1166	68.84	<0.0001
Married	0	0	0	0	0	0		
Risk								
Nonstandard	1	0.0068	0.7%	0.0054	-0.0037	0.0173	1.61	0.2050
Standard	0	0	0	0	0	0		
State								
Alabama	1	-0.1699	-15.6%	0.0132	-0.1959	-0.1440	164.63	<0.0001
Alaska	1	0.0553	5.7%	0.0307	-0.0048	0.1154	3.25	0.0713
Arizona	1	-0.1895	-17.3%	0.0092	-0.2074	-0.1716	428.62	<0.0001
Arkansas	1	-0.1729	-15.9%	0.0199	-0.2119	-0.1339	75.54	<0.0001
Colorado	1	-0.1530	-14.2%	0.0087	-0.1700	-0.1361	312.54	<0.0001
Connecticut	1	-0.2660	-23.4%	0.0102	-0.2859	-0.2460	683.71	<0.0001
Delaware	1	-0.1270	-11.9%	0.0158	-0.1580	-0.0959	64.22	<0.0001
Dist of Columbia	1	0.0676	7.0%	0.0201	0.0282	0.1070	11.33	0.0008
Florida	1	-0.3686	-30.8%	0.0052	-0.3788	-0.3585	5059.93	<0.0001
Georgia	1	-0.2480	-22.0%	0.0084	-0.2644	-0.2316	876.50	<0.0001
Hawaii	1	-0.0726	-7.0%	0.0162	-0.1043	-0.0410	20.20	<0.0001
Idaho	1	-0.3187	-27.3%	0.0224	-0.3626	-0.2749	202.94	<0.0001
Illinois	1	-0.2218	-19.9%	0.0069	-0.2352	-0.2083	1045.55	<0.0001
Indiana	1	-0.2304	-20.6%	0.0110	-0.2519	-0.2089	442.45	<0.0001
Iowa	1	-0.2939	-25.5%	0.0179	-0.3289	-0.2588	269.69	<0.0001
Kansas	1	-0.3309	-28.2%	0.0156	-0.3614	-0.3004	452.06	<0.0001
Kentucky	1	-0.3190	-27.3%	0.0139	-0.3462	-0.2917	527.52	<0.0001
Louisiana	1	-0.0868	-8.3%	0.0121	-0.1106	-0.0631	51.37	<0.0001
Maine	1	-0.2122	-19.1%	0.0238	-0.2588	-0.1655	79.46	<0.0001
Maryland	1	-0.1699	-15.6%	0.0076	-0.1848	-0.1550	499.52	<0.0001
Massachusetts	1	0.1511	16.3%	0.0086	0.1342	0.1679	308.91	<0.0001
Michigan	1	0.0245	2.5%	0.0111	0.0028	0.0463	4.87	0.0273

Appendix C: Illustrative regression results — collision claim frequency

Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	p value	
Minnesota	1	-0.2369	-21.1%	0.0089	-0.2543	-0.2195	712.87	<0.0001	
Mississippi	1	-0.1230	-11.6%	0.0209	-0.1639	-0.0821	34.69	<0.0001	
Missouri	1	-0.2809	-24.5%	0.0104	-0.3013	-0.2604	726.40	<0.0001	
Montana	1	-0.1629	-15.0%	0.0372	-0.2357	-0.0900	19.19	<0.0001	
Nebraska	1	-0.2824	-24.6%	0.0175	-0.3166	-0.2482	261.46	<0.0001	
Nevada	1	-0.1172	-11.1%	0.0127	-0.1421	-0.0924	85.36	<0.0001	
New Hampshire	1	-0.0930	-8.9%	0.0152	-0.1227	-0.0633	37.56	<0.0001	
New Jersey	1	-0.2258	-20.2%	0.0065	-0.2386	-0.2130	1192.00	<0.0001	
New Mexico	1	-0.1874	-17.1%	0.0178	-0.2223	-0.1525	110.77	<0.0001	
New York	1	-0.0812	-7.8%	0.0056	-0.0922	-0.0702	209.52	<0.0001	
North Carolina	1	-0.3507	-29.6%	0.0081	-0.3666	-0.3349	1871.86	<0.0001	
North Dakota	1	-0.1219	-11.5%	0.0430	-0.2061	-0.0376	8.03	0.0046	
Ohio	1	-0.3522	-29.7%	0.0076	-0.3670	-0.3374	2173.08	<0.0001	
Oklahoma	1	-0.2886	-25.1%	0.0146	-0.3172	-0.2600	390.96	<0.0001	
Oregon	1	-0.2465	-21.8%	0.0102	-0.2666	-0.2265	581.39	<0.0001	
Pennsylvania	1	-0.1190	-11.2%	0.0060	-0.1307	-0.1072	392.19	<0.0001	
Rhode Island	1	-0.1278	-12.0%	0.0181	-0.1633	-0.0923	49.85	<0.0001	
South Carolina	1	-0.3381	-28.7%	0.0125	-0.3626	-0.3135	729.33	<0.0001	
South Dakota	1	-0.1766	-16.2%	0.0350	-0.2453	-0.1080	25.43	<0.0001	
Tennessee	1	-0.2076	-18.7%	0.0106	-0.2283	-0.1868	384.59	<0.0001	
Texas	1	-0.2139	-19.3%	0.0051	-0.2239	-0.2039	1752.12	<0.0001	
Utah	1	-0.2668	-23.4%	0.0120	-0.2902	-0.2433	497.75	<0.0001	
Vermont	1	-0.2021	-18.3%	0.0306	-0.2620	-0.1421	43.68	<0.0001	
Virginia	1	-0.2076	-18.7%	0.0075	-0.2222	-0.1930	772.67	<0.0001	
Washington	1	-0.2103	-19.0%	0.0073	-0.2245	-0.1960	837.75	<0.0001	
West Virginia	1	-0.2696	-23.6%	0.0262	-0.3210	-0.2182	105.79	<0.0001	
Wisconsin	1	-0.3093	-26.6%	0.0109	-0.3307	-0.2879	804.37	<0.0001	
Wyoming	1	-0.1176	-11.1%	0.0509	-0.2174	-0.0178	5.33	0.0210	
California	0	0	0	0	0	0			
Registered vehicle density	0–99	1	-0.1590	-14.7%	0.0049	-0.1685	-0.1494	1066.76	<0.0001
	100–499	1	-0.1042	-9.9%	0.0029	-0.1099	-0.0985	1280.16	<0.0001
	500+	0	0	0	0	0	0		
Deductible range	0–250	1	0.1583	17.2%	0.0036	0.1512	0.1653	1944.17	<0.0001
	501–1,000	1	-0.1758	-16.1%	0.0030	-0.1817	-0.1700	3459.28	<0.0001
	1,001+	1	-0.4742	-37.8%	0.0105	-0.4948	-0.4536	2041.04	<0.0001
	251–500	0	0	0	0	0	0		
Bundle A: Front AEB and FCW	1	-0.0265	-2.6%	0.0059	-0.0380	-0.0150	20.30	<0.0001	
Bundle B: Front AEB, FCW, ACC, LDW, and high beam assist	1	-0.0382	-3.7%	0.0085	-0.0549	-0.0216	20.26	<0.0001	
Bundle C: Front AEB, FCW, ACC, LDW, high beam assist, and lane departure prevention	1	-0.0562	-5.5%	0.0091	-0.0741	-0.0384	38.18	<0.0001	
Bundle D: Front AEB with pedestrian detection, FCW, ACC, LDW, high beam assist, and lane departure prevention	1	-0.1771	-16.2%	0.0544	-0.2837	-0.0704	10.59	0.0011	

Appendix C: Illustrative regression results — collision claim frequency

Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	p value
Bundle E: Front AEB with pedestrian detection, FCW, ACC, LDW, high beam assist, lane departure prevention, and Driver Attention Alert	1	-0.1416	-13.2%	0.0594	-0.2580	-0.0253	5.69	0.0171
Bundle F: Front AEB with pedestrian detection, FCW, ACC, LDW, high beam assist, lane departure prevention, Driver Attention Alert, and rear AEB	1	-0.1897	-17.3%	0.0566	-0.3005	-0.0788	11.24	0.0008
Blind spot detection with rear cross traffic alert	1	-0.0354	-3.5%	0.0037	-0.0427	-0.0282	91.48	<0.0001
Curve-adaptive headlights	1	-0.0231	-2.3%	0.0044	-0.0316	-0.0145	27.89	<0.0001
Heads-up display	1	-0.0273	-2.7%	0.0050	-0.0370	-0.0176	30.32	<0.0001
Traffic Sign Recognition	1	0.0109	1.1%	0.0116	-0.0118	0.0337	0.89	0.3463



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

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