2013–17 BMW collision avoidance features — a 2021 update

▸ **Summary**

This is the second Highway Loss Data Institute (HLDI) study examining changes in insurance losses associated with collision avoidance features on 2013–17 BMW vehicles. This bulletin updates the prior study (HLDI, 2019) by adding 35 percent more vehicle exposure. The features analyzed included advanced front crash prevention systems, side- and lane-assist systems, advanced headlight technologies, and parking-assist systems. Many of BMW's systems were associated with significant reductions in the frequency of both vehicle damage and injury claims.

Claim frequency results are shown in the following table and are consistent with the prior results (statistically significant results are bolded). BMW's forward collision warning (FCW) and lane departure warning (LDW) package (Forward Alerts) was associated with claim frequency increases under collision, property damage liability (PDL), and bodily injury (BI) liability coverages, but none were statistically significant. Although studies for other manufacturers suggest that FCW combined with LDW usually reduce claim frequencies under all coverage types (HLDI, 2020), these increases are consistent with the prior BMW results and the reasons for them are unclear. The claim frequencies for medical payments (MedPay) and personal injury protection (PIP) showed reductions, with the result for MedPay being significant.

However, encouragingly, the benefits return for BMW's more advanced front crash prevention system, the Forward Alerts/Automatic Braking package, which also includes automatic emergency braking. This package showed frequency benefits for all coverage types, with collision, PDL, and BI results being statistically significant. Results for the Driving Assistance package, which adds active cruise control, showed even larger benefits for claim frequencies, but only the PDL result was statistically significant. The most advanced Driving Assistance Plus package, which includes the features in the Driving Assistance package plus front cross-traffic alert and lane-steering assistant, also showed large benefits under all coverages, and the results for collision, PDL, and BI were statistically significant.

Other systems also showed frequency benefits for most coverage types. Blind spot detection was associated with claim frequency reductions for most coverage types except for collision, with the PIP result being significant; the Night Vision package, which includes a night vision camera and adaptive headlights, showed significant and larger benefits for collision and PDL claim frequencies than adaptive headlights by themselves; vehicles with both a rearview camera and park distance control were associated with benefits across the board with statistically significant results found for all coverages; the advanced parking-assist package Parking Assistant Plus reduced the claim frequencies for all coverages, with the results for collision and MedPay being statistically significant.

Summary of estimated changes in claim frequency for BMW's collision avoidance systems							
Vehicle damage coverage type	Forward Alerts package	Forward Alerts/ Automatic Braking package	Driving Assistance package	Driving Assistance Plus package	Blind spot detection	High-beam assistant	Adaptive headlights
Collision	1.2%	**-7.0%**	-6.7%	**-8.6%**	0.0%	**1.5%**	**-1.2%**
Property damage liability	2.7%	**-12.8%**	**-24.7%**	**-25.0%**	-1.0%	-1.6%	**-8.4%**
Injury coverage type							
Bodily injury liability	6.9%	**-18.9%**	-25.9%	**-31.0%**	-8.2%	3.9%	**-7.9%**
Medical payment	**-26.6%**	-9.0%	-10.0%	-12.1%	-2.3%	0.8%	-2.9%
Personal injury protection	-12.7%	-3.3%	-15.8%	-10.3%	**-9.9%**	-1.9%	-2.8%

Vehicle damage coverage type	Night Vision package	Park distance control	Rearview camera and park distance control	Surround View package	Parking Assistant package	Parking Assistant Plus package
Collision	**-4.7%**	-0.3%	**-1.2%**	0.1%	1.9%	**-7.9%**
Property damage liability	**-17.2%**	**-3.3%**	**-5.8%**	-1.1%	-0.5%	-3.2%
Injury coverage type						
Bodily injury liability	-14.6%	-4.2%	**-5.8%**	-1.4%	1.9%	-11.5%
Medical payment	-11.8%	**-8.7%**	**-4.9%**	-1.4%	-7.4%	**-33.1%**
Personal injury protection	-15.2%	-3.2%	**-4.0%**	-2.9%	3.1%	-0.7%

In addition, many of BMW's systems are also reducing claim severity and overall losses. The three front crash prevention packages, Forward Alerts/Automatic Braking, Driving Assistance, and Driving Assistance Plus packages were all associated with significant reductions to collision and PDL overall losses. Although PDL claim severity increased for the Night Vision package, this was offset by the frequency benefits; consequently, overall losses were down for PDL claims. The rearview camera and park distance control combination were associated with significant increases in collision and PDL claim severities. However, this was a result of a shift in the severity distribution with the systems preventing low-cost claims. As a result, overall losses were reduced for PDL.

▶ Introduction

This Highway Loss Data Institute (HLDI) bulletin provides an updated look at the effect of BMW's collision avoidance features on insurance losses. The following features are included in this study:

Front crash prevention systems

Forward collision warning (FCW) uses sensors in the front bumper and a video camera to monitor traffic in front of the vehicle and can recognize vehicles that are in the detection range of the sensors and video camera. If a front vehicle that is moving brakes abruptly, a quick reaction may be required. To assist this, the system will help optimize the response time with a two-step warning: the first warning step is the preliminary warning. It will signal a warning when a collision is imminent or if the distance to the front vehicle is too short, and at the same time, the brake system prepares for a possible full application. The second warning step is the acute warning in the event of an imminent danger of collision. The symbol at the instrument panel will begin to flash, and an audible warning signal will sound at the same time.

Automatic emergency braking (AEB) expands on the functionality of forward collision warning by providing automatic braking intervention in situations where the driver does not respond to warnings of an imminent collision. The system is controlled by a video camera in the area of the rearview mirror and can provide braking intervention at city speeds. On some vehicles the system is controlled by a radar sensor in conjunction with the camera, which provides braking intervention at both city and highway speeds.

Active cruise control (ACC) is a system that uses radar sensors (or the existing camera hardware in some vehicles) to monitor traffic ahead and maintain the driver's selected following distance or speed. A desired distance or speed to be maintained can be set while driving on an unobstructed road, and to maintain the distance, the system automatically reduces the acceleration and may apply slight braking to a complete stop, if necessary under specific conditions. The system will automatically accelerate when the vehicle in front of the driver begins to move again after standing still for a few seconds. Once the front lane is clear, the system accelerates to the desired speed.

Front cross-traffic alert assists the driver when maneuvering out of a parking space and in daily situations when it is difficult to see crossing traffic, such as blind entrances or exits. The vehicle detects objects approaching the vehicle and will warn the driver with visual and acoustic signals. The camera provides a panoramic view, and within the control display, the visual warning appears as red bars on the left or right side. If the vehicle is moving, acoustic warnings will be added.

Side-assist systems

Blind spot detection detects traffic situations that could pose a risk if the driver changes lanes. Such traffic situations include vehicles approaching quickly from behind or vehicles in the driver's blind spot. When the system is activated, the sensors in the rear bumper monitor an area behind and next to the vehicle. An illuminated triangular warning LED appears in the exterior mirror if there is a vehicle in this critical area. The activation speed of blind spot detection varies between 15 and 30 mph depending on the model year and will function up to 130 mph. This safety system can also be enhanced by steering intervention, which can be enabled or disabled by the driver. On some 2017 model year vehicles, rear cross-traffic alert was added in conjunction with blind spot detection. Rear cross-traffic alert shares the same sensors with blind spot detection and provides the same functionality as front cross-traffic alert while the vehicle moves in reverse. However, HLDI was not able to separate out the effect of rear cross-traffic alert based on the data provided.

Lane departure warning (LDW) uses a camera embedded in the rearview mirror to detect painted lines in the road. The system can be activated or deactivated by the driver, and is only functional at speeds over 40 mph. When the system is active, an indicator with two roadway lines appears in the instrument cluster. When lane lines are detected, an image of an arrow will appear on the left or right of the indicator. If the driver begins a lane change without indicating with a turn signal, the system produces a gentle but noticeable vibration in the steering wheel to warn of a potentially unsafe lane change.

Lane-steering assistant assists the driver in keeping the vehicle in the center of the lane by initiating corrective steering interventions. A multitude of radar sensors and a stereo camera monitor the vehicle environment and transmit signals to a control unit, a stereo camera responsible for lean and object recognition, a front-radar sensor and four side-radar sensors for vehicle environment monitoring. By evaluating these signals, the system is able to determine the optimum steering assistance at speeds of up to 130 mph. Two-lane dividing lines must be recognized by the system, and at speeds below 40 mph, the system can also recognize the vehicle driving in front.

Night-assist systems

High-beam assistant monitors driving conditions and, if necessary, automatically turns the vehicle's high-beam lights on or off. A sensor near the inside rearview mirror monitors an area in front of the vehicle. When the high-beam assistant detects the headlight of oncoming traffic, the high beams are switched off. In addition, it also detects the taillights of vehicles driving ahead and automatically adapts the high-beam lights so that they do not create a glare for other drivers.

Adaptive headlights optimally adjust the vehicle's headlamp light to an extremely broad range of road situations. It follows the course of the road depending on the steering angle. As a result, the inside area of curves are illuminated better. In tight curves or when turning, the respective turning lamp is also switched on to further enlarge the illuminated area.

Night vision with pedestrian detection warns drivers about the presence of pedestrians or animals at night. A thermographic camera scans an area in front of the vehicle. People or animals of a certain size are recognized by the system. As soon as a person or animal appears in the warning range, a warning is signaled. In case of an increased danger of collision, there is an audio and visual acute warning in the instrument cluster. Additionally, a thermal image can be displayed in the control display.

Parking-assist systems

Rearview camera shows an area behind the vehicle on the control display and supports the driver during parking and maneuvering. The system is switched on automatically if the selector lever position R is engaged when the engine is running.

Park distance control supports the driver during parking and maneuvering. It uses ultrasonic sensors to monitor surroundings and alert the driver of any obstacles in their path. The sensors are located in the front and rear bumpers for most BMW vehicles, and are only on the rear of some Mini vehicles. The system can be activated by pressing the "Parking Assistant" button or choosing the reverse gear. The LED light will illuminate, and the parking view will be displayed. If the system detects an obstacle within the parking distance, acoustic warning tones will sound and the approach will be shown schematically on the display screen.

Surround view provides support in a number of traffic situations by allowing the driver to see various camera angles around the vehicle in the control display. When the vehicle enters streets or intersections with a poor view, the cameras in the front or rear of the vehicle can be activated. The road area is shown on the control display. When the vehicle is being parked in reverse, a camera in the rear can display the area behind the vehicle. The cameras in the exterior mirrors together with the front and rear cameras provide a bird's-eye view of the area surrounding the vehicle. In addition, the ultrasonic sensors monitor whether there are obstacles in the immediate vicinity in front of or behind the vehicle.

Parking assistant helps identify suitable parking spaces and supports the driver when parallel parking. The system uses ultrasonic sensors to measure parking spaces on both sides of the vehicle and can be activated at speeds under 22 mph. It calculates the ideal parking line and takes over steering. If the active park distance control is included, the vehicle handles braking and acceleration during the process of parking. If the active park distance control is not included, the driver retains control of braking and acceleration.

Active park distance control advances the features of park distance control. It uses the same technology as park distance control while adding braking intervention. If an obstruction is detected while driving in reverse, the active park distance control will activate breaking below speeds of 3 mph.

Feature dependencies

As driver assistance technology has evolved, many of the sensor and camera systems provide functionality for more than one collision avoidance feature. For example, the forward-sensing camera used with automatic emergency braking can also be used for forward collision warning and to identify lane markings for lane departure warning. Consequently, all vehicles with automatic emergency braking also have forward collision warning and lane departure warning.

BMW also has multiple systems that provide similar functionality, but one system is more advanced or provides additional functionality over a similar system. For example, both park distance control and active park distance control provide the basic functionality of warning the driver of any obstacles in the parking path. However, active park distance control expands on that functionality by also providing braking intervention to help prevent an unintended collision.

Similarly, BMW has four versions of front crash prevention packages. All versions include at least forward collision warning and lane departure warning. On a large proportion of the vehicles with forward collision warning and lane departure warning, the automatic emergency braking system is provided. It was not possible to get the automatic emergency braking system without already having forward collision warning and lane departure warning. For some vehicles with automatic emergency braking, an optional upgrade package that includes active cruise control is available.

Furthermore, even when different sensor systems are used, manufactures may choose to bundle different driver assistance technologies together as part of an optional package or on different trim levels. Consequently, some driver assistance features are never available independently from other features. For example, BMW provides an advanced driving assistance package named Driving Assistant Plus, which includes not only the forward collision warning, lane departure warning, automatic emergency braking, and active cruise control systems mentioned previously, but also lane-steering assistant and front cross-traffic alert, which are not available independently. Because the insurance data provided to HLDI do not contain information on the type of crash that led to a claim, it is not always possible to separate out the individual effect on insurance losses for driver assistance features that are only available with other features. In these circumstances, HLDI evaluates the effect of the combined group of features. The *Method* section contains additional details about how systems were chosen to be grouped and evaluated by HLDI.

▸ Method

Vehicles

Although some features are available as standard equipment for certain model years and trim levels, other features are offered as optional equipment. The presence or absence of these optional features is not discernible from the information encoded in the Vehicle Identification Numbers (VINs), but rather this must be determined from the build information maintained by the manufacturer. BMW supplied HLDI with the VINs for any vehicles that were equipped with at least one of the collision avoidance features listed previously. Vehicles of the same model year and series not identified by BMW were assumed not to have any of these features and thus served as the control vehicles in the analysis. Hybrid and electric vehicles were excluded from the analysis. Table 1A lists the collision exposure for the vehicle series and model years included in the analysis. The percent of overall exposure of each feature is shown in Table 1B.

Table 1A: Exposure by vehicle series			
Make	**Series**	**Model year range**	**Total exposure**
BMW	2 series	2014–17	173,754
BMW	3 series	2013–17	2,074,497
BMW	4 series	2014–17	587,007
BMW	5 series	2013–17	1,012,695
BMW	5 Series GT	2013–17	28,157
BMW	6 series	2013–17	160,932
BMW	7 series	2013–17	194,930
BMW	X1	2013–17	536,669
BMW	X3	2013–17	902,597
BMW	X4	2015–17	60,853
BMW	X5	2013–17	938,241
BMW	X6	2013–17	128,104
Mini	Clubman	2016–17	59,445
Mini	Cooper	2013–17	788,004
Mini	Countryman	2013–17	375,463
Total collision exposure			**8,021,349**

Table 1B: Percent of collision exposure with feature	
Feature	**Collision exposure with feature**
Forward collision warning	11%
Automatic emergency braking	10%
Active cruise control	< 1%
Driving Assistant Plus package	2%
Blind spot detection	14%
Lane departure warning	11%
High-beam assistant	11%
Adaptive headlights	53%
Night vision with pedestrian detection	< 1%
Rearview camera	63%
Park distance control	66%
Surround view	14%
Parking assistant	5%
Active park distance control	1%

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 one vehicle insured for 1 year, two vehicles insured for 6 months, etc.

Because different crash avoidance features may affect different types of insurance coverage, it is important to understand how coverages vary among the states and how this affects inclusion in the analyses. Collision coverage insures against vehicle damage to an at-fault driver's vehicle sustained in a crash with an object or another vehicle; this coverage is common to all 50 states. PDL coverage insures against vehicle damage that at-fault drivers cause to other people's vehicles and property in crashes. This coverage exists in all states except Michigan, where vehicle damage is covered on a no-fault basis (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 liability 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 (PIP coverage) that pay up to a specified amount for injuries to occupants of the insured vehicles involved in a collision, regardless of who is at fault in the collision. The District of Columbia has a hybrid insurance system for injuries and is excluded from the injury analysis.

Driver assistance system groupings

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

For example, the majority of vehicles equipped with forward collision warning also have lane departure warning. There are very limited data available for vehicles equipped with only one, but not both, of these systems. To make the results more reliable, the records of vehicles with only one of these features were excluded. Similarly, the rearview camera is the base for many advanced parking-assist packages, and many of the vehicles equipped with the camera also have other parking-assist systems (such as parking sensors); thus, the insurance data for vehicles with only the rearview camera (and no other parking systems) were not included in this study.

In some situations, the model can derive separate estimates for a system that always comes with a different system. And in other situations, estimating the combined effect of the systems may be more judicious. HLDI uses its best judgement in determining whether to present results for an individual or a combined system based on examination of the results, the available data, and how features are grouped by the manufacturer. Future analyses may attempt to separate out effects as data continue to develop and mature. Table 2 shows the way systems were grouped and evaluated for this study. Some features may appear in multiple packages, but those packages are mutually exclusive, which means they cannot be equipped in the same vehicle.

Table 2: HLDI grouping of collision avoidance features			
Feature type	Package or feature name	Feature description	Relationship
Front crash prevention systems	Forward Alerts package	Forward collision warning	Forward Alerts, Forward Alerts/Automatic Braking, Driving Assistance, and Driving Assistance Plus packages are mutually exclusive
		Lane departure warning	
	Forward Alerts/Automatic Braking package	Automatic emergency braking	
		Forward collision warning	
		Lane departure warning	
	Driving Assistance	Active cruise control	
		Automatic emergency braking	
		Forward collision warning	
		Lane departure warning	
	Driving Assistance Plus	Active cruise control	
		Automatic emergency braking	
		Forward collision warning	
		Lane departure warning	
		Front cross-traffic alert	
		Lane-steering assistant	
Side-assist system	Blind spot detection	Blind spot detection	
Night-assist systems	High-beam assistant	High-beam assistant	Adaptive headlights and the Night Vision package are mutually exclusive
	Adaptive headlights	Adaptive headlights	
	Night Vision package	Night vision with pedestrian detection	
		Adaptive headlights	
Parking-assist systems	Park distance control	Park distance control	Park distance control and rearview camera and park distance control are mutually exclusive; Parking Assistant and the Parking Assistant Plus packages are mutually exclusive
	Rearview camera and park distance control	Rearview camera	
		Park distance control	
	Surround View package	Surround view	
		Rearview camera	
	Parking Assistant package	Parking assistant	
		Rearview camera	
	Parking Assistant Plus package	Active park distance control	
		Parking assistant	
		Rearview camera	

Statistical methods

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

Claim frequency was modeled using a Poisson distribution, whereas claim severity (average loss payment per claim) was modeled using a Gamma distribution. Both models used a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models. Estimates for claim frequency, claim severity, and overall losses are presented for collision and PDL coverages. For PIP, BI, and MedPay coverages, 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 claim 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: 73.6 percent for PIP, 70.5 percent

for BI, and 60.2 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.

For space reasons, only the estimates for the individual crash avoidance features are shown on the following pages. To illustrate the analyses, 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 resultant multiplied by 100. The resulting number corresponds to the effect of the feature on that loss measure. For example, the estimate of the Driving Assistance package on collision claim frequency was −0.0694; thus, vehicles with the Driving Assistance package had 6.7 percent fewer collision claims than vehicles without the Driving Assistance package (exp(−0.0694)−1×100=−6.7).

▸ Results

Results for BMW's collision avoidance features are summarized in the following tables. For all tables, the lower and upper bounds represent the 95 percent confidence limits for the estimates. Estimates that are statistically significant at the 95 percent confidence level are bolded.

Table 3 summarizes the results for BMW's Forward Alerts package, which includes forward collision warning and lane departure warning systems. For vehicle damage losses, collision claim frequency was up by 1 percent, and PDL claim frequency was up by 3 percent. Both collision and PDL claim severities were up by 5 percent, resulting in a 6 percent increase in collision overall losses and a 7 percent increase in PDL overall losses. None of the estimates were statistically significant.

For injury losses, the results were mixed and only the overall claim frequency for MedPay was statistically significant.

Table 3: Change in insurance losses for the Forward Alerts package (forward collision warning and lane departure warning)									
Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-3.5%	1.2%	6.1%	-0.4%	5.0%	10.7%	-1.1%	6.2%	14.1%
Property damage liability	-4.7%	2.7%	10.7%	-2.9%	4.5%	12.4%	-3.4%	7.3%	19.1%

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW-SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH-SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-12.4%	6.9%	30.4%	-27.5%	4.4%	50.2%	-7.3%	23.8%	65.3%
Medical payment	-44.1%	**-26.6%**	-3.6%	-84.0%	-56.8%	16.8%	-48.0%	-24.0%	11.0%
Personal injury protection	-28.2%	-12.7%	6.0%	-50.0%	-16.1%	40.8%	-27.9%	-7.5%	18.6%

Results for the Forward Alerts/Automatic Braking package are summarized in **Table 4**. These estimates indicate the change in insurance losses for vehicles equipped with all three features (automatic emergency braking, forward collision warning, and lane departure warning), compared with vehicles without any of these features.

Collision coverage showed a 7 percent decrease in claim frequency, and a 1 percent decrease in severity, resulting in an 8 percent decrease in overall losses. PDL claim frequency was down by 13 percent, with severity down by 4 percent, leading to a 16 percent decrease in overall losses. All the results were statistically significant, except for collision claim severity.

For injury losses, overall claim frequencies were lower than expected for all three injury coverage types, but only the result for BI was statistically significant. Low-severity claim frequency for BI and MedPay showed statistically significant reductions of 33 and 36 percent, respectively.

Table 4: Change in insurance losses for the Forward Alerts/Automatic Braking package (automatic emergency braking, forward collision warning and lane departure warning)								
Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-8.9%	**-7.0%**	-5.1%	-3.3%	-1.1%	1.2%	-10.8%	**-8.0%**	-5.1%
Property damage liability	-15.8%	**-12.8%**	-9.6%	-7.2%	**-3.9%**	-0.4%	-20.3%	**-16.2%**	-11.9%

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	-26.3%	**-18.9%**	-10.8%	-43.5%	**-32.6%**	-19.5%	-20.4%	-7.6%	7.2%
Medical payment	-18.0%	-9.0%	1.1%	-52.8%	**-35.6%**	-12.3%	-17.4%	-4.2%	11.2%
Personal injury protection	-10.5%	-3.3%	4.4%	-8.2%	12.2%	37.3%	-18.2%	-9.4%	0.2%

Table 5 shows the results for the Driving Assistance package. The grouping of systems included active cruise control, automatic emergency braking, forward collision warning, and lane departure warning. Similarly, the estimates indicate the change in insurance losses for vehicles equipped with all features included in the package, compared with vehicles without any of these features.

For vehicle damage losses, claim frequency was down by 7 and 25 percent for collision and PDL, respectively, with the result for PDL being significant. Claim severity for both collision and PDL decreased by 9 percent, with the result for collision being statistically significant. This resulted in a significant 15 percent decrease in overall losses for collision and a significant 32 percent decrease for PDL.

For injury losses, overall claim frequencies were down by 26, 10, and 16 percent for BI, MedPay, and PIP, respectively, but none of the results were statistically significant. Paid claim data for the three injury coverages were sparse, resulting in large confidence bounds for the low- and high-severity claim frequency estimates. Only PIP coverage showed a significant 42 percent decrease in high-severity claim frequency.

Table 5: Change in insurance losses for the Driving Assistance package (active cruise control, automatic emergency braking, forward collision warning, and lane departure warning)								
Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-13.6%	-6.7%	0.7%	-16.1%	**-8.5%**	-0.3%	-24.0%	**-14.7%**	-4.3%
Property damage liability	-34.8%	**-24.7%**	-13.0%	-21.4%	-9.4%	4.4%	-44.3%	**-31.8%**	-16.5%

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	-48.8%	-25.9%	7.1%	-62.9%	-28.8%	36.6%	-58.6%	-27.0%	28.8%
Medical payment	-44.2%	-10.0%	45.1%	-88.4%	-35.2%	262.4%	-25.4%	36.4%	149.5%
Personal injury protection	-41.2%	-15.8%	20.6%	-4.7%	105.4%	342.6%	-65.3%	**-41.5%**	-1.6%

Table 6 summarizes the result for the Driving Assistance Plus package, which includes all features in the Driving Assistance package plus front cross-traffic alert and lane-steering assistant. These estimates indicate the change in insurance losses for vehicles equipped with all these features, compared with vehicles without any of the aforementioned features.

Driving Assistance Plus was associated with significant reductions to both collision and PDL claim frequencies of 9 and 25 percent, respectively, while the claim severities were down insignificantly by 1 and 5 percent, respectively, leading to a significant 9 percent decrease in overall losses for collision and a significant 28 percent decrease for PDL.

For injury losses, overall claim frequencies for all coverage types were lower than expected, with the result for BI being statistically significant (31 percent). Among paid claims, reductions were observed for all low- and high-severity claim frequencies, with the results for low- and high-severity BI, and high-severity MedPay claims being statistically significant (46, 24, and 20 percent, respectively).

Table 6: Change in insurance losses for the Driving Assistance Plus package (active cruise control, automatic emergency braking, forward collision warning, lane departure warning, front cross-traffic alert and lane-steering assistant)

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-11.2%	**-8.6%**	-5.9%	-4.1%	-0.9%	2.4%	-13.3%	**-9.4%**	-5.4%
Property damage liability	-28.8%	**-25.0%**	-21.0%	-9.4%	-4.5%	0.5%	-33.5%	**-28.4%**	-22.9%

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	-39.9%	**-31.0%**	-20.7%	-59.1%	**-46.3%**	-29.6%	-38.4%	**-23.5%**	-5.0%
Medical payment	-23.9%	-12.1%	1.5%	-56.7%	-32.5%	5.2%	-34.7%	**-19.6%**	-0.9%
Personal injury protection	-20.1%	-10.3%	0.7%	-49.2%	-28.3%	1.2%	-25.2%	-12.9%	1.3%

Results for BMW's blind spot detection system are shown in **Table 7**. Collision claim frequency remained essentially unchanged, and PDL claim frequency showed a slight 1 percent reduction. Collision claim severity was insignificantly down by 2 percent, resulting in an insignificant 2 percent decrease in overall losses. PDL claim severity decreased significantly by 4 percent. Consequently, PDL overall losses decreased by 4 percent, but the result was not statistically significant.

Overall claim frequencies for all three injury coverages were down, with the PIP result being statistically significant (10 percent).

Table 7: Change in insurance losses for blind spot detection

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-2.0%	0.0%	2.0%	-4.2%	-2.0%	0.2%	-5.0%	-2.1%	1.0%
Property damage liability	-4.3%	-1.0%	2.5%	-6.7%	**-3.5%**	-0.2%	-9.0%	-4.4%	0.3%

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	-16.2%	-8.2%	0.5%	-7.5%	9.3%	29.3%	-29.8%	**-19.0%**	-6.6%
Medical payment	-11.7%	-2.3%	8.1%	8.0%	**44.8%**	94.0%	-17.5%	-4.7%	10.1%
Personal injury protection	-16.4%	**-9.9%**	-2.9%	-31.7%	-16.7%	1.7%	-15.3%	-6.7%	2.7%

Table 8 shows the results for high-beam assistant. Claim frequency for collision was significantly up by 2 percent, while frequency for PDL showed an insignificant 2 percent decrease. Claim severities for collision and PDL were significantly up by 5 and 3 percent, respectively, resulting in a significant 6 percent increase in overall losses for collision, and an insignificant 1 percent increase for PDL.

Under injury coverages, the results were mixed and none of them were statistically significant.

Table 8: Change in insurance losses for high-beam assistant

Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	0.5%	**1.5%**	2.6%	3.4%	**4.6%**	5.9%	4.5%	**6.2%**	7.9%
Property damage liability	-3.4%	-1.6%	0.3%	0.9%	**2.7%**	4.6%	-1.4%	1.1%	3.8%

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	-0.9%	3.9%	8.9%	-1.7%	7.7%	18.0%	-6.6%	0.4%	7.9%
Medical payment	-4.6%	0.8%	6.4%	-2.6%	15.1%	36.1%	-7.1%	0.3%	8.3%
Personal injury protection	-5.8%	-1.9%	2.2%	-17.1%	-7.2%	3.8%	-7.4%	-2.3%	3.0%

Table 9 summarizes the results for adaptive headlights. For vehicle damage losses, claim frequencies were down by 1 and 8 percent for collision and PDL coverages, respectively, with both results being significant. Claim severity was up by 8 percent for collision and up by 1 percent for PDL, but only the result for collision was significant. Consequently, collision overall losses went up significantly by 6 percent, and PDL overall losses went down significantly by 8 percent.

Reductions in claim frequency were observed for all injury coverages. Only the results for overall and low-severity BI claims were statistically significant.

Table 9: Change in insurance losses for adaptive headlights								
Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-2.2%	**-1.2%**	-0.2%	6.3%	**7.5%**	8.7%	4.6%	**6.2%**	7.8%
Property damage liability	-9.9%	**-8.4%**	-6.9%	-0.9%	0.7%	2.4%	-9.8%	**-7.8%**	-5.6%

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW-SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH-SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-11.8%	**-7.9%**	-3.8%	-17.5%	**-10.4%**	-2.8%	-11.6%	-5.5%	0.9%
Medical payment	-7.5%	-2.9%	2.0%	-16.5%	-3.9%	10.6%	-7.2%	-0.5%	6.6%
Personal injury protection	-6.2%	-2.8%	0.8%	-10.8%	-2.4%	6.8%	-5.2%	-0.6%	4.3%

Changes in insurance losses for vehicles with night vision with pedestrian detection and adaptive headlights are summarized in Table 10. Similarly, vehicles with both of these features were compared with vehicles without either of these two features. Collision coverage showed a significant decrease in claim frequency of 5 percent, while claim severity went up significantly by 19 percent. This resulted in a significant 13 percent increase in overall losses. PDL claim frequency was down significantly by 17 percent, with severity significantly up by 11 percent, resulting in an insignificant 8 percent decrease in overall losses.

For injury losses, overall claim frequency was lower than expected for all coverages, but none of the changes were statistically significant. High-severity claim frequency for PIP declined significantly by 31 percent.

Table 10: Change in insurance losses for the Night Vision package (night vision with pedestrian detection and adaptive headlights)								
Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-8.9%	**-4.7%**	-0.2%	12.7%	**18.7%**	24.9%	5.6%	**13.1%**	21.2%
Property damage liability	-24.1%	**-17.2%**	-9.8%	2.0%	**11.1%**	21.0%	-18.5%	-8.0%	3.8%

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	-32.1%	-14.6%	7.3%	-43.1%	-11.9%	36.5%	-40.9%	-15.1%	21.9%
Medical payment	-30.8%	-11.8%	12.5%	-80.6%	-46.3%	48.2%	-25.4%	3.6%	43.8%
Personal injury protection	-30.0%	-15.2%	2.8%	-28.9%	17.7%	94.9%	-47.8%	**-31.0%**	-8.7%

Table 11 summarizes the results for vehicles with park distance control (rear, or both front and rear) but no rearview camera. Collision coverage showed essentially no change for claim frequency, while it showed a significant 3 percent increase in claim severity. Consequently, the overall losses for collision increased significantly by 3 percent. Claim frequency for PDL decreased by 3 percent, and claim severity increased by 2 percent, which led to a 2 percent decrease in overall losses. Only the PDL claim frequency result was statistically significant.

Under injury coverages, claim frequency was lower for all three coverage types, with the reduction for MedPay being statistically significant (9 percent). Among paid claims, reductions were also observed for all coverages except for low-severity MedPay claims, and only the high-severity MedPay claims were associated with a significant decrease in frequency (11 percent).

Table 11: Change in insurance losses for park distance control								
Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-1.7%	-0.3%	1.1%	1.4%	**3.0%**	4.6%	0.6%	**2.7%**	4.9%
Property damage liability	-5.4%	**-3.3%**	-1.1%	-0.6%	1.6%	3.8%	-4.7%	-1.8%	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	-9.5%	-4.2%	1.4%	-18.0%	-8.5%	2.1%	-12.4%	-4.5%	4.1%
Medical payment	-14.5%	**-8.7%**	-2.5%	-14.0%	3.6%	24.9%	-19.3%	**-11.2%**	-2.2%
Personal injury protection	-7.8%	-3.2%	1.7%	-17.1%	-5.4%	7.9%	-9.2%	-3.2%	3.2%

Table 12 displays the results for vehicles with both a rearview camera and park distance control. For vehicle damage losses, collision claim frequency was down by 1 percent, and claim severity was up by 4 percent, leading to a 3 percent increase in overall losses. PDL claim frequency was down by 6 percent, and claim severity was up by 3 percent, resulting in a 3 percent decrease in overall losses. All results were statistically significant.

For injury losses, overall claim frequency was significantly lower than expected for all three coverage types. Among paid claims, significant reductions were observed for high-severity BI and PIP claims (7 and 6 percent, respectively).

Table 12: Change in insurance losses for rearview camera and park distance control								
Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-2.0%	**-1.2%**	-0.5%	3.5%	**4.4%**	5.3%	2.0%	**3.1%**	4.3%
Property damage liability	-7.0%	**-5.8%**	-4.7%	2.1%	**3.4%**	4.6%	-4.4%	**-2.7%**	-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	-8.8%	**-5.8%**	-2.7%	-9.3%	-3.6%	2.5%	-11.7%	**-7.3%**	-2.7%
Medical payment	-8.5%	**-4.9%**	-1.3%	-16.7%	-6.8%	4.3%	-8.6%	-3.6%	1.8%
Personal injury protection	-6.5%	**-4.0%**	-1.4%	-4.4%	2.6%	10.0%	-9.2%	**-6.0%**	-2.7%

The results for vehicles with surround view along with rearview camera are shown in **Table 13**. Collision claim frequency showed essentially no change, while claim severity went up by 2 percent, resulting in a 2 percent increase in overall losses. PDL claim frequency was down by 1 percent, and claim severity was up by 2 percent, which offset the frequency benefits and led to the essentially unchanged overall losses. None of the results were statistically significant.

For injury losses, the results were mixed and none of them were statistically significant.

Table 13: Change in insurance losses for the Surround View package (surround view and rearview camera)								
Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-1.8%	0.1%	2.2%	-0.3%	1.9%	4.3%	-0.9%	2.1%	5.2%
Property damage liability	-4.3%	-1.1%	2.2%	-1.7%	1.5%	4.8%	-4.1%	0.4%	5.1%

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW-SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH-SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-9.5%	-1.4%	7.5%	-6.7%	10.1%	30.0%	-17.4%	-5.8%	7.5%
Medical payment	-10.7%	-1.4%	8.9%	-32.0%	-8.6%	22.8%	-14.2%	-1.1%	14.0%
Personal injury protection	-9.8%	-2.9%	4.5%	-14.8%	4.0%	26.9%	-14.6%	-6.0%	3.4%

Table 14 shows the change in insurance losses for parking assistant with rearview camera. For collision coverage, claim frequency increased by an insignificant 2 percent and claim severity increased by a significant 3 percent, resulting in a significant 5 percent increase in overall losses. The results for PDL losses were essentially unchanged, and none of the results were significant.

The results for injury losses were mixed and none of them were statistically significant.

Table 14: Change in insurance losses for the Parking Assistant package (parking assistant and rearview camera)								
Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-0.2%	1.9%	4.0%	0.7%	**3.0%**	5.3%	1.8%	**5.0%**	8.2%
Property damage liability	-4.0%	-0.5%	3.1%	-2.6%	0.8%	4.3%	-4.5%	0.3%	5.3%

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	-7.0%	1.9%	11.7%	-6.0%	11.8%	32.9%	-14.2%	-1.0%	14.3%
Medical payment	-16.5%	-7.4%	2.8%	-29.0%	-3.2%	32.0%	-24.6%	-12.3%	2.0%
Personal injury protection	-4.8%	3.1%	11.7%	-20.0%	-0.8%	23.0%	-10.0%	0.1%	11.3%

Table 15 summarizes the results for the Parking Assistant Plus package, including active park distance control, parking assistant, and rearview camera. A statistically significant reduction in claim frequency was estimated for collision coverage (8 percent), while the claim severity showed an insignificant 2 percent increase, resulting in an insignificant 6 percent decrease in overall losses.

For injury losses, all three coverages were associated with reductions in overall claim frequency, with the result for MedPay being significant (33 percent). Among paid claims, a significant reduction was observed for high-severity MedPay claims (33 percent).

Table 15: Change in insurance losses for the Parking Assistant Plus package (active park distance control, parking assistant, and rearview camera)									
Vehicle damage coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	SEVERITY	Upper bound	Lower bound	OVERALL LOSSES	Upper bound
Collision	-12.0%	**-7.9%**	-3.6%	-3.3%	1.8%	7.2%	-12.5%	-6.3%	0.4%
Property damage liability	-11.1%	-3.2%	5.5%	-3.5%	5.3%	14.8%	-9.8%	1.9%	15.1%
Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW-SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH-SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-28.1%	-11.5%	9.0%	-31.9%	4.2%	59.4%	-33.2%	-8.2%	26.0%
Medical payment	-46.2%	**-33.1%**	-16.8%	-69.1%	-32.9%	45.7%	-50.5%	**-33.1%**	-9.5%
Personal injury protection	-18.0%	-0.7%	20.3%	-45.9%	-1.2%	80.6%	-23.7%	-2.0%	25.8%

Finally, **Table 16** compares the claim frequency results of the prior HLDI study (2019) with the current results. Compared with the estimates of the 2019 study, the results are consistent with minor changes. The MedPay reduction for the Forward Alerts package, the PDL reduction for park distance control, and the collision reduction for rearview camera and park distance control are now statistically significant. The collision disbenefit for the Parking Assistant package is smaller and no longer significant. For some systems, the benefits are smaller and no longer significant, but all estimates are within the confidence bounds of the prior results.

Table 16: Change in claim frequencies by collision avoidance feature, initial vs. updated results														
	Forward Alerts package		Forward Alerts/Automatic Braking package		Driving Assistance package		Driving Assistance Plus package		Blind spot detection		High-beam assistant		Adaptive headlights	
Vehicle damage coverage type	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report
Collision	2.1%	1.2%	**-5.3%**	**-7.0%**	-5.8%	-6.7%	**-7.3%**	**-8.6%**	-0.9%	0.0%	**1.4%**	**1.5%**	**-1.3%**	**-1.2%**
Property damage liability	4.6%	2.7%	**-11.0%**	**-12.8%**	**-27.3%**	-24.7%	**-26.1%**	-25.0%	-2.0%	-1.0%	**-2.3%**	-1.6%	**-9.4%**	**-8.4%**
Injury coverage type	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report
Bodily injury liability	10.9%	6.9%	**-15.8%**	**-18.9%**	**-37.4%**	-25.9%	**-29.2%**	**-31.0%**	**-11.3%**	-8.2%	1.6%	3.9%	**-7.8%**	**-7.9%**
Medical payment	-17.8%	**-26.6%**	-3.4%	-9.0%	-10.2%	-10.0%	-12.6%	-12.1%	-7.1%	-2.3%	-0.4%	0.8%	-0.4%	-2.9%
Personal injury protection	-2.7%	-12.7%	-4.3%	-3.3%	-13.5%	-15.8%	-10.6%	-10.3%	**-9.4%**	**-9.9%**	-3.2%	-1.9%	-3.3%	-2.8%

	Night Vision package		Park distance control		Rearview camera and park distance control		Surround view package		Parking Assistant package		Parking Assistant Plus package	
Vehicle damage coverage type	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report
Collision	**-6.6%**	**-4.7%**	-0.4%	-0.3%	-0.8%	**-1.2%**	1.0%	0.1%	**2.5%**	1.9%	**-9.3%**	**-7.9%**
Property damage liability	**-16.6%**	**-17.2%**	-2.3%	**-3.3%**	**-4.7%**	**-5.8%**	-0.9%	-1.1%	-0.4%	-0.5%	-4.4%	-3.2%
Injury coverage type	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report	Dec. 2019	Current report
Bodily injury liability	-20.7%	-14.6%	-1.9%	-4.2%	**-3.9%**	**-5.8%**	-2.4%	-1.4%	5.5%	1.9%	-17.6%	-11.5%
Medical payment	-5.2%	-11.8%	**-10.1%**	**-8.7%**	-5.0%	-4.9%	1.2%	-1.4%	**-13.9%**	-7.4%	**-33.1%**	**-33.1%**
Personal injury protection	-12.3%	-15.2%	-2.1%	-3.2%	**-4.3%**	**-4.0%**	-2.7%	-2.9%	1.1%	3.1%	-9.2%	-0.7%

▸ Discussion

This is the second study examining changes in insurance losses associated with collision avoidance features on 2013–17 BMW vehicles. Typically, the changes were estimated based on the insurance loss data including the most recent calendar year available. However, the global pandemic caused by COVID-19 has changed the way people work and live, and many workers have shifted from office work to telecommuting. This resulted in many changes to traffic conditions, vehicle miles traveled, and driving behaviors, which may have impacted the effectiveness of collision avoidance technologies in 2020. Prior to completing this analysis, HLDI conducted an analysis of several manufacturers and found that the effectiveness of their collision avoidance features in 2020 differed little from previous years. A similar analysis was done for BMW's collision avoidance technologies in 2020, and there were no substantial differences in the estimated losses for 2020 when compared with the previous years. Therefore, the 2020 loss data was included in this study.

Front crash prevention systems

Four types of front crash prevention packages were analyzed in this study, all of which contain at least the forward collision warning (FCW) system. These bundled packages are designed to primarily prevent front-to-rear crashes, which typically result in PDL and BI claims. The results for the Forward Alerts package are somewhat puzzling, however. A previous study found that estimates for FCW that includes LDW are assumed to mostly reflect the effect of FCW, and it would be expected that FCW results in claim frequency benefits (HLDI, 2020). Consistent with the prior BMW research (HLDI, 2019), the Forward Alerts package in the current study was associated with claim frequency increases under collision, PDL, and BI coverages, but none of the results were statistically significant. A possible reason could be that the vehicles with the Forward Alerts package were all from model years 2013–14, and the claim data were limited. More data may be needed to be confident in the result. Encouragingly, vehicles with the Forward Alerts/Automatic Braking package, which also includes the automatic emergency braking system, had lower claim frequencies under all coverage types, with the results for collision, PDL, and BI being statistically significant. These vehicles also had lower claim severities for collision and PDL coverages; therefore, collision and PDL overall losses declined significantly by 8 and 16 percent, respectively.

The more advanced Driving Assistance package that includes the active cruise control system showed larger claim frequency benefits for most coverages, with the results for PDL being statistically significant. The frequency benefits for the Driving Assistance Plus package increased even more, with collision, PDL, and BI results being significant. In addition, benefits for claim severity and overall losses were observed for the two packages as well. However, the Driving Assistance package showed larger benefits for collision and PDL claim severity and overall losses, although it contains fewer features than the Driving Assistance Plus package.

In sum, although further study may be needed for the Forward Alerts package, BMW's front crash prevention systems appear to be reducing front-to-rear crashes with observable benefits for PDL and BI coverages. The large benefits for PDL and BI claim frequencies for the three advanced front crash prevention packages are consistent with our expectations and indicate that the systems are having a quantifiable impact on the intended population of crashes. The findings are consistent with the results of other manufacturers. It should be noted that all of the front crash prevention systems mentioned above are bundled with lane departure warning.

Side-assist systems

BMW offers three side assist systems: blind spot detection, lane departure warning, and lane-steering assistant. The latter two systems were bundled with the front crash prevention packages mentioned in the previous section and are not discussed in this section.

Claim frequency benefits were observed under most coverage types for blind spot detection, except for collision. Collision and PDL coverages also showed reductions in claim severity and overall losses, with the results for PDL claim severity being significant. The blind spot detection system is designed to prevent incursion into occupied adjacent lanes that would result in multivehicle crashes that lead to PDL and BI claims, which is consistent with the results for BMW's system. Blind spot detection is also intended to assist with lane changes that typically occur on multilane roads, many

of which are higher speed roads, and it is expected that the system would help prevent high-speed crashes and the injuries involved. All the injury coverages were associated with reductions in overall claim frequency, with PIP being statistically significant. Benefits in reducing high-severity injury claim frequencies were also observed for all coverages, with the BI result statistically significant. It should be noted that rear cross-traffic alert was added to some later model year vehicles in conjunction with blind spot detection. However, HLDI was not able to separate out the effect of rear cross-traffic alert based on the data provided.
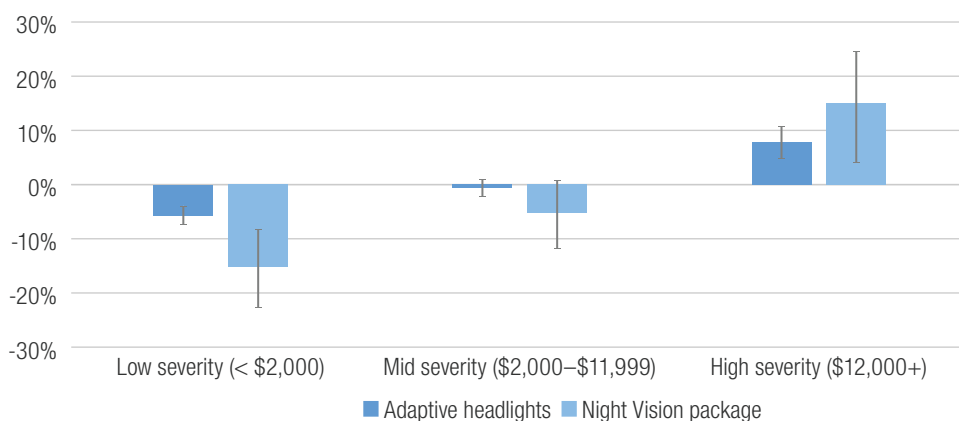
Night-assist systems

BMW's high-beam assistant did not show a large impact on claim frequency for all coverage types. A slight but significant increase was observed for collision claim frequency (2 percent), and an insignificant decrease was observed for PDL (2 percent). The claim severity for collision and PDL showed small and significant increases (5 and 3 percent, respectively), which resulted in a significant 6 percent increase in collision overall losses and an insignificant 1 percent increase in PDL overall losses.

BMW's adaptive headlights showed significant frequency reductions to collision, PDL, and BI claims and slight and insignificant reductions to MedPay and PIP claims, which is consistent with other manufacturers. These results suggest that the technology prevented multivehicle crashes or possibly crashes with pedestrians or other vulnerable road users. It is possible that the additional visibility provided by adaptive headlights helps oncoming drivers detect vehicles earlier on curved roads. However, adaptive headlights tend to be more expensive to repair or replace, which increased collision claim severity. Consequently, the system was associated with a significant 6 percent increase in overall losses for collision. The essentially unchanged PDL claim severity and the significant frequency reduction resulted in a significant 8 percent decrease in PDL overall losses.

BMW's night vision with pedestrian detection was only available with adaptive headlights. The combined systems presented a larger benefit than adaptive headlights alone. Claim frequencies decreased for vehicles equipped with both systems under all coverage types, and the results for collision and PDL were statistically significant. Similar to the adaptive headlights results, collision claim severity increased significantly. However, the severity increase was over double that of adaptive headlights alone (8 versus 19 percent).

Both adaptive headlights and the Night Vision package are associated with decreases in collision claim frequency but increases in severity. Although a higher cost for repairing or replacing the damaged systems could be a reason for the increased claim severity, a shift in the distribution of claim costs could be another possible reason. **Figure 1** summarizes the collision claim frequency for the two night-assist systems by severity range. It suggests that both adaptive headlights alone and the Night Vision package were associated with a significant increase in the frequency of high-severity collision claims, but a reduction in the frequency of low-severity claims. Although not significant, mid-severity claim frequency also decreased. Consequently, some of the increases in overall collision claim severity for both adaptive headlights and the Night Vision package may be attributable to a shift in the distribution of claim costs. In particular, by reducing many of the lower cost claims, the distribution of claim severity has shifted to a higher mean.

Figure 1: Change in collision claim frequency by severity range for night-assist systems

Parking-assist systems

BMW's park distance control was associated with reductions in claim frequency under all coverage types, with the results for PDL and MedPay being significant. Vehicles equipped with both a rearview camera and park distance control showed frequency reductions under all coverage types as well, with all results being statistically significant. Collision and PDL claim severities increased significantly for vehicles with both systems, such that overall losses were significantly higher for collision and significantly lower for PDL. While the increase in collision costs might be explained by the expense of replacing damaged sensors and cameras that support the systems, the increase in the average collision and PDL costs may indicate a possible shift in mean claim severity, eliminating or reducing low-dollar claims.

Previous studies (HLDI, 2017, 2018) suggested that parking sensors with rearview cameras may be associated with reductions to lower severity collision and PDL claims, as would be expected from parking-assistance systems. An examination of collision and PDL claim frequency by severity range confirmed this. As shown in **Figures 2–3**, collision and PDL claim frequencies for low-severity claims decreased for vehicles with both a rearview camera and park distance control and only park distance control, while the frequencies for high-severity claims increased. For vehicles with only park distance control and both a rearview camera and park distance control, the frequency of mid-severity claims increased for collision but decreased for PDL.

Figure 2: Change in collision claim frequency by severity range for rearview camera and park distance control
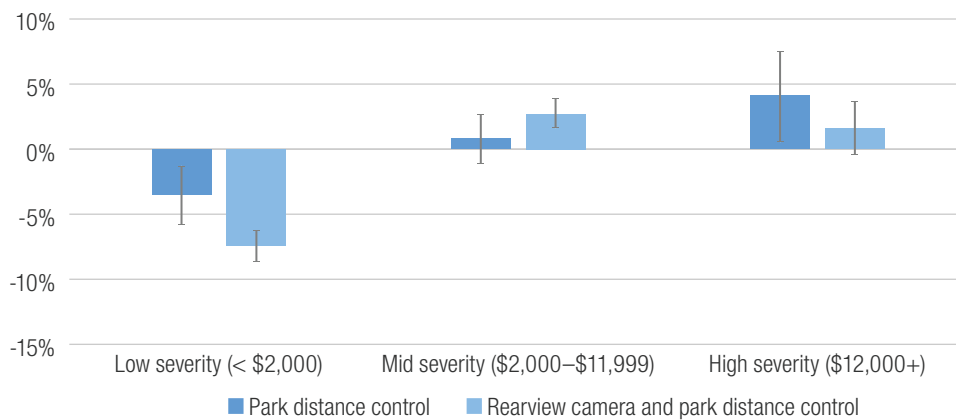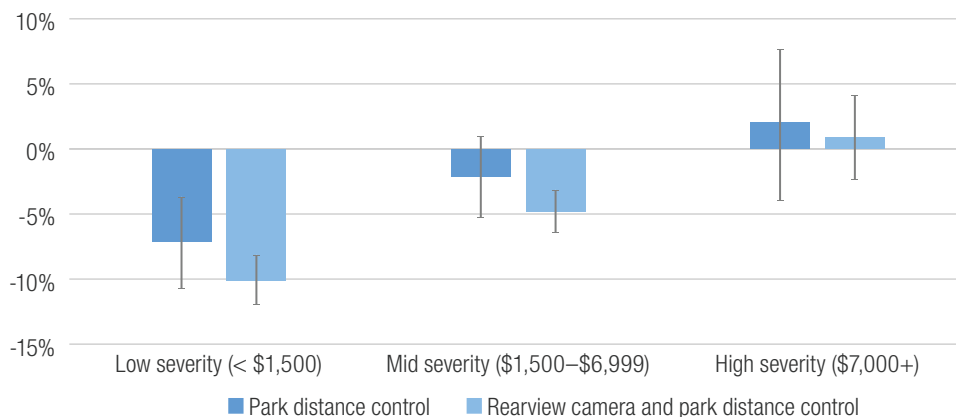

Figure 3: Change in PDL claim frequency by severity range for rearview camera and park distance control

Different from the results of rearview camera and park distance control, collision and PDL claim frequencies for BMW's Surround View package remained essentially unchanged, and the results for collision claim severity and over-all losses showed slight increases. None of the results were statistically significant. These results are puzzling as the surround view system provides additional camera views around the vehicle that presumably would aid the driver in parking situations. It is not clear why the system does not provide benefits similar to those provided by the rearview camera and park distance control system.

Parking assistant is designed to help a driver with parallel parking by automatically steering the vehicle into a detected parking space. The system was only associated with benefits for PDL and MedPay claim frequencies, but none of the results were statistically significant. However, it is unclear how often drivers may be using this system and if the relevant crash situations produce enough claims for any potential benefit due to the system to currently be detectable with the available exposure.

The Parking Assistant Plus package that contains active park distance control, parking assistant and rearview camera additionally provides braking intervention during parking. The results were promising for all coverage types. However, as the data were limited and it is unclear how often people may be using the systems, further analysis may be needed to confirm the results.

▸ 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, if any, of the drivers in these vehicles had manually turned off the system prior to the crash. However, surveys conducted by the Insur-ance Institute for Highway Safety indicate that large majorities of drivers with these types of systems leave them on (Reagan, Cicchino, Kerfoot, & Weast, 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 does not include detailed crash information. The specific crash types ad-dressed by the different technologies cannot be isolated in these analyses. 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 this camera is active. All collisions, regardless of the ability of a feature to mitigate or prevent the crash, are included in the analysis.

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

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▸ Appendix

Appendix: Illustrative regression results — collision frequency								
Parameter		**Degrees of freedom**	**Estimate**	**Effect**	**Standard error**	**Wald 95% confidence limits**		**Chi-square**	**P-value**
Intercept		1	-8.2370		0.0698	-8.3740	-8.1000	13886.90	<0.0001
Calendar year	2012	1	-0.2637	-23.2%	0.0297	-0.3220	-0.2054	78.61	<0.0001
	2013	1	0.0068	0.7%	0.0090	-0.0109	0.0247	0.57	0.4503
	2014	1	0.0441	4.5%	0.0063	0.0316	0.0566	48.16	<0.0001
	2015	1	0.0664	6.9%	0.0051	0.0562	0.0765	164.88	<0.0001
	2016	1	0.0477	4.9%	0.0046	0.0386	0.0567	106.13	<0.0001
	2017	1	0.0340	3.5%	0.0043	0.0255	0.0424	61.80	<0.0001
	2018	1	0.0203	2.1%	0.0042	0.0120	0.0287	22.85	<0.0001
	2020	1	-0.3547	-29.9%	0.0047	-0.3640	-0.3453	5533.09	<0.0001
	2019	0	0	0.0%	0	0	0		
Vehicle model year and series	2014 BMW 228 I 2dr	1	-0.2653	-23.3%	0.0754	-0.4131	-0.1175	12.38	0.0004
	2015 BMW 228 I 2dr	1	-0.2896	-25.1%	0.0773	-0.4413	-0.1379	14.01	0.0002
	2016 BMW 228 I 2dr	1	-0.2445	-21.7%	0.0754	-0.3924	-0.0966	10.50	0.0012
	2015 BMW 228 I convertible	1	-0.2530	-22.4%	0.0881	-0.4258	-0.0803	8.25	0.0041
	2016 BMW 228 I convertible	1	-0.2482	-22.0%	0.0790	-0.4031	-0.0933	9.87	0.0017
	2015 BMW 228 XI 2dr 4WD	1	-0.2416	-21.5%	0.0789	-0.3964	-0.0868	9.36	0.0022
	2016 BMW 228 XI 2dr 4WD	1	-0.2192	-19.7%	0.0779	-0.3719	-0.0665	7.92	0.0049
	2015 BMW 228 XI convertible 4WD	1	-0.3092	-26.6%	0.0878	-0.4813	-0.1371	12.40	0.0004
	2016 BMW 228 XI convertible 4WD	1	-0.2489	-22.0%	0.0795	-0.4049	-0.0930	9.79	0.0018
	2017 BMW 230 I 2dr	1	-0.2525	-22.3%	0.0859	-0.4210	-0.0840	8.63	0.0033
	2017 BMW 230 I convertible	1	-0.2732	-23.9%	0.0880	-0.4459	-0.1006	9.63	0.0019
	2017 BMW 230 XI 2dr 4WD	1	-0.2059	-18.6%	0.0933	-0.3889	-0.0229	4.86	0.0274
	2017 BMW 230 XI convertible 4WD	1	-0.2962	-25.6%	0.0930	-0.4786	-0.1138	10.13	0.0015
	2013 BMW 320 I 4dr	1	-0.1975	-17.9%	0.0729	-0.3406	-0.0545	7.33	0.0068
	2014 BMW 320 I 4dr	1	-0.1971	-17.9%	0.0706	-0.3356	-0.0586	7.78	0.0053
	2015 BMW 320 I 4dr	1	-0.1664	-15.3%	0.0707	-0.3051	-0.0278	5.54	0.0186
	2016 BMW 320 I 4dr	1	-0.1146	-10.8%	0.0714	-0.2546	0.0253	2.57	0.1086
	2017 BMW 320 I 4dr	1	-0.1443	-13.4%	0.0729	-0.2873	-0.0013	3.91	0.0479
	2013 BMW 320 XI 4dr 4WD	1	-0.2180	-19.6%	0.0736	-0.3623	-0.0736	8.76	0.0031
	2014 BMW 320 XI 4dr 4WD	1	-0.1770	-16.2%	0.0708	-0.3159	-0.0381	6.24	0.0125
	2015 BMW 320 XI 4dr 4WD	1	-0.1791	-16.4%	0.0712	-0.3187	-0.0395	6.33	0.0119
	2016 BMW 320 XI 4dr 4WD	1	-0.1107	-10.5%	0.0720	-0.2518	0.0303	2.37	0.1240
	2017 BMW 320 XI 4dr 4WD	1	-0.1393	-13.0%	0.0737	-0.2839	0.0052	3.57	0.0589
	2014 BMW 328 D 4dr	1	-0.2100	-18.9%	0.0729	-0.3529	-0.0672	8.31	0.0040
	2015 BMW 328 D 4dr	1	-0.2524	-22.3%	0.0859	-0.4209	-0.0839	8.63	0.0033
	2016 BMW 328 D 4dr	1	-0.1191	-11.2%	0.1073	-0.3295	0.0912	1.23	0.2669
	2017 BMW 328 D 4dr	1	-0.1453	-13.5%	0.1217	-0.3840	0.0932	1.43	0.2325
	2014 BMW 328 D 4dr 4WD	1	-0.2170	-19.5%	0.0732	-0.3606	-0.0734	8.78	0.0030
	2015 BMW 328 D 4dr 4WD	1	-0.1726	-15.9%	0.0881	-0.3454	0.0001	3.83	0.0502
	2016 BMW 328 D 4dr 4WD	1	-0.4493	-36.2%	0.1261	-0.6966	-0.2020	12.68	0.0004

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	2017 BMW 328 D 4dr 4WD	1	-0.1961	-17.8%	0.1267	-0.4445	0.0522	2.40	0.1217
	2014 BMW 328 D station wagon 4WD	1	-0.2614	-23.0%	0.0791	-0.4165	-0.1062	10.91	0.0010
	2015 BMW 328 D station wagon 4WD	1	-0.2623	-23.1%	0.0815	-0.4221	-0.1024	10.34	0.0013
	2016 BMW 328 D station wagon 4WD	1	-0.2451	-21.7%	0.0945	-0.4305	-0.0598	6.72	0.0095
	2017 BMW 328 D station wagon 4WD	1	-0.2260	-20.2%	0.1059	-0.4337	-0.0183	4.55	0.0329
	2013 BMW 328 I 4dr	1	-0.2112	-19.0%	0.0698	-0.3481	-0.0742	9.13	0.0025
	2014 BMW 328 I 4dr	1	-0.2011	-18.2%	0.0701	-0.3385	-0.0637	8.23	0.0041
	2015 BMW 328 I 4dr	1	-0.2123	-19.1%	0.0701	-0.3499	-0.0747	9.15	0.0025
	2016 BMW 328 I 4dr	1	-0.0947	-9.0%	0.0705	-0.2329	0.0434	1.81	0.1788
	2013 BMW 328 I/IC convertible	1	-0.2415	-21.5%	0.0716	-0.3818	-0.1011	11.37	0.0007
	2013 BMW 328 I/IS/CI 2dr	1	-0.0251	-2.5%	0.0739	-0.1700	0.1197	0.12	0.7341
	2013 BMW 328 XI 2dr 4WD	1	-0.1265	-11.9%	0.0751	-0.2738	0.0208	2.83	0.0924
	2013 BMW 328 XI 4dr 4WD	1	-0.1886	-17.2%	0.0699	-0.3257	-0.0515	7.27	0.0070
	2014 BMW 328 XI 4dr 4WD	1	-0.2047	-18.5%	0.0702	-0.3425	-0.0669	8.48	0.0036
	2015 BMW 328 XI 4dr 4WD	1	-0.2225	-19.9%	0.0702	-0.3602	-0.0849	10.05	0.0015
	2016 BMW 328 XI 4dr 4WD	1	-0.1269	-11.9%	0.0708	-0.2658	0.0119	3.21	0.0733
	2014 BMW 328 XI GT 5dr 4WD	1	-0.1607	-14.8%	0.0729	-0.3037	-0.0177	4.85	0.0276
	2015 BMW 328 XI GT 5dr 4WD	1	-0.1378	-12.9%	0.0730	-0.2810	0.0053	3.56	0.0592
	2016 BMW 328 XI GT 5dr 4WD	1	-0.1756	-16.1%	0.0756	-0.3240	-0.0272	5.38	0.0203
	2014 BMW 328 XI station wagon 4WD	1	-0.3074	-26.5%	0.0762	-0.4568	-0.1580	16.26	0.0001
	2015 BMW 328 XI station wagon 4WD	1	-0.3348	-28.5%	0.0793	-0.4903	-0.1792	17.80	<0.0001
	2016 BMW 328 XI station wagon 4WD	1	-0.2877	-25.0%	0.0866	-0.4576	-0.1178	11.02	0.0009
	2017 BMW 330 I 4dr	1	-0.1815	-16.6%	0.0720	-0.3228	-0.0402	6.34	0.0118
	2017 BMW 330 XI 4dr 4WD	1	-0.1577	-14.6%	0.0721	-0.2992	-0.0163	4.78	0.0287
	2017 BMW 330 XI GT 5dr 4WD	1	-0.2304	-20.6%	0.0845	-0.3961	-0.0648	7.44	0.0064
	2017 BMW 330 XI station wagon 4WD	1	-0.2074	-18.7%	0.0848	-0.3738	-0.0410	5.97	0.0145
	2013 BMW 335 I 4dr	1	-0.2671	-23.4%	0.0718	-0.4080	-0.1262	13.81	0.0002
	2014 BMW 335 I 4dr	1	-0.1948	-17.7%	0.0727	-0.3374	-0.0522	7.17	0.0074
	2015 BMW 335 I 4dr	1	-0.0969	-9.2%	0.0735	-0.2411	0.0472	1.74	0.1875
	2013 BMW 335 I/IS 2dr	1	-0.0673	-6.5%	0.0758	-0.2160	0.0814	0.79	0.3750
	2013 BMW 335 I/IS convertible	1	-0.1421	-13.2%	0.0732	-0.2855	0.0013	3.77	0.0522
	2013 BMW 335 XI 2dr 4WD	1	-0.1353	-12.7%	0.0820	-0.2961	0.0254	2.72	0.0990
	2013 BMW 335 XI 4dr 4WD	1	-0.1967	-17.9%	0.0720	-0.3379	-0.0555	7.46	0.0063
	2014 BMW 335 XI 4dr 4WD	1	-0.2014	-18.2%	0.0726	-0.3437	-0.0591	7.70	0.0055
	2015 BMW 335 XI 4dr 4WD	1	-0.2565	-22.6%	0.0740	-0.4016	-0.1115	12.02	0.0005
	2014 BMW 335 XI GT 5dr 4WD	1	-0.1831	-16.7%	0.0821	-0.3440	-0.0221	4.97	0.0258
	2015 BMW 335 XI GT 5dr 4WD	1	-0.2248	-20.1%	0.0866	-0.3946	-0.0550	6.74	0.0094
	2016 BMW 335 XI GT 5dr 4WD	1	-0.3118	-26.8%	0.0986	-0.5052	-0.1185	9.99	0.0016
	2016 BMW 340 I 4dr	1	-0.1140	-10.8%	0.0751	-0.2612	0.0332	2.30	0.1290
	2017 BMW 340 I 4dr	1	-0.1396	-13.0%	0.0819	-0.3002	0.0209	2.91	0.0882
	2016 BMW 340 XI 4dr 4WD	1	-0.1080	-10.2%	0.0745	-0.2540	0.0379	2.10	0.1471

Appendix: Illustrative regression results — collision frequency								
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	2017 BMW 340 XI 4dr 4WD	1	-0.0436	-4.3%	0.0785	-0.1976	0.1103	0.31	0.5787
	2017 BMW 340 XI GT 5dr 4WD	1	-0.1131	-10.7%	0.1162	-0.3409	0.1146	0.95	0.3304
	2014 BMW 428 I 2dr	1	-0.0649	-6.3%	0.0711	-0.2044	0.0744	0.83	0.3611
	2015 BMW 428 I 2dr	1	-0.0218	-2.2%	0.0718	-0.1626	0.1189	0.09	0.7610
	2016 BMW 428 I 2dr	1	-0.0379	-3.7%	0.0748	-0.1847	0.1087	0.26	0.6118
	2014 BMW 428 I convertible	1	-0.1501	-13.9%	0.0740	-0.2952	-0.0050	4.12	0.0425
	2015 BMW 428 I convertible	1	-0.1820	-16.6%	0.0728	-0.3249	-0.0392	6.24	0.0125
	2016 BMW 428 I convertible	1	-0.1644	-15.2%	0.0749	-0.3112	-0.0175	4.81	0.0282
	2015 BMW 428 I Gran Coupe 5dr	1	-0.0503	-4.9%	0.0718	-0.1911	0.0903	0.49	0.4830
	2016 BMW 428 I Gran Coupe 5dr	1	-0.0345	-3.4%	0.0718	-0.1754	0.1063	0.23	0.6304
	2014 BMW 428 XI 2dr 4WD	1	0.0049	0.5%	0.0712	-0.1347	0.1447	0.00	0.9443
	2015 BMW 428 XI 2dr 4WD	1	-0.0489	-4.8%	0.0731	-0.1922	0.0943	0.45	0.5031
	2016 BMW 428 XI 2dr 4WD	1	0.1098	11.6%	0.0772	-0.0415	0.2611	2.02	0.1549
	2014 BMW 428 XI convertible 4WD	1	-0.2391	-21.3%	0.0797	-0.3954	-0.0828	8.99	0.0027
	2015 BMW 428 XI convertible 4WD	1	-0.2862	-24.9%	0.0758	-0.4348	-0.1376	14.25	0.0002
	2016 BMW 428 XI convertible 4WD	1	-0.1730	-15.9%	0.0781	-0.3262	-0.0198	4.90	0.0269
	2015 BMW 428 XI Gran Coupe 5dr 4WD	1	-0.0456	-4.5%	0.0725	-0.1877	0.0965	0.40	0.5292
	2016 BMW 428 XI Gran Coupe 5dr 4WD	1	-0.0384	-3.8%	0.0732	-0.1818	0.1050	0.28	0.5998
	2017 BMW 430 I 2dr	1	-0.0492	-4.8%	0.0801	-0.2062	0.1078	0.38	0.5392
	2017 BMW 430 I convertible	1	-0.1795	-16.4%	0.0800	-0.3364	-0.0226	5.03	0.0249
	2017 BMW 430 I Gran Coupe 5dr	1	0.0201	2.0%	0.0745	-0.1258	0.1662	0.07	0.7864
	2017 BMW 430 XI 2dr 4WD	1	0.0361	3.7%	0.0853	-0.1311	0.2034	0.18	0.6718
	2017 BMW 430 XI convertible 4WD	1	-0.1466	-13.6%	0.0853	-0.3138	0.0205	2.95	0.0857
	2017 BMW 430 XI Gran Coupe 5dr 4WD	1	0.0289	2.9%	0.0766	-0.1213	0.1791	0.14	0.7060
	2014 BMW 435 I 2dr	1	-0.0991	-9.4%	0.0729	-0.2421	0.0437	1.85	0.1739
	2015 BMW 435 I 2dr	1	-0.0618	-6.0%	0.0747	-0.2083	0.0846	0.68	0.4081
	2016 BMW 435 I 2dr	1	-0.1584	-14.6%	0.0818	-0.3187	0.0019	3.75	0.0528
	2014 BMW 435 I convertible	1	-0.3263	-27.8%	0.0783	-0.4798	-0.1727	17.35	<0.0001
	2015 BMW 435 I convertible	1	-0.2031	-18.4%	0.0776	-0.3552	-0.0510	6.85	0.0089
	2016 BMW 435 I convertible	1	-0.1951	-17.7%	0.0845	-0.3609	-0.0293	5.32	0.0211
	2015 BMW 435 I Gran Coupe 5dr	1	-0.0793	-7.6%	0.0771	-0.2306	0.0718	1.06	0.3035
	2016 BMW 435 I Gran Coupe 5dr	1	-0.0962	-9.2%	0.0806	-0.2543	0.0617	1.42	0.2326
	2014 BMW 435 XI 2dr 4WD	1	-0.0619	-6.0%	0.0735	-0.2060	0.0821	0.71	0.3992
	2015 BMW 435 XI 2dr 4WD	1	-0.0860	-8.2%	0.0765	-0.2361	0.0639	1.26	0.2609
	2016 BMW 435 XI 2dr 4WD	1	-0.1054	-10.0%	0.0840	-0.2702	0.0593	1.57	0.2099
	2015 BMW 435 XI convertible 4WD	1	-0.3382	-28.7%	0.0803	-0.4957	-0.1807	17.71	<0.0001
	2016 BMW 435 XI convertible 4WD	1	-0.2317	-20.7%	0.0869	-0.4021	-0.0613	7.11	0.0077
	2015 BMW 435 XI Gran Coupe 5dr 4WD	1	-0.1158	-10.9%	0.0811	-0.2749	0.0432	2.04	0.1536
	2016 BMW 435 XI Gran Coupe 5dr 4WD	1	-0.0417	-4.1%	0.0830	-0.2044	0.1209	0.25	0.6152
	2017 BMW 440 I 2dr	1	-0.0021	-0.2%	0.0906	-0.1797	0.1755	0.00	0.9813

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	2017 BMW 440 I convertible	1	-0.2593	-22.8%	0.1031	-0.4616	-0.0571	6.32	0.0120
	2017 BMW 440 I Gran Coupe 5dr	1	-0.0325	-3.2%	0.0883	-0.2056	0.1406	0.14	0.7128
	2017 BMW 440 XI 2dr 4WD	1	0.0031	0.3%	0.0939	-0.1810	0.1874	0.00	0.9730
	2017 BMW 440 XI convertible 4WD	1	-0.2031	-18.4%	0.0988	-0.3969	-0.0093	4.22	0.0399
	2017 BMW 440 XI Gran Coupe 5dr 4WD	1	-0.0247	-2.4%	0.0896	-0.2005	0.1509	0.08	0.7822
	2013 BMW 528 I 4dr	1	-0.2517	-22.3%	0.0706	-0.3903	-0.1132	12.68	0.0004
	2014 BMW 528 I 4dr	1	-0.2795	-24.4%	0.0709	-0.4187	-0.1404	15.51	0.0001
	2015 BMW 528 I 4dr	1	-0.2590	-22.8%	0.0712	-0.3987	-0.1193	13.21	0.0003
	2016 BMW 528 I 4dr	1	-0.2266	-20.3%	0.0715	-0.3668	-0.0863	10.03	0.0015
	2013 BMW 528 XI 4dr 4WD	1	-0.2045	-18.5%	0.0705	-0.3428	-0.0661	8.39	0.0038
	2014 BMW 528 XI 4dr 4WD	1	-0.2175	-19.5%	0.0713	-0.3573	-0.0777	9.30	0.0023
	2015 BMW 528 XI 4dr 4WD	1	-0.2607	-22.9%	0.0715	-0.4010	-0.1204	13.27	0.0003
	2016 BMW 528 XI 4dr 4WD	1	-0.2431	-21.6%	0.0719	-0.3842	-0.1020	11.41	0.0007
	2017 BMW 530 I 4dr	1	-0.0986	-9.4%	0.0767	-0.2489	0.0517	1.65	0.1986
	2017 BMW 530 XI 4dr 4WD	1	-0.0594	-5.8%	0.0766	-0.2096	0.0907	0.60	0.4378
	2014 BMW 535 D 4dr	1	-0.3063	-26.4%	0.0766	-0.4565	-0.1560	15.97	0.0001
	2015 BMW 535 D 4dr	1	-0.3213	-27.5%	0.1024	-0.5221	-0.1205	9.84	0.0017
	2016 BMW 535 D 4dr	1	-0.3736	-31.2%	0.1059	-0.5812	-0.1660	12.45	0.0004
	2014 BMW 535 D 4dr 4WD	1	-0.2914	-25.3%	0.0771	-0.4425	-0.1402	14.28	0.0002
	2015 BMW 535 D 4dr 4WD	1	-0.4576	-36.7%	0.1118	-0.6768	-0.2384	16.74	<0.0001
	2016 BMW 535 D 4dr 4WD	1	-0.1121	-10.6%	0.1131	-0.3339	0.1096	0.98	0.3216
	2013 BMW 535 I GT 5dr	1	-0.2789	-24.3%	0.0878	-0.4511	-0.1068	10.09	0.0015
	2014 BMW 535 I GT 5dr	1	-0.1632	-15.1%	0.0929	-0.3454	0.0190	3.08	0.0792
	2015 BMW 535 I GT 5dr	1	-0.1037	-9.9%	0.0997	-0.2992	0.0917	1.08	0.2982
	2016 BMW 535 I GT 5dr	1	-0.2133	-19.2%	0.1208	-0.4503	0.0235	3.12	0.0775
	2017 BMW 535 I GT 5dr	1	-0.0820	-7.9%	0.1375	-0.3516	0.1874	0.36	0.5505
	2013 BMW 535 I/535 IS 4dr	1	-0.2659	-23.3%	0.0708	-0.4048	-0.1271	14.10	0.0002
	2014 BMW 535 I/535 IS 4dr	1	-0.3128	-26.9%	0.0712	-0.4523	-0.1732	19.30	<0.0001
	2015 BMW 535 I/535 IS 4dr	1	-0.2802	-24.4%	0.0718	-0.4210	-0.1393	15.21	0.0001
	2016 BMW 535 I/535 IS 4dr	1	-0.2292	-20.5%	0.0723	-0.3709	-0.0875	10.05	0.0015
	2013 BMW 535 XI 4dr 4WD	1	-0.2346	-20.9%	0.0709	-0.3736	-0.0956	10.95	0.0009
	2014 BMW 535 XI 4dr 4WD	1	-0.3014	-26.0%	0.0712	-0.4410	-0.1619	17.93	<0.0001
	2015 BMW 535 XI 4dr 4WD	1	-0.2633	-23.1%	0.0718	-0.4041	-0.1225	13.44	0.0002
	2016 BMW 535 XI 4dr 4WD	1	-0.2864	-24.9%	0.0724	-0.4283	-0.1444	15.65	0.0001
	2013 BMW 535 XI GT 5dr 4WD	1	-0.0761	-7.3%	0.0853	-0.2433	0.0911	0.80	0.3725
	2014 BMW 535 XI GT 5dr 4WD	1	-0.1401	-13.1%	0.0942	-0.3249	0.0445	2.21	0.1370
	2015 BMW 535 XI GT 5dr 4WD	1	-0.1943	-17.7%	0.1023	-0.3948	0.0062	3.60	0.0576
	2016 BMW 535 XI GT 5dr 4WD	1	-0.1468	-13.7%	0.1208	-0.3837	0.0900	1.48	0.2244
	2017 BMW 535 XI GT 5dr 4WD	1	-0.2231	-20.0%	0.1413	-0.5001	0.0538	2.49	0.1144
	2017 BMW 540 I 4dr	1	-0.1031	-9.8%	0.0787	-0.2574	0.0511	1.72	0.1902
	2017 BMW 540 XI 4dr 4WD	1	-0.0862	-8.3%	0.0784	-0.2399	0.0673	1.21	0.2711
	2013 BMW 550 I 4dr	1	-0.2926	-25.4%	0.0763	-0.4423	-0.1429	14.68	0.0001
	2014 BMW 550 I 4dr	1	-0.2452	-21.7%	0.0773	-0.3967	-0.0937	10.06	0.0015

Appendix: Illustrative regression results — collision frequency								
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	2015 BMW 550 I 4dr	1	-0.3201	-27.4%	0.0887	-0.4942	-0.1461	13.00	0.0003
	2016 BMW 550 I 4dr	1	-0.1858	-17.0%	0.0860	-0.3545	-0.0172	4.66	0.0308
	2013 BMW 550 I GT 5dr	1	-0.3376	-28.7%	0.1588	-0.6489	-0.0262	4.52	0.0336
	2014 BMW 550 I GT 5dr	1	-0.1839	-16.8%	0.1659	-0.5092	0.1414	1.23	0.2679
	2015 BMW 550 I GT 5dr	1	-0.1867	-17.0%	0.2674	-0.7108	0.3373	0.49	0.4849
	2013 BMW 550 XI 4dr 4WD	1	-0.1983	-18.0%	0.0762	-0.3478	-0.0488	6.77	0.0093
	2014 BMW 550 XI 4dr 4WD	1	-0.2171	-19.5%	0.0776	-0.3693	-0.0649	7.82	0.0052
	2015 BMW 550 XI 4dr 4WD	1	-0.2382	-21.2%	0.0876	-0.4101	-0.0663	7.38	0.0066
	2016 BMW 550 XI 4dr 4WD	1	-0.1660	-15.3%	0.0846	-0.3320	-0.0001	3.85	0.0499
	2013 BMW 550 XI GT 5dr 4WD	1	-0.2434	-21.6%	0.1551	-0.5476	0.0607	2.46	0.1167
	2014 BMW 550 XI GT 5dr 4WD	1	-0.2086	-18.8%	0.1676	-0.5372	0.1199	1.55	0.2132
	2015 BMW 550 XI GT 5dr 4WD	1	-0.1572	-14.5%	0.1926	-0.5349	0.2203	0.67	0.4143
	2016 BMW 550 XI GT 5dr 4WD	1	-0.1938	-17.6%	0.2013	-0.5884	0.2008	0.93	0.3358
	2017 BMW 550 XI GT 5dr 4WD	1	-0.0780	-7.5%	0.2348	-0.5383	0.3822	0.11	0.7397
	2013 BMW 640 I 2dr	1	-0.0702	-6.8%	0.1053	-0.2767	0.1363	0.44	0.5053
	2014 BMW 640 I 2dr	1	-0.0274	-2.7%	0.1148	-0.2525	0.1977	0.06	0.8115
	2015 BMW 640 I 2dr	1	-0.0043	-0.4%	0.1266	-0.2524	0.2438	0.00	0.9728
	2016 BMW 640 I 2dr	1	-0.4207	-34.3%	0.2045	-0.8215	-0.0198	4.23	0.0397
	2017 BMW 640 I 2dr	1	0.0112	1.1%	0.1873	-0.3559	0.3783	0.00	0.9523
	2013 BMW 640 I convertible	1	-0.4779	-38.0%	0.1123	-0.6982	-0.2577	18.09	<0.0001
	2014 BMW 640 I convertible	1	-0.3089	-26.6%	0.1097	-0.5240	-0.0938	7.93	0.0049
	2015 BMW 640 I convertible	1	-0.1569	-14.5%	0.1107	-0.3739	0.0600	2.01	0.1562
	2016 BMW 640 I convertible	1	-0.2960	-25.6%	0.1315	-0.5537	-0.0382	5.07	0.0244
	2017 BMW 640 I convertible	1	-0.2226	-20.0%	0.1446	-0.5060	0.0608	2.37	0.1237
	2013 BMW 640 I Gran Coupe 5dr	1	-0.0039	-0.4%	0.0800	-0.1608	0.1529	0.00	0.9608
	2014 BMW 640 I Gran Coupe 5dr	1	-0.0417	-4.1%	0.0826	-0.2038	0.1202	0.26	0.6135
	2015 BMW 640 I Gran Coupe 5dr	1	-0.1571	-14.5%	0.0826	-0.3192	0.0048	3.62	0.0572
	2016 BMW 640 I Gran Coupe 5dr	1	0.0293	3.0%	0.0864	-0.1400	0.1988	0.12	0.7339
	2017 BMW 640 I Gran Coupe 5dr	1	-0.0403	-3.9%	0.1089	-0.2539	0.1733	0.14	0.7115
	2014 BMW 640 XI 2dr 4WD	1	-0.0718	-6.9%	0.1251	-0.3171	0.1735	0.33	0.5662
	2015 BMW 640 XI 2dr 4WD	1	-0.0031	-0.3%	0.1675	-0.3314	0.3251	0.00	0.9851
	2016 BMW 640 XI 2dr 4WD	1	0.0113	1.1%	0.1804	-0.3423	0.3651	0.00	0.9497
	2017 BMW 640 XI 2dr 4WD	1	-0.4249	-34.6%	0.3237	-1.0594	0.2095	1.72	0.1893
	2014 BMW 640 XI convertible 4WD	1	-0.4164	-34.1%	0.1131	-0.6382	-0.1947	13.55	0.0002
	2015 BMW 640 XI convertible 4WD	1	-0.4097	-33.6%	0.1315	-0.6675	-0.1520	9.71	0.0018
	2016 BMW 640 XI convertible 4WD	1	-0.1632	-15.1%	0.1614	-0.4796	0.1532	1.02	0.3121
	2017 BMW 640 XI convertible 4WD	1	-0.2473	-21.9%	0.1826	-0.6053	0.1106	1.83	0.1757
	2014 BMW 640 XI Gran Coupe 5dr 4WD	1	0.0073	0.7%	0.0841	-0.1575	0.1722	0.01	0.9305
	2015 BMW 640 XI Gran Coupe 5dr 4WD	1	-0.0512	-5.0%	0.0852	-0.2184	0.1159	0.36	0.5481
	2016 BMW 640 XI Gran Coupe 5dr 4WD	1	-0.1105	-10.5%	0.0982	-0.3030	0.0819	1.27	0.2602
	2017 BMW 640 XI Gran Coupe 5dr 4WD	1	0.0042	0.4%	0.1164	-0.2240	0.2324	0.00	0.9712

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	Appendix: Illustrative regression results — collision frequency								
	2013 BMW 650 I 2dr	1	-0.0796	-7.7%	0.1063	-0.2879	0.1287	0.56	0.4539
	2014 BMW 650 I 2dr	1	-0.0626	-6.1%	0.1094	-0.2770	0.1518	0.33	0.5672
	2015 BMW 650 I 2dr	1	-0.2917	-25.3%	0.1574	-0.6002	0.0167	3.44	0.0638
	2016 BMW 650 I 2dr	1	-0.2091	-18.9%	0.1981	-0.5974	0.1792	1.11	0.2912
	2017 BMW 650 I 2dr	1	0.0911	9.5%	0.2196	-0.3394	0.5217	0.17	0.6783
	2013 BMW 650 I convertible	1	-0.1357	-12.7%	0.1035	-0.3387	0.0672	1.72	0.1898
	2014 BMW 650 I convertible	1	-0.2325	-20.7%	0.1004	-0.4295	-0.0356	5.36	0.0206
	2015 BMW 650 I convertible	1	-0.2468	-21.9%	0.1019	-0.4466	-0.0469	5.86	0.0155
	2016 BMW 650 I convertible	1	-0.0337	-3.3%	0.1366	-0.3015	0.2340	0.06	0.8051
	2017 BMW 650 I convertible	1	-0.4712	-37.6%	0.1804	-0.8248	-0.1175	6.82	0.0090
	2013 BMW 650 I Gran Coupe 5dr	1	-0.0924	-8.8%	0.0923	-0.2734	0.0885	1.00	0.3169
	2014 BMW 650 I Gran Coupe 5dr	1	-0.0857	-8.2%	0.0858	-0.2539	0.0824	1.00	0.3178
	2015 BMW 650 I Gran Coupe 5dr	1	0.0171	1.7%	0.0808	-0.1412	0.1756	0.05	0.8319
	2016 BMW 650 I Gran Coupe 5dr	1	0.0430	4.4%	0.0982	-0.1495	0.2356	0.19	0.6613
	2017 BMW 650 I Gran Coupe 5dr	1	0.1633	17.7%	0.1265	-0.0847	0.4113	1.67	0.1969
	2013 BMW 650 XI 2dr 4WD	1	-0.2466	-21.9%	0.1266	-0.4949	0.0016	3.79	0.0515
	2014 BMW 650 XI 2dr 4WD	1	-0.1602	-14.8%	0.1161	-0.3877	0.0673	1.90	0.1676
	2015 BMW 650 XI 2dr 4WD	1	-0.0897	-8.6%	0.1587	-0.4008	0.2213	0.32	0.5717
	2016 BMW 650 XI 2dr 4WD	1	-0.0057	-0.6%	0.1898	-0.3779	0.3663	0.00	0.9756
	2017 BMW 650 XI 2dr 4WD	1	0.0815	8.5%	0.2396	-0.3882	0.5512	0.12	0.7338
	2013 BMW 650 XI convertible 4WD	1	-0.2013	-18.2%	0.1105	-0.4179	0.0153	3.32	0.0686
	2014 BMW 650 XI convertible 4WD	1	-0.3629	-30.4%	0.1106	-0.5798	-0.1460	10.76	0.0010
	2015 BMW 650 XI convertible 4WD	1	-0.4233	-34.5%	0.1145	-0.6478	-0.1988	13.66	0.0002
	2016 BMW 650 XI convertible 4WD	1	-0.2992	-25.9%	0.1538	-0.6006	0.0022	3.78	0.0517
	2017 BMW 650 XI convertible 4WD	1	-0.2551	-22.5%	0.1587	-0.5663	0.0559	2.58	0.1080
	2013 BMW 650 XI Gran Coupe 5dr 4WD	1	0.0388	4.0%	0.0875	-0.1326	0.2104	0.20	0.6570
	2014 BMW 650 XI Gran Coupe 5dr 4WD	1	-0.0399	-3.9%	0.0866	-0.2099	0.1299	0.21	0.6447
	2015 BMW 650 XI Gran Coupe 5dr 4WD	1	0.0014	0.1%	0.0807	-0.1567	0.1597	0.00	0.9853
	2016 BMW 650 XI Gran Coupe 5dr 4WD	1	0.0167	1.7%	0.0933	-0.1662	0.1996	0.03	0.8580
	2017 BMW 650 XI Gran Coupe 5dr 4WD	1	0.0160	1.6%	0.1171	-0.2136	0.2457	0.02	0.8912
	2013 BMW 740 I 4dr	1	-0.2534	-22.4%	0.0832	-0.4166	-0.0901	9.26	0.0023
	2014 BMW 740 I 4dr	1	-0.2349	-20.9%	0.0882	-0.4079	-0.0620	7.09	0.0078
	2015 BMW 740 I 4dr	1	-0.1361	-12.7%	0.0869	-0.3065	0.0341	2.46	0.1171
	2016 BMW 740 I 4dr	1	0.0693	7.2%	0.0774	-0.0823	0.2211	0.80	0.3701
	2017 BMW 740 I 4dr	1	0.0653	6.7%	0.0842	-0.0997	0.2303	0.60	0.4378
	2015 BMW 740 LD XDrive 4dr 4WD	1	-0.0207	-2.0%	0.1208	-0.2575	0.2160	0.03	0.8636
	2013 BMW 740 LI 4dr	1	-0.1980	-18.0%	0.0794	-0.3537	-0.0422	6.21	0.0127
	2014 BMW 740 LI 4dr	1	-0.1332	-12.5%	0.0856	-0.3010	0.0345	2.42	0.1197
	2015 BMW 740 LI 4dr	1	-0.0015	-0.1%	0.0868	-0.1717	0.1686	0.00	0.9857

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	2013 BMW 740 LXI 4dr 4WD	1	-0.1363	-12.7%	0.0803	-0.2937	0.0211	2.88	0.0897
	2014 BMW 740 LXI 4dr 4WD	1	-0.0641	-6.2%	0.0923	-0.2451	0.1167	0.48	0.4869
	2015 BMW 740 LXI 4dr 4WD	1	-0.2351	-21.0%	0.0930	-0.4175	-0.0526	6.38	0.0115
	2017 BMW 740 XI 4dr 4WD	1	0.2691	30.9%	0.0918	0.0891	0.4491	8.59	0.0034
	2013 BMW 750 I 4dr	1	-0.1865	-17.0%	0.0831	-0.3496	-0.0235	5.03	0.0249
	2014 BMW 750 I 4dr	1	-0.1403	-13.1%	0.0859	-0.3088	0.0280	2.67	0.1024
	2015 BMW 750 I 4dr	1	-0.3119	-26.8%	0.0965	-0.5012	-0.1227	10.44	0.0012
	2016 BMW 750 I 4dr	1	0.0844	8.8%	0.0879	-0.0879	0.2569	0.92	0.3370
	2017 BMW 750 I 4dr	1	0.0545	5.6%	0.0935	-0.1287	0.2379	0.34	0.5595
	2013 BMW 750 LI 4dr	1	-0.0801	-7.7%	0.0744	-0.2259	0.0656	1.16	0.2812
	2014 BMW 750 LI 4dr	1	-0.0533	-5.2%	0.0757	-0.2017	0.0950	0.50	0.4811
	2015 BMW 750 LI 4dr	1	-0.1019	-9.7%	0.0825	-0.2638	0.0599	1.52	0.2173
	2013 BMW 750 LXI 4dr 4WD	1	-0.0422	-4.1%	0.0751	-0.1895	0.1050	0.32	0.5738
	2014 BMW 750 LXI 4dr 4WD	1	-0.0295	-2.9%	0.0763	-0.1792	0.1201	0.15	0.6984
	2015 BMW 750 LXI 4dr 4WD	1	-0.0280	-2.8%	0.0816	-0.1881	0.1319	0.12	0.7312
	2013 BMW 750 XI 4dr 4WD	1	-0.0771	-7.4%	0.0833	-0.2404	0.0861	0.86	0.3545
	2014 BMW 750 XI 4dr 4WD	1	-0.1233	-11.6%	0.0894	-0.2987	0.0520	1.90	0.1680
	2015 BMW 750 XI 4dr 4WD	1	-0.1002	-9.5%	0.0964	-0.2892	0.0888	1.08	0.2987
	2016 BMW 750 XI 4dr 4WD	1	0.0811	8.4%	0.0764	-0.0687	0.2309	1.13	0.2886
	2017 BMW 750 XI 4dr 4WD	1	0.0379	3.9%	0.0846	-0.1279	0.2038	0.20	0.6540
	2013 BMW 760 LI 4dr	1	0.1705	18.6%	0.1752	-0.1729	0.5139	0.95	0.3305
	2014 BMW 760 LI 4dr	1	0.0342	3.5%	0.3099	-0.5732	0.6416	0.01	0.9121
	2015 BMW 760 LI 4dr	1	-0.4261	-34.7%	0.5049	-1.4159	0.5635	0.71	0.3987
	2016 BMW M2 2dr	1	-0.6457	-47.6%	0.3603	-1.3519	0.0604	3.21	0.0731
	2017 BMW M2 2dr	1	-0.6680	-48.7%	0.1375	-0.9375	-0.3984	23.59	<0.0001
	2014 BMW M235 I 2dr	1	-0.2993	-25.9%	0.0799	-0.4561	-0.1426	14.01	0.0002
	2015 BMW M235 I 2dr	1	-0.2923	-25.3%	0.0771	-0.4435	-0.1411	14.36	0.0002
	2016 BMW M235 I 2dr	1	-0.3104	-26.7%	0.0786	-0.4646	-0.1562	15.56	0.0001
	2015 BMW M235 I convertible	1	-0.2586	-22.8%	0.0878	-0.4309	-0.0864	8.66	0.0032
	2016 BMW M235 I convertible	1	-0.2646	-23.2%	0.0906	-0.4422	-0.0869	8.52	0.0035
	2015 BMW M235 XI 2dr 4WD	1	-0.3023	-26.1%	0.0832	-0.4654	-0.1392	13.20	0.0003
	2016 BMW M235 XI 2dr 4WD	1	-0.2517	-22.3%	0.0838	-0.4160	-0.0873	9.01	0.0027
	2016 BMW M235 XI convertible 4WD	1	-0.4004	-33.0%	0.0943	-0.5853	-0.2155	18.02	<0.0001
	2017 BMW M240 I 2dr	1	-0.2640	-23.2%	0.0900	-0.4406	-0.0875	8.59	0.0034
	2017 BMW M240 I convertible	1	-0.2617	-23.0%	0.1015	-0.4607	-0.0626	6.64	0.0100
	2017 BMW M240 XI 2dr 4WD	1	-0.2617	-23.0%	0.0943	-0.4466	-0.0768	7.70	0.0055
	2017 BMW M240 XI convertible 4WD	1	-0.2749	-24.0%	0.1149	-0.5002	-0.0496	5.72	0.0168
	2015 BMW M3 4dr	1	-0.2577	-22.7%	0.0749	-0.4046	-0.1108	11.82	0.0006
	2016 BMW M3 4dr	1	-0.1690	-15.5%	0.0756	-0.3172	-0.0208	5.00	0.0254
	2017 BMW M3 4dr	1	-0.1260	-11.8%	0.0772	-0.2774	0.0253	2.66	0.1026
	2013 BMW M3/M3 CI 2dr	1	-0.5523	-42.4%	0.0769	-0.7031	-0.4015	51.52	<0.0001
	2013 BMW M3/M3 CI convertible	1	-0.6022	-45.2%	0.0881	-0.7750	-0.4294	46.65	<0.0001
	2015 BMW M4 2dr	1	-0.1118	-10.6%	0.0719	-0.2529	0.0292	2.42	0.1202

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	2016 BMW M4 2dr	1	-0.1545	-14.3%	0.0749	-0.3013	-0.0077	4.26	0.0391
	2017 BMW M4 2dr	1	-0.0422	-4.1%	0.0840	-0.2070	0.1224	0.25	0.6149
	2015 BMW M4 convertible	1	-0.1776	-16.3%	0.0782	-0.3310	-0.0243	5.16	0.0232
	2016 BMW M4 convertible	1	-0.2115	-19.1%	0.0812	-0.3707	-0.0523	6.79	0.0092
	2017 BMW M4 convertible	1	-0.1714	-15.8%	0.1087	-0.3845	0.0416	2.49	0.1149
	2016 BMW M4 GTS Coupe 2dr	1	-1.7018	-81.8%	0.3089	-2.3072	-1.0963	30.35	<0.0001
	2013 BMW M5 4dr	1	-0.1785	-16.3%	0.0859	-0.3469	-0.0100	4.31	0.0378
	2014 BMW M5 4dr	1	-0.1847	-16.9%	0.0787	-0.3391	-0.0304	5.50	0.0190
	2015 BMW M5 4dr	1	-0.1502	-13.9%	0.0854	-0.3176	0.0172	3.09	0.0787
	2016 BMW M5 4dr	1	-0.0051	-0.5%	0.0906	-0.1828	0.1724	0.00	0.9544
	2013 BMW M6 2dr	1	-0.2134	-19.2%	0.1527	-0.5128	0.0858	1.95	0.1622
	2014 BMW M6 2dr	1	-0.0801	-7.7%	0.1006	-0.2773	0.1170	0.63	0.4257
	2015 BMW M6 2dr	1	-0.1712	-15.7%	0.1395	-0.4448	0.1023	1.50	0.2199
	2016 BMW M6 2dr	1	-0.0283	-2.8%	0.1332	-0.2895	0.2329	0.05	0.8318
	2017 BMW M6 2dr	1	0.2377	26.8%	0.1707	-0.0969	0.5725	1.94	0.1639
	2013 BMW M6 convertible	1	-0.6526	-47.9%	0.2289	-1.1014	-0.2038	8.12	0.0044
	2014 BMW M6 convertible	1	-0.3567	-30.0%	0.1029	-0.5584	-0.1550	12.02	0.0005
	2015 BMW M6 convertible	1	-0.2523	-22.3%	0.1286	-0.5044	-0.0002	3.85	0.0498
	2016 BMW M6 convertible	1	-0.1212	-11.4%	0.1308	-0.3776	0.1352	0.86	0.3543
	2017 BMW M6 convertible	1	-0.1055	-10.0%	0.1952	-0.4881	0.2771	0.29	0.5889
	2014 BMW M6 Gran Coupe 5dr	1	-0.0443	-4.3%	0.0860	-0.2130	0.1242	0.27	0.6061
	2015 BMW M6 Gran Coupe 5dr	1	0.0385	3.9%	0.0968	-0.1513	0.2284	0.16	0.6905
	2016 BMW M6 Gran Coupe 5dr	1	0.0041	0.4%	0.1048	-0.2013	0.2096	0.00	0.9685
	2017 BMW M6 Gran Coupe 5dr	1	-0.1681	-15.5%	0.1561	-0.4742	0.1378	1.16	0.2815
	2017 BMW M760 XI 4dr 4WD	1	0.2856	33.1%	0.2209	-0.1474	0.7188	1.67	0.1961
	2013 BMW X1 4dr	1	-0.4571	-36.7%	0.0725	-0.5994	-0.3148	39.66	<0.0001
	2014 BMW X1 4dr	1	-0.4730	-37.7%	0.0715	-0.6132	-0.3327	43.69	<0.0001
	2015 BMW X1 4dr	1	-0.4318	-35.1%	0.0719	-0.5729	-0.2907	35.99	<0.0001
	2017 BMW X1 4dr	1	-0.4183	-34.2%	0.0748	-0.5650	-0.2715	31.21	<0.0001
	2013 BMW X1 4dr 4WD	1	-0.4555	-36.6%	0.0709	-0.5946	-0.3163	41.17	<0.0001
	2014 BMW X1 4dr 4WD	1	-0.4813	-38.2%	0.0706	-0.6198	-0.3428	46.39	<0.0001
	2015 BMW X1 4dr 4WD	1	-0.4865	-38.5%	0.0709	-0.6257	-0.3474	46.97	<0.0001
	2016 BMW X1 4dr 4WD	1	-0.4466	-36.0%	0.0709	-0.5857	-0.3075	39.59	<0.0001
	2017 BMW X1 4dr 4WD	1	-0.4492	-36.2%	0.0715	-0.5893	-0.3090	39.47	<0.0001
	2015 BMW X3 4dr	1	-0.4786	-38.0%	0.0812	-0.6378	-0.3194	34.73	<0.0001
	2016 BMW X3 4dr	1	-0.4373	-35.4%	0.0776	-0.5895	-0.2852	31.75	<0.0001
	2017 BMW X3 4dr	1	-0.4075	-33.5%	0.0717	-0.5482	-0.2669	32.28	<0.0001
	2013 BMW X3 4dr 4WD	1	-0.4799	-38.1%	0.0699	-0.6171	-0.3427	47.02	<0.0001
	2014 BMW X3 4dr 4WD	1	-0.4647	-37.2%	0.0699	-0.6019	-0.3275	44.09	<0.0001
	2015 BMW X3 4dr 4WD	1	-0.4396	-35.6%	0.0704	-0.5777	-0.3015	38.93	<0.0001
	2016 BMW X3 4dr 4WD	1	-0.4586	-36.8%	0.0702	-0.5963	-0.3210	42.67	<0.0001
	2017 BMW X3 4dr 4WD	1	-0.4280	-34.8%	0.0702	-0.5657	-0.2903	37.14	<0.0001
	2015 BMW X4 4dr 4WD	1	-0.2639	-23.2%	0.0731	-0.4072	-0.1205	13.02	0.0003
	2016 BMW X4 4dr 4WD	1	-0.2511	-22.2%	0.0728	-0.3939	-0.1083	11.88	0.0006

		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Parameter									
	2017 BMW X4 4dr 4WD	1	-0.3248	-27.7%	0.0768	-0.4754	-0.1742	17.87	<0.0001
	2014 BMW X5 4dr	1	-0.4026	-33.1%	0.0735	-0.5468	-0.2584	29.96	<0.0001
	2015 BMW X5 4dr	1	-0.4084	-33.5%	0.0733	-0.5521	-0.2647	31.02	<0.0001
	2016 BMW X5 4dr	1	-0.3712	-31.0%	0.0736	-0.5155	-0.2270	25.44	<0.0001
	2017 BMW X5 4dr	1	-0.3992	-32.9%	0.0728	-0.5420	-0.2563	30.01	<0.0001
	2013 BMW X5 4dr 4WD	1	-0.3801	-31.6%	0.0698	-0.5170	-0.2433	29.65	<0.0001
	2014 BMW X5 4dr 4WD	1	-0.3877	-32.1%	0.0702	-0.5254	-0.2501	30.49	<0.0001
	2015 BMW X5 4dr 4WD	1	-0.3865	-32.1%	0.0698	-0.5234	-0.2496	30.65	<0.0001
	2016 BMW X5 4dr 4WD	1	-0.3672	-30.7%	0.0701	-0.5047	-0.2297	27.41	<0.0001
	2017 BMW X5 4dr 4WD	1	-0.3675	-30.8%	0.0704	-0.5055	-0.2294	27.23	<0.0001
	2013 BMW X5 M 4dr 4WD	1	-0.4022	-33.1%	0.0899	-0.5785	-0.2260	20.01	<0.0001
	2015 BMW X5 M 4dr 4WD	1	-0.1641	-15.1%	0.0978	-0.3558	0.0276	2.81	0.0935
	2016 BMW X5 M 4dr 4WD	1	-0.2990	-25.8%	0.0859	-0.4675	-0.1304	12.09	0.0005
	2017 BMW X5 M 4dr 4WD	1	-0.1734	-15.9%	0.0907	-0.3513	0.0043	3.65	0.0559
	2015 BMW X6 4dr	1	-0.1980	-18.0%	0.1045	-0.4030	0.0069	3.59	0.0583
	2016 BMW X6 4dr	1	-0.0923	-8.8%	0.0840	-0.2570	0.0723	1.21	0.2717
	2017 BMW X6 4dr	1	-0.0826	-7.9%	0.0953	-0.2695	0.1043	0.75	0.3864
	2013 BMW X6 4dr 4WD	1	-0.1219	-11.5%	0.0720	-0.2630	0.0191	2.87	0.0904
	2014 BMW X6 4dr 4WD	1	-0.1498	-13.9%	0.0725	-0.2921	-0.0076	4.26	0.0389
	2015 BMW X6 4dr 4WD	1	-0.1343	-12.6%	0.0733	-0.2781	0.0095	3.35	0.0672
	2016 BMW X6 4dr 4WD	1	-0.1389	-13.0%	0.0727	-0.2815	0.0037	3.64	0.0563
	2017 BMW X6 4dr 4WD	1	-0.0630	-6.1%	0.0757	-0.2114	0.0852	0.69	0.4046
	2013 BMW X6 M 4dr 4WD	1	-0.2170	-19.5%	0.1039	-0.4207	-0.0134	4.36	0.0367
	2014 BMW X6 M 4dr 4WD	1	-0.0862	-8.3%	0.0933	-0.2691	0.0967	0.85	0.3557
	2015 BMW X6 M 4dr 4WD	1	-0.0183	-1.8%	0.0994	-0.2132	0.1766	0.03	0.8540
	2017 BMW X6 M 4dr 4WD	1	-0.0409	-4.0%	0.1036	-0.2441	0.1622	0.16	0.6929
	2013 Mini Cooper Clubman 2dr	1	-0.6270	-46.6%	0.0736	-0.7714	-0.4827	72.48	<0.0001
	2014 Mini Cooper Clubman 2dr	1	-0.6102	-45.7%	0.0762	-0.7596	-0.4607	64.06	<0.0001
	2016 Mini Cooper Clubman station wagon	1	-0.3681	-30.8%	0.0738	-0.5128	-0.2234	24.87	<0.0001
	2017 Mini Cooper Clubman station wagon	1	-0.3228	-27.6%	0.0775	-0.4747	-0.1709	17.35	<0.0001
	2017 Mini Cooper Clubman station wagon 4WD	1	-0.3322	-28.3%	0.0737	-0.4767	-0.1876	20.29	<0.0001
	2013 Mini Cooper convertible	1	-0.7441	-52.5%	0.0745	-0.8901	-0.5980	99.72	<0.0001
	2014 Mini Cooper convertible	1	-0.7197	-51.3%	0.0766	-0.8700	-0.5695	88.14	<0.0001
	2015 Mini Cooper convertible	1	-0.7342	-52.0%	0.0772	-0.8855	-0.5828	90.40	<0.0001
	2016 Mini Cooper convertible	1	-0.5339	-41.4%	0.0786	-0.6881	-0.3796	46.03	<0.0001
	2017 Mini Cooper convertible	1	-0.5814	-44.1%	0.0771	-0.7326	-0.4302	56.79	<0.0001
	2013 Mini Cooper Coupe 2dr	1	-0.5765	-43.8%	0.0767	-0.7269	-0.4260	56.41	<0.0001
	2014 Mini Cooper Coupe 2dr	1	-0.7139	-51.0%	0.0897	-0.8899	-0.5379	63.21	<0.0001
	2015 Mini Cooper Coupe 2dr	1	-0.4973	-39.2%	0.1049	-0.7030	-0.2915	22.44	<0.0001
	2013 Mini Cooper Hardtop 2dr	1	-0.5778	-43.9%	0.0701	-0.7153	-0.4404	67.89	<0.0001
	2014 Mini Cooper Hardtop 2dr	1	-0.5031	-39.5%	0.0713	-0.6430	-0.3632	49.67	<0.0001
	2015 Mini Cooper Hardtop 2dr	1	-0.4820	-38.2%	0.0705	-0.6202	-0.3438	46.73	<0.0001
	2016 Mini Cooper Hardtop 2dr	1	-0.4860	-38.5%	0.0724	-0.6280	-0.3440	45.03	<0.0001

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	2017 Mini Cooper Hardtop 2dr	1	-0.4228	-34.5%	0.0729	-0.5657	-0.2799	33.63	<0.0001
	2015 Mini Cooper Hardtop 4dr	1	-0.4193	-34.2%	0.0712	-0.5590	-0.2796	34.62	<0.0001
	2016 Mini Cooper Hardtop 4dr	1	-0.3995	-32.9%	0.0718	-0.5404	-0.2586	30.90	<0.0001
	2017 Mini Cooper Hardtop 4dr	1	-0.3773	-31.4%	0.0741	-0.5227	-0.2319	25.87	<0.0001
	2013 Mini Cooper Roadster convertible	1	-0.7362	-52.1%	0.0767	-0.8867	-0.5857	91.96	<0.0001
	2014 Mini Cooper Roadster convertible	1	-0.7974	-55.0%	0.0862	-0.9665	-0.6284	85.48	<0.0001
	2015 Mini Cooper Roadster convertible	1	-0.6618	-48.4%	0.0898	-0.8379	-0.4857	54.26	<0.0001
	2013 Mini Countryman station wagon	1	-0.7011	-50.4%	0.0719	-0.8422	-0.5600	94.87	<0.0001
	2014 Mini Countryman station wagon	1	-0.6595	-48.3%	0.0714	-0.7995	-0.5195	85.26	<0.0001
	2015 Mini Countryman station wagon	1	-0.6441	-47.5%	0.0723	-0.7860	-0.5022	79.16	<0.0001
	2016 Mini Countryman station wagon	1	-0.6345	-47.0%	0.0741	-0.7797	-0.4892	73.29	<0.0001
	2017 Mini Countryman station wagon	1	-0.6352	-47.0%	0.0827	-0.7974	-0.4730	58.93	<0.0001
	2013 Mini Countryman station wagon 4WD	1	-0.6912	-49.9%	0.0730	-0.8344	-0.5479	89.42	<0.0001
	2014 Mini Countryman station wagon 4WD	1	-0.6562	-48.1%	0.0726	-0.7985	-0.5139	81.70	<0.0001
	2015 Mini Countryman station wagon 4WD	1	-0.6793	-49.3%	0.0731	-0.8227	-0.5359	86.25	<0.0001
	2016 Mini Countryman station wagon 4WD	1	-0.6287	-46.7%	0.0733	-0.7725	-0.4849	73.42	<0.0001
	2017 Mini Countryman station wagon 4WD	1	-0.5800	-44.0%	0.0773	-0.7315	-0.4285	56.30	<0.0001
	2016 BMW X6 M 4dr 4WD	0	0	0.0%	0	0	0		
Rated driver age group	14–24	1	0.2266	25.4%	0.0060	0.2147	0.2385	1388.16	<0.0001
	25–29	1	0.2141	23.9%	0.0055	0.2032	0.2251	1463.38	<0.0001
	30–39	1	0.0776	8.1%	0.0041	0.0694	0.0857	351.98	<0.0001
	50–59	1	-0.0727	-7.0%	0.0041	-0.0808	-0.0646	311.75	<0.0001
	60–64	1	-0.1238	-11.6%	0.0057	-0.1352	-0.1125	458.32	<0.0001
	65–69	1	-0.1124	-10.6%	0.0065	-0.1252	-0.0996	298.04	<0.0001
	70+	1	-0.0132	-1.3%	0.0060	-0.0250	-0.0014	4.81	0.0283
	Unknown	1	-0.0468	-4.6%	0.0079	-0.0625	-0.0312	34.45	<0.0001
	40–49	0	0	0.0%	0	0	0		
Rated driver gender	Male	1	-0.0303	-3.0%	0.0027	-0.0357	-0.0248	117.86	<0.0001
	Unknown	1	-0.1227	-11.5%	0.0111	-0.1446	-0.1009	121.41	<0.0001
	Female	0	0	0.0%	0	0	0		
Rated driver marital status	Single	1	0.2401	27.1%	0.0030	0.2341	0.2462	6118.53	<0.0001
	Unknown	1	0.1147	12.2%	0.0104	0.0942	0.1351	120.91	<0.0001
	Married	0	0	0.0%	0	0	0		
Risk	Nonstandard	1	0.3173	37.3%	0.0061	0.3052	0.3294	2635.32	<0.0001
	Standard	0	0	0.0%	0	0	0		
State	Alabama	1	-0.0026	-0.3%	0.0162	-0.0345	0.0292	0.03	0.8710
	Alaska	1	0.2737	31.5%	0.0320	0.2109	0.3364	73.12	<0.0001
	Arizona	1	0.0236	2.4%	0.0113	0.0014	0.0459	4.35	0.0370
	Arkansas	1	-0.0024	-0.2%	0.0280	-0.0575	0.0525	0.01	0.9294

Appendix: Illustrative regression results — collision frequency								
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
	California	1	0.2847	32.9%	0.0054	0.2741	0.2953	2758.10	<0.0001
	Colorado	1	0.0493	5.1%	0.0111	0.0274	0.0712	19.50	<0.0001
	Connecticut	1	-0.0059	-0.6%	0.0114	-0.0283	0.0164	0.27	0.6032
	Delaware	1	0.0455	4.7%	0.0242	-0.0019	0.0930	3.54	<0.0001
	Dist of Columbia	1	0.3377	40.2%	0.0185	0.3014	0.3739	333.03	<0.0001
	Florida	1	-0.0514	-5.0%	0.0063	-0.0639	-0.0389	65.10	<0.0001
	Georgia	1	-0.0079	-0.8%	0.0086	-0.0249	0.0089	0.85	0.3561
	Hawaii	1	0.1791	19.6%	0.0175	0.1447	0.2134	104.47	<0.0001
	Idaho	1	-0.1441	-13.4%	0.0387	-0.2201	-0.0680	13.81	0.0002
	Illinois	1	-0.0163	-1.6%	0.0089	-0.0339	0.0013	3.29	0.0697
	Indiana	1	-0.0437	-4.3%	0.0167	-0.0765	-0.0108	6.80	0.0091
	Iowa	1	-0.1627	-15.0%	0.0292	-0.2200	-0.1054	30.95	<0.0001
	Kansas	1	-0.0672	-6.5%	0.0240	-0.1143	-0.0200	7.80	0.0052
	Kentucky	1	-0.2193	-19.7%	0.0225	-0.2635	-0.1750	94.55	<0.0001
	Louisiana	1	0.1147	12.2%	0.0154	0.0843	0.1450	54.83	<0.0001
	Maine	1	0.0329	3.3%	0.0380	-0.0416	0.1076	0.75	0.3868
	Maryland	1	0.1418	15.2%	0.0094	0.1232	0.1604	223.43	<0.0001
	Massachusetts	1	0.5215	68.5%	0.0097	0.5023	0.5407	2840.33	<0.0001
	Michigan	1	0.2965	34.5%	0.0130	0.2710	0.3220	520.26	<0.0001
	Minnesota	1	-0.1318	-12.3%	0.0147	-0.1606	-0.1030	80.38	<0.0001
	Mississippi	1	0.0852	8.9%	0.0271	0.0319	0.1385	9.84	0.0017
	Missouri	1	-0.0363	-3.6%	0.0167	-0.0691	-0.0035	4.72	0.0297
	Montana	1	-0.0392	-3.8%	0.0715	-0.1793	0.1008	0.30	0.5831
	Nebraska	1	-0.1320	-12.4%	0.0339	-0.1985	-0.0655	15.15	0.0001
	Nevada	1	0.1332	14.2%	0.0141	0.1055	0.1609	88.87	<0.0001
	New Hampshire	1	0.1188	12.6%	0.0202	0.0791	0.1584	34.50	<0.0001
	New Jersey	1	0.0224	2.3%	0.0075	0.0077	0.0371	8.94	0.0028
	New Mexico	1	0.1024	10.8%	0.0230	0.0572	0.1477	19.69	<0.0001
	New York	1	0.2639	30.2%	0.0067	0.2508	0.2770	1551.76	<0.0001
	North Carolina	1	-0.1851	-16.9%	0.0106	-0.2060	-0.1642	302.00	<0.0001
	North Dakota	1	0.0692	7.2%	0.0848	-0.0970	0.2355	0.67	0.4145
	Ohio	1	-0.1512	-14.0%	0.0119	-0.1746	-0.1279	160.88	<0.0001
	Oklahoma	1	-0.0254	-2.5%	0.0202	-0.0651	0.0142	1.58	0.2093
	Oregon	1	-0.0420	-4.1%	0.0140	-0.0695	-0.0145	8.99	0.0027
	Pennsylvania	1	0.1489	16.1%	0.0083	0.1325	0.1653	317.71	<0.0001
	Rhode Island	1	0.1197	12.7%	0.0217	0.0772	0.1623	30.40	<0.0001
	South Carolina	1	-0.1627	-15.0%	0.0145	-0.1912	-0.1342	125.10	<0.0001
	South Dakota	1	-0.1298	-12.2%	0.0656	-0.2586	-0.0011	3.91	0.0480
	Tennessee	1	-0.0068	-0.7%	0.0137	-0.0337	0.0201	0.25	0.6202
	Utah	1	-0.1232	-11.6%	0.0221	-0.1665	-0.0798	31.02	<0.0001
	Vermont	1	-0.0608	-5.9%	0.0414	-0.1420	0.0203	2.16	0.1419
	Virginia	1	0.0488	5.0%	0.0090	0.0310	0.0666	29.00	<0.0001
	Washington	1	0.0054	0.5%	0.0105	-0.0152	0.0260	0.26	0.6085
	West Virginia	1	-0.0400	-3.9%	0.0377	-0.1139	0.0338	1.13	0.2884

		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Appendix: Illustrative regression results — collision frequency									
Parameter									
	Wisconsin	1	-0.1024	-9.7%	0.0188	-0.1393	-0.0654	29.52	<0.0001
	Wyoming	1	-0.0587	-5.7%	0.0687	-0.1935	0.0761	0.73	0.3935
	Texas	0	0	0.0%	0	0	0		
Deductible range	0–250	1	0.0940	9.9%	0.0038	0.0865	0.1015	609.14	<0.0001
	501–1000	1	-0.1942	-17.7%	0.0031	-0.2004	-0.1880	3781.34	<0.0001
	1001+	1	-0.5523	-42.4%	0.0118	-0.5756	-0.5290	2162.52	<0.0001
	251–500	0	0	0.0%	0	0	0		
Registered vehicle density	0–99	1	-0.1854	-16.9%	0.0060	-0.1973	-0.1735	932.43	<0.0001
	100–499	1	-0.1436	-13.4%	0.0035	-0.1506	-0.1366	1620.32	<0.0001
	500+	0	0	0.0%	0	0	0		
Forward Alerts package		1	0.0118	1.2%	0.0241	-0.0356	0.0592	0.24	0.6252
Forward Alerts/Automatic Braking package		1	-0.0728	-7.0%	0.0104	-0.0933	-0.0523	48.49	<0.0001
Driving Assistance package		1	-0.0694	-6.7%	0.0390	-0.1459	0.0070	3.17	0.0752
Driving Assistance Plus package		1	-0.0899	-8.6%	0.0148	-0.1190	-0.0609	36.84	<0.0001
Blind spot detection		1	-0.0003	0.0%	0.0102	-0.0205	0.0197	0.00	0.9699
High-beam assistant		1	0.0153	1.5%	0.0054	0.0046	0.0260	7.86	0.0051
Adaptive headlights		1	-0.0123	-1.2%	0.0051	-0.0223	-0.0023	5.84	0.0157
Night Vision package		1	-0.0477	-4.7%	0.0233	-0.0935	-0.0020	4.19	0.0406
Park distance control		1	-0.0029	-0.3%	0.0070	-0.0167	0.0108	0.17	0.6781
Rearview camera and park distance control		1	-0.0121	-1.2%	0.0038	-0.0198	-0.0045	9.76	0.0018
Surround View package		1	0.0013	0.1%	0.0102	-0.0186	0.0213	0.02	0.8929
Parking Assistant package		1	0.0188	1.9%	0.0104	-0.0015	0.0393	3.27	0.0705
Parking Assistant Plus package		1	-0.0827	-7.9%	0.0232	-0.1282	-0.0371	12.67	0.0004