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The Honorable Steven S. Cliff
Administrator
National Highway Traffic Safety Administration
1200 New Jersey Avenue, SE
Washington, DC 20590

Request for Comments, New Car Assessment Program, Docket Number NHTSA-2021-0002

Dear Administrator Cliff:

The Insurance Institute for Highway Safety (IIHS) is encouraged that the National Highway Traffic Safety Administration (NHTSA) is moving forward to revive the New Car Assessment Program (NCAP) by adding to its list of recommended safety technologies and developing a roadmap for evaluating advanced driver assistance systems (ADAS). NCAP, like our own vehicle safety evaluations, has been instrumental in helping improve vehicle safety and providing consumers with objective information about the safety of vehicles. But NCAP has suffered from stasis for too long.

Many of the proposed activities described in the request for comments (RFC) are long overdue, some by long enough that they are unlikely to serve any public benefit because we are already providing the public with information like that which NHTSA proposes to add to NCAP and to which automakers already have responded by offering safer vehicles.

As NHTSA develops its NCAP roadmap and processes for its updates, we urge you to better coordinate with IIHS and other consumer-facing sources of vehicle safety information (e.g., Consumer Reports) to avoid further duplication of efforts. A coordinated effort by the various sources of vehicle safety information has the potential to encourage faster and broader safety improvements to the vehicle fleet than the current situation. IIHS has been promoting and evaluating pedestrian-detecting automatic emergency braking (AEB) since 2019 and will be augmenting those evaluations with nighttime testing in the coming weeks. Likewise, we recently began evaluating advanced seat belt reminder (SBR) systems, which NHTSA is considering for future NCAP assessment. NHTSA's effort would be better spent devising regulatory requirements for AEB, including pedestrian detection, and for advanced SBR systems than adding evaluations of these to NCAP.

IIHS also recommends that NHTSA dedicate resources to creating regulatory requirements for alcohol-impaired driving-mitigation technology and intelligent speed assistance (ISA) systems rather than contemplate adding them to NCAP. The agency's RFC correctly notes the magnitude and devastation associated with impaired-driving and excessive-speed crashes. As indicated in our comment, public support for these interventions is tepid. So, consumer information by itself is unlikely to result in the widespread availability of these technologies in the vehicle fleet. Any delay in requiring vehicles to be equipped with them will only prolong the unnecessary carnage on our country's roads.

Our detailed answers to select questions posed by NHTSA follows and includes both suggestions for augmenting the evaluation of currently recommended safety technologies and ideas for future consideration by NCAP. We appreciate the opportunity to share our information and suggestions with NHTSA and look forward to working with its NCAP to further improve the safety of the United States' vehicle fleet.

Sincerely,

David S. Zuby

Executive Vice President and Chief Research Officer
Insurance Institute for Highway Safety

Answers to select questions posed by NHTSA in Docket No. NHTSA-2021-0002

Q.8: Should NHTSA consider adding Euro NCAP's road edge detection test to its NCAP program to begin addressing crashes where lane markings may not be present? If not, why? If so, should the test be added for LDW [lane departure warning], LKS [lane keeping support], or both technologies?

IIHS supports incorporating Euro NCAP's road edge detection test in NCAP's evaluation. Crashes with fixed objects, a common consequence of vehicles leaving the road, accounted for 32% of passenger vehicle occupant deaths (7,253 people) in 2019. Forty-four percent of these deaths occurred on minor roads, which are more likely than other road types to have unmarked road edges. Additionally, systems able to detect unmarked road edges likely would be better able to detect marked road edges where lane markers are worn or obscured by debris. Euro NCAP has been encouraging lane support systems that can detect unmarked road edges since 2018, so automakers should be reasonably familiar with the test procedures and are already developing, if not implementing, features with this capability in their vehicles. It would be reasonable to adopt the test for both LDW and LKS, with the priority given to LKS. IIHS research suggests that drivers are more likely to use the latter than the former (Reagan et al., 2018). We also found that lane keeping systems that provided steering input earlier and more often to avoid crossing lane markers were used more by drivers than systems with later and less frequent interventions to imminent lane departures (Reagan et al., 2019).

Q.11: The Agency would like to be assured that when a vehicle is redirected after an LKS system intervenes to prevent a lane departure when tested on one side, if it approaches the lane marker on the side not tested, the LKS will again engage to prevent a secondary lane departure by not exceeding the same maximum excursion limit established for the first side. To prevent potential secondary lane departures, should the Agency consider modifying the Euro NCAP "lane keep assist" evaluation criteria to be consistent with language developed for NHTSA's BSI [blind spot intervention] test procedure to prevent this issue? Why or why not? NHTSA's test procedure states the SV [subject vehicle] BSI intervention shall not cause the SV to travel 0.3 m (1 ft) or more beyond the inboard edge of the lane line separating the SV 209 travel lane from the lane adjacent and to the right of it within the validity period. To assess whether this occurs, a second lane line is required (only one line is specified in the Euro NCAP LSS [lane support system] protocol for LKS testing). Does the introduction of a second lane line have the potential to confound LKS testing? Why or why not?

While we cannot comment on the specifics of NHTSA's proposed BSI or Euro NCAP's "lane keep assist" evaluations, we share NHTSA's concern about the consequences of LKS interventions, as many of these may be due to driver physical conditions that would prevent their taking effective control of vehicle steering. Our research (Cicchino & Zuby, 2017) shows that 34% of drivers who crashed because they drifted from their lanes were sleeping or otherwise incapacitated. These drivers would be unlikely to regain full control of their vehicles if an active safety system only prevented their initial drift. An additional 13% of these drivers had a non-incapacitating medical issue, a blood alcohol concentration (BAC) of 0.08%, or other physical factor that could impair their ability to safely control a vehicle. Crashes involving serious or fatal injuries had higher proportions of drivers with these afflictions—42% were sleeping or otherwise incapacitated and 14% had a non-incapacitating medical issue, a BAC of 0.08%, or other physical factor. We encourage NHTSA to consider promoting systems that could detect these distressed drivers and utilize automated vehicle control capabilities to bring their vehicles to a safe stop, ideally at the side of the road. The 2022 Lexus 500H and Toyota Mirai, when equipped with Teammate with Advanced Drive, already have this capability. If it is not practical to incorporate this into NCAP in the near term, then NHTSA should make this a target as it develops the NCAP roadmap.

Q.24: The Agency has proposed to include Scenarios S1 a-e and S4 a-c in its NCAP assessment. Is it necessary for the Agency to perform all test scenarios and test conditions proposed in this RFC notice to address the safety problem adequately, or could NCAP test only certain scenarios or conditions to minimize test burden but still address an adequate proportion of the safety problem? Why or why not? If it is not necessary for the Agency to perform all test scenarios or test conditions, which scenarios/conditions should be assessed? Although they are not currently proposed for inclusion, should the Agency also adopt the false positive test conditions, S1f and S1g? Why or why not?

We appreciate NHTSA's plan to add pedestrian detection to NCAP's evaluation of AEB systems. However, it is not clear to what extent the effort will hasten the adoption of these features by consumers, given that IIHS has been promoting pedestrian-detecting AEB since 2019 and requires systems rated advanced or superior to be available for models to be eligible for our Top Safety Pick awards. Our evaluation assigns ratings of no credit, basic, advanced, and superior based on the results of tests involving scenarios S1a, S1d, and S4c. Of 186 systems on vehicles from 29 automakers that we examined in 2021, 46% were superior, 34% were advanced, 5% were basic, 1% received no credit, and 13% were not available with pedestrian detection. Of those rated advanced or superior, 68% were standard equipment rather than optional features. Systems receiving a superior rating can avoid or substantially reduce the impact speed in almost all, if not all, three scenarios.

Rather than add pedestrian detection to NCAP's crash avoidance recommendations, we urge NHTSA to expedite its efforts to require AEB by regulation and include pedestrian detection among the performance specifications, as indicated in our March 22, 2022, petition to the agency. NHTSA's plan to initiate rulemaking by 2024 will delay for too long the life-saving benefits of pedestrian AEB (PAEB) on all light vehicles sold in the U.S.

If NHTSA decides to include pedestrian detection within NCAP, then it could reduce its test burden by focusing on those scenarios not included in the IIHS evaluation. This could lead to consumer confusion, but this could be mitigated by making it clear that IIHS and NCAP evaluations are complimentary and that consumers should seek systems recognized by both organizations.

We do not recommend that NHTSA include tests intended to mitigate false-positive interventions by PAEB. It seems unlikely that including a single or small number of tests to demonstrate immunity to some known sources of false-positive activation will provide assurance that these problems are rare.
IIHS believes that automakers are sufficiently compelled by customer satisfaction concerns to minimize the incidence of false-positive interventions by AEB. Furthermore, recalls by automakers and investigations by NHTSA suggest that false-positive braking problems are being addressed as they arise in the field. According to the Center for Auto Safety, as reported by the *Wall Street Journal*, automakers recalled nearly 180,000 vehicles for AEB problems between 2015 and August 2019 (Foldy, 2019).

Q.25: Given that a large portion of pedestrian fatalities and injuries occur under dark lighting conditions, the Agency has proposed to perform testing for the included test conditions (i.e., S1 a-e and S4 a-c) under dark lighting conditions (i.e., nighttime) in addition to daylight test conditions for test speed range 10 kph (6.2 mph) to 60 kph (37.3 mph). NHTSA proposes that a vehicle's lower beams would provide the source of light during the nighttime assessments. However, if the SV is equipped with advanced lighting systems such as semiautomatic headlamp beam switching and/or adaptive driving beam head lighting system, they shall be enabled during the nighttime PAEB assessment. Is this testing approach appropriate? Why or why not? Should the Agency conduct PAEB evaluation tests with only the vehicle's lower beams and disable or not use any other advanced lighting systems?

NHTSA's proposed testing to promote PAEB that functions in darkness is sound. It addresses one of the known limitations of current systems (Cicchino, 2022) and is consistent with the protocols IIHS will implement in its new evaluation of PAEB function in darkness.

Our evaluation will be based on performance in scenarios S1a at 20 and 40 kph (12.4 and 24.9 mph), and S4c at 40 and 60 kph (24.9 and 37.3 mph), all without overhead lighting. We plan to test PAEB with both low- and high-beam headlights. For models equipped with high beam assist (HBA), we intend to give more weight to high-beam results in those tests at speeds above the threshold for HBA functionality. Our recent evaluations of headlighting systems suggest that a large portion of the new vehicle fleet is equipped with standard HBA—66% of 182 models—and also note that these represent 401 unique headlighting systems, which may affect PAEB performance in the dark.

As indicated earlier and in our petition to NHTSA, we believe that the effort to develop a PAEB NCAP evaluation would be better spent expediting regulatory action requiring these systems with nighttime functionality on all light duty vehicles.

Q.28: Is a performance criterion of "no contact" appropriate for the proposed PAEB test conditions? Why or why not? Alternatively, should the Agency require minimum speed reductions or specify a maximum allowable SV-to-mannequin impact speed for any or all of the proposed test conditions (i.e., test scenario and test speed combination)? If yes, why, and for which test conditions? For those test conditions, what speed reductions would be appropriate? Alternatively, what maximum allowable impact speed would be appropriate?

IIHS does not support NHTSA requiring PAEB to avoid contact with a surrogate target on a single trial or multiple follow-up trials thereafter in its NCAP assessment. Speed reduction reduces injury severity, and NHTSA's NCAP assessment should acknowledge this benefit even among systems that cannot avoid contact in all crash scenarios.

A study of U.S. pedestrian crashes showed that the average risk of severe injury to a pedestrian increased from 10% when hit at 17 mph (27.4 kph) to 25% at 25 mph (40.2 kph), 50% at 33 mph (53.1 kph), 75% at 41 mph (66.0 kph), and 90% at 48 mph (77.2 kph) (Tefft, 2013). This injury risk reduction also manifests in real-world evaluations of PAEB that show larger reductions in injury-producing crashes than crashes of any severity (Cicchino, 2022). Many contacts in our testing are at a speed significantly lower than the test speed, indicating an injury reduction benefit. IIHS is concerned that only acknowledging systems that completely avoid the collision may lead to more false-positive interventions and possibly discourage manufacturers from equipping vehicles with the systems that can provide injury-mitigating safety benefits, even if unable to avoid crashes in all the tested scenarios.

Q.31: Given previous support from commenters to include S2 and S3 scenarios in the program at some point in the future and the results of AAA's testing for one of the turning conditions, NHTSA seeks comment on an appropriate timeframe for including S2 and S3 scenarios into the Agency's NCAP. Also, NHTSA requests from vehicle manufacturers information on any currently available models designed to address, and ideally achieve crash avoidance during conduct of the S2 and S3 scenarios to support Agency evaluation for a future program upgrade.

NHTSA should consider including the turning vehicle with the pedestrian-crossing-the-road test (S2) in its NCAP evaluation of PAEB. Doing so would meaningfully add to the information about PAEB that consumers already gain from IIHS testing, which does not include this scenario. Moreover, this scenario may become a greater contributor to pedestrian injury and death as the number of pickups and SUVs is growing (Highway Loss Data Institute [HLDI], 2019). Recent IIHS research shows that these vehicle types are substantially more likely than cars to hit pedestrians when making turns (Hu & Cicchino, 2022).

Q.39b: For the Agency's CIB [crash imminent braking] tests: Should the Agency consider adopting additional higher tests speeds (i.e., 60, 70, and/or 80 kph [37.3, 43.5, and/or 49.7 mph] for the CIB (and potentially DBS [dynamic brake support]) LVD [lead vehicle decelerating] test scenario in NCAP? Why or why not? If additional speeds are included, what headway and deceleration magnitude would be appropriate for each additional test speed, and why?

IIHS supports NHTSA adopting higher test speeds in its evaluation of CIB. Our research indicates that nearly 80% of police-reported rear-end crashes occur on roads with speed limits ranging from 30–65 mph (48.3–104.6 kph) (Kidd, 2022a), and subsequent research shows that the speed of the striking vehicle is more than 40 kph (24.9 mph), even on roads with a limit of 25 mph (40.2 kph) (Kidd, 2022b).

Q.39c: For the Agency's CIB tests: Is a performance criterion of "no contact" appropriate for the proposed CIB and DBS test conditions? Why or why not? Alternatively, should the Agency require minimum speed reductions or specify a maximum allowable SV-to-POV impact speed for any or all of the proposed test conditions (i.e., test scenario and test speed combination)? If yes, why, and for which test conditions? For those test conditions, what speed reductions would be appropriate? Alternatively, what maximum allowable impact speed would be appropriate?

IIHS does not support NHTSA requiring CIB to avoid contact with a surrogate principal other vehicle (POV) on a single trial or multiple follow-up trials thereafter in its NCAP assessment. Speed reduction reduces vehicle damage, the risk of injury, and injury severity. NHTSA's NCAP assessment should acknowledge this benefit even among systems that cannot avoid contact in all crash scenarios.

IIHS crash tests involving 2013 Mercedes-Benz C-Class vehicles striking the rear of a stationary 2012 Chevrolet Malibu at both 25 and 13 mph (40.2 and 20.9 kph) illustrate the damage-reducing effect. The cost to repair the resulting damage to both vehicles in the higher speed test was estimated to be $28,000, with the Malibu judged a total loss. At the lower speed, both vehicles could be repaired for an estimated $5,700 (IIHS, 2013). A similar speed reduction in a higher speed crash with CIB intervening would also reduce injury risk (Kraft et al., 2009). This effect of reduced injury risk is supported by real-world evaluations of AEB that found a larger reduction in injury-producing crashes than in crashes of any severity (Cicchino, 2017).

Q.43: As fused camera-radar forward-looking sensors are becoming more prevalent in the vehicle fleet, and the Agency has not observed any instances of false positive test failures during any of its CIB or DBS testing, is it appropriate to remove the false 220 positive STP [steel trench plate] assessments from NCAP's AEB (i.e., CIB and DBS) evaluation matrix in this NCAP update? Why or why not?

We do not recommend that NHTSA include tests intended to mitigate false-positive interventions by AEB. Despite including the trench-plate immunity test in its current CIB assessment and only observing test failures among vehicles using only radar to implement CIB, NHTSA has received numerous complaints about false-positive braking and has even opened investigations of these complaints, some of which involve systems that use both radar and cameras (e.g., preliminary investigation PE 22-003 involving 2017–2019 Honda CR-V and 2018–2019 Honda Accord vehicles). It seems unlikely that including a single or small number of tests to demonstrate immunity to some known sources of false-positive activation will provide assurance that these problems are rare.

As noted above, IIHS believes that automakers are sufficiently compelled by customer satisfaction concerns to minimize the incidence of false-positive interventions by AEB. Furthermore, recalls by automakers and investigations by NHTSA suggest that false-positive braking problems are being addressed as they arise in the field.

Q.45: Should NCAP adopt any additional AEB tests or alter its current tests to address the "changing" rear-end crash problem? If so, what tests should be added, or how should current tests be modified?

IIHS research has previously identified crash factors that are overrepresented in front-to-rear crashes involving an AEB-equipped striking vehicle (Cicchino & Zuby, 2019). Crash-involved vehicles with autobrake were more likely to be turning, to strike a vehicle that was turning or changing lanes, to strike a non-passenger vehicle or special-use vehicle (medium or heavy trucks or motorcycles, for example), and to crash on a snowy or icy road, or on a road with a 70 mph (112.7 kph) or higher speed limit than control-group vehicles. Including tests representing these conditions in NCAP's AEB evaluations has the potential to improve the real-world effectiveness of AEB. Follow-up investigation confirmed that these crash characteristics were rare in front-to-rear crashes, but those in which a motorcycle or large truck were struck accounted for about 40% of fatal rear-end crashes (Kidd, 2022a). Thus, including tests involving a POV representing a motorcycle of large truck could improve the life-saving capabilities of AEB.

Q.48: Should the Agency pursue research in the future to assess AEB system performance under less-than-ideal environmental conditions? If so, what environmental conditions would be appropriate?

As indicated earlier, rear crashes on slippery roads are rare but AEB-equipped vehicles are overrepresented in such crashes. Testing conducted by IIHS showed that AEB systems initiate automated braking with the same force and timing on slippery roads as on snowy roads. Due to the reduced friction between the vehicles' tires and the road surface, crashes occurred at speeds they wouldn't have on a dry surface. Real AEB effectiveness could be slightly improved if AEB systems adjusted brake force and intervened earlier on slippery roads. Adding tests on surfaces with reduced friction to NCAP's evaluation could encourage such innovation.

Q.54: With regard to a future ADAS rating system, the Agency seeks comments on the appropriateness of using target populations and technology effectiveness estimates to determine weights or proportions to assign to individual test conditions, corresponding test combinations, or an overall ADAS award.

Whether NHTSA chooses to rate or recommend ADAS features separately or create an overall rating, we agree that these should help consumers understand which technologies or combinations confer the greatest safety benefit. NHTSA's suggestion to use target populations and effectiveness estimates could achieve this end. The severity of crash outcomes also could be a factor for weighting certain features as more important than others. For example, AEB with pedestrian detection has a much greater life-saving potential than AEB designed to address only front-to-rear collisions between motor vehicles (Jermakian, 2011).

Q.58: With regard to a future ADAS rating system, the Agency seeks comments on the effective communication of ADAS ratings, including the appropriateness of using a points-based ADAS rating system in lieu of, or in addition to, a star rating system.

IIHS agrees that ADAS ratings should convey the general crash avoidance benefit of these features even among those that perform less well in NCAP testing. The proposed medal scheme (bronze, silver, gold) would accomplish this and is similar to our own ratings of not available, basic, and advanced. NHTSA should avoid conveying the idea that systems with lower levels of performance are in any way unsafe.

Q.59: With regard to a roadmap, NHTSA requests feedback on the identification of safety opportunities or technologies in development that could be included in future roadmaps.

IIHS suggests that NHTSA consider promoting enhanced hazard lighting through NCAP. Each year during 2016–2018, an average of 566 people were killed and 14,371 were injured in crashes on all types of U.S. roads involving a disabled vehicle in which visibility was likely a factor (Spicer et al., 2021). Research conducted by the Virginia Tech Transportation Institute for Emergency Safety Solutions suggests that hazard lights that blink at a faster rate were more easily noticed by drivers (Terry et al., 2021). An evaluation of advanced hazard lighting also could include consideration of flasher color with amber lights receiving better ratings, as research suggests they elicit earlier braking responses by other drivers than red flashing lights (Guofa et al., 2014).

The problem of vehicle-to-animal crashes also could be addressed in future NCAP by including large animal detection in evaluations of AEB. The Federal Highway Administration (FHWA) estimates that about 1 million deer-vehicle collisions occur annually, resulting in a total economic loss of $8.4 billion (FHWA, 2008). The number of collisions and associated losses involving animals of any kind certainly are greater and caused on average more than 190 fatalities annually in the decade from 2009 to 2019 (IIHS, 2022a). Moreover, recent research by HLDI suggests that Subaru vehicles equipped with the Eyesight system may be helping drivers avoid these collisions (see the attached HLDI Bulletin *2013–21 Subaru collision avoidance features and animal-strike losses*).

Q.60: With regard to a roadmap, NHTSA requests feedback on the opportunities to benefit from collaboration or harmonization with other rating programs.

The U.S. is fortunate to have at least three robust sources of consumer information about vehicle safety—Consumer Reports, IIHS, and NCAP. As suggested elsewhere in this comment, there is little to be gained by these organizations duplicating the efforts of one another. When NCAP added AEB to its list of recommended safety technologies for the 2018 model year, for example, IIHS already had been promoting AEB for 5 years. We added the availability of AEB rated basic as a requirement for our 2016 *Top Safety Pick*, while the *Top Safety Pick+* award required AEB to be rated advanced or superior. Nearly

70% of 2018 models that we evaluated met this higher requirement. Thus, it remains unclear what was achieved by NHTSA's efforts to promote AEB through NCAP.

We follow this logic in our own efforts to manage our consumer information programs. Note that we plan to discontinue roof strength testing now that nearly every model we test meets the requirements for our highest rating and because the improvement made since the rating was first published is now backstopped by Federal Motor Vehicle Safety Standard 216a. NHTSA, like IIHS, has limited resources to commit to consumer information programs and could realize more efficient use of them by coordinating with us.

Past experience indicates that consumer information programs motivate consumer choices and vehicle safety improvements (e.g., Zuby, 2015). Working together, NHTSA and its partners in vehicle safety information could encourage changes to the vehicle fleet that address a broader scope of safety issues than has occurred with our separate efforts sometimes focusing on solutions to the same problems. IIHS recommends that NHTSA formally coordinate with IIHS and other sources of vehicle safety consumer information to avoid a duplication of efforts as it develops its NCAP roadmap.

Q.62: What are the capabilities of the various available approaches to driver monitoring systems (e.g., steering wheel sensors, eye tracking cameras, etc.) to detect or infer different driver state measurement or estimations (e.g., visual attention, drowsiness, medical incapacity, etc.)? What is the associated confidence or reliability in detecting or inferring such driver states and what supporting data exist?

IIHS research has focused on monitoring the driver's behavior during driving, primarily in the context of partially automated assistance use (e.g., Tesla Autopilot, Cadillac Super Cruise). Automakers are using cameras focused on the driver's face and/or sensors in the steering wheel to infer compliance with the attentional requirements for safe use of these assistance features. Neither sensor type alone can measure the extent to which drivers are paying attention but used together or in conjunction with measures from other sensors may be able to accurately determine the degree to which a driver is attending to driving.

A driver must see the road ahead and the road around their vehicle to avoid crashing. Data from naturalistic driving studies show that the risk of a crash or a near-crash increases considerably when the driver looks away from the forward roadway for longer than 2 seconds (Klauer et al., 2006). Other research shows that eye gaze direction and scanning are effective indicators of driver disengagement (Dobres et al., 2016; He et al., 2011; Victor et al., 2005, 2018). We are not aware of current production designs that directly monitor gaze direction, probably because current eye trackers require individual calibration to precisely determine where a person is looking (e.g., Crabb et al., 2010). Several suppliers have mentioned to us that they are developing ways to monitor gaze direction without an individual calibration requirement. In the meantime, tracking head pose is being used as a coarse proxy for eye glance behavior (Lee et al., 2018) and can be predictive of driver disengagement (Gaspar et al., 2018; Radwin et al., 2017) and drowsiness (Fridman et al., 2016). Tracking head pose on its own generally cannot detect when the driver is looking away if their head is facing forward (Fridman et al., 2016). Head pose monitors are currently being used in conjunction with some partially automated assistance features (e.g., General Motors Super Cruise, Ford BlueCruise, Lexus Advanced Drive).

Physical contact with the steering wheel and shared control of steering in partially automated assistance features help to keep the driver in the loop of the driving task (Mulder et al., 2012, Navarro et al., 2020; Petermeijer et al., 2015, Wen et al., 2019). In many modern vehicles, steering wheels are instrumented to monitor the torque applied by the driver or the presence of the driver's hand within the electromagnetic field on the instrumented portion of the wheel. Many partially automated assistance systems rely solely upon such sensors to infer that the driver is attending to driving.

Driver-facing cameras may also be used to measure the percentage of eye closure (PERCLOS), which has been shown useful for detecting drowsiness (e.g., Jamson et al., 2013; Poursadeghiyan et al., 2017). DriverFocus, an optional feature on 2019–2021 Subaru Forester and 2020–2021 Subaru Legacy and Outback models, uses a driver-facing camera to monitor the driver's head pose and PERCLOS to issue audible alerts when the driver is inattentive or drowsy. A recent preliminary analysis by HLDI found that the presence of this feature was associated with a statistically significant lower claim frequency under collision and property damage liability coverage types and a nonsignificant lower claim frequency under bodily injury liability coverage compared with the same models not equipped with DriverFocus (see the attached HLDI Bulletin *2013–21 Subaru collision avoidance features*). While these reductions cannot yet be directly linked to the prevention of distracted- and drowsy-driving crashes, they may be an early indication of its effectiveness.

Q.63: Of further interest are the types of system actions taken based on a driver monitoring system's estimate of a driver's state. What are the types and modes of associated warnings, interventions, and other mitigation strategies that are most effective for different driver states or impairments (e.g., drowsy, medical, distraction)? What research data exist that substantiate effectiveness of these interventions?

There is considerable research investigating the efficacy of interventions to address drivers' inattention to driving. IIHS review of this research suggests that attention reminders should escalate in two ways when inattention persists. Later reminders should convey a greater sense of urgency through changes in color or directness of text in visual reminders; volume, pitch, and frequency for audible alerts; amplitude and frequency for haptic alerts. Later stages of alerting also should employ added modes of communication (e.g., adding haptic vibration or vehicle slowing to a presented audible signal). The initial alert and subsequent escalation need to be issued in a timely manner to prevent prolonged inappropriate behavior (Mueller et al., 2021). NCAP should encourage this kind of intervention if it evaluates driver attention monitoring systems.

Severe states of impairment, sleeping, and medical impairment should invoke automated control of the vehicle's steering and speed to slow or stop the vehicle, ideally on the road shoulder if present. Several current partially automated assistance features will stop in the lane within which the vehicle is moving when faced with continued ignorance of attention reminders (e.g., General Motors Super Cruise, Nissan ProPilot Assist). The recently introduced Lexus Teammate Advance Drive system includes an Emergency Driving Stop System (EDDS) that additionally monitors eyes for closure and body pose for slumping and can steer the vehicle to stop on the road's shoulder if triggered when the vehicle is in the rightmost lane (Lexus, 2022). Little is known about the efficacy of this type of intervention, but as mentioned in response to **Question 11,** 47% drivers who crashed because they drifted from their lanes would be unlikely to regain full control in response to a mere alert. That proportion rises to 57% in such crashes with serious and fatal injuries. Promoting systems like Lexus EDDS through NCAP could address a large safety problem.

Q.67: What in-vehicle and HMI [Human-Machine Interface] design characteristics would be most helpful to include in an NCAP rating that focuses on ease of use? What research data exist to support objectively characterizing ease of use for vehicle controls and displays?

Research from the second Strategic Highway Research Program (SHRP2) (Dingus et al., 2016, 2019) suggests that visual-manual interaction with in-vehicle systems unrelated to the radio or climate control functions (e.g., touch screens) was associated with a 4.1 increased odds of crash risk relative to model driving. Although this may suggest that designers should endeavor to make systems that impose less visual-manual demand, it is unclear how more usable interfaces will affect safety. Ease of use is typically associated with increased perceptions of usefulness and acceptance, which point to the likelihood that increased usability will lead to more interaction, so the overall prevalence of distraction may increase despite the design of systems that are “easier” to use. As ease of use does not equate to safety, IIHS argues against including usability evaluations of in-vehicle interfaces in NCAP.

Q.68: What are specific countermeasures or approaches to mitigate driver distraction, and what are the associated effectiveness metrics that may be feasible and appropriate for inclusion in the NCAP program? Methods may include driver monitoring and action strategies, HMI design considerations, expanded in-motion secondary task lockouts, phone application/notification limitations while paired with the vehicle, etc.

Driver monitoring systems, currently primarily deployed to ensure driver engagement when using partial automation features, are a promising approach to mitigate driver distraction that could be promoted through NCAP.

As stated in our response to **Question 62**, the most robust driver monitoring strategies use multiple simultaneous methods. The most robust single method of monitoring driver attention is eye gaze. Several publications demonstrate the inadequacy of monitoring only hands-on-wheel behavior during partial automation use (Gaspar & Carney, 2019; Morando et al., 2021a, 2021b). In contrast, emerging and yet unpublished work by the Massachusetts Institute of Technology Advanced Vehicle Technology consortium shows a large advantage for the in-cabin camera-monitoring-of-head-pose approach used with General Motors Super Cruise compared with monitoring steering wheel torque. When this benefit is considered in conjunction with naturalistic driving studies (e.g., Dingus et al., 2016, 2019) that show the primary crash risk with distraction is associated with visual Inattention, the need for camera-based driver monitoring systems is clear.

Crash avoidance technology may be the most promising avenue for reducing crash risks related to distractions of any type. Warnings can redirect a distracted driver’s attention back to the roadway if it detects the potential for a collision. Some systems invoke automated braking or steering to attempt avoiding the collision if a driver does not respond fast enough or does not respond at all. Front crash prevention and land departure warning and prevention have all proven effective in reducing rear-end and lane-drift crashes that are highly associated with visual distraction (Cicchino, 2017, 2018, 2022; Owens et al., 2018). IIHS welcomes, with caveats and the suggestions noted earlier, NHTSA’s intent to promote crash avoidance features through its NCAP.

Finally, we suggest that NCAP could be used to recommend vehicle models with infotainment systems that conform to NHTSA’s visual-manual distraction guidelines, so that tasks that exceed the visual-manual distraction thresholds are not permitted when the vehicle in motion.

Q.70: Are there opportunities for including alcohol-impairment technology in NCAP? What types of metrics, thresholds, and tests could be considered? Could voluntary deployment or adoption be positively influenced through NCAP credit?

We do not recommend that NHTSA pursue adding alcohol-impairment technology to its NCAP at the present time. The effort to establish a consumer-friendly evaluation of these systems would be better directed toward satisfying the obligations imposed on NHTSA in the Advanced Impaired Driving Technology section of the Infrastructure Investment and Jobs Act. Once regulatory requirements are set, NCAP could consider rating systems based on the degree to which a given system exceeds the mandatory accuracy and precision requirements or based on the estimated crash risk reduction associated with the system’s intervention (i.e., issuing a warning, preventing the vehicle from being driven, using automated control technology to end a trip when a driver is impaired).

Q.72: When a system detects alcohol-impairment during the course of a trip, what actions could the system take in a safe manner? What are the safety considerations related to various options that manufacturers may be considering (e.g., speed reduction, performing a safe stop, pulling over, or flasher activation)? How should various actions be considered for NCAP credit?

Ideally, systems intended to mitigate alcohol-impaired driving crashes would prevent impaired drivers from operating motor vehicles. Some portion of impaired driving, however, may not be detectable at the start of a trip because of the lag between ingestion of alcoholic beverages and the presence of alcohol in the blood. Consequently, systems that could detect impairment after the start of a trip also may be warranted if the trip can be ended safely. Automated vehicle control may be able to safely support this end.

While preventing alcohol-impaired driving is desirable, preventing the use of a vehicle or ending a trip before the intended destination are not risk free. Initiating the provision of an alternate means of transport should be a consideration in rating possible interventions. Similarly, preventing a vehicle from being shifted out of Park may be preferrable to preventing ignition of the motor in cases when the driver may need to shelter from extreme heat or cold. Slowing or stopping a vehicle within its lane as a response to detecting driver impairment raises the risk of a rear crash by an inattentive following driver, so consideration should be given to enhancing the conspicuity of vehicles in these situations.

If NHTSA were to decide to rate systems intended to mitigate alcohol-impaired driving, then we suggest that the ratings could be based on the estimated effectiveness at preventing alcohol-impaired driving (e.g., a better rating for systems that prevent an alcohol-impaired trip than those that merely alert drivers of their impaired states; combined with some consideration of mitigating risks associated with the intervention (e.g., a better rating for automatically parking the vehicle at the side of the road than stopping within the lane).

Q.73: What is known related to consumer acceptance of alcohol-impaired driving detection and mitigation functions, and how may that differ with respect to direct measurement approaches versus estimation techniques using a driver monitoring system? What consumer interest or feedback data exist relating to this topic? Are there privacy concerns or privacy protection strategies with various approaches? What are the related privacy protection strategies?

Past IIHS research examined consumer interest in a direct measurement approach to prevent impaired driving (McCartt et al., 2010). A nationally representative survey of people aged 18 years and older found that 36% said such systems were a very good idea, 28% said they were a good idea, 6% were undecided, 19% said they were a bad idea, and 11% said they were a very bad idea. However, those who thought it was a good idea were not willing to pay more for it.

Q.74: Should NCAP consider credit for a seat belt reminder system with a continuous or intermittent audible signal that does not cease until the seat belt is properly buckled (i.e., after the 60 second FMVSS No. 208 minimum)? What data are available to support associated effectiveness? Are certain audible signal characteristics more effective than others?

As indicated below, there is ample evidence to support the promotion of seat belt reminder systems that present a more persistent signal than the minimum required under FMVSS 208. Based on this evidence, IIHS has itself undertaken the rating of SBR systems (IIHS. 2022b). Consequently, there exists little need for NHTSA to create credits for better SBR systems within its NCAP. Rather, we urge NHTSA to require by regulation more persistent reminders as allowed under the Moving Ahead for Progress in the 21st Century Act (MAP-21).

Seat belt reminder systems that meet FMVSS No. 208 and do not exceed it are not effective for increasing seat belt use (Robertson & Haddon, 1974). Enhanced reminders with intermittent audible signals that cycle between a short period of audible signals (e.g., 5 seconds) and a longer period of silence (e.g., 25 seconds or longer) increase seat belt use up to 6 percentage points relative to reminders that only meet FMVSS 208 (Ferguson et al., 2007; Williams et al., 2002).

More persistent enhanced reminders that continuously provide an audible signal for 90 seconds or longer increase seat belt use even more. Relative to an intermittent reminder that provided a 7-second audible signal at ignition, 105 seconds after ignition, and 255 seconds after that, an audible reminder lasting 100 seconds and an audible reminder that continued until the belt was used increased seat belt use by 30% and 34% among drivers who do not routinely use a belt (Kidd & Singer, 2019b). Intermittent reminders that present at least 90 seconds of audible signals over a longer period of time may prove similarly effective for increasing seat belt use, as continuous audible signals are less annoying (Kidd, 2012), but the effect on belt use may be delayed, leading to longer periods of unbelted driving at the beginning of a trip and increased injury risk. Furthermore, most people who sit in the front row report routinely using a seat belt (Kidd & McCartt, 2014) and would never experience the increased annoyance of more persistent audible seat belt reminders.

Q.75: Is there an opportunity for including a seat belt interlock assessment in NCAP?

IIHS does not agree with NHTSA's promoting seat belt interlocks through its NCAP, and our position is based on our research. Encouraging manufacturers to equip vehicles with seat belt interlocks of any type risks public backlash without providing the necessary added benefit. Instead, we suggest that NHTSA amend FMVSS 208 to require SBR with more persistent seat belt reminders for every seating position. Manufacturers appear to be open to equipping vehicles with seat belt interlock systems that address limited use cases (e.g., Ford MyKey, intended for new drivers, mutes the audio system when the driver or front passenger is unbuckled and General Motors Belt Assurance system, which prevents the vehicle from being shifted out of Park for a brief period after ignition if a front-row passenger is unbuckled, was available to fleet customers for a period of time). However, consumer perceptions of seat belt interlock systems remain unfavorable.

Past research consistently shows negative public sentiment towards different seat belt interlock systems. In an IIHS national survey, a little less than one third of respondents who reported not always using a seat belt said systems that restricted speed, prevented use of the entertainment system, or made the gas pedal more difficult to push would be acceptable in their vehicle; 61% said chimes and visual displays were acceptable (Kidd & McCartt, 2014). Some of the negativity toward interlocks may be related to consumers being unfamiliar with the technology, and opinions about interlocks may become more positive once the technology is introduced and consumers get hands-on experience with it (Kidd & Singer 2019a, 2019b). But safety concerns about the technology limiting vehicle function may overwhelm any positive opinions and undermine broad public acceptance of it.
Critically, IIHS research has shown that interlocks that prevent shifting out of Park or that restrict speed are no more effective at increasing seat belt use than seat belt reminders with persistent audible signals lasting at least 90 seconds (Kidd & Singer, 2019b), which do not face the same ire from consumers.

Q.77: Should seat belt interlocks be considered for all seating positions in the vehicle, or only the front seats? Could there be an opportunity for differentiation in this respect?

If NCAP were to adopt an evaluation of SBR technology, it should encourage systems that address every seating position. Rear seats are less frequently occupied, but seat belt use there is lower (80% in 2020) than in front seats (90.3% in 2020) based on daytime observations at controlled intersections (National Center for Statistics and Analysis, 2021). Unbelted rear occupants increase not only their own injury risk but also the injury risk of other belted occupants in the vehicle (MacLennan et al., 2004). As such, the

IIHS SBR evaluation mentioned earlier requires persistent reminders for second-row seats for a rating of good. Recognizing that drivers have some influence on the behavior of their passengers, our rating does not require rear seat reminders to persist as long as those for front seat positions (IIHS, 2021b).

Q.78: What information is known or anticipated with respect to consumer acceptance of seatbelt interlock systems and/or persistent seat belt reminder systems in vehicles? What consumer interest or feedback data exist on this topic?

Please see our answer to **Question 75**.

Q.79: Could there be an NCAP opportunity in a selectable feature that could be optionally engaged such as in the context of a “teen mode” feature?

NHTSA should promote SBR technologies that are effective at motivating seat belt use for all vehicle occupants at all times. We do not recommend awarding NCAP credit for systems that only can be optionally engaged as in the context of a “teen mode” feature.

Q.80: Should NHTSA take into consideration systems, such as intelligent speed assist systems, which determine current speed limits and warn the driver or adjust the maximum traveling speed accordingly? Should there be a differentiation between warning and intervention type intelligent speed assist systems in this consideration? Should systems that allow for some small amount of speeding over the limit before intervening be treated the same or differently than systems that are specifically keyed to a road’s speed limit? What about for systems that allow driver override versus systems that do not?

IIHS agrees with NHTSA’s assessment of the severity of the speeding problem in the U.S. As such, we have partnered with the Governors Highway Safety Association and the National Road Safety Foundation to fund and evaluate demonstration projects aimed at reducing speeding (IIHS, 2021a). These projects are based on public information campaigns combined with targeted enforcement activities and road engineering countermeasures. Vehicle-based countermeasures like intelligent speed assistance (ISA) systems represent another promising countermeasure to reduce speeding and its consequences. We support NHTSA’s using its NCAP to promote wider adoption of ISA.

Furthermore, including ISA among its recommended safety technology presents an opportunity for NHTSA to align with Euro NCAP, which has already added ISA to its ratings. Euro NCAP awards full credit to ISA systems that detect speed limits and automatically adjust the speed of the vehicle to the posted limit or prevent the driver from exceeding it. The systems must permit the driver to override them, but the ISA system is to be activated on the subsequent ignition cycle. European researchers have thoroughly documented systems that alert the driver versus ones that limit to the posted speed limit, with the latter being associated with a larger reduction in speeding (Biding & Lind, 2002; Ryan, 2018). IIHS agrees with the Euro NCAP approach and recommends that NHTSA adopt it rather than promote systems that merely inform drivers of the limit on the road they are driving on and warn them when they speed.

Q.81: Are there specific protocols that should be considered when evaluating speed assist system functionality?

The Euro NCAP ISA evaluation is based on the features of the systems and does not include tests for accuracy, reliability or comprehensiveness of the underlying speed limit information. We are not aware of any standardized tests of these system attributes.

Q.82: What information is known or anticipated with respect to consumer acceptance of intelligent speed assist systems? What consumer interest or feedback data exist on this topic?

Consumer acceptance of ISA has been lukewarm. Public acceptance research conducted in the United Kingdom found that 53% of respondents favored the technology (Carsten, 2002). Other research suggests that acceptance varies with the type of intervention. Systems that alert the driver are more preferrable than those that automatically slow the vehicle, but they are also less effective in reducing speeding behavior (Arhin et al., 2008). Overall, this research indicates that drivers who experienced ISA in field trials had higher levels of acceptance than the average driver. The lukewarm acceptability of ISA among potential users is evident in a field study planned in Europe that sought to recruit 300 volunteer drivers and follow them for 3 years (Lahrmann et al., 2012). The researchers were able to recruit only 153 drivers, and the study period was terminated early.

Q.84: If NHTSA considers [rear seat child reminder systems designed to prevent vehicular heatstroke] technology for inclusion in NCAP, are door logic solutions sufficient? Should NHTSA only consider systems that detect the presence of a child?

Data on the exact incidence and circumstances surrounding vehicular heatstroke are limited, but the surveillance data NHTSA cited in its RFC provide some insight into the applicability of door-logic vs. presence-detection systems. Door-logic solutions are relevant to about half of vehicular heatstroke cases where drivers left a child in the vehicle unintentionally. However, a quarter of the cases involved children gaining access to the vehicle by themselves, such as when a child enters an unlocked vehicle to play, and another 20% of cases involved a child intentionally left in the vehicle, neither of which likely would be addressed by door-logic systems. As such, door-logic solutions seem like an inadequate solution to these tragically preventable deaths. We urge NHTSA to use NCAP to promote the use of presence-detection systems as soon as practical.

We additionally note that promoting wider adoption of presence-detection systems would be consistent with NHTSA’s interest in promoting highly automated vehicle (HAV) technology. HAVs likely will need to monitor occupant presence and status before initiating a trip. Hastening the development and deployment of occupant presence detection as a countermeasure against vehicular heatstroke would be a stepping-stone to these future needs.

Q.86: Are there specific protocols that should be considered when evaluating these in-vehicle rear seat child reminder systems?

Euro NCAP has a test and assessment protocol for child presence detection, which could, at least in part, be the basis for NHTSA’s promotion of rear seat child reminder systems. Using what Euro NCAP has developed would help align NHTSA with efforts by other consumer information programs.

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HLDI
Highway Loss Data Institute

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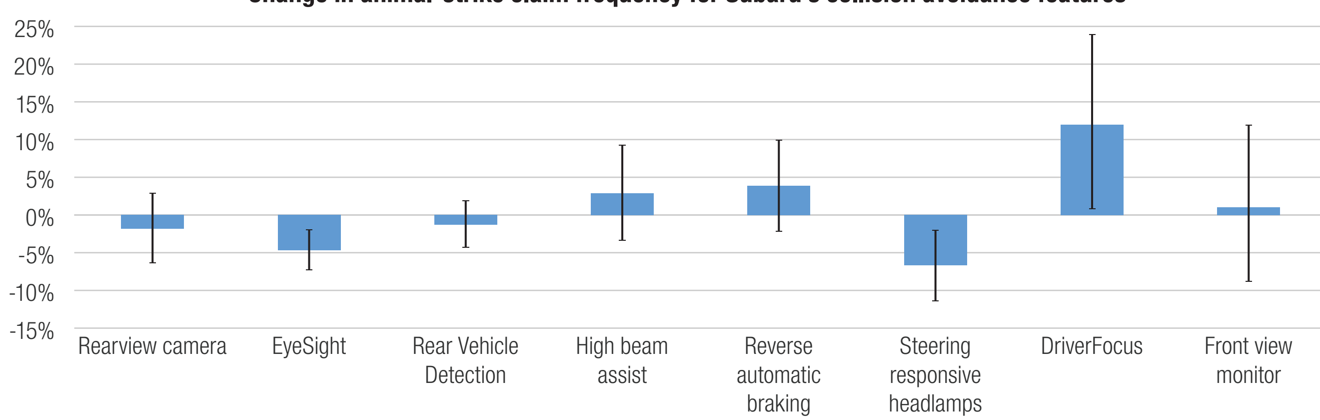
2013–21 Subaru collision avoidance features and animal-strike losses

Summary

Animal-involved crashes are responsible for a substantial number of insurance claims every year and are associated with large monetary costs. Vehicle-animal collisions caused an average of 190 vehicle-occupant fatalities per year from 2009 to 2019 and over 4 million claims from 2006 to 2020. Hence, a system that could avoid or mitigate vehicle-animal collisions would be beneficial. A prior HLDI study showed that Subaru vehicles equipped with EyeSight reduced pedestrian-related claim frequency by 35 percent (HLDI, 2017). While Subaru does not claim that its front crash prevention system (EyeSight) can detect animals, we hypothesized that it could possibly prevent crashes with animals given that Eyesight was associated with reductions in pedestrian-related claims. We also hypothesized that other available advanced driver assistance systems might also prevent crashes with animals such as the advanced lighting systems or the driver monitoring system known as DriverFocus.

As shown in the figure below, EyeSight and steering responsive headlamps were both associated with significant animal-strike claim frequency reductions of 5 percent and 7 percent, respectively. However, high beam assist, Subaru's other advanced lighting system, did not show benefits and DriverFocus was associated with a significant increase (12 percent) in animal-strike claim frequency.

Change in animal-strike claim frequency for Subaru's collision avoidance features



Introduction

Animal-involved crashes are responsible for a substantial number of insurance claims every year and are associated with large monetary costs. A recent Highway Loss Data Institute (HLDI, 2021) study shows that more than 4 million claims were animal-strike related from 2006 to 2020. The average cost of an animal-strike claim over the 15-year period was $3,385. A study sponsored by the Federal Highway Administration estimated that vehicle-animal crashes had an annual cost of over 8 billion U.S. dollars (Huijser et al., 2008). In addition, according to the Insurance Institute for Highway Safety's (IIHS's) analysis of the Fatality Analysis Reporting System (FARS), there was a general upward trend in fatal collisions with animals from 1975 to the mid-2000s (IIHS & HLDI, 2019). Although this trend was relatively consistent between 2009 and 2019, there was still an average of 190 fatal crashes per year. Hence, a system that could avoid or mitigate vehicle-animal collisions would be beneficial.

This Highway Loss Data Institute (HLDI) bulletin provides a first look at the potential effects of Subaru's available collision avoidance systems on animal-strike losses.

Method

Vehicles

EyeSight, rearview camera, Rear Vehicle Detection, reverse automatic braking, steering responsive headlamps, high beam assist, DriverFocus, and front view monitor are offered as optional equipment on various Subaru models. The presence or absence of these features is discernible from the information encoded in the Vehicle Identification Number (VIN).

EyeSight is offered as optional equipment on several 2013–21 Subaru vehicles. Rear-view camera is offered as optional equipment on some 2013–14 Subaru vehicles and is a standard feature on the 2015–21 Subaru vehicles. Rear Vehicle Detection is offered as optional equipment on several 2015–21 Subaru vehicles. Reverse automatic braking, steering responsive headlamps, and high beam assist are offered as optional on some 2017–21 Subaru vehicles. DriverFocus and front view monitor are offered as optional on some 2019-21 Subaru vehicles. Subaru vehicles without these features served as the control vehicles in this analysis. **Tables 1 and 2** list the total exposure, measured in insured vehicle years, and the exposure of each feature as a percentage of total exposure.

Table 1: Vehicle series exposure

Series	Model year range	Exposure
Outback station wagon 4WD	2013–21	5,153,182
Forester 4dr 4WD	2014–21	4,996,087
Crosstrek station wagon 4WD	2015–21	1,982,241
Legacy 4dr 4WD	2013–21	1,651,689
Impreza station wagon 4WD	2015–21	927,353
WRX 4dr 4WD	2016–21	522,638
Impreza 4dr 4WD	2015–21	441,979
Ascent 4dr 4WD	2019–21	356,444
Total collision exposure		**16,031,613**

Table 2: Percent exposure with feature

Feature	Exposure with feature
Rearview camera	92%
EyeSight	42%
Rear Vehicle Detection	40%
High beam assist	20%
Reverse automatic braking	17%
Steering responsive headlights	14%
DriverFocus	2%
Front view monitor	1%

EyeSight uses a dual-camera system located behind the windshield to assess the risk of a collision with leading traffic. EyeSight functionality includes the following functions:

> **Forward collision warning with autonomous braking** uses the cameras to assess the risk of a rear-end collision with an obstacle in front and warns the driver with an audible alert. If the driver does not take evasive action, the brakes are automatically applied to reduce impact damage or, if possible, prevent the collision. EyeSight is capable of avoiding a collision with a speed difference to the obstacle in front as high as 30 mph (48 km/h). However, not every situation under these conditions will result in full collision avoidance. Some of this functionality may be turned off by the driver and can be activated/deactivated via the instrument cluster controls but will reactivate at the next ignition cycle.

Adaptive cruise control with complete stop is a system that uses the dual cameras to monitor traffic ahead and maintain the driver's selected speed and following distance. As traffic conditions dictate, the system employs braking force to maintain the set speed and following distance. Adaptive cruise control is available at speeds up to 90 mph (145 km/h) and can bring the car to a stop in traffic. Forward collision warning remains active even when adaptive cruise control is turned off.

Lane departure warning utilizes the dual cameras to identify traffic lane markings. Audio and visual warnings will indicate if the vehicle path deviates from the lane and the turn signal is not on. The system is functional at speeds at or above 32 mph (51 km/h). The system may be deactivated by the driver but will reactivate at the next ignition cycle.

Lead vehicle start alert notifies the driver by means of an audible tone and the lead vehicle indicator on the multi-informational display when the driver's vehicle remains stopped after the vehicle in front has started to move forward. When the EyeSight-equipped vehicle has stopped within 32 feet of a stationary vehicle and both remain stopped for several seconds, this system will alert the driver of the EyeSight vehicle if their car remains stationary after the lead vehicle has moved 10 feet.

Rearview camera is an optical parking aid that uses a rear-facing camera mounted at the rear of the vehicle to show the area behind the vehicle on a central display screen. The image includes static distance/guidance lines to aid the driver in parking maneuvers. The display is activated when the reverse gear is engaged.

Rear Vehicle Detection uses radar sensors mounted inside the rear bumper cover to monitor the rear and side areas of a vehicle when in forward or rearward motion. This system includes the following three features:

Blind spot detection alerts drivers to vehicles that are adjacent to them. If a vehicle has been detected in the blind spot, a warning light on the appropriate side mirror is illuminated and will flash if a turn signal is activated. The system is functional at speeds above 8 mph (13 km/h) and can be deactivated by the driver. At the next ignition cycle, it will be in the previous on/off setting.

Lane change assist alerts drivers to vehicles that are approaching at a high rate of speed in neighboring lanes. If a vehicle has been detected, a warning light on the appropriate side mirror is illuminated and will flash if a turn signal is activated. The system is functional at speeds above 8 mph (13 km/h) and can be deactivated by the driver. At the next ignition cycle, it will be in the previous on/off setting.

Rear cross-traffic alert alerts drivers to vehicles that are approaching from the side and may move into the path of the reversing vehicle. If a vehicle has been detected, a warning light flashes on the appropriate side mirror and an auditory warning is given. Vehicles with a rearview camera also receive a warning indication in the display. The system can be deactivated by the driver. At the next ignition cycle, it will be in the previous on/off setting.

Reverse automatic braking detects objects behind the vehicle using sonar sensors installed in the rear bumper and automatically stops the vehicle from backing up when an object is detected. If the system detects a possible collision with an object in the reversing direction, automatic deceleration will be activated along with a beeping sound. If the vehicle is further reversed, automatic hard braking will be applied, and a continuous beeping sound will activate. Reverse automatic braking is functional between 1 and 9 mph (1.6 and 15 km/h).

High beam assist works in conjunction with EyeSight and automatically switches the headlights between the low and high settings when an oncoming vehicle is detected. When the vehicle speed increases to 20 mph (32 km/h) the high beams will turn on, but only if it is dark, there is no preceding or oncoming vehicle, and the road does not have a sharp curve. The headlights will change to low beam when the speed decreases to 10 mph (16 km/h), the forward area of the vehicle is bright, and a preceding or oncoming vehicle is detected. The default setting is on, but the dealer can turn it off.

Steering responsive headlamps respond to the driver turning the wheel and aim in the direction the driver is steering, rather than pointing straight ahead. This function helps to improve visibility at night by illuminating the road ahead at corners and intersections; it only activates when the vehicle is traveling at speeds of 5 mph (8 km/h) or higher and can be turned off.

DriverFocus is a driver monitoring system that recognizes individual drivers and monitors for cases when the driver is not paying attention to the forward direction. This system warns the driver of inattentive/drowsy driving and can support safe and comfortable driving by automatically retrieving settings including the driver's seating position, climate control, and other settings. When a driver is registered, various settings are automatically retrieved when the driver enters the vehicle.

Front view monitor provides 180-degree visibility from the front grille of the vehicle. This function improves visibility when making turns with an obstructed view or pulling into a narrow parking spot. Front view monitor is only active when the vehicle speed is below 12 mph (20 km/h).

Insurance data

Automobile insurance covers damage to vehicles and property in crashes plus injuries to people involved in the crashes. Different insurance coverages pay for vehicle damage versus injuries, and different coverages may apply depending on who is at fault. The current study is based on comprehensive coverage. Comprehensive coverage insures against theft and physical damage to the insured vehicle that occurs for reasons other than crashes. Losses due to animal strikes are covered under comprehensive coverage. Information on the type of animal involved in a collision is not available in HLDI's data, but most of the crashes are believed to involve larger animals such as deer.

Of the 43 companies that currently report comprehensive coverage to HLDI, only 25 provide information on animal strikes covered under comprehensive insurance. Vehicle exposure from these 25 companies represents 36 percent of the HLDI database.

Statistical methods

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

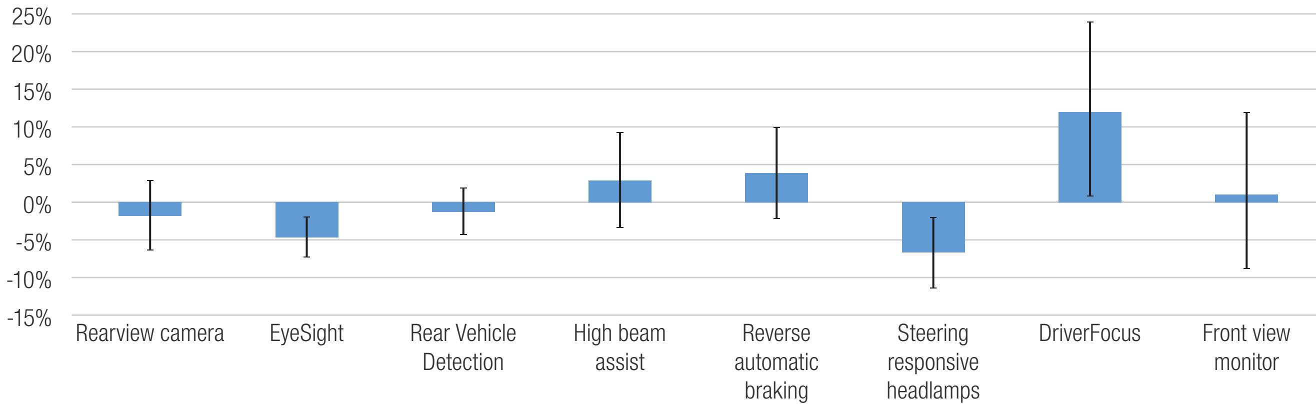
Claim frequency was modeled using a Poisson distribution, whereas claim severity (average loss payment per claim) was modeled using a Gamma distribution. Both models used a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models. Estimates for frequency, severity, and overall losses are presented for animal strikes.

Results

Table 3 illustrates the difference in animal-strike losses between Subaru vehicles with and without the collision avoidance features. The lower and upper bounds represent the 95 percent confidence limits for the estimates. Estimates that are statistically significant at the 95 percent confidence level are bolded. EyeSight was associated with a 5 percent reduction in claim frequency and a 1 percent increase in claim severity, resulting in a significant 4 percent reduction in overall losses. Steering responsive headlamps were associated with a significant 7 percent reduction in claim frequency and nearly no change in claim severity, leading to a significant 7 percent reduction in overall losses. High beam assist was associated with an insignificant 3 percent increase in claim frequency and an insignificant 2 percent reduction in claim severity. This resulted in a 1 percent increase in overall losses. Figure 1 illustrates the changes in animal-strike claim frequency for Subaru vehicles with collision avoidance features.

Table 3: Change in animal-strike losses for the Subaru collision avoidance features									
Feature	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Rearview camera	-6.2%	-1.8%	2.8%	-2.8%	1.3%	5.5%	-6.5%	-0.5%	5.8%
EyeSight	-7.4%	**-4.7%**	-1.8%	-1.8%	0.7%	3.3%	-7.6%	**-4.0%**	-0.2%
Rear Vehicle Detection	-4.3%	-1.3%	1.9%	-1.3%	1.5%	4.3%	-3.9%	0.2%	4.4%
High beam assist	-3.1%	2.9%	9.3%	-6.7%	-1.6%	3.7%	-6.5%	1.2%	9.6%
Reverse automatic braking	-1.8%	3.9%	9.9%	3.1%	**8.4%**	14.0%	4.4%	**12.6%**	21.4%
Steering responsive headlamps	-11.3%	**-6.7%**	-1.8%	-4.3%	0.1%	4.6%	-12.7%	**-6.6%**	-0.1%
DriverFocus	0.9%	**12.0%**	24.3%	-12.7%	-4.5%	4.5%	-6.9%	6.9%	22.7%
Front view monitor	-8.9%	1.0%	12.0%	-2.9%	6.4%	16.7%	-6.4%	7.5%	23.5%

Figure 1: Change in animal-strike claim frequency for Subaru's collision avoidance features



Discussion

It is encouraging that Subaru's EyeSight system and steering responsive headlamps were associated with significant 5 and 7 percent reductions in animal-strike claim frequency. It was expected that the forward-facing systems such as EyeSight, steering responsive headlamps and high beam assist would be beneficial for reducing animal-vehicle collisions. Additionally, DriverFocus, which helps ensure drivers are alert, could also be beneficial in reducing animal-strike claims. Neither high-beam assist nor DriverFocus showed the anticipated reductions in animal strike frequencies. The 12 percent increase associated with DriverFocus is somewhat puzzling, as it monitors the driver's attention. Although the increase associated with DriverFocus is significant, very few vehicles have the system installed and the result may be a statistical anomaly. Benefits were not expected for rearview camera, Rear Vehicle Detection, reverse automatic braking, or front view monitor.

Accidents with animals are more likely to occur on rural roads with speed limits of 55 mph (88 km/h) or higher, in darkness, and during dusk and dawn (HLDI, 2016; Williams & Wells, 2005). Steering responsive headlamps help to improve visibility at night by illuminating the road ahead at corners and intersections. Subaru's steering responsive headlamps have shown a significant 7 percent reduction in the frequency of animal-strike claims. Furthermore, high-beam assist was expected to be beneficial, as it allows drivers to more easily use their high-beams more often by automatically switching to low beams when an oncoming vehicle is detected. This system shows an insignificant 3 percent increase in this study. However, this may be a limitation of the available data in conjunction with the analytical approaches used to evaluate the system. High beam assist works with the EyeSight system and is present with reverse automatic braking on some vehicle models. HLDI will continue to monitor the changes associated with high beam assist as more data and models become available.

Next steps

As crashes with animals are most likely to occur during dusk, dawn, and nighttime, future research is needed to evaluate the effects of advanced headlights and front crash prevention systems on animal-strike losses, segmented by the time of day.

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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. DW202204 DH

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2013–21 Subaru collision avoidance features

Summary

Subaru introduced its front crash prevention system, EyeSight, in model year 2013 on the Legacy and Outback. HLDI's first analysis of the system was published in 2014 and rearview camera was the only other collision avoidance technology available at the time. By the 2016 model year, every Subaru name plate except the BRZ could be purchased with the EyeSight system. In the 2017 model year, three new features were introduced on Subaru vehicles including reverse automatic braking, steering responsive headlamps, and high beam assist. Subaru added a driver monitoring system (DriverFocus) and front view monitor as optional equipment starting in the 2019 model year. Since 2013, EyeSight has undergone several evolutions and enhancements. Subaru has identified two distinct generations of EyeSight where the first generation utilized dual black-and-white stereo cameras (version 2) and the second generation shifted to color cameras along with other enhancements (version 3). Within the second generation, Subaru enhanced EyeSight by adding lane keep assist to some later model year vehicles (version 3+) and followed up with the latest available version, which added lane-centering functionality (version 3++). For the purposes of this analysis we refer to these four versions of EyeSight as version 2, version 3, version 3+ and version 3++.

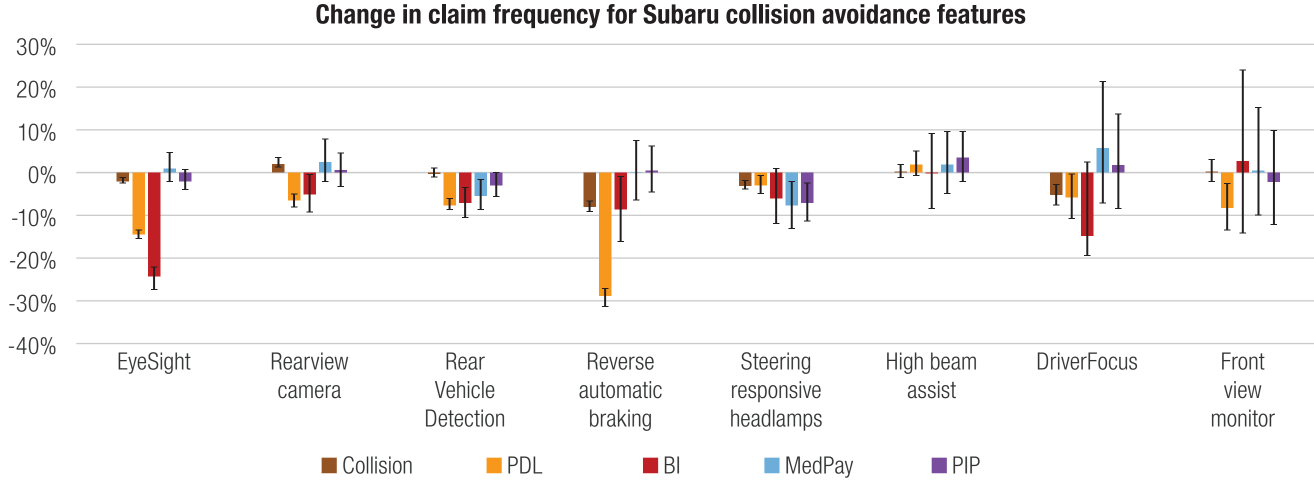
The presence or absence of these features is discernible from the information encoded in the first 10 positions of the Vehicle Identification Number (VIN), providing an opportunity for HLDI to study Subaru vehicles without the need for Subaru to provide 17-digit VINs and associated reference data. The high sales volume of Subaru vehicles equipped with collision avoidance features has allowed HLDI to not only understand the benefits of Subaru's features by coverage type but also answer secondary questions including how the feature benefits vary over time and vary by mileage, vehicle age, and driver age. To date HLDI has conducted more than 15 studies on Subaru vehicles with collision avoidance features.

This 2022 HLDI bulletin extends the 2019 analysis with two new collision avoidance features (DriverFocus and front view monitor), three additional model years (2019–21), a new vehicle series (Ascent four-door 4WD), and 56 percent more exposure.

The claim frequency benefits of the EyeSight system have persisted as later model years were added, as additional vehicles implemented the system, and as the vehicles aged. The EyeSight changes have had measurable increased benefits for collision. The PDL and bodily injury (BI) liability benefits also showed an increase from version 2 to version 3, but those increased benefits were not associated with the later enhanced EyeSight versions 3+ and 3++. Furthermore, preliminary results from Subaru's Level 2 driving automation technology EyeSight version 3++ alone showed a benefit in PDL but not in collision.

Reverse automatic braking, which automatically stops a backing vehicle when objects are detected, is substantially reducing vehicle damage claim frequency, ranging from a significant 8 percent reduction in collision claim frequency to a significant 29 percent claim frequency reduction under property damage liability (PDL). Rearview camera also significantly reduced claim frequency for PDL. However, both reverse automatic braking and rearview camera systems were associated with significant increases in claim severity for collision and PDL due to a shift in the distribution of claim costs.

Change in claim frequency for Subaru collision avoidance features



Introduction

This Highway Loss Data Institute (HLDI) bulletin provides a look at the effects of available Subaru collision avoidance systems on insurance losses. The prior HLDI (2014, 2015a, 2016a, 2016b, 2017a, 2018a, 2019) reports indicate that EyeSight, rearview camera, Rear Vehicle Detection, reverse automatic braking, and steering responsive headlamps are having some benefits. This HLDI bulletin extends the 2019 analysis with new collision avoidance features (DriverFocus and front view monitor), three additional model years (2019–21), a new series (Ascent four-door 4WD), and 56 percent more exposure.

EyeSight uses a dual-camera system located behind the windshield to assess the risk of a collision with leading traffic. The first generation of the EyeSight system was available on the 2013–14 Legacy and Outback vehicles and on the 2014–16 Forester. In model year 2015, Subaru introduced a second generation of the EyeSight system on the Legacy and Outback. It also appeared for the first time on the XV Crosstrek and Impreza four-door and five-door in 2015.

The first generation utilized dual black-and-white stereo cameras, while the second generation shifted to color cameras along with longer and wider detection ranges, an increased ability to handle the speed differential with leading vehicles, and brake light detection. An important enhancement to the second generation of the EyeSight system is the increased speed differential. The first generation of EyeSight was fully functional when the speed difference between the EyeSight-equipped vehicle and another vehicle was up to 19 mph (31 km/h). However, on the second generation, Subaru increased the speed differential to 30 mph (48 km/h). At higher speed differentials, the EyeSight system may only be able to mitigate the crash.

After the release of the second generation of EyeSight, Subaru further improved the EyeSight system with the addition of lane keep assist technology on the 2016 WRX, Legacy, and Outback. Following that, it debuted on the 2017 Forester and Impreza, 2018 Crosstrek, and 2019 Ascent. The refined system includes lane keep assist with a lane departure prevention function. The system uses the stereo cameras to detect lane markings to help prevent departure from the lane. When driving on expressways, freeways, or interstate highways at speeds above approximately 40 mph (65 km/h), if the vehicle is about to depart from the lane, the system assists the steering operation by turning it to the direction that will help prevent the lane departure.

In model year 2020, Subaru made another enhancement on Forester, Outback, and Legacy models. These models were the first to feature a lane-centering function. This function can be used when adaptive cruise control is activated. When driving at speeds of up to approximately 90 mph (145 km/h), the system detects the lane markings and the lead vehicle and assists the driver with steering control to help keep the vehicle close to the center of the lane and follow the lead vehicle on expressways, freeways, and interstate highways. Subaru also introduced this function on the 2021 Crosstrek and Ascent. This enhanced EyeSight system featuring adaptive cruise control with a lane-centering function meets the SAE International definition of Level 2 automation (2018).

It should be noted that although EyeSight has undergone several evolutions and enhancements, Subaru has identified only two generations of EyeSight. The specific version names in each generation, according to Subaru, are as follows:

- The first-generation of EyeSight: version 2
- The second-generation of EyeSight: version 3
- The second-generation of EyeSight including lane keep assist: version 3+
- The second-generation of EyeSight including lane centering: version 3++

All EyeSight generations (v2, v3, v3+, v3++) include the following four features:

Forward collision warning with autonomous braking uses the cameras to assess the risk of a rear-end collision with an obstacle in front and warns the driver with an audible alert. If the driver does not take evasive action, the brakes are automatically applied to reduce impact damage or, if possible, prevent the collision. EyeSight is capable of avoiding a collision with a speed difference to the obstacle in front as high as 30 mph (48 km/h). However, not every situation under these conditions will result in full collision avoidance. Some of this functionality may be turned off by the driver and can be activated/deactivated via the instrument cluster controls but will reactivate at the next ignition cycle.

Adaptive cruise control with complete stop is a system that uses the dual cameras to monitor traffic ahead and maintain the driver's selected speed and following distance. As traffic conditions dictate, the system employs braking force to maintain the set speed or following distance. Adaptive cruise control is available at speeds up to 90 mph (145 km/h) and can bring the car to a stop in traffic. Forward collision warning remains active even when adaptive cruise control is turned off.

Lane departure warning utilizes the dual cameras to identify traffic lane markings. Audio and visual warnings will indicate if the vehicle path deviates from the lane and the turn signal is not on. The system is functional at speeds at or above 32 mph (51 km/h). The system may be deactivated by the driver but will reactivate at the next ignition cycle.

Lead vehicle start alert notifies the driver by means of an audible tone and the lead vehicle indicator on the multi-informational display when the driver's vehicle remains stopped after the vehicle in front has started to move forward. When the EyeSight-equipped vehicle has stopped within 32 feet of a stationary vehicle and both remain stopped for several seconds, this system will alert the driver of the EyeSight vehicle if their car remains stationary after the lead vehicle has moved 10 feet.

Rearview camera is an optical parking aid that uses a rear-facing camera mounted at the rear of the vehicle to show the area behind the vehicle on a central display screen. The image includes static distance/guidance lines to aid the driver in parking maneuvers. The display is activated when the reverse gear is engaged.

Rear Vehicle Detection uses radar sensors mounted inside the rear bumper cover to monitor the rear and side areas of a vehicle when in forward or rearward motion. The Rear Vehicle Detection system includes the following three features:

Blind spot detection alerts drivers to vehicles that are adjacent to them. If a vehicle has been detected in the blind spot, a warning light on the appropriate side mirror is illuminated and will flash if a turn signal is activated. The system is functional at speeds above 8 mph (13 km/h) and can be deactivated by the driver. At the next ignition cycle, it will be in the previous on/off setting.

Lane change assist alerts drivers to vehicles that are approaching at a high rate of speed in neighboring lanes. If a vehicle has been detected, a warning light on the appropriate side mirror is illuminated and will flash if a turn signal is activated. The system is functional at speeds above 8 mph (13 km/h) and can be deactivated by the driver. At the next ignition cycle, it will be in the previous on/off setting.

Rear cross-traffic alert alerts drivers to vehicles that are approaching from the side and may move into the path of the reversing vehicle. If a vehicle has been detected, a warning light flashes on the appropriate side mirror and an auditory warning is given. Vehicles with a rearview camera also receive a warning indication in the display. The system can be deactivated by the driver. At the next ignition cycle, it will be in the previous on/off setting.

Reverse automatic braking (RAB) detects objects behind the vehicle using sonar sensors installed in the rear bumper and automatically stops the vehicle from backing up when an object is detected. If the system detects a possible collision with an object in the reversing direction, automatic deceleration will be activated along with a beeping sound. If the vehicle is further reversed, automatic hard braking will be applied, and a continuous beeping sound will activate. Reverse automatic braking is functional between 1 and 9 mph (1.6 and 15 km/h).

High beam assist works in conjunction with EyeSight and automatically switches the headlights between the low and high settings when an oncoming vehicle is detected. When the vehicle speed increases to 20 mph (32 km/h) the high beams will turn on, but only if it is dark, there is no preceding or oncoming vehicle, and the road does not have a sharp curve. The headlights will change to low beam when the speed decreases to 10 mph (16 km/h), the forward area of the vehicle is bright, and a preceding or oncoming vehicle is detected. The default setting is on, but the dealer can turn it off.

Steering responsive headlamps (SRH) respond to the driver turning the wheel and aim in the direction the driver is steering, rather than pointing straight ahead. This function helps to improve visibility at night by illuminating the road ahead at corners and intersections; it only activates when the vehicle is traveling at speeds of 5 mph (8 km/h) or higher and can be turned off.

DriverFocus is a driver monitoring system that serves as a safety monitor and convenience feature. It uses a camera to monitor the driver for signs of inattention or drowsiness and warns the driver if their attention is not focused on the forward roadway. The system also recognizes individual drivers and can retrieve settings including the driver's seating position, climate control, and other settings. When a driver is registered, various settings are automatically retrieved when the driver enters the vehicle.

Front view monitor provides 180-degree visibility from the front grille of the vehicle. This function improves visibility when making turns with an obstructed view or pulling into a narrow parking spot. Front view monitor is only active when the vehicle speed is below 12 mph (20 km/h).

Vehicles

EyeSight, rearview camera, Rear Vehicle Detection, reverse automatic braking, steering responsive headlamps, high beam assist, DriverFocus, and front view monitor are offered as optional equipment on various Subaru models. The presence or absence of these features is discernible from the information encoded in the Vehicle Identification Numbers (VINs). EyeSight is offered as optional equipment on several 2013–21 Subaru vehicles. Rearview camera is offered as optional equipment on some 2013–14 Subaru vehicles and is a standard feature on the 2015–21 Subaru vehicles. Rear Vehicle Detection is offered as optional equipment on several 2015–21 Subaru vehicles. Reverse automatic braking, steering responsive headlamps, and high beam assist are offered as optional on some 2017–21 Subaru vehicles. DriverFocus and front view monitor are offered as optional on some 2019–21 Subaru vehicles. Subaru vehicles without these features served as the control vehicles in this analysis. **Table 1** lists the total exposure, measured in insured vehicle years, and the exposure of each feature as a percentage of total exposure.

Table 1: Feature exposure by vehicle series

Make	Series	Model year range	Rear-view camera	EyeSight version 2	EyeSight version 3	EyeSight version 3+	EyeSight version 3++	Rear Vehicle Detection	Rear auto-brake	Steering responsive head-lamps	High beam assist	Driver-Focus	Front view monitor	Total exposure
Subaru	Forester 4dr 4WD	2014–16	94%	18%	0%	0%	0%	0%	0%	0%	0%	0%	0%	3,012,878
Subaru	Forester 4dr 4WD	2017–19	100%	0%	0%	60%	0%	63%	29%	29%	32%	3%	0%	1,647,151
Subaru	Forester 4dr 4WD	2020–21	100%	0%	0%	0%	100%	77%	48%	50%	64%	11%	0%	329,582
Subaru	Outback station wagon 4WD	2013–14	51%	9%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1,596,009
Subaru	Outback station wagon 4WD	2015–15	100%	0%	40%	0%	0%	67%	0%	0%	0%	0%	0%	847,095
Subaru	Outback station wagon 4WD	2016–19	100%	0%	0%	72%	0%	79%	40%	20%	51%	0%	0%	2,460,747
Subaru	Outback station wagon 4WD	2020–21	100%	0%	0%	0%	100%	93%	75%	79%	100%	59%	31%	242,896
Subaru	Legacy 4dr 4WD	2013–14	22%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	513,968
Subaru	Legacy 4dr 4WD	2015–15	100%	0%	28%	0%	0%	51%	0%	0%	0%	0%	0%	385,265
Subaru	Legacy 4dr 4WD	2016–19	100%	0%	0%	57%	0%	59%	24%	9%	33%	0%	0%	711,746
Subaru	Legacy 4dr 4WD	2020–21	100%	0%	0%	0%	100%	80%	66%	69%	100%	49%	10%	36,513
Subaru	Impreza 4dr 4WD	2015–16	100%	0%	9%	0%	0%	0%	0%	0%	0%	0%	0%	200,419
Subaru	Impreza 4dr 4WD	2017–21	100%	0%	0%	43%	0%	38%	9%	10%	9%	0%	0%	240,416
Subaru	Impreza station wagon 4WD	2015–16	100%	0%	12%	0%	0%	0%	0%	0%	0%	0%	0%	427,162
Subaru	Impreza station wagon 4WD	2017–21	100%	0%	0%	45%	0%	39%	11%	13%	11%	0%	0%	498,202
Subaru	WRX 4dr 4WD	2016–21	100%	0%	0%	5%	0%	21%	3%	18%	2%	0%	0%	520,690
Subaru	XV Crosstrek station wagon 4WD	2015–15	100%	0%	20%	0%	0%	0%	0%	0%	0%	0%	0%	370,750
Subaru	Crosstrek station wagon 4WD	2016–17	100%	0%	34%	0%	0%	59%	0%	0%	0%	0%	0%	574,723
Subaru	Crosstrek station wagon 4WD	2018–20	100%	0%	0%	60%	0%	64%	30%	33%	30%	0%	0%	929,930
Subaru	Crosstrek station wagon 4WD	2021–21	100%	0%	0%	0%	96%	64%	33%	33%	33%	0%	0%	104,871
Subaru	Ascent 4dr 4WD	2019–20	100%	0%	0%	100%	0%	99%	96%	68%	68%	0%	28%	316,413
Subaru	Ascent 4dr 4WD	2021–21	100%	0%	0%	0%	100%	99%	98%	100%	100%	0%	29%	40,558

Insurance data

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

Because different crash avoidance features may affect different types of insurance coverage, it is important to understand how coverages vary among the states and how this affects inclusion in the analysis. Collision coverage insures against vehicle damage to an at-fault driver's vehicle sustained in a crash with an object or other vehicle; this coverage is common to all 50 states. 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 (each insured vehicle pays for its own damage in a crash, regardless of who is at fault).

Coverage of injuries is more complex. BI liability coverage insures against medical, hospital, and other expenses for injuries that at-fault drivers inflict on occupants of other vehicles or others on the road. Although motorists in most states may have BI coverage, this information is analyzed only in states where the at-fault driver has first obligation to pay for injuries (33 states with traditional tort insurance systems). 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 (personal injury protection, or 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.

Statistical methods

Regression analysis was used to quantify the effect of vehicle features while controlling for other covariates. The covariates included calendar year, model year, garaging state, vehicle density (number of registered vehicles per square mile), rated driver age group, rated driver gender, rated driver marital status, deductible range (collision coverage only), and risk. For each safety feature studied, a 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 frequency, severity, and overall losses are presented for collision and PDL. For PIP, BI, and MedPay, three frequency estimates are presented. The first frequency is the frequency for all claims, including those that already have been paid and those for which money has been set aside for possible payment in the future, known as claims with reserves. The other two frequencies include only paid claims separated into low- and high-severity ranges. Note that the percentage of all injury claims that were paid by the date of analysis varies by coverage: 74 percent for PIP, 69 percent for BI, and 63 percent for MedPay. The low-severity range was less than $1,000 for PIP and MedPay, less than $5,000 for BI; high severity covered all loss payments greater than that.

A separate regression was performed for each insurance loss measure for a total of 15 regressions (5 coverages x 3 loss measures each). For space reasons, only the estimates for the individual crash avoidance features are shown on the following pages. To illustrate the analysis, however, the **Appendix** contains full model results for collision claim frequencies. To further simplify the presentation here, the exponent of the parameter estimate was calculated, 1 was subtracted, and the result multiplied by 100. The resulting number corresponds to the effect of the feature on that loss measure. For example, the estimate of the effect of EyeSight on collision claim frequency was −0.0210; thus, vehicles with the feature had 2.1 percent fewer collision claims than vehicles without EyeSight ($(\exp(-0.0210)-1) \times 100 = -2.1$).

Results

Table 2 displays the results for Subaru's version 2 (first-generation EyeSight). The lower and upper bounds represent the 95 percent confidence limits for the estimates. Estimates that are statistically significant at the 95 percent confidence level are bolded. Claim frequency decreased significantly for collision (2 percent) and PDL (15 percent). Claim severities exhibit statistically significant increases for both collision and PDL. This resulted in essentially no change to collision overall losses and a statistically significant reduction of 13 percent to PDL overall losses.

For injury losses, overall claim frequency decreased 25 percent, 2 percent, and 1 percent for BI, MedPay. and PIP, respectively. The BI benefit is statistically significant. Among low- and high-severity paid claims, BI liability shows reductions that are statistically significant.

Table 2: Change in insurance losses for EyeSight version 2 (first generation)

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-2.6%	**-1.5%**	-0.4%	0.5%	**1.7%**	3.0%	-1.5%	0.2%	1.9%
Property damage liability	-16.4%	**-14.9%**	-13.4%	0.6%	**2.3%**	4.0%	-15.1%	**-13.0%**	-10.9%

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW-SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH-SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-28.7%	**-24.8%**	-20.6%	-36.1%	**-29.2%**	-21.6%	-31.4%	**-25.5%**	-19.1%
Medical payment	-6.3%	-1.8%	3.0%	-19.2%	-8.1%	4.4%	-2.8%	3.8%	10.9%
Personal injury protection	-5.0%	-1.2%	2.8%	-14.2%	-6.3%	2.4%	-4.0%	1.2%	6.6%

In the second generation of the EyeSight technology, Subaru made several enhancements to the system, as described in the Introduction. **Table 3** displays the results for Subaru's version 3 (second-generation featuring just lane departure warning), which was introduced for the model year 2015 on the XV Crosstrek, Impreza, Legacy, and Outback. For vehicle damage losses, claim frequency continues to decrease significantly for both collision and PDL, and there are slightly larger benefits compared with the first generation results shown in **Table 2**.

For injury losses, reductions in BI liability claim frequencies continue to be significantly lower.

Table 3: Change in insurance losses for EyeSight version 3 (second generation)

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-3.3%	**-2.1%**	-1.0%	-0.5%	0.8%	2.1%	-3.1%	-1.4%	0.4%
Property damage liability	-17.4%	**-15.8%**	-14.1%	-1.0%	0.8%	2.8%	-17.3%	**-15.1%**	-12.7%

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW-SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH-SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-32.3%	**-28.2%**	-23.8%	-40.1%	**-33.1%**	-25.3%	-34.3%	**-28.0%**	-21.0%
Medical payment	-4.7%	0.6%	6.3%	-19.5%	-6.6%	8.5%	0.3%	**8.4%**	17.1%
Personal injury protection	-5.0%	-0.9%	3.4%	-11.4%	-2.8%	6.7%	-5.3%	0.3%	6.4%

Table 4 displays the results for EyeSight versions 3+ and 3++. Version 3+ was introduced for the 2016 model year on the WRX, Legacy, and Outback; the 2017 Impreza and Forester; the 2018 Crosstrek; and the 2019 Ascent. Version 3++ was introduced for the 2020 Forester, Legacy, and Outback and the 2021 Crosstrek and Ascent. For vehicle damage losses, claim frequency decreased 3 percent for collision and 13 percent for PDL. Both results are statistically significant. Claim severity decreased 2 percent for collision and 1 percent for PDL with the collision result being significant. Overall losses decreased significantly for both collision and PDL.

For injury losses, overall claim frequencies are lower and statistically significant for BI and PIP. Low- and high-severity claim frequency for BI and high-severity claim frequency for PIP also show statistically significant reductions.

Table 4: Change in insurance losses for EyeSight versions v3+ and v3++ (second generation)

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-3.7%	**-2.6%**	-1.6%	-3.2%	**-2.0%**	-0.9%	-6.1%	**-4.6%**	-3.1%
Property damage liability	-14.3%	**-12.8%**	-11.2%	-2.2%	-0.5%	1.3%	-15.4%	**-13.2%**	-11.0%

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW-SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH-SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-24.3%	**-19.9%**	-15.3%	-35.1%	**-27.7%**	-19.4%	-28.5%	**-21.8%**	-14.4%
Medical payment	-0.4%	4.9%	10.4%	-14.3%	-1.3%	13.7%	1.5%	**9.3%**	17.7%
Personal injury protection	-7.8%	**-4.0%**	-0.2%	-10.5%	-2.3%	6.7%	-10.8%	**-5.8%**	-0.6%

Results for all EyeSight generations combined are summarized in **Table 5**. The analysis covers vehicles included in the results detailed in **Tables 2–4**. For vehicle damage losses, claim frequency decreased for collision and PDL coverages. Both decreases are statistically significant. Claim severity remained unchanged for collision and increased slightly for PDL. None of these increases are statistically significant. This resulted in significant reductions of 2 percent and 14 percent to collision and PDL overall losses, respectively.

For injury losses, overall claim frequency is lower for BI liability and PIP but not for MedPay, and the BI benefit is statistically significant. Among low- and high-severity claims, BI shows significant reductions. **Tables 2–5** demonstrate that the changes and enhancements Subaru made to its EyeSight system did not shift the benefits greatly.

Table 5: Change in insurance losses for EyeSight

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-2.7%	**-2.1%**	-1.4%	-0.6%	0.1%	0.8%	-3.0%	**-2.0%**	-1.0%
Property damage liability	-15.4%	**-14.5%**	-13.5%	-0.1%	1.0%	2.1%	-14.9%	**-13.6%**	-12.3%

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW-SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH-SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-26.8%	**-24.3%**	-21.7%	-34.3%	**-29.9%**	-25.3%	-29.0%	**-25.1%**	-21.1%
Medical payment	-2.2%	0.9%	4.0%	-13.3%	-5.7%	2.5%	2.1%	**6.6%**	11.4%
Personal injury protection	-4.4%	-2.1%	0.4%	-9.0%	-3.9%	1.4%	-4.7%	-1.4%	1.9%

Results for Subaru's rearview camera are summarized in **Table 6**. Again, the lower and upper bounds represent the 95 percent confidence limits for the estimates. For vehicle damage losses, claim frequencies declined significantly for PDL and increased slightly but significantly for collision. Claim severities increased significantly for collision and PDL, resulting in a significant increase in overall losses for collision and a significant decrease for PDL.

For injury coverages, claim frequency is lower for BI but not for PIP or MedPay, and only the difference for BI is statistically significant.

Table 6: Change in insurance losses for rearview camera

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	0.9%	**2.0%**	3.1%	1.4%	**2.6%**	3.9%	3.0%	**4.7%**	6.4%
Property damage liability	-8.0%	**-6.5%**	-5.1%	2.1%	**3.6%**	5.2%	-5.2%	**-3.1%**	-1.0%

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW-SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH-SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-9.4%	**-5.1%**	-0.6%	-16.3%	**-9.0%**	-1.0%	-7.1%	-0.1%	7.4%
Medical payment	-2.2%	2.4%	7.3%	-5.8%	6.8%	21.1%	-3.6%	3.0%	10.0%
Personal injury protection	-3.2%	0.5%	4.4%	-7.4%	0.7%	9.5%	-2.6%	2.6%	8.0%

Results for Subaru's Rear Vehicle Detection are summarized in **Table 7**. For vehicle damage losses, claim frequency shows a 0.3 percent reduction for collision and a significant 8 percent reduction for PDL. Claim severity increased for both collision and PDL with the collision result being significant. As a result, overall losses show a 1 percent increase for collision and an 8 percent reduction for PDL with both results being significant.

For injury losses, overall claim frequencies are lower and statistically significant for all three injury coverage types. Low- and high-severity claim frequency for BI and high-severity claim frequency for MedPay are also showing statistically significant reductions.

Table 7: Change in insurance losses for Rear Vehicle Detection

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-1.0%	-0.3%	0.5%	0.6%	**1.4%**	2.3%	0.0%	**1.2%**	2.3%
Property damage liability	-8.8%	**-7.6%**	-6.5%	-1.0%	0.2%	1.4%	-9.1%	**-7.5%**	-5.8%

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW-SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH-SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-10.6%	**-7.1%**	-3.5%	-14.5%	**-8.1%**	-1.3%	-14.8%	**-9.5%**	-3.8%
Medical payment	-8.8%	**-5.4%**	-1.8%	-17.6%	-8.9%	0.7%	-12.6%	**-7.9%**	-2.9%
Personal injury protection	-5.7%	**-3.0%**	-0.2%	-2.8%	3.4%	10.1%	-6.9%	-3.2%	0.6%

Results for Subaru's reverse automatic braking are summarized in **Table 8**. For vehicle damage losses, claim frequency decreased significantly for both collision (8 percent) and PDL (29 percent). There are significant increases in claim severity for both collision and PDL, resulting in a statistically significant reduction in overall losses for PDL and a small increase in overall losses for collision.

For injury losses, overall claim frequencies are lower significantly for BI but not for MedPay and PIP.

Table 8: Change in insurance losses for reverse automatic braking

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-9.3%	**-8.0%**	-6.7%	8.2%	**9.9%**	11.6%	-1.0%	1.1%	3.2%
Property damage liability	-30.6%	**-28.8%**	-26.9%	15.4%	**18.3%**	21.4%	-18.8%	**-15.8%**	-12.6%

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW-SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH-SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-15.9%	**-8.6%**	-0.8%	-23.7%	-10.0%	6.2%	-22.2%	-10.9%	2.0%
Medical payment	-6.6%	0.0%	7.1%	-10.1%	9.2%	32.6%	-12.6%	-3.7%	6.0%
Personal injury protection	-4.9%	0.4%	6.0%	-13.3%	-1.6%	11.6%	-8.9%	-2.0%	5.5%

Results for Subaru's steering responsive headlamps are summarized in **Table 9**. For vehicle damage losses, claim frequency is showing significant reductions for both collision and PDL (3 percent). Claim severities increased, leading to reductions in collision and PDL overall losses that are not statistically significant.

For injury losses, overall claim frequencies are lower for the BI, MedPay, and PIP injury coverage types with MedPay and PIP being statistically significant. MedPay shows significant reductions in both low- and high-severity frequencies, and PIP shows a significant reduction in low-severity claim frequency.

Table 9: Change in insurance losses for steering responsive headlamps

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-4.3%	**-3.1%**	-1.8%	0.8%	**2.2%**	3.7%	-2.8%	-0.9%	1.0%
Property damage liability	-5.2%	**-3.0%**	-0.7%	-1.1%	1.1%	3.5%	-5.0%	-1.9%	1.3%

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW-SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH-SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-12.2%	-6.0%	0.6%	-17.4%	-5.6%	8.0%	-9.8%	0.7%	12.3%
Medical payment	-13.2%	**-7.7%**	-1.8%	-29.6%	**-16.1%**	-0.1%	-16.5%	**-8.7%**	-0.3%
Personal injury protection	-11.5%	**-7.1%**	-2.5%	-21.7%	**-12.3%**	-1.8%	-11.2%	-5.2%	1.2%

Results for Subaru's high beam assist are summarized in **Table 10**. For vehicle damage losses, claim frequency increased for collision and PDL. Claim severity decreased significantly for both collision and PDL, resulting in a significant 2 percent reduction to collision overall losses and a 3 percent reduction to PDL overall losses.

For injury losses, overall claim frequencies are lower for BI and higher for MedPay and PIP, and none are statistically significant.

Table 10: Change in insurance losses for high beam assist

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-1.3%	0.2%	1.7%	-4.2%	**-2.6%**	-1.0%	-4.6%	**-2.4%**	-0.3%
Property damage liability	-0.8%	1.8%	4.5%	-6.8%	**-4.4%**	-2.0%	-6.2%	-2.7%	0.9%

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW-SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH-SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-8.2%	-0.2%	8.6%	-15.6%	-0.3%	17.8%	-12.8%	0.2%	15.0%
Medical payment	-5.3%	1.9%	9.5%	-19.2%	-0.9%	21.6%	-5.1%	5.2%	16.6%
Personal injury protection	-2.3%	3.5%	9.6%	-9.8%	2.7%	16.9%	-2.4%	5.4%	13.9%

Results for Subaru's new 2019–21 collision avoidance features are summarized in the following tables. For these systems, data on paid claims for the three injury coverages were limited. Due to the sparse data, results for the high- and low-severity injury coverage frequency estimates for the systems are not presented.

Results for DriverFocus are summarized in **Table 11**. For vehicle damage losses, claim frequency decreased significantly for collision (5 percent) and PDL (6 percent). Claim severity increased 1 percent for collision and decreased 3 percent for PDL. This resulted in a 4 percent reduction for collision overall losses and a significant 8 percent reduction for PDL overall losses.

For injury losses, overall claim frequencies are lower for BI but not for MedPay and PIP. None of the results are statistically significant.

Table 11: Change in insurance losses for DriverFocus

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-7.7%	**-5.2%**	-2.6%	-1.6%	1.3%	4.4%	-7.7%	-3.9%	0.0%
Property damage liability	-10.8%	**-5.8%**	-0.5%	-7.7%	-2.6%	2.7%	-15.0%	**-8.2%**	-0.9%

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW-SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH-SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-29.1%	-14.8%	2.4%						
Medical payment	-7.3%	5.7%	20.4%						
Personal injury protection	-8.6%	1.7%	13.2%						

Results for Subaru's front view monitor are summarized in **Table 12**. Claim frequency, severity, and overall losses increased for collision, though none are statistically significant. For PDL, claim frequency decreased significantly by 8 percent. Claim severity increased 2 percent, resulting in an insignificant 6 percent reduction in overall losses.

For injury losses, overall claim frequencies are lower for PIP but higher for BI liability and MedPay. None of the results are statistically significant and they have very wide confidence intervals.

Table 12: Change in insurance losses for front view monitor

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-2.4%	0.2%	2.9%	-0.5%	2.4%	5.5%	-1.3%	2.7%	6.8%
Property damage liability	-13.5%	**-8.3%**	-2.8%	-3.4%	2.2%	8.2%	-13.6%	-6.3%	1.7%

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW-SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH-SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-14.3%	2.7%	23.0%						
Medical payment	-12.0%	0.4%	14.7%						
Personal injury protection	-12.6%	-2.1%	9.7%						

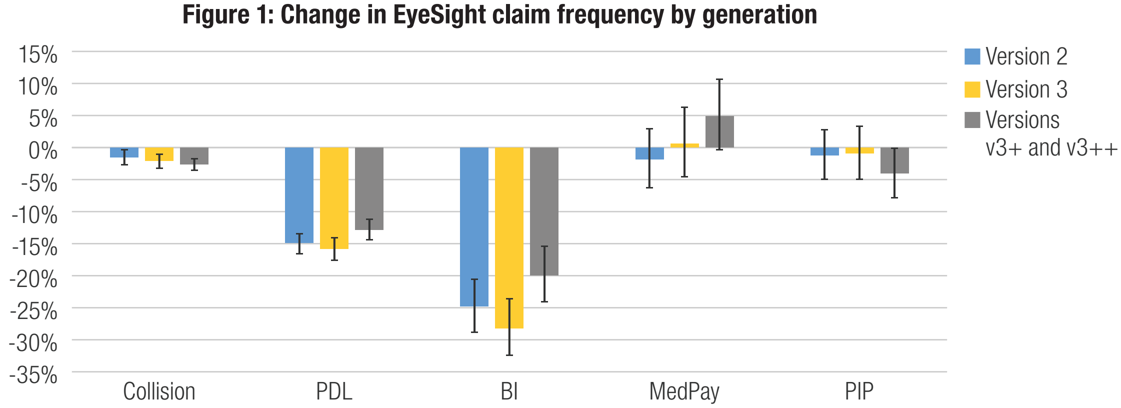
Discussion

EyeSight generations

Claim frequency

Subaru's first generation of EyeSight utilized dual black-and-white cameras, while the second generation shifted to color cameras along with longer and wider detection ranges, an increased ability to handle the speed differential with leading vehicles, and brake light detection. Thereafter, Subaru made several other enhancements to the second generation of EyeSight including the addition of lane keep assist and lane centering. **Figure 1** shows the estimated claim frequency by EyeSight generation. The EyeSight changes have had a measurable, increased benefit for collision. Collision claim frequency was reduced by 2.6 percent for the most recent EyeSight versions (3+ and 3++), followed by 2.1 percent for version 3, and 1.5 percent for version 2. The benefits under PDL and BI showed an increase from version 2 to version 3, but the benefits did not continue to increase with the combination of version 3+ and version 3++.

Figure 1: Change in EyeSight claim frequency by generation

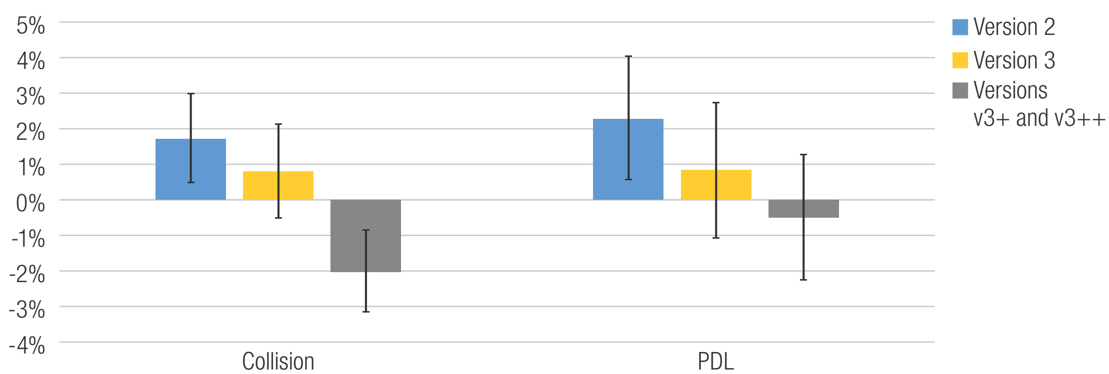


The comparison between EyeSight version 2 and version 3 parallels a comparison between our earlier results for Volvo City Safety and Mercedes-Benz Distronic. Volvo's City Safety technology operates at travel speeds up to 19 mph (31 km/h) and HLDI found large insurance benefits across all coverage types including a 14.3 percent reduction in PDL claim frequency (HLDI, 2015b). In contrast, Mercedes-Benz's Distronic Plus system, which functions at speeds at or above 20 mph (32 km/h), resulted in an 11.8 percent reduction in PDL claim frequency, smaller than that for City Safety (HLDI, 2018b), even though increasing benefits were expected for the Distronic Plus system, given its larger speed range.

Claim severity

Benefits in claim severity increased as EyeSight evolved. **Figure 2** shows that the changes in claim severities have attenuated for both collision and PDL. The latest enhanced EyeSight version 3+ and version 3++ were associated with reductions for collision and PDL claim severity. It is possible that the newest EyeSight is reducing high-severity claims and therefore decreasing overall claim severity. BMW's Driver Assistance package, a combination of several systems (active cruise control, automatic emergency braking, forward collision warning, and lane departure warning), was associated with reductions in claim severity of 8.5 percent for collision and 9.4 percent for PDL (HLDI, 2021b). Results were greater than those of the similar Forward Alerts/Automatic Braking package, which includes automatic emergency braking, forward collision warning, and lane departure warning, but not adaptive cruise control (a 1.1 percent reduction for collision and a 3.9 percent reduction for PDL). This suggest the severity reductions may be attributable to the increased system functionality.

Figure 2: Change in EyeSight claim severity by generation

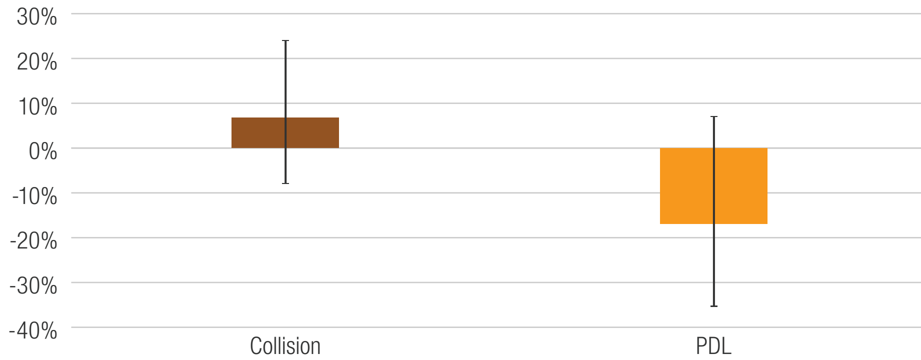


Level 2 driving automation system

The absence of additional benefits for EyeSight versions v3+ and v3++ over the prior versions is similar to what HLDI has reported for Nissan ProPilot Assist and BMW Driving Assistance Plus (2021a, 2021b). Adding lane-centering functionality did not increase claim frequency benefits beyond those associated with other crash avoidance features. Adding Intelligence Cruise Control and ProPilot Assist to Nissan vehicles already equipped with Forward Emergency Braking did not provide significant additional benefits to claim frequency beyond those provided by Forward Emergency Braking. In fact, the PDL and BI claim frequency benefits with these systems included were lower compared with Forward Emergency Braking alone. Similarly, the addition of lane steering to BMW vehicles yielded only slightly larger frequency benefits than the system without the lane-centering functionality.

Figure 3 displays the estimated change in claim frequency for Subaru's EyeSight version 3++, a Level 2 driving system. The preliminary results are a 17 percent reduction for PDL but a 7 percent increase for collision. Neither result is statistically significant. However, this may be because of the limited data in conjunction with the analytical approach used to evaluate the system. Since EyeSight version 3++ is standard on most models and only optional on the 2021 Crosstrek, it is the only model that can be used for comparison when analyzing version 3++ of EyeSight. This has resulted in extremely limited data in the comparison group, with just 194 claims for collision and 68 claims for PDL. Therefore, research on the real-world effects of Level 2 driving automation on Subaru vehicles has thus far been limited. HLDI will continue to monitor Subaru's EyeSight version 3++ as more data become available.

Figure 3: Change in EyeSight claim frequency for version 3++

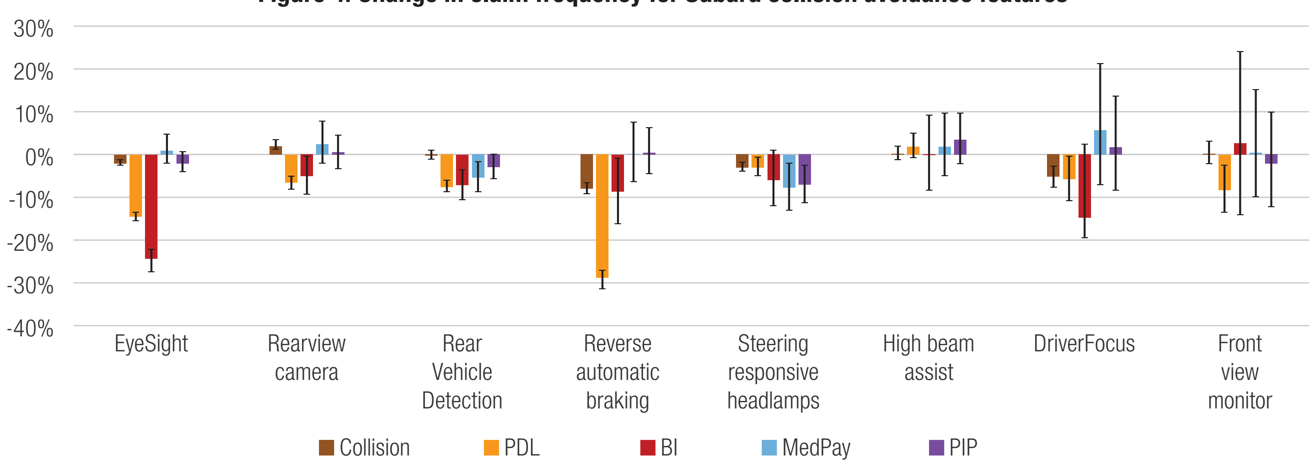


Model year 2017–21 features

Subaru added three new optional features to the 2017 model year vehicles (reverse automatic braking, steering responsive headlamps, and high beam assist). These features were also available on the 2018–21 model year vehicles. There are reductions for collision, PDL, and BI coverages for reverse automatic braking, and all reductions are statistically significant with an 8 percent reduction for collision, 28.8 percent for PDL and 8.6 percent for BI. Steering responsive headlamps are showing significant reductions in both collision and PDL (3.0 percent). Advanced headlights tend to be expensive, and one steering responsive headlamp costs about $900 to replace. As a result, collision severity is significantly higher (2.2 percent). High beam assist works in conjunction with EyeSight and automatically switches the headlights between the high and low settings when an oncoming vehicle is detected. High beam assist is not associated with any significant changes in claim frequency. However, this may be because of the limited data that was available in conjunction with the analytical approach used to evaluate the system. High beam assist is on nearly every vehicle with second generation EyeSight, and with the exception of the late model Legacy, Outback, Forester, and Ascent models, high beam assist is present with reverse automatic braking.

In addition, Subaru added two more optional features to the 2019–21 model year vehicles (DriverFocus and front view monitor). DriverFocus was associated with significant reductions in claim frequency for collision (5 percent) and PDL (6 percent). Front view monitor is showing a significant 8 percent reduction in PDL claim frequency. The large confidence bounds for the effects of these two features on injury coverages highlights the limited amount of data, so the results should be interpreted with caution.

Figure 4: Change in claim frequency for Subaru collision avoidance features



Reverse automatic braking

Reverse automatic braking significantly reduced claim frequency under collision and PDL coverages. However, reverse automatic braking was associated with significant increases in claim severity under collision and PDL. Although a higher cost for repairing or replacing the damaged sensors that support the system could be a reason for the increased claim severity, a shift in the distribution of claim costs could be another reason.

The purpose of reverse automatic braking is to assist drivers while performing backing maneuvers. Because backing is typically done at low speeds, the expectation is that this system would be more likely to prevent low-severity collision and PDL claims as opposed to high-severity claims. An examination of collision and PDL claim frequency by severity range confirmed this. As shown in **Figure 5**, collision claim frequency shows a 16 percent reduction with the presence of reverse automatic braking for low-severity claims, a 3 percent reduction for mid-severity claims, and a 2 percent increase for high-severity claims. For PDL, a similar pattern emerged; the benefits to claim frequency were lessened as the claim severity range increased (**Figure 6**). Consequently, some of the observed increase in collision and PDL claim severity are likely attributable to a greater reduction in lower severity claims, resulting in the claim severity distribution shifting towards a higher mean.

Figure 5: Change in collision claim frequency by severity range

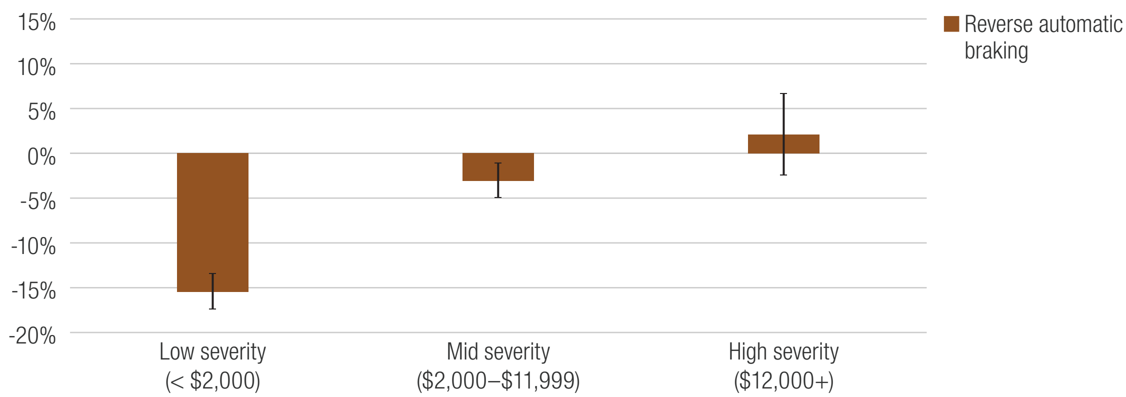
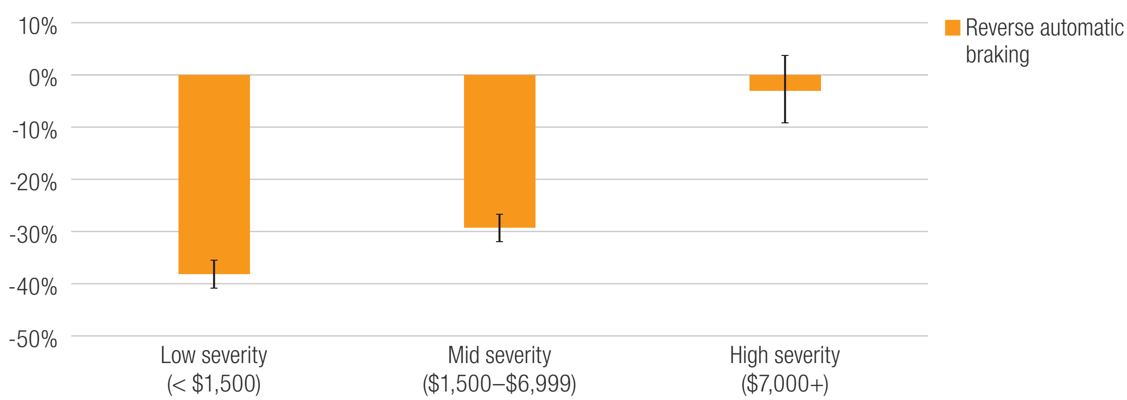


Figure 6: Change in PDL claim frequency by severity range



Results over time

Table 13 shows the differences in claim frequency estimates between the initial results published in December 2014; the results published in 2015, 2016, 2017, 2018, and 2019; and the updated results included in this report. The updated results for the oldest features have stabilized, with the effectiveness estimates for EyeSight and rearview camera changing only minimally since the previous report. The PDL and BI benefits remain significant, but the magnitude of the results has changed over time. This is the sixth examination of Subaru's Rear Vehicle Detection system. Results for the system have shifted but seem to have stabilized somewhat. Collision claim frequency for Rear Vehicle Detection shows a reduction (0.3 percent) for the first time.

Table 13: Change in claim frequencies by collision avoidance feature, initial vs. updated results

	EyeSight							
Vehicle damage coverage type	**Dec 2014**	**April 2015**	**April 2016**	**Dec 2016**	**April 2017**	**April 2018**	**May 2019**	**April 2022**
Collision	3.5%	0.5%	0.5%	-1.4%	-0.7%	-1.1%	**-1.5%**	**-2.1%**
Property damage liability	**-10.6%**	**-15.1%**	**-16.0%**	**-15.7%**	**-16.1%**	**-14.8%**	**-15.0%**	**-14.5%**
Injury coverage type	**Dec 2014**	**April 2015**	**April 2016**	**Dec 2016**	**April 2017**	**April 2018**	**May 2019**	**April 2022**
Bodily injury liability	**-40.3%**	**-34.7%**	**-24.1%**	**-28.8%**	**-29.3%**	**-28.3%**	**-27.0%**	**-24.3%**
Medical payment	20.5%	22.4%	6.8%	5.5%	1.0%	3.3%	1.5%	0.9%
Personal injury protection	-10.1%	-2.9%	2.9%	2.7%	0.7%	3.1%	2.3%	-2.1%

	Rearview camera							
Vehicle damage coverage type	**Dec 2014**	**April 2015**	**April 2016**	**Dec 2016**	**April 2017**	**April 2018**	**May 2019**	**April 2022**
Collision	-2.5%	-1.2%	0.3%	0.9%	1.7%	1.0%	**1.6%**	**2.0%**
Property damage liability	**-6.4%**	**-7.0%**	**-6.1%**	**-6.7%**	**-7.0%**	**-8.3%**	**-8.7%**	**-6.5%**
Injury coverage type	**Dec 2014**	**April 2015**	**April 2016**	**Dec 2016**	**April 2017**	**April 2018**	**May 2019**	**April 2022**
Bodily injury liability	4.1%	-1.6%	-4.8%	-0.6%	-2.5%	-3.5%	-4.1%	**-5.1%**
Medical payment	9.3%	4.8%	4.5%	4.4%	5.4%	3.9%	3.5%	2.4%
Personal injury protection	-2.0%	1.4%	1.2%	2.8%	1.8%	1.4%	1.2%	0.5%

	Rear Vehicle Detection					
Vehicle damage coverage type	**April 2016**	**Dec 2016**	**April 2017**	**April 2018**	**May 2019**	**April 2022**
Collision	3.0%	4.0%	2.4%	0.8%	0.6%	-0.3%
Property damage liability	-7.3%	-3.6%	**-5.4%**	**-7.3%**	**-7.1%**	**-7.6%**
Injury coverage type	**April 2016**	**Dec 2016**	**April 2017**	**April 2018**	**May 2019**	**April 2022**
Bodily injury liability	-5.6%	-10.7%	-9.7%	-8.3%	**-6.5%**	**-7.1%**
Medical payment	-5.6%	-7.9%	-11.6%	**-8.5%**	-4.6%	**-5.4%**
Personal injury protection	**-21.7%**	-10.4%	-4.6%	-5.5%	-2.4%	**-3.0%**

How does Subaru compare?

EyeSight's 15 percent reduction in PDL claim frequency continues to be one of the largest among HLDI's evaluations of forward collision systems that include automatic breaking—slightly higher than other systems with an average benefit around 14 percent. EyeSight's BI liability benefit of 24 percent is also larger than that of several other systems. The large PDL frequency benefit for Subaru's rearview camera is larger than that for most other manufacturers, and the small increase in collision claim frequency is in line with results for other systems (HLDI, 2020). Subaru's Rear Vehicle Detection is a combination of features that includes blind spot warning, a system that has shown significant claim frequency reductions across coverage types for the other studied systems.

For Subaru's reverse automatic braking, the 8 percent and 29 percent reductions for collision and PDL, respectively, are similar to those found in GM vehicles. GM vehicles equipped with reverse automatic braking showed a 13 percent reduction in claim frequency for collision and a 26 percent reduction in claim frequency for PDL. The Insurance Institute for Highway Safety (IIHS) is now rating rear crash prevention systems, and the 2017–19 Subaru Outback, the 2018–19 Subaru Crosstrek, the 2018–19 Subaru Impreza, the 2018–19 Subaru Legacy, the 2018–19 Subaru WRX, and the 2019 Subaru Ascent all earned the highest rating of superior when equipped with reverse automatic braking (IIHS, 2019).

The steering responsive headlamps show statistically significant claim frequency reductions under collision and PDL, which are in line with other systems studied by HLDI. The collision severity increase associated with the steering responsive headlamps is also in line with other manufacturers (HLDI, 2020).

The front view monitor displays a statistically significant reduction under PDL, which is comparable to the 2015 Nissan Rogue's Around View Monitor (HLDI, 2021c). As additional data become available, HLDI will continue to monitor changes in Subaru's front view monitor and DriverFocus.

Limitations

There are limitations to the data used in this analysis. At the time of a crash, the status of a feature is not known. The features in this study can be deactivated by the driver, and there is no way to know how many of the drivers in these vehicles turned off a system before the crash. However, surveys conducted by the Insurance Institute for Highway Safety indicate that large majorities of drivers with these types of systems leave them on (Reagan et al., 2018). If a significant number of drivers do turn these features off, any reported reductions may actually be underestimates of the true effectiveness of these systems.

Additionally, the data supplied to HLDI do not include detailed crash information. The specific crash types addressed by the different technologies cannot be isolated in this analysis. For example, it is not known how many of the crashes in the rearview camera analysis involved backing up, which is the only maneuver during which the camera is active. All collisions, regardless of the ability of a feature to mitigate or prevent the crash, are included in the analysis.

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

Next steps

As exposure for the 2021 model year increases and later model year vehicles can be studied, HLDI will continue to examine the effects of the collision avoidance features on insurance losses, as well as the effects of Subaru's EyeSight versions.

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Appendix

Appendix: Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Intercept		1	-9.1363		0.018	-9.1717	-9.101	256576.76	<0.0001
Calendar year	2012	1	0.3939	48.3%	0.0407	0.3141	0.4738	93.57	<0.0001
	2013	1	0.5045	65.6%	0.0119	0.4811	0.5279	1791.49	<0.0001
	2014	1	0.5316	70.2%	0.0075	0.5167	0.5465	4897.78	<0.0001
	2015	1	0.5425	72.0%	0.0055	0.5316	0.5535	9421.70	<0.0001
	2016	1	0.508	66.2%	0.0046	0.4988	0.5172	11784.86	<0.0001
	2017	1	0.4658	59.3%	0.0042	0.4575	0.474	12110.27	<0.0001
	2018	1	0.4269	53.2%	0.0039	0.4192	0.4346	11772.80	<0.0001
	2019	1	0.3905	47.8%	0.0037	0.3832	0.3977	11126.40	<0.0001
	2021	1	0.1245	13.3%	0.0037	0.1171	0.1318	1106.40	<0.0001
	2020	0	0	0	0	0	0		
Vehicle model year and series	2019 Ascent	1	0.0762	7.9%	0.0194	0.0382	0.1143	15.44	<0.0001
	2020 Ascent	1	0.0927	9.7%	0.0218	0.05	0.1355	18.10	<0.0001
	2021 Ascent	1	0.2105	23.4%	0.0281	0.1552	0.2657	55.81	<0.0001
	2014 Forester	1	-0.1657	-15.3%	0.0165	-0.1981	-0.1332	100.16	<0.0001
	2015 Forester	1	-0.1462	-13.6%	0.0163	-0.1782	-0.1142	80.29	<0.0001
	2016 Forester	1	-0.1136	-10.7%	0.0165	-0.1461	-0.0810	46.86	<0.0001
	2017 Forester	1	-0.0865	-8.3%	0.0165	-0.1189	-0.0541	27.41	<0.0001
	2018 Forester	1	-0.0894	-8.6%	0.0170	-0.1229	-0.0559	27.42	<0.0001
	2019 Forester	1	-0.0713	-6.9%	0.0174	-0.1055	-0.0371	16.69	<0.0001
	2020 Forester	1	-0.0230	-2.3%	0.0184	-0.0591	0.0131	1.56	0.2122
	2021 Forester	1	0.0433	4.4%	0.0240	-0.0037	0.0905	3.26	0.0710
	2015 Impreza 4dr	1	0.2641	30.2%	0.0189	0.2269	0.3013	193.53	<0.0001
	2019 Impreza 4dr	1	0.2776	32.0%	0.0196	0.2390	0.3161	198.97	<0.0001
	2020 Impreza 4dr	1	0.2863	33.1%	0.0195	0.2479	0.3246	213.82	<0.0001
	2021 Impreza 4dr	1	0.3267	38.6%	0.0209	0.2856	0.3677	243.00	<0.0001
	2016 Impreza 4dr	1	0.3167	37.3%	0.0223	0.2729	0.3604	201.00	<0.0001
	2017 Impreza 4dr	1	0.4124	51.0%	0.0328	0.3481	0.4768	157.96	<0.0001
	2018 Impreza 4dr	1	0.3142	36.9%	0.0612	0.1941	0.4343	26.30	<0.0001
	2015 Impreza station wagon	1	0.1728	18.9%	0.0174	0.1386	0.2071	97.72	<0.0001
	2016 Impreza station wagon	1	0.2120	23.6%	0.0179	0.1767	0.2472	139.08	<0.0001
	2017 Impreza station wagon	1	0.2091	23.3%	0.0179	0.1738	0.2443	135.03	<0.0001
	2018 Impreza station wagon	1	0.2560	29.2%	0.0185	0.2197	0.2924	190.25	<0.0001
	2019 Impreza station wagon	1	0.2772	31.9%	0.0191	0.2396	0.3147	209.71	<0.0001
	2020 Impreza station wagon	1	0.3427	40.9%	0.0252	0.2932	0.3923	183.81	<0.0001
	2021 Impreza station wagon	1	0.4162	51.6%	0.0409	0.3359	0.4965	103.24	<0.0001
	2013 Legacy	1	0.0991	10.4%	0.0180	0.0638	0.1344	30.33	<0.0001
	2014 Legacy	1	0.1155	12.2%	0.0182	0.0797	0.1512	40.03	<0.0001
	2015 Legacy	1	0.1071	11.3%	0.0170	0.0737	0.1405	39.61	<0.0001

Appendix: Illustrative regression results — collision frequency

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	2016 Legacy	1	0.1443	15.5%	0.0174	0.1102	0.1784	68.73	<0.0001
	2017 Legacy	1	0.1991	22.0%	0.0178	0.1641	0.2340	124.55	<0.0001
	2018 Legacy	1	0.2391	27.0%	0.0196	0.2007	0.2776	148.66	<0.0001
	2019 Legacy	1	0.2376	26.8%	0.0215	0.1954	0.2797	122.09	<0.0001
	2020 Legacy	1	0.2675	30.7%	0.0319	0.2050	0.3301	70.35	<0.0001
	2021 Legacy	1	0.3489	41.8%	0.0440	0.2626	0.4351	62.84	<0.0001
	2013 Outback	1	-0.1284	-12.0%	0.0169	-0.1616	-0.0953	57.71	<0.0001
	2014 Outback	1	-0.1263	-11.9%	0.0168	-0.1593	-0.0933	56.35	<0.0001
	2015 Outback	1	-0.0952	-9.1%	0.0165	-0.1276	-0.0627	33.05	<0.0001
	2016 Outback	1	-0.0567	-5.5%	0.0166	-0.0893	-0.0241	11.65	0.0006
	2017 Outback	1	-0.0238	-2.4%	0.0168	-0.0569	0.0092	2.00	0.1576
	2018 Outback	1	0.0239	2.4%	0.0169	-0.0092	0.0571	2.00	0.1577
	2019 Outback	1	0.0610	6.3%	0.0178	0.0260	0.0960	11.70	0.0006
	2020 Outback	1	0.0778	8.1%	0.0218	0.0349	0.1206	12.68	0.0004
	2021 Outback	1	0.1100	11.6%	0.0245	0.0618	0.1582	20.04	<0.0001
	2016 WRX	1	0.2498	28.4%	0.0182	0.2140	0.2857	186.83	<0.0001
	2017 WRX	1	0.3259	38.5%	0.0182	0.2902	0.3617	319.10	<0.0001
	2018 WRX	1	0.3504	42.0%	0.0192	0.3126	0.3881	330.93	<0.0001
	2019 WRX	1	0.3929	48.1%	0.0219	0.3500	0.4358	321.65	<0.0001
	2020 WRX	1	0.5324	70.3%	0.0252	0.4829	0.5819	444.81	<0.0001
	2021 WRX	1	0.4993	64.8%	0.0455	0.4101	0.5885	120.40	<0.0001
	2015 XV Crosstrek	1	-0.0688	-6.6%	0.0172	-0.1027	-0.0350	15.94	<0.0001
	2016 Crosstrek	1	-0.0111	-1.1%	0.0170	-0.0444	0.0222	0.43	0.5141
	2017 Crosstrek	1	0.0110	1.1%	0.0193	-0.0269	0.0489	0.32	0.5687
	2018 Crosstrek	1	-0.0389	-3.8%	0.0170	-0.0723	-0.0055	5.22	0.0223
	2019 Crosstrek	1	-0.0348	-3.4%	0.0172	-0.0687	-0.0010	4.08	0.0433
	2021 Crosstrek	1	0.0461	4.7%	0.0210	0.0049	0.0873	4.82	0.0281
	2020 Crosstrek	0	0	0	0	0	0		
Rated driver age group	14–24	1	0.2679	30.7%	0.0053	0.2574	0.2784	2498.56	0.0000
	25–29	1	0.1177	12.5%	0.0048	0.1081	0.1272	583.01	<0.0001
	30–39	1	-0.0031	-0.3%	0.0040	-0.0111	0.0048	0.60	0.4395
	50–59	1	-0.0361	-3.5%	0.0041	-0.0444	-0.0279	74.28	<0.0001
	60–64	1	-0.0753	-7.3%	0.0048	-0.0849	-0.0657	237.94	<0.0001
	65–69	1	-0.0361	-3.5%	0.0049	-0.0458	-0.0265	54.26	<0.0001
	70+	1	0.1088	11.5%	0.0042	0.1005	0.1171	663.68	<0.0001
	Unknown	1	-0.0227	-2.2%	0.0074	-0.0372	-0.0082	9.43	0.0021
	40–49	0	0	0	0	0	0		
Rated driver gender	Male	1	-0.0371	-3.6%	0.0023	-0.0417	-0.0325	250.27	<0.0001
	Unknown	1	-0.1855	-16.9%	0.0092	-0.2035	-0.1674	405.40	<0.0001
	Female	0	0	0	0	0	0		
Rated driver marital status	Single	1	0.1645	17.9%	0.0025	0.1594	0.1695	4104.59	0.0000
	Unknown	1	0.1729	18.9%	0.009	0.1552	0.1905	367.71	<0.0001
	Married	0	0	0	0	0	0		

Appendix: Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Risk	Nonstandard	1	0.2205	24.7%	0.0064	0.2078	0.2331	1170.99	<0.0001
	Standard	0	0	0	0	0	0		
State	Alabama	1	0.0254	2.6%	0.0181	-0.0102	0.0610	1.95	0.1621
	Alaska	1	0.1167	12.4%	0.0164	0.0844	0.1490	50.24	<0.0001
	Arizona	1	0.1075	11.3%	0.0108	0.0862	0.1287	98.13	<0.0001
	Arkansas	1	0.0389	4.0%	0.0175	0.0046	0.0732	4.95	0.0262
	California	1	0.2419	27.4%	0.0064	0.2292	0.2546	1400.15	<0.0001
	Colorado	1	0.1296	13.8%	0.0073	0.1153	0.1440	312.64	<0.0001
	Connecticut	1	-0.0545	-5.3%	0.0085	-0.0713	-0.0377	40.63	<0.0001
	Delaware	1	-0.0251	-2.5%	0.0184	-0.0612	0.0109	1.86	0.1727
	Dist of Columbia	1	0.2910	33.8%	0.0221	0.2477	0.3344	173.30	<0.0001
	Florida	1	-0.0858	-8.2%	0.0083	-0.1022	-0.0694	105.27	<0.0001
	Georgia	1	-0.0539	-5.2%	0.0112	-0.0761	-0.0318	22.84	<0.0001
	Hawaii	1	0.1362	14.6%	0.0193	0.0982	0.1742	49.45	<0.0001
	Idaho	1	-0.0284	-2.8%	0.0134	-0.0548	-0.0019	4.44	0.0350
	Illinois	1	0.0064	0.6%	0.0081	-0.0095	0.0225	0.63	0.4272
	Indiana	1	0.0083	0.8%	0.0115	-0.0142	0.0309	0.53	0.4681
	Iowa	1	-0.0367	-3.6%	0.0155	-0.0671	-0.0063	5.63	0.0177
	Kansas	1	-0.0576	-5.6%	0.0164	-0.0898	-0.0255	12.34	0.0004
	Kentucky	1	-0.1378	-12.9%	0.0162	-0.1697	-0.1058	71.60	<0.0001
	Louisiana	1	0.0666	6.9%	0.0190	0.0293	0.1038	12.28	0.0005
	Maine	1	0.0483	4.9%	0.0127	0.0234	0.0732	14.47	0.0001
	Maryland	1	0.0099	1.0%	0.0088	-0.0073	0.0273	1.27	0.2592
	Massachusetts	1	0.4867	62.7%	0.0082	0.4705	0.5029	3467.91	<0.0001
	Michigan	1	0.3258	38.5%	0.0097	0.3066	0.3449	1112.12	<0.0001
	Minnesota	1	-0.0137	-1.4%	0.0092	-0.0319	0.0044	2.20	0.1381
	Mississippi	1	0.0631	6.5%	0.0328	-0.0012	0.1275	3.69	0.0546
	Missouri	1	-0.0662	-6.4%	0.0124	-0.0905	-0.0419	28.49	<0.0001
	Montana	1	0.1118	11.8%	0.0158	0.0807	0.1429	49.69	<0.0001
	Nebraska	1	-0.0682	-6.6%	0.0154	-0.0985	-0.0378	19.41	<0.0001
	Nevada	1	0.1386	14.9%	0.0122	0.1146	0.1626	128.00	<0.0001
	New Hampshire	1	0.1290	13.8%	0.0112	0.1069	0.1510	131.24	<0.0001
	New Jersey	1	-0.0329	-3.2%	0.0077	-0.0480	-0.0178	18.22	<0.0001
	New Mexico	1	0.1092	11.5%	0.0146	0.0804	0.1380	55.30	<0.0001
	New York	1	0.0749	7.8%	0.0067	0.0618	0.0880	125.04	<0.0001
	North Carolina	1	-0.1604	-14.8%	0.0095	-0.1792	-0.1416	279.47	<0.0001
	North Dakota	1	0.1911	21.1%	0.0226	0.1467	0.2354	71.33	<0.0001
	Ohio	1	-0.1526	-14.2%	0.0085	-0.1694	-0.1358	316.78	<0.0001
	Oklahoma	1	-0.0456	-4.5%	0.0161	-0.0772	-0.0140	8.01	0.0046
	Oregon	1	-0.0069	-0.7%	0.0085	-0.0236	0.0098	0.66	0.4183
	Pennsylvania	1	0.0780	8.1%	0.0067	0.0647	0.0914	131.87	<0.0001
	Rhode Island	1	0.1266	13.5%	0.0152	0.0968	0.1564	69.36	<0.0001
	South Carolina	1	-0.1178	-11.1%	0.0146	-0.1465	-0.0891	64.56	<0.0001
	South Dakota	1	0.0681	7.0%	0.0224	0.0241	0.1121	9.20	0.0024

Appendix: Illustrative regression results — collision frequency									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	Tennessee	1	0.0097	1.0%	0.0114	-0.0128	0.0322	0.72	0.3978
	Utah	1	0.0092	0.9%	0.0105	-0.0114	0.0299	0.77	0.3800
	Vermont	1	0.0918	9.6%	0.0140	0.0643	0.1193	42.77	<0.0001
	Virginia	1	0.0158	1.6%	0.0081	-0.0001	0.0318	3.79	0.0515
	Washington	1	0.0174	1.8%	0.0073	0.0030	0.0317	5.68	0.0172
	West Virginia	1	-0.0603	-5.9%	0.0131	-0.0861	-0.0345	21.03	<0.0001
	Wisconsin	1	-0.0862	-8.3%	0.0097	-0.1054	-0.0670	77.64	<0.0001
	Wyoming	1	0.0749	7.8%	0.0219	0.0319	0.1179	11.68	0.0006
	Texas	0	0	0	0	0	0		
Deductible range	0–250	1	0.166	18.1%	0.0028	0.1603	0.1716	3311.68	<0.0001
	1,001+	1	-0.6476	-47.7%	0.0145	-0.6761	-0.6191	1983.17	<0.0001
	501–1,000	1	-0.2631	-23.1%	0.0031	-0.2692	-0.2570	7077.33	<0.0001
	251–500	0	0	0	0	0	0		
Registered vehicle density	0–99	1	-0.2074	-18.7%	0.0035	-0.2142	-0.2005	3505.61	<0.0001
	100–499	1	-0.1304	-12.2%	0.0026	-0.1355	-0.1252	2494.20	<0.0001
	500+	0	0	0	0	0	0		
EyeSight		1	-0.0210	-2.1%	0.0034	-0.0278	-0.0142	37.21	<0.0001
Rearview camera		1	0.0194	2.0%	0.0054	0.0086	0.0301	12.48	0.0004
Rear Vehicle Detection		1	-0.0026	-0.3%	0.0038	-0.0102	0.0049	0.48	0.4905
Reverse automatic braking		1	-0.0832	-8.0%	0.0071	-0.0972	-0.0692	136.60	<0.0001
Steering responsive headlamps		1	-0.0310	-3.1%	0.0064	-0.0437	-0.0182	22.77	<0.0001
High beam assist		1	0.0018	0.2%	0.0075	-0.0129	0.0166	0.06	0.8045
DriverFocus		1	-0.0529	-5.2%	0.0137	-0.0798	-0.0260	14.93	0.0001
Front view monitor		1	0.0022	0.2%	0.0136	-0.0244	0.0289	0.03	0.8682

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