



2013–17 BMW collision avoidance features

► Summary

This study examines collision avoidance features offered by BMW on its vehicles from model years 2013–17 and the effects of these features on insurance losses. Some of the features available include advanced front crash prevention systems, side- and lane-assist systems, advanced headlight technologies, and parking-assist systems. Claim frequency results for BMW's collision avoidance features are shown in the table below. Statistically significant results are bolded. Many of BMW's systems were associated with significant reductions in the frequency of both vehicle damage and injury claims.

The Forward Alerts package, which includes forward collision warning and lane departure warning, was associated with claim frequency increases under collision, property damage liability (PDL), and bodily injury (BI) liability coverages, but none of the results were statistically significant. It is unclear why the Forward Alerts package would result in claim frequency increases. However, BMW's more advanced front crash prevention system, the Forward Alerts/Automatic Braking package, which additionally includes an automatic emergency braking system, 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 on reducing claim frequency for all coverage types, but only the results for PDL and BI were statistically significant. The most advanced Driving Assistance Plus package includes the features in the Driving Assistance package as well as front cross-traffic alert and lane-steering assistant. This package also showed large benefits under all coverages, and the results for collision, PDL, and BI were 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	2.1%	-5.3%	-5.8%	-7.3%	-0.9%	1.4%	-1.3%
Property damage liability	4.6%	-11.0%	-27.3%	-26.1%	-2.0%	-2.3%	-9.4%
Injury coverage type							
Bodily injury liability	10.9%	-15.8%	-37.4%	-29.2%	-11.3%	1.6%	-7.8%
Medical payment	-17.8%	-3.4%	-10.2%	-12.6%	-7.1%	-0.4%	-0.4%
Personal injury protection	-2.7%	-4.3%	-13.5%	-10.6%	-9.4%	-3.2%	-3.3%
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	-6.6%	-0.4%	-0.8%	1.0%	2.5%	-9.3%	
Property damage liability	-16.6%	-2.3%	-4.7%	-0.9%	-0.4%	-4.4%	
Injury coverage type							
Bodily injury liability	-20.7%	-1.9%	-3.9%	-2.4%	5.5%	-17.6%	
Medical payment	-5.2%	-10.1%	-5.0%	1.2%	-13.9%	-33.1%	
Personal injury protection	-12.3%	-2.1%	-4.3%	-2.7%	1.1%	-9.2%	

Other systems also showed frequency benefits for most coverage types. Blind spot detection was associated with claim frequency reductions for all coverage types, especially for BI and personal injury protection; the Night Vision package, which includes a night vision camera and adaptive headlights, showed significant and larger benefits on 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 benefits found for nearly all coverages; the advanced parking-assist package Parking Assistant Plus reduced the claim frequencies for all coverages, with the results for collision and medical payment being statistically significant.

In addition to the strong claim frequency benefits, 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, 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, for this night-assist package, overall losses were down for the 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 due to the systems primarily preventing low-cost claims. As a result, overall losses were reduced for PDL.

► Introduction

The Highway Loss Data Institute (HLDI) has evaluated and reported on collision avoidance technologies since 2009. This bulletin provides a first look at the effect of BMW's collision avoidance features on insurance losses. The following features were 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 which signals a warning with an emerging danger of collision or if the distance to the vehicle in front is very short, and at the same time, the brake system will be made ready for a possible full application of the brake. The second warning step is the acute warning in the event of an imminent 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 up 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 (FCTA) assists the driver when maneuvering out of a parking space and in daily situations when it is difficult to see crossing traffic, such as at 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 using a turn signal, the system produces a gentle but noticeable vibration in the steering wheel to warn of an unintended drift.

Lane-steering assistant (LSA) 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 lane 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 level of 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 (HBA) 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 adjust the vehicle's headlamp lights to follow 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 acute visual warning in the instrument cluster. Additionally, a thermal image can be displayed in the control display.

Parking-assist systems

Rearview camera (RVC) 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 (PDC) 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 of 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 (APDC) 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 braking 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, manufacturers 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 instead 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	119,655
BMW	3 series	2013–17	1,558,365
BMW	4 series	2014–17	424,319
BMW	5 series	2013–17	763,048
BMW	5 Series GT	2013–17	21,129
BMW	6 series	2013–17	122,124
BMW	7 series	2013–17	142,410
BMW	X1	2013–17	393,945
BMW	X3	2013–17	663,739
BMW	X4	2015–17	42,781
BMW	X5	2013–17	686,964
BMW	X6	2013–17	94,032
Mini	Clubman	2016–17	36,681
Mini	Cooper	2013–17	592,331
Mini	Countryman	2013–17	279,773
Total collision exposure			5,941,297

Table 1B: Percent of collision exposure with feature

Feature	Collision exposure with feature
Forward collision warning	10%
Automatic emergency breaking	10%
Active cruise control	<1%
Driving Assistant Plus package	2%
Blind spot detection	14%
Lane departure warning	11%
High-beam assistant	11%
Adaptive headlights	54%
Night vision with pedestrian detection	<1%
Rearview camera	62%
Park distance control	65%
Surround view	13%
Parking assistant	4%
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, because manufacturers are increasingly bundling systems and individual sensors 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 feature 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 regression 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 appropriate. HLDI uses its best judgement in determining whether to present results for an individual or a combined system based on an 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 package	Active cruise control	
		Automatic emergency braking	
		Forward collision warning	
	Driving Assistance Plus package	Lane departure warning	
		Active cruise control	
		Automatic emergency braking	
		Forward collision warning	
Lane departure warning			
Driving Assistance Plus package	Front cross-traffic alert		
	Lane-steering assistant		
	Lane departure warning		
	Forward collision warning		
	Automatic emergency braking		
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	
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	
	Surround View package	Rearview camera	
		Parking assistant	
	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: 72.8 percent for PIP, 66.5 percent for BI, and 59.2 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 -0.06 ; thus, vehicles with the Driving Assistance package had 5.8 percent fewer collision claims than vehicles without the Driving Assistance package ($(\exp(-0.06)-1)\times 100=-5.8$).

► 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 2 percent, and PDL claim frequency was up by 5 percent. Both collision and PDL claim severities were up by 7 percent, resulting in a 9 percent increase in collision overall losses and an 11 percent increase in PDL overall losses. Only the estimates for collision claim severity and overall losses were statistically significant.

For injury losses, the results were mixed and none of them were 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	-3.0%	2.1%	7.5%	0.6%	6.7%	13.1%	0.8%	8.9%	17.8%
Property damage liability	-3.6%	4.6%	13.5%	-1.7%	6.5%	15.3%	-0.6%	11.4%	24.9%

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	-11.0%	10.9%	38.1%	-30.9%	4.6%	58.3%	-14.0%	20.6%	69.2%
Medical payment	-38.3%	-17.8%	9.6%	-73.3%	-34.5%	60.7%	-45.8%	-18.4%	22.9%
Personal injury protection	-20.8%	-2.7%	19.5%	-42.8%	-2.1%	67.7%	-19.0%	5.3%	36.9%

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 (forward collision warning, automatic emergency braking, and lane departure warning), compared with vehicles without any of these features.

Collision coverage showed a 5 percent decrease in claim frequency, and a 1 percent decrease in severity, resulting in a 6 percent decrease in overall losses. PDL claim frequency was down by 11 percent, with severity down by 3 percent, leading to a 14 percent decrease in overall losses. All the vehicle damage claim frequency and overall losses results were statistically significant.

For injury losses, claim frequencies were lower for vehicles equipped with this package compared with their counterparts without under all three injury coverage types, but only the result for BI was statistically significant. Low-severity claim frequency for BI and MedPay and high-severity claim frequency for PIP showed statistically significant reductions of 25, 33, and 11 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	-7.5%	-5.3%	-3.1%	-3.7%	-1.1%	1.5%	-9.6%	-6.4%	-3.1%
Property damage liability	-14.5%	-11.0%	-7.3%	-6.9%	-3.2%	0.8%	-18.6%	-13.8%	-8.8%

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	-24.7%	-15.8%	-5.9%	-38.8%	-24.5%	-6.9%	-24.3%	-9.2%	8.9%
Medical payment	-14.3%	-3.4%	8.9%	-52.7%	-32.5%	-3.6%	-14.8%	1.2%	20.2%
Personal injury protection	-12.5%	-4.3%	4.6%	-13.4%	9.2%	37.6%	-21.3%	-11.4%	-0.3%

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 6 and 27 percent for collision and PDL, respectively, with the result for PDL being significant. Claim severity for both collision and PDL decreased (11 and 9 percent, respectively), with the result for collision being statistically significant. This resulted in a significant 16 percent decrease in overall losses for collision and a significant 34 percent decrease for PDL.

For injury losses, overall claim frequencies were down by 37, 10, and 14 percent for BI, MedPay, and PIP, respectively, but only the result for BI was 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.

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%	-5.8%	2.6%	-19.5%	-11.3%	-2.1%	-26.6%	-16.4%	-4.8%
Property damage liability	-38.4%	-27.3%	-14.3%	-22.3%	-8.5%	7.6%	-47.3%	-33.5%	-16.2%

Injury coverage type	Lower bound	FREQUENCY	Upper bound	Lower bound	LOW-SEVERITY FREQUENCY	Upper bound	Lower bound	HIGH-SEVERITY FREQUENCY	Upper bound
Bodily injury liability	-60.1%	-37.4%	-1.8%	-62.8%	-20.3%	70.8%	-63.1%	-26.0%	48.3%
Medical payment	-46.7%	-10.2%	51.1%	-96.4%	-68.5%	176.5%	-26.6%	43.7%	181.3%
Personal injury protection	-41.6%	-13.5%	28.1%	0.4%	124.1%	400.3%	-67.7%	-42.5%	2.6%

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 in both collision and PDL claim frequencies by 7 and 26 percent, respectively, while the claim severities were down insignificantly by 1 and 3 percent, leading to a significant 8 percent decrease in overall losses for collision and a significant 28 percent decrease for PDL.

For injury losses, claim frequencies for all coverage types were lower, with the result for BI being statistically significant (29 percent). Among paid claims, reductions were observed for all low- and high-severity claim frequencies, with the results for low-severity BI and MedPay claims being statistically significant (45 and 47 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	-10.3%	-7.3%	-4.2%	-4.3%	-0.5%	3.4%	-12.4%	-7.8%	-3.0%
Property damage liability	-30.4%	-26.1%	-21.5%	-8.5%	-2.8%	3.3%	-34.0%	-28.2%	-21.8%

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	-40.1%	-29.2%	-16.5%	-60.7%	-45.1%	-23.4%	-41.7%	-23.3%	0.8%
Medical payment	-26.2%	-12.6%	3.4%	-69.4%	-47.1%	-8.3%	-34.5%	-16.3%	7.0%
Personal injury protection	-22.0%	-10.6%	2.5%	-45.6%	-19.4%	19.5%	-30.0%	-16.0%	0.9%

Results for BMW’s blind spot detection system are shown in **Table 7**. Both collision and PDL claim frequencies showed slight insignificant decreases. Collision claim severity was significantly down by 3 percent, resulting in a significant 4 percent decrease in overall losses. PDL claim severity decreased significantly by 4 percent. Consequently, PDL overall losses decreased by a significant 6 percent.

Overall claim frequencies for the injury coverages were down, with BI and PIP results statistically significant.

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	-3.1%	-0.9%	1.4%	-5.6%	-3.1%	-0.6%	-7.2%	-3.9%	-0.6%
Property damage liability	-5.8%	-2.0%	1.8%	-7.7%	-4.1%	-0.4%	-11.0%	-6.1%	-0.8%

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	-20.2%	-11.3%	-1.5%	-12.8%	5.9%	28.7%	-37.1%	-25.3%	-11.4%
Medical payment	-17.2%	-7.1%	4.2%	0.7%	40.3%	95.5%	-22.1%	-8.2%	8.3%
Personal injury protection	-16.8%	-9.4%	-1.4%	-35.6%	-19.4%	1.0%	-14.3%	-4.2%	7.0%

Table 8 shows the results for high-beam assistant. Claim frequency for collision was significantly up by 1 percent, while frequency for PDL showed a significant 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 only the low-severity claim frequency for PIP was associated with a significant reduction (14 percent).

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	0.2%	1.4%	2.6%	3.3%	4.8%	6.2%	4.3%	6.2%	8.2%
Property damage liability	-4.3%	-2.3%	-0.2%	1.1%	3.2%	5.3%	-2.1%	0.8%	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	-3.9%	1.6%	7.4%	-8.0%	2.6%	14.4%	-10.8%	-2.5%	6.6%
Medical payment	-6.4%	-0.4%	6.0%	-5.7%	14.0%	37.8%	-9.2%	-0.8%	8.5%
Personal injury protection	-7.7%	-3.2%	1.4%	-24.5%	-13.9%	-1.7%	-9.8%	-4.0%	2.2%

Table 9 summarizes the results for adaptive headlights. For vehicle damage losses, claim frequencies were down by 1 and 9 percent for collision and PDL coverages, respectively, with both results being significant. Claim severity for collision was up by 8 percent and remained essentially unchanged for PDL, but only the result for collision was significant. Consequently, collision overall losses went up significantly by 7 percent, and PDL overall losses went down significantly by 9 percent.

Reductions in claim frequency were observed for all injury coverages, with the exception of the high-severity MedPay claims. Only the results for overall and low-severity claims for BI 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	-2.4%	-1.3%	-0.2%	6.7%	8.1%	9.5%	4.8%	6.7%	8.5%
Property damage liability	-11.1%	-9.4%	-7.7%	-1.7%	0.1%	1.9%	-11.6%	-9.3%	-6.9%

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	-12.3%	-7.8%	-3.0%	-18.4%	-10.3%	-1.3%	-10.4%	-3.0%	5.1%
Medical payment	-5.7%	-0.4%	5.3%	-17.3%	-3.1%	13.6%	-6.4%	1.4%	9.7%
Personal injury protection	-7.2%	-3.3%	0.8%	-13.9%	-4.7%	5.5%	-6.0%	-0.7%	4.9%

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 7 percent, while claim severity went up significantly by 17 percent. This resulted in a significant 9 percent increase in overall losses. PDL claim frequency was down by 17 percent, with severity up by 9 percent, resulting in a 10 percent decrease in overall losses. Only the PDL result for claim frequency was statistically significant.

For injury losses, claim frequency was lower for all coverages, but none of the changes were statistically significant. High-severity claim frequency for PIP declined significantly by 29 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	-11.4%	-6.6%	-1.5%	9.6%	16.5%	23.8%	0.4%	8.8%	18.0%
Property damage liability	-24.5%	-16.6%	-8.0%	-1.7%	8.5%	19.7%	-21.3%	-9.6%	3.9%

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	-40.1%	-20.7%	5.0%	-55.5%	-22.3%	35.7%	-46.6%	-15.2%	34.6%
Medical payment	-28.2%	-5.2%	25.3%	-69.9%	-16.0%	134.7%	-23.4%	11.7%	62.9%
Personal injury protection	-29.9%	-12.3%	9.7%	-34.4%	16.8%	107.9%	-49.1%	-28.9%	-0.7%

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 2 percent. Claim frequency for PDL decreased by 2 percent, and the severity increased by 2 percent, which offset the frequency benefits and led to the unchanged overall losses. None of the PDL results were significant.

Under injury coverages, claim frequency was lower for all three coverage types, with the reduction for MedPay being statistically significant (10 percent). Among paid claims, the results were mixed 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	-2.0%	-0.4%	1.1%	1.1%	2.8%	4.7%	0.0%	2.4%	4.8%
Property damage liability	-4.7%	-2.3%	0.2%	-0.3%	2.2%	4.7%	-3.5%	-0.2%	3.3%

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	-8.1%	-1.9%	4.8%	-19.7%	-8.7%	3.8%	-9.9%	-0.1%	10.7%
Medical payment	-16.5%	-10.1%	-3.1%	-12.8%	7.4%	32.4%	-20.6%	-11.4%	-1.2%
Personal injury protection	-7.4%	-2.1%	3.5%	-15.2%	-1.9%	13.6%	-11.9%	-5.1%	2.2%

Table 12 displays the results for vehicles with both rearview camera and park distance control. For vehicle damage losses, collision claim frequency was down by 1 percent, and claim severity was up by 5 percent, leading to a 4 percent increase in overall losses. PDL claim frequency was down by 5 percent, and claim severity was up by 4 percent, resulting in a 1 percent decrease in overall losses. All results except collision claim frequency and PDL overall losses were statistically significant.

For injury losses, claim frequency was significantly lower for all three coverage types. Among paid claims, significant reductions were observed for low-severity MedPay claims (13 percent) and high-severity BI and PIP claims (6 and 7 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	-1.7%	-0.8%	0.1%	3.6%	4.6%	5.7%	2.4%	3.8%	5.2%
Property damage liability	-6.1%	-4.7%	-3.4%	2.1%	3.6%	5.0%	-3.3%	-1.3%	0.6%

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	-7.4%	-3.9%	-0.2%	-8.6%	-1.8%	5.6%	-11.8%	-6.4%	-0.6%
Medical payment	-9.0%	-5.0%	-0.9%	-23.5%	-13.2%	-1.5%	-9.7%	-4.0%	2.2%
Personal injury protection	-7.2%	-4.3%	-1.3%	-6.2%	1.5%	9.8%	-10.9%	-7.2%	-3.4%

The results for vehicles with surround view along with rearview camera are shown in **Table 13**. No significant claim frequency reductions were found. Collision claim severity went up significantly by 3 percent, resulting in a significant 4 percent increase in overall losses.

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	-1.3%	1.0%	3.3%	0.5%	3.1%	5.8%	0.6%	4.1%	7.8%
Property damage liability	-4.5%	-0.9%	2.9%	-2.5%	1.1%	4.9%	-4.9%	0.2%	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	-11.7%	-2.4%	8.0%	-11.4%	7.9%	31.4%	-15.6%	-0.9%	16.3%
Medical payment	-9.7%	1.2%	13.4%	-42.2%	-19.0%	13.4%	-17.8%	-3.0%	14.5%
Personal injury protection	-10.6%	-2.7%	6.0%	-17.2%	3.8%	30.2%	-13.4%	-3.2%	8.4%

Table 14 shows the change in insurance losses for parking assistant with rearview camera. Collision claims were associated with a significant 3 percent increase in frequency and an insignificant 1 percent increase in severity, resulting in a significant 4 percent increase in overall losses. The results for PDL losses showed essentially no change, and none of the results were significant. Significant reductions in overall and high-severity MedPay claim frequencies were observed.

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	0.1%	2.5%	5.0%	-1.3%	1.3%	4.1%	0.3%	3.9%	7.7%
Property damage liability	-4.4%	-0.4%	3.8%	-4.6%	-0.7%	3.4%	-6.6%	-1.0%	4.8%

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	-5.5%	5.5%	17.6%	-6.8%	14.9%	41.7%	-15.6%	1.0%	20.9%
Medical payment	-24.0%	-13.9%	-2.5%	-48.0%	-22.9%	14.1%	-33.7%	-20.3%	-4.3%
Personal injury protection	-8.2%	1.1%	11.3%	-25.6%	-3.5%	25.2%	-11.9%	0.1%	13.8%

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 (9 percent), while the claim severity remained essentially unchanged, resulting in a significant 9 percent decrease in overall losses.

For injury losses, all three coverages were associated with reductions in overall claim frequency, with MedPay showing a significant 33 percent reduction.

**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	-14.2%	-9.3%	-4.2%	-5.7%	0.6%	7.3%	-16.2%	-8.8%	-0.7%
Property damage liability	-13.8%	-4.4%	6.1%	-8.0%	2.5%	14.2%	-15.6%	-2.0%	13.9%

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	-36.5%	-17.6%	6.9%	-34.1%	14.0%	97.3%	-45.2%	-16.1%	28.2%
Medical payment	-48.7%	-33.1%	-12.8%	-69.7%	-26.6%	78.0%	-51.7%	-30.0%	1.4%
Personal injury protection	-29.0%	-9.2%	16.2%	-43.2%	27.6%	186.7%	-38.1%	-13.8%	20.0%

► Discussion

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) and lane departure warning (LDW) systems. The FCW and automatic braking functions of these packages are designed to primarily prevent front-to-rear crashes, while the LDW functions are intended to prevent crashes associated with drifting into an adjacent lane. The results for the BMW's Forward Alerts package (includes FCW and LDW) are puzzling because previous HLDI analyses found claim frequency benefits associated with this combination of features (HLDI, 2018b). The claim frequency increases under collision, PDL and BI coverages observed in the present study were not statistically significant but inconsistent with previous research. A possible reason could be that the Forward Alerts package was only available on relatively few 2013–14 model year vehicles, and thus 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 additionally includes the automatic emergency braking system, was associated with claim frequency reductions under all coverage types, with the results for collision, PDL, and BI being statistically significant. Although the benefits for collision and PDL claim severity were not significant, collision and PDL overall losses declined significantly by 6 and 14 percent, respectively.

The more advanced Driving Assistance package that includes the active cruise control system showed larger frequency benefits across the board, with the results for PDL and BI being statistically significant. The Driving Assistance Plus package was also associated with frequency benefits, 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. The Driving Assistance Plus package reductions for PDL and BI claim frequencies were similar to the package with fewer features. The findings are consistent with the results of other manufacturers.

Side-assist systems

BMW offers three side-assist systems: blind spot detection, lane departure warning, and lane-steering assistant. The latter two systems were grouped within the front crash prevention packages mentioned in the previous section.

Claim frequency benefits were observed under all coverage types for blind spot detection. Collision and PDL coverages also showed significant reductions in claim severity and overall losses. 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 both BI and 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.

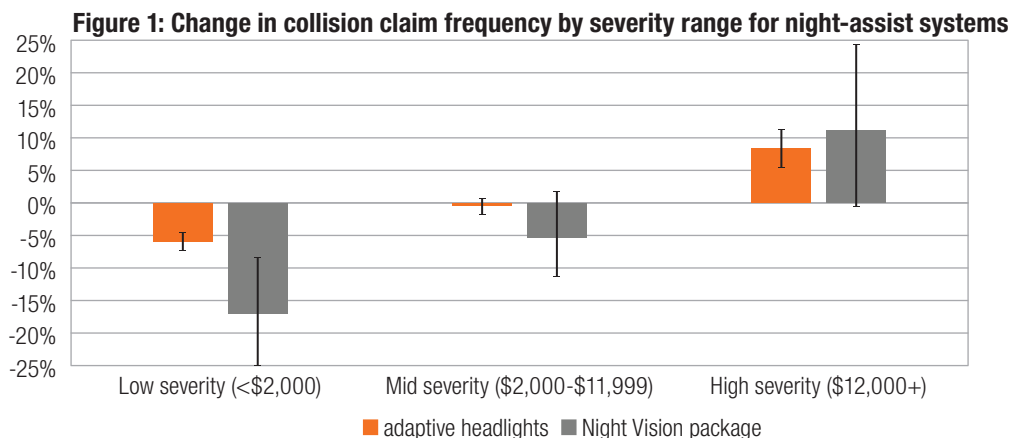
Night-assist systems

BMW's high-beam assistant did not show a consistent pattern of changes in claim frequency for all coverage types. A slight but significant increase was observed for collision claim frequency (1 percent), and a significant 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 system 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 and are associated with increased collision claim severities. For example, the cost of a single side headlight assembly for a 2013 3-series vehicle was approximately \$550 for the basic version, and over \$1,500 for adaptive headlights. Consequently, the system was associated with a significant 7 percent increase in overall losses for collision. The essentially unchanged PDL claim severity and the significant frequency reduction resulted in a significant 9 percent decrease in 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 headlight results, collision claim severity increased significantly. However, the severity increase was over double that of adaptive headlights alone (16 versus 8 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 the adaptive headlights system was associated with an increase in the frequency of high-severity collision claims, but a reduction in the frequency of low-severity claims. Mid-severity claim frequency was unchanged. The Night Vision package, on the other hand, was associated with reductions to both low- and mid-severity collision claim frequencies and an increase in high-severity collision claims. 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.



Parking-assist systems

BMW's park distance control was associated with reductions in claim frequency under all coverage types, with only the result for MedPay being significant. Vehicles equipped with both rearview camera and park distance control showed frequency reductions under all coverage types as well, with almost 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 slightly but insignificantly 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, 2018a) 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**, the collision and PDL claim frequencies for low-severity claims were lower for vehicles with both rearview camera and park distance control and only park distance control, while the frequencies for high-severity claims increased. Vehicles with only park distance control did not have much impact on mid-severity claim frequencies for both collision and PDL. Vehicles with both rearview camera and park distance control could increase the frequency for mid-severity collision claims but showed benefits on PDL claims.

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

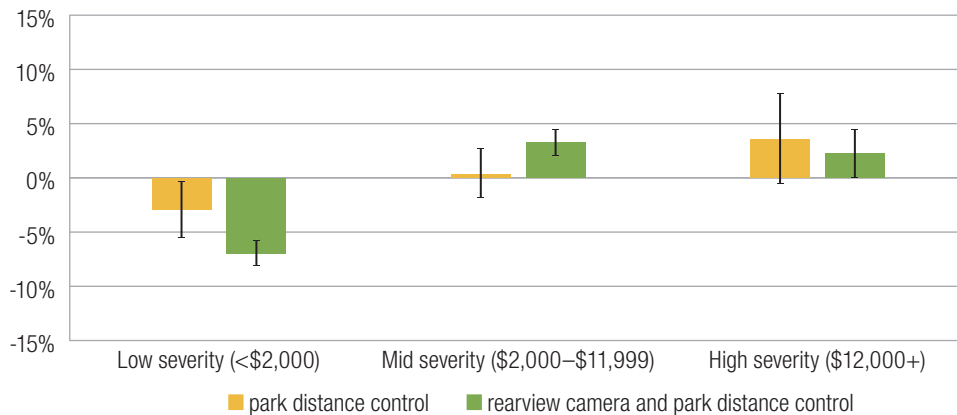
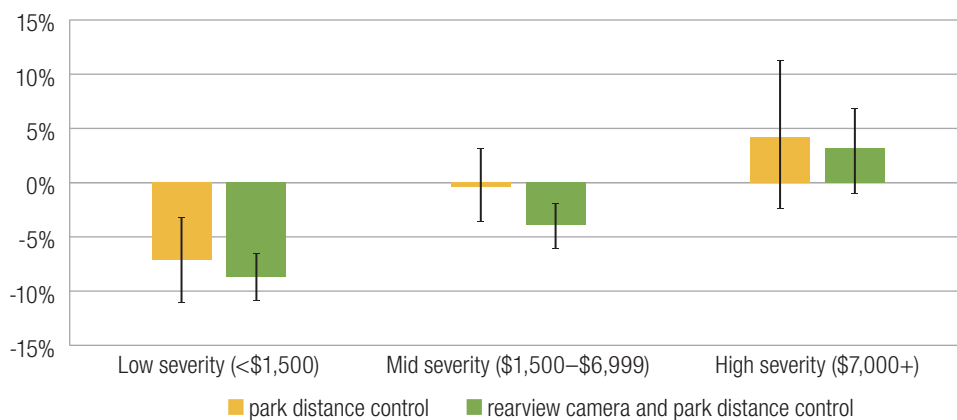


Figure 3: Change in PDL claim frequency by severity range for rearview camera and park distance control



Collision and PDL claim frequencies for BMW's Surround view package remained essentially unchanged, and the result for collision claim severity and overall losses were similar to those of rearview camera and park distance control. These results are somewhat 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 the rearview camera and park distance control results.

The parking assistant is designed to help the driver with parallel parking by automatically steering the vehicle into a detected parking space. The system was only associated with significant benefits on MedPay claim frequency. However, it is unclear how often people may be using this system, and if the relevant crash situations produce enough claims for any potential benefit from 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 Insurance 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 addressed 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	-8.2292		0.0823	-8.3906	-8.0679	9988.98	<0.0001
Calendar year	2012	1	-0.2816	-24.5%	0.0297	-0.3399	-0.2232	89.40	<0.0001
	2013	1	-0.0127	-1.3%	0.0091	-0.0307	0.0052	1.93	0.1646
	2014	1	0.0252	2.6%	0.0064	0.0126	0.0378	15.45	0.0001
	2015	1	0.0480	4.9%	0.0052	0.0378	0.0582	85.14	<0.0001
	2016	1	0.0304	3.1%	0.0046	0.0214	0.0395	43.34	<0.0001
	2017	1	0.0174	1.8%	0.0042	0.0090	0.0259	16.54	<0.0001
	2019	1	-0.0669	-6.5%	0.0053	-0.0774	-0.0564	156.16	<0.0001
	2018	0	0	0	0	0	0		
Vehicle model year and series	2014 BMW 228 I 2dr	1	-0.2133	-19.2%	0.0878	-0.3855	-0.0412	5.90	0.0151
	2015 BMW 228 I 2dr	1	-0.2828	-24.6%	0.0904	-0.4602	-0.1055	9.77	0.0018
	2016 BMW 228 I 2dr	1	-0.2187	-19.6%	0.0887	-0.3926	-0.0448	6.08	0.0137
	2015 BMW 228 I convertible	1	-0.1827	-16.7%	0.1012	-0.3812	0.0157	3.26	0.0711
	2016 BMW 228 I convertible	1	-0.2747	-24.0%	0.0933	-0.4577	-0.0917	8.66	0.0033
	2015 BMW 228 XI 2dr 4WD	1	-0.2191	-19.7%	0.0921	-0.3997	-0.0386	5.66	0.0173
	2016 BMW 228 XI 2dr 4WD	1	-0.1808	-16.5%	0.0915	-0.3602	-0.0013	3.90	0.0483
	2015 BMW 228 XI convertible 4WD	1	-0.2579	-22.7%	0.1013	-0.4565	-0.0593	6.48	0.0109
	2016 BMW 228 XI convertible 4WD	1	-0.2157	-19.4%	0.0933	-0.3987	-0.0327	5.34	0.0208
	2017 BMW 230 I 2dr	1	-0.2710	-23.7%	0.1042	-0.4753	-0.0668	6.77	0.0093
	2017 BMW 230 I convertible	1	-0.2459	-21.8%	0.1063	-0.4542	-0.0375	5.35	0.0207
	2017 BMW 230 XI 2dr 4WD	1	-0.2492	-22.1%	0.1147	-0.4741	-0.0243	4.72	0.0298
	2017 BMW 230 XI convertible 4WD	1	-0.1946	-17.7%	0.1108	-0.4119	0.0226	3.08	0.0792
	2013 BMW 320 I 4dr	1	-0.1720	-15.8%	0.0853	-0.3393	-0.0046	4.06	0.0440
	2014 BMW 320 I 4dr	1	-0.1828	-16.7%	0.0831	-0.3457	-0.0199	4.84	0.0278
	2015 BMW 320 I 4dr	1	-0.1751	-16.1%	0.0833	-0.3383	-0.0118	4.42	0.0355
	2016 BMW 320 I 4dr	1	-0.1310	-12.3%	0.0842	-0.2961	0.0341	2.42	0.1200
	2017 BMW 320 I 4dr	1	-0.1802	-16.5%	0.0867	-0.3503	-0.0101	4.32	0.0378
	2013 BMW 320 XI 4dr 4WD	1	-0.2040	-18.5%	0.0861	-0.3728	-0.0351	5.61	0.0179
	2014 BMW 320 XI 4dr 4WD	1	-0.1562	-14.5%	0.0833	-0.3196	0.0070	3.52	0.0608
	2015 BMW 320 XI 4dr 4WD	1	-0.1815	-16.6%	0.0838	-0.3459	-0.0172	4.69	0.0304
	2016 BMW 320 XI 4dr 4WD	1	-0.1236	-11.6%	0.0849	-0.2901	0.0429	2.11	0.1459
	2017 BMW 320 XI 4dr 4WD	1	-0.1951	-17.7%	0.0881	-0.3678	-0.0224	4.91	0.0268
	2014 BMW 328 D 4dr	1	-0.2010	-18.2%	0.0854	-0.3685	-0.0336	5.54	0.0186
	2015 BMW 328 D 4dr	1	-0.2467	-21.9%	0.1000	-0.4428	-0.0505	6.08	0.0137
	2016 BMW 328 D 4dr	1	-0.0892	-8.5%	0.1252	-0.3348	0.1562	0.51	0.4761
	2017 BMW 328 D 4dr	1	-0.2099	-18.9%	0.1567	-0.5171	0.0972	1.79	0.1805
	2014 BMW 328 D 4dr 4WD	1	-0.2125	-19.1%	0.0858	-0.3808	-0.0442	6.13	0.0133
	2015 BMW 328 D 4dr 4WD	1	-0.1200	-11.3%	0.1018	-0.3196	0.0794	1.39	0.2382
	2016 BMW 328 D 4dr 4WD	1	-0.3579	-30.1%	0.1441	-0.6404	-0.0754	6.17	0.0130
2017 BMW 328 D 4dr 4WD	1	-0.4312	-35.0%	0.1731	-0.7705	-0.0919	6.21	0.0127	

Appendix: Illustrative regression results — collision frequency

Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
2014 BMW 328 D station wagon 4WD	1	-0.2432	-21.6%	0.0919	-0.4234	-0.0629	7.00	0.0082
2015 BMW 328 D station wagon 4WD	1	-0.2811	-24.5%	0.0954	-0.4683	-0.0940	8.67	0.0032
2016 BMW 328 D station wagon 4WD	1	-0.2462	-21.8%	0.1116	-0.4650	-0.0274	4.86	0.0274
2017 BMW 328 D station wagon 4WD	1	-0.1634	-15.1%	0.1277	-0.4138	0.0868	1.64	0.2005
2013 BMW 328 I 4dr	1	-0.2000	-18.1%	0.0823	-0.3614	-0.0387	5.91	0.0151
2014 BMW 328 I 4dr	1	-0.1921	-17.5%	0.0825	-0.3539	-0.0303	5.42	0.0199
2015 BMW 328 I 4dr	1	-0.2121	-19.1%	0.0826	-0.3742	-0.0501	6.58	0.0103
2016 BMW 328 I 4dr	1	-0.1146	-10.8%	0.0831	-0.2776	0.0484	1.90	0.1682
2013 BMW 328 I/IC convertible	1	-0.2201	-19.8%	0.0840	-0.3849	-0.0554	6.86	0.0088
2013 BMW 328 I/IS/Ci 2dr	1	-0.0138	-1.4%	0.0863	-0.1831	0.1554	0.03	0.8725
2013 BMW 328 XI 2dr 4WD	1	-0.1096	-10.4%	0.0876	-0.2814	0.0621	1.57	0.2109
2013 BMW 328 XI 4dr 4WD	1	-0.1700	-15.6%	0.0823	-0.3315	-0.0085	4.26	0.0390
2014 BMW 328 XI 4dr 4WD	1	-0.1908	-17.4%	0.0827	-0.3530	-0.0286	5.32	0.0211
2015 BMW 328 XI 4dr 4WD	1	-0.2202	-19.8%	0.0827	-0.3824	-0.0580	7.09	0.0078
2016 BMW 328 XI 4dr 4WD	1	-0.1373	-12.8%	0.0836	-0.3012	0.0265	2.70	0.1005
2014 BMW 328 XI GT 5dr 4WD	1	-0.1418	-13.2%	0.0854	-0.3093	0.0256	2.76	0.0969
2015 BMW 328 XI GT 5dr 4WD	1	-0.1369	-12.8%	0.0858	-0.3052	0.0313	2.54	0.1108
2016 BMW 328 XI GT 5dr 4WD	1	-0.1746	-16.0%	0.0893	-0.3497	0.0005	3.82	0.0507
2014 BMW 328 XI station wagon 4WD	1	-0.3081	-26.5%	0.0890	-0.4825	-0.1336	11.98	0.0005
2015 BMW 328 XI station wagon 4WD	1	-0.3248	-27.7%	0.0927	-0.5067	-0.1430	12.26	0.0005
2016 BMW 328 XI station wagon 4WD	1	-0.2477	-21.9%	0.1015	-0.4467	-0.0487	5.96	0.0147
2017 BMW 330 I 4dr	1	-0.2276	-20.4%	0.0856	-0.3955	-0.0596	7.05	0.0079
2017 BMW 330 XI 4dr 4WD	1	-0.1942	-17.7%	0.0857	-0.3624	-0.0261	5.13	0.0235
2017 BMW 330 XI GT 5dr 4WD	1	-0.2627	-23.1%	0.1037	-0.4660	-0.0595	6.42	0.0113
2017 BMW 330 XI station wagon 4WD	1	-0.1847	-16.9%	0.1025	-0.3857	0.0163	3.24	0.0717
2013 BMW 335 I 4dr	1	-0.2635	-23.2%	0.0843	-0.4288	-0.0982	9.76	0.0018
2014 BMW 335 I 4dr	1	-0.1952	-17.7%	0.0853	-0.3625	-0.0279	5.23	0.0221
2015 BMW 335 I 4dr	1	-0.0793	-7.6%	0.0863	-0.2485	0.0898	0.85	0.3579
2013 BMW 335 I/IS 2dr	1	-0.0492	-4.8%	0.0883	-0.2223	0.1238	0.31	0.5772
2013 BMW 335 I/IS convertible	1	-0.1329	-12.4%	0.0857	-0.3009	0.0350	2.41	0.1209
2013 BMW 335 XI 2dr 4WD	1	-0.0702	-6.8%	0.0941	-0.2547	0.1142	0.56	0.4553
2013 BMW 335 XI 4dr 4WD	1	-0.1738	-16.0%	0.0844	-0.3394	-0.0082	4.23	0.0396
2014 BMW 335 XI 4dr 4WD	1	-0.1904	-17.3%	0.0851	-0.3573	-0.0234	5.00	0.0254
2015 BMW 335 XI 4dr 4WD	1	-0.2531	-22.4%	0.0869	-0.4235	-0.0827	8.48	0.0036
2014 BMW 335 XI GT 5dr 4WD	1	-0.1399	-13.1%	0.0947	-0.3256	0.0458	2.18	0.1399
2015 BMW 335 XI GT 5dr 4WD	1	-0.1962	-17.8%	0.1005	-0.3932	0.0008	3.81	0.0510
2016 BMW 335 XI GT 5dr 4WD	1	-0.3441	-29.1%	0.1177	-0.5750	-0.1133	8.54	0.0035
2016 BMW 340 I 4dr	1	-0.1310	-12.3%	0.0887	-0.3050	0.0429	2.18	0.1398
2017 BMW 340 I 4dr	1	-0.1789	-16.4%	0.0993	-0.3736	0.0158	3.24	0.0718
2016 BMW 340 XI 4dr 4WD	1	-0.1223	-11.5%	0.0879	-0.2946	0.0500	1.94	0.1642

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	-0.0026	-0.3%	0.0935	-0.1860	0.1807	0.00	0.9773
2017 BMW 340 XI GT 5dr 4WD	1	-0.2205	-19.8%	0.1502	-0.5149	0.0739	2.15	0.1421
2014 BMW 428 I 2dr	1	-0.0657	-6.4%	0.0836	-0.2296	0.0982	0.62	0.4319
2015 BMW 428 I 2dr	1	-0.0240	-2.4%	0.0844	-0.1895	0.1414	0.08	0.7761
2016 BMW 428 I 2dr	1	-0.0355	-3.5%	0.0881	-0.2084	0.1372	0.16	0.6866
2014 BMW 428 I convertible	1	-0.1647	-15.2%	0.0867	-0.3347	0.0052	3.61	0.0575
2015 BMW 428 I convertible	1	-0.1685	-15.5%	0.0855	-0.3362	-0.0008	3.88	0.0488
2016 BMW 428 I convertible	1	-0.1596	-14.8%	0.0882	-0.3325	0.0133	3.27	0.0705
2015 BMW 428 I Gran Coupe 5dr	1	-0.0621	-6.0%	0.0844	-0.2276	0.1033	0.54	0.4616
2016 BMW 428 I Gran Coupe 5dr	1	-0.0502	-4.9%	0.0847	-0.2163	0.1158	0.35	0.5532
2014 BMW 428 XI 2dr 4WD	1	0.0236	2.4%	0.0837	-0.1405	0.1878	0.08	0.7777
2015 BMW 428 XI 2dr 4WD	1	-0.0504	-4.9%	0.0859	-0.2189	0.1179	0.34	0.5570
2016 BMW 428 XI 2dr 4WD	1	0.0695	7.2%	0.0914	-0.1096	0.2486	0.58	0.4469
2014 BMW 428 XI convertible 4WD	1	-0.2513	-22.2%	0.0930	-0.4337	-0.0690	7.30	0.0069
2015 BMW 428 XI convertible 4WD	1	-0.2720	-23.8%	0.0887	-0.4459	-0.0981	9.40	0.0022
2016 BMW 428 XI convertible 4WD	1	-0.1168	-11.0%	0.0915	-0.2962	0.0625	1.63	0.2019
2015 BMW 428 XI Gran Coupe 5dr 4WD	1	-0.0495	-4.8%	0.0852	-0.2166	0.1174	0.34	0.5608
2016 BMW 428 XI Gran Coupe 5dr 4WD	1	-0.0634	-6.1%	0.0864	-0.2329	0.1059	0.54	0.4626
2017 BMW 430 I 2dr	1	-0.0426	-4.2%	0.0954	-0.2298	0.1444	0.20	0.6549
2017 BMW 430 I convertible	1	-0.1748	-16.0%	0.0955	-0.3621	0.0123	3.35	0.0672
2017 BMW 430 I Gran Coupe 5dr	1	0.0178	1.8%	0.0884	-0.1555	0.1911	0.04	0.8405
2017 BMW 430 XI 2dr 4WD	1	-0.0004	0.0%	0.1028	-0.2020	0.2012	0.00	0.9967
2017 BMW 430 XI convertible 4WD	1	-0.1682	-15.5%	0.1024	-0.3689	0.0324	2.70	0.1005
2017 BMW 430 XI Gran Coupe 5dr 4WD	1	-0.0086	-0.9%	0.0916	-0.1882	0.1709	0.01	0.9249
2014 BMW 435 I 2dr	1	-0.0927	-8.9%	0.0854	-0.2602	0.0748	1.18	0.2781
2015 BMW 435 I 2dr	1	-0.0670	-6.5%	0.0876	-0.2389	0.1047	0.59	0.4442
2016 BMW 435 I 2dr	1	-0.1586	-14.7%	0.0963	-0.3473	0.0301	2.71	0.0996
2014 BMW 435 I convertible	1	-0.3577	-30.1%	0.0915	-0.5371	-0.1783	15.28	0.0001
2015 BMW 435 I convertible	1	-0.1717	-15.8%	0.0905	-0.3491	0.0056	3.60	0.0578
2016 BMW 435 I convertible	1	-0.1619	-14.9%	0.0990	-0.3560	0.0321	2.67	0.1020
2015 BMW 435 I Gran Coupe 5dr	1	-0.0640	-6.2%	0.0900	-0.2405	0.1125	0.50	0.4775
2016 BMW 435 I Gran Coupe 5dr	1	-0.1231	-11.6%	0.0952	-0.3097	0.0635	1.67	0.1962
2014 BMW 435 XI 2dr 4WD	1	-0.0559	-5.4%	0.0861	-0.2247	0.1129	0.42	0.5163
2015 BMW 435 XI 2dr 4WD	1	-0.0860	-8.2%	0.0897	-0.2619	0.0897	0.92	0.3374
2016 BMW 435 XI 2dr 4WD	1	-0.0615	-6.0%	0.0984	-0.2545	0.1314	0.39	0.5319
2015 BMW 435 XI convertible 4WD	1	-0.2824	-24.6%	0.0932	-0.4653	-0.0996	9.17	0.0025
2016 BMW 435 XI convertible 4WD	1	-0.1684	-15.5%	0.1012	-0.3668	0.0299	2.77	0.0961
2015 BMW 435 XI Gran Coupe 5dr 4WD	1	-0.1519	-14.1%	0.0953	-0.3387	0.0348	2.54	0.1110

Appendix: Illustrative regression results — collision frequency

Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
2016 BMW 435 XI Gran Coupe 5dr 4WD	1	-0.0330	-3.2%	0.0977	-0.2246	0.1585	0.11	0.7356
2017 BMW 440 I 2dr	1	-0.0553	-5.4%	0.1101	-0.2713	0.1605	0.25	0.6152
2017 BMW 440 I convertible	1	-0.2934	-25.4%	0.1249	-0.5382	-0.0486	5.52	0.0188
2017 BMW 440 I Gran Coupe 5dr	1	-0.0293	-2.9%	0.1059	-0.2369	0.1782	0.08	0.7819
2017 BMW 440 XI 2dr 4WD	1	-0.0254	-2.5%	0.1136	-0.2482	0.1973	0.05	0.8229
2017 BMW 440 XI convertible 4WD	1	-0.1089	-10.3%	0.1160	-0.3364	0.1186	0.88	0.3481
2017 BMW 440 XI Gran Coupe 5dr 4WD	1	-0.0448	-4.4%	0.1081	-0.2568	0.1670	0.17	0.6780
2013 BMW 528 I 4dr	1	-0.2455	-21.8%	0.0831	-0.4084	-0.0826	8.73	0.0031
2014 BMW 528 I 4dr	1	-0.2664	-23.4%	0.0834	-0.4299	-0.1028	10.19	0.0014
2015 BMW 528 I 4dr	1	-0.2674	-23.5%	0.0838	-0.4318	-0.1030	10.17	0.0014
2016 BMW 528 I 4dr	1	-0.2437	-21.6%	0.0844	-0.4091	-0.0782	8.33	0.0039
2013 BMW 528 XI 4dr 4WD	1	-0.1969	-17.9%	0.0830	-0.3597	-0.0341	5.63	0.0177
2014 BMW 528 XI 4dr 4WD	1	-0.2187	-19.6%	0.0838	-0.3830	-0.0543	6.80	0.0091
2015 BMW 528 XI 4dr 4WD	1	-0.2836	-24.7%	0.0842	-0.4488	-0.1184	11.33	0.0008
2016 BMW 528 XI 4dr 4WD	1	-0.2603	-22.9%	0.0849	-0.4268	-0.0937	9.38	0.0022
2017 BMW 530 I 4dr	1	-0.0678	-6.6%	0.0914	-0.2469	0.1113	0.55	0.4582
2017 BMW 530 XI 4dr 4WD	1	-0.0677	-6.5%	0.0916	-0.2474	0.1118	0.55	0.4595
2014 BMW 535 D 4dr	1	-0.2977	-25.7%	0.0893	-0.4728	-0.1226	11.11	0.0009
2015 BMW 535 D 4dr	1	-0.2793	-24.4%	0.1178	-0.5103	-0.0483	5.62	0.0178
2016 BMW 535 D 4dr	1	-0.2748	-24.0%	0.1217	-0.5133	-0.0363	5.10	0.0239
2014 BMW 535 D 4dr 4WD	1	-0.2774	-24.2%	0.0899	-0.4537	-0.1011	9.51	0.0020
2015 BMW 535 D 4dr 4WD	1	-0.4291	-34.9%	0.1284	-0.6808	-0.1774	11.16	0.0008
2016 BMW 535 D 4dr 4WD	1	-0.0324	-3.2%	0.1320	-0.2912	0.2263	0.06	0.8060
2013 BMW 535 I GT 5dr	1	-0.3055	-26.3%	0.1011	-0.5038	-0.1073	9.12	0.0025
2014 BMW 535 I GT 5dr	1	-0.1643	-15.2%	0.1071	-0.3742	0.0456	2.35	0.1251
2015 BMW 535 I GT 5dr	1	-0.1297	-12.2%	0.1161	-0.3574	0.0980	1.25	0.2642
2016 BMW 535 I GT 5dr	1	-0.2857	-24.9%	0.1470	-0.5738	0.0023	3.78	0.0519
2017 BMW 535 I GT 5dr	1	-0.1137	-10.7%	0.1746	-0.4561	0.2286	0.42	0.5151
2013 BMW 535 I/535 IS 4dr	1	-0.2680	-23.5%	0.0832	-0.4312	-0.1047	10.36	0.0013
2014 BMW 535 I/535 IS 4dr	1	-0.3106	-26.7%	0.0836	-0.4747	-0.1466	13.78	0.0002
2015 BMW 535 I/535 IS 4dr	1	-0.2797	-24.4%	0.0845	-0.4454	-0.1141	10.96	0.0009
2016 BMW 535 I/535 IS 4dr	1	-0.2627	-23.1%	0.0854	-0.4301	-0.0953	9.46	0.0021
2013 BMW 535 XI 4dr 4WD	1	-0.2221	-19.9%	0.0833	-0.3855	-0.0587	7.10	0.0077
2014 BMW 535 XI 4dr 4WD	1	-0.2914	-25.3%	0.0837	-0.4555	-0.1273	12.12	0.0005
2015 BMW 535 XI 4dr 4WD	1	-0.2881	-25.0%	0.0846	-0.4539	-0.1223	11.60	0.0007
2016 BMW 535 XI 4dr 4WD	1	-0.3019	-26.1%	0.0855	-0.4695	-0.1343	12.47	0.0004
2013 BMW 535 XI GT 5dr 4WD	1	-0.0486	-4.7%	0.0979	-0.2405	0.1432	0.25	0.6192
2014 BMW 535 XI GT 5dr 4WD	1	-0.1678	-15.4%	0.1091	-0.3817	0.0460	2.37	0.1240
2015 BMW 535 XI GT 5dr 4WD	1	-0.2166	-19.5%	0.1195	-0.4508	0.0175	3.29	0.0699
2016 BMW 535 XI GT 5dr 4WD	1	-0.1187	-11.2%	0.1434	-0.3998	0.1623	0.69	0.4076
2017 BMW 535 XI GT 5dr 4WD	1	-0.1877	-17.1%	0.1763	-0.5333	0.1578	1.13	0.2869
2017 BMW 540 I 4dr	1	-0.0929	-8.9%	0.0940	-0.2773	0.0914	0.98	0.3233

Appendix: Illustrative regression results — collision frequency

Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
2017 BMW 540 XI 4dr 4WD	1	-0.0700	-6.8%	0.0936	-0.2535	0.1135	0.56	0.4546
2013 BMW 550 I 4dr	1	-0.2612	-23.0%	0.0887	-0.4351	-0.0873	8.67	0.0032
2014 BMW 550 I 4dr	1	-0.2328	-20.8%	0.0900	-0.4093	-0.0564	6.69	0.0097
2015 BMW 550 I 4dr	1	-0.3555	-29.9%	0.1038	-0.5591	-0.1519	11.71	0.0006
2016 BMW 550 I 4dr	1	-0.2065	-18.7%	0.1020	-0.4065	-0.0065	4.10	0.0430
2013 BMW 550 I GT 5dr	1	-0.4163	-34.1%	0.1817	-0.7725	-0.0601	5.25	0.0220
2014 BMW 550 I GT 5dr	1	-0.2839	-24.7%	0.1948	-0.6657	0.0979	2.12	0.1450
2015 BMW 550 I GT 5dr	1	-0.1482	-13.8%	0.3000	-0.7363	0.4399	0.24	0.6213
2013 BMW 550 XI 4dr 4WD	1	-0.1860	-17.0%	0.0887	-0.3601	-0.0120	4.39	0.0361
2014 BMW 550 XI 4dr 4WD	1	-0.2227	-20.0%	0.0906	-0.4003	-0.0450	6.04	0.0140
2015 BMW 550 XI 4dr 4WD	1	-0.2836	-24.7%	0.1029	-0.4853	-0.0818	7.59	0.0059
2016 BMW 550 XI 4dr 4WD	1	-0.1839	-16.8%	0.1005	-0.3808	0.0130	3.35	0.0673
2013 BMW 550 XI GT 5dr 4WD	1	-0.2863	-24.9%	0.1764	-0.6321	0.0594	2.63	0.1046
2014 BMW 550 XI GT 5dr 4WD	1	-0.3742	-31.2%	0.2001	-0.7666	0.0181	3.49	0.0616
2015 BMW 550 XI GT 5dr 4WD	1	-0.1523	-14.1%	0.2241	-0.5916	0.2869	0.46	0.4966
2016 BMW 550 XI GT 5dr 4WD	1	-0.1252	-11.8%	0.2330	-0.5821	0.3315	0.29	0.5909
2017 BMW 550 XI GT 5dr 4WD	1	-0.1153	-10.9%	0.3007	-0.7048	0.4741	0.15	0.7013
2013 BMW 640 I 2dr	1	-0.0635	-6.2%	0.1187	-0.2962	0.1691	0.29	0.5924
2014 BMW 640 I 2dr	1	-0.1063	-10.1%	0.1333	-0.3677	0.1549	0.64	0.4249
2015 BMW 640 I 2dr	1	-0.0162	-1.6%	0.1447	-0.2999	0.2674	0.01	0.9105
2016 BMW 640 I 2dr	1	-0.4282	-34.8%	0.2380	-0.8947	0.0382	3.24	0.0720
2017 BMW 640 I 2dr	1	-0.0359	-3.5%	0.2329	-0.4925	0.4206	0.02	0.8774
2013 BMW 640 I convertible	1	-0.4531	-36.4%	0.1253	-0.6987	-0.2075	13.08	0.0003
2014 BMW 640 I convertible	1	-0.2672	-23.4%	0.1230	-0.5084	-0.0260	4.72	0.0299
2015 BMW 640 I convertible	1	-0.0811	-7.8%	0.1245	-0.3253	0.1629	0.43	0.5144
2016 BMW 640 I convertible	1	-0.3161	-27.1%	0.1576	-0.6250	-0.0072	4.02	0.0449
2017 BMW 640 I convertible	1	-0.0799	-7.7%	0.1699	-0.4129	0.2531	0.22	0.6382
2013 BMW 640 I Gran Coupe 5dr	1	-0.0086	-0.9%	0.0926	-0.1902	0.1728	0.01	0.9252
2014 BMW 640 I Gran Coupe 5dr	1	-0.0508	-5.0%	0.0957	-0.2386	0.1368	0.28	0.5951
2015 BMW 640 I Gran Coupe 5dr	1	-0.1295	-12.1%	0.0958	-0.3174	0.0582	1.83	0.1763
2016 BMW 640 I Gran Coupe 5dr	1	0.0134	1.3%	0.1022	-0.1868	0.2138	0.02	0.8950
2017 BMW 640 I Gran Coupe 5dr	1	-0.0953	-9.1%	0.1347	-0.3594	0.1686	0.50	0.4790
2014 BMW 640 XI 2dr 4WD	1	-0.0174	-1.7%	0.1390	-0.2899	0.2550	0.02	0.9002
2015 BMW 640 XI 2dr 4WD	1	0.1353	14.5%	0.1816	-0.2206	0.4913	0.56	0.4562
2016 BMW 640 XI 2dr 4WD	1	-0.0714	-6.9%	0.2198	-0.5024	0.3594	0.11	0.7450
2017 BMW 640 XI 2dr 4WD	1	-0.5571	-42.7%	0.4163	-1.3731	0.2588	1.79	0.1808
2014 BMW 640 XI convertible 4WD	1	-0.4766	-37.9%	0.1307	-0.7328	-0.2203	13.29	0.0003
2015 BMW 640 XI convertible 4WD	1	-0.4461	-36.0%	0.1536	-0.7472	-0.1449	8.43	0.0037
2016 BMW 640 XI convertible 4WD	1	-0.1270	-11.9%	0.1877	-0.4949	0.2408	0.46	0.4986
2017 BMW 640 XI convertible 4WD	1	-0.3473	-29.3%	0.2329	-0.8039	0.1093	2.22	0.1360

Appendix: Illustrative regression results — collision frequency

Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
2014 BMW 640 XI Gran Coupe 5dr 4WD	1	-0.0011	-0.1%	0.0974	-0.1921	0.1898	0.00	0.9903
2015 BMW 640 XI Gran Coupe 5dr 4WD	1	-0.0497	-4.8%	0.0994	-0.2445	0.1450	0.25	0.6167
2016 BMW 640 XI Gran Coupe 5dr 4WD	1	-0.1663	-15.3%	0.1172	-0.3961	0.0635	2.01	0.1561
2017 BMW 640 XI Gran Coupe 5dr 4WD	1	-0.1209	-11.4%	0.1484	-0.4119	0.1700	0.66	0.4151
2013 BMW 650 I 2dr	1	-0.0975	-9.3%	0.1209	-0.3345	0.1394	0.65	0.4197
2014 BMW 650 I 2dr	1	-0.0780	-7.5%	0.1251	-0.3233	0.1671	0.39	0.5325
2015 BMW 650 I 2dr	1	-0.3172	-27.2%	0.1815	-0.6731	0.0385	3.05	0.0805
2016 BMW 650 I 2dr	1	-0.1306	-12.2%	0.2238	-0.5694	0.3081	0.34	0.5596
2017 BMW 650 I 2dr	1	-0.2223	-19.9%	0.3123	-0.8345	0.3898	0.51	0.4765
2013 BMW 650 I convertible	1	-0.0576	-5.6%	0.1153	-0.2837	0.1684	0.25	0.6174
2014 BMW 650 I convertible	1	-0.1701	-15.6%	0.1132	-0.3920	0.0517	2.26	0.1329
2015 BMW 650 I convertible	1	-0.2391	-21.3%	0.1172	-0.4688	-0.0093	4.16	0.0413
2016 BMW 650 I convertible	1	-0.0286	-2.8%	0.1597	-0.3416	0.2844	0.03	0.8579
2017 BMW 650 I convertible	1	-0.5877	-44.4%	0.2329	-1.0443	-0.1312	6.37	0.0116
2013 BMW 650 I Gran Coupe 5dr	1	-0.0925	-8.8%	0.1053	-0.2989	0.1139	0.77	0.3798
2014 BMW 650 I Gran Coupe 5dr	1	-0.0724	-7.0%	0.0987	-0.2659	0.1211	0.54	0.4632
2015 BMW 650 I Gran Coupe 5dr	1	0.0205	2.1%	0.0943	-0.1643	0.2055	0.05	0.8272
2016 BMW 650 I Gran Coupe 5dr	1	-0.0893	-8.5%	0.1205	-0.3255	0.1468	0.55	0.4582
2017 BMW 650 I Gran Coupe 5dr	1	0.1280	13.7%	0.1575	-0.1808	0.4368	0.66	0.4165
2013 BMW 650 XI 2dr 4WD	1	-0.2513	-22.2%	0.1421	-0.5298	0.0272	3.13	0.0771
2014 BMW 650 XI 2dr 4WD	1	-0.1860	-17.0%	0.1328	-0.4463	0.0742	1.96	0.1613
2015 BMW 650 XI 2dr 4WD	1	-0.1484	-13.8%	0.1855	-0.5120	0.2152	0.64	0.4238
2016 BMW 650 XI 2dr 4WD	1	-0.1387	-13.0%	0.2329	-0.5953	0.3179	0.35	0.5515
2017 BMW 650 XI 2dr 4WD	1	0.0367	3.7%	0.3000	-0.5512	0.6248	0.02	0.9024
2013 BMW 650 XI convertible 4WD	1	-0.0955	-9.1%	0.1212	-0.3331	0.1419	0.62	0.4305
2014 BMW 650 XI convertible 4WD	1	-0.3138	-26.9%	0.1241	-0.5572	-0.0704	6.39	0.0115
2015 BMW 650 XI convertible 4WD	1	-0.3794	-31.6%	0.1302	-0.6347	-0.1241	8.49	0.0036
2016 BMW 650 XI convertible 4WD	1	-0.2567	-22.6%	0.1762	-0.6021	0.0885	2.12	0.1451
2017 BMW 650 XI convertible 4WD	1	-0.1741	-16.0%	0.1877	-0.5421	0.1937	0.86	0.3534
2013 BMW 650 XI Gran Coupe 5dr 4WD	1	0.0466	4.8%	0.1003	-0.1500	0.2433	0.22	0.6419
2014 BMW 650 XI Gran Coupe 5dr 4WD	1	-0.0545	-5.3%	0.1003	-0.2513	0.1421	0.30	0.5866
2015 BMW 650 XI Gran Coupe 5dr 4WD	1	-0.0011	-0.1%	0.0943	-0.1859	0.1837	0.00	0.9906
2016 BMW 650 XI Gran Coupe 5dr 4WD	1	-0.0228	-2.3%	0.1111	-0.2406	0.1949	0.04	0.8368
2017 BMW 650 XI Gran Coupe 5dr 4WD	1	0.0886	9.3%	0.1402	-0.1861	0.3635	0.40	0.5272
2013 BMW 740 I 4dr	1	-0.2458	-21.8%	0.0959	-0.4338	-0.0578	6.57	0.0104
2014 BMW 740 I 4dr	1	-0.2353	-21.0%	0.1018	-0.4350	-0.0357	5.34	0.0209

Appendix: Illustrative regression results — collision frequency

Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
2015 BMW 740 I 4dr	1	-0.1682	-15.5%	0.1017	-0.3676	0.0311	2.74	0.0981
2016 BMW 740 I 4dr	1	0.0530	5.4%	0.0916	-0.1264	0.2326	0.34	0.5623
2017 BMW 740 I 4dr	1	0.0000	0.0%	0.1023	-0.2005	0.2005	0.00	1.0000
2015 BMW 740 LD XDrive 4dr 4WD	1	-0.0620	-6.0%	0.1420	-0.3404	0.2164	0.19	0.6625
2013 BMW 740 LI 4dr	1	-0.1919	-17.5%	0.0920	-0.3723	-0.0115	4.35	0.0370
2014 BMW 740 LI 4dr	1	-0.1329	-12.4%	0.0989	-0.3269	0.0610	1.80	0.1792
2015 BMW 740 LI 4dr	1	-0.0288	-2.8%	0.1017	-0.2282	0.1704	0.08	0.7764
2013 BMW 740 LXI 4dr 4WD	1	-0.1188	-11.2%	0.0929	-0.3011	0.0633	1.63	0.2011
2014 BMW 740 LXI 4dr 4WD	1	-0.0841	-8.1%	0.1066	-0.2932	0.1249	0.62	0.4302
2015 BMW 740 LXI 4dr 4WD	1	-0.3058	-26.3%	0.1100	-0.5214	-0.0901	7.72	0.0054
2017 BMW 740 XI 4dr 4WD	1	0.3052	35.7%	0.1106	0.0883	0.5222	7.61	0.0058
2013 BMW 750 I 4dr	1	-0.1790	-16.4%	0.0957	-0.3668	0.0087	3.49	0.0616
2014 BMW 750 I 4dr	1	-0.1648	-15.2%	0.0998	-0.3605	0.0309	2.72	0.0989
2015 BMW 750 I 4dr	1	-0.3049	-26.3%	0.1120	-0.5244	-0.0854	7.41	0.0065
2016 BMW 750 I 4dr	1	0.0535	5.5%	0.1051	-0.1525	0.2595	0.26	0.6107
2017 BMW 750 I 4dr	1	0.1061	11.2%	0.1121	-0.1135	0.3259	0.90	0.3435
2013 BMW 750 LI 4dr	1	-0.0991	-9.4%	0.0870	-0.2697	0.0714	1.30	0.2546
2014 BMW 750 LI 4dr	1	-0.0529	-5.2%	0.0885	-0.2264	0.1206	0.36	0.5500
2015 BMW 750 LI 4dr	1	-0.0878	-8.4%	0.0965	-0.2771	0.1014	0.83	0.3631
2013 BMW 750 LXI 4dr 4WD	1	-0.0489	-4.8%	0.0877	-0.2209	0.1231	0.31	0.5773
2014 BMW 750 LXI 4dr 4WD	1	-0.0480	-4.7%	0.0894	-0.2234	0.1272	0.29	0.5909
2015 BMW 750 LXI 4dr 4WD	1	-0.0591	-5.7%	0.0961	-0.2475	0.1292	0.38	0.5383
2013 BMW 750 XI 4dr 4WD	1	-0.0923	-8.8%	0.0964	-0.2813	0.0965	0.92	0.3380
2014 BMW 750 XI 4dr 4WD	1	-0.1303	-12.2%	0.1037	-0.3337	0.0730	1.58	0.2092
2015 BMW 750 XI 4dr 4WD	1	-0.1167	-11.0%	0.1129	-0.3380	0.1045	1.07	0.3011
2016 BMW 750 XI 4dr 4WD	1	0.0324	3.3%	0.0908	-0.1455	0.2104	0.13	0.7207
2017 BMW 750 XI 4dr 4WD	1	-0.0593	-5.8%	0.1034	-0.2619	0.1433	0.33	0.5662
2013 BMW 760 LI 4dr	1	0.1627	17.7%	0.1982	-0.2258	0.5513	0.67	0.4117
2014 BMW 760 LI 4dr	1	0.1065	11.2%	0.3438	-0.5674	0.7805	0.10	0.7567
2015 BMW 760 LI 4dr	1	-0.8078	-55.4%	0.7119	-2.2032	0.5875	1.29	0.2565
2016 BMW M2 2dr	1	-0.8717	-58.2%	0.5066	-1.8648	0.1212	2.96	0.0853
2017 BMW M2 2dr	1	-0.6815	-49.4%	0.1701	-1.0149	-0.3481	16.05	0.0001
2014 BMW M235 I 2dr	1	-0.2409	-21.4%	0.0924	-0.4221	-0.0596	6.79	0.0092
2015 BMW M235 I 2dr	1	-0.3080	-26.5%	0.0904	-0.4854	-0.1307	11.59	0.0007
2016 BMW M235 I 2dr	1	-0.3191	-27.3%	0.0927	-0.5009	-0.1372	11.83	0.0006
2015 BMW M235 I convertible	1	-0.2603	-22.9%	0.1025	-0.4613	-0.0594	6.45	0.0111
2016 BMW M235 I convertible	1	-0.1264	-11.9%	0.1041	-0.3305	0.0776	1.47	0.2247
2015 BMW M235 XI 2dr 4WD	1	-0.3170	-27.2%	0.0972	-0.5076	-0.1264	10.63	0.0011
2016 BMW M235 XI 2dr 4WD	1	-0.2014	-18.2%	0.0980	-0.3935	-0.0093	4.22	0.0399
2016 BMW M235 XI convertible 4WD	1	-0.3627	-30.4%	0.1105	-0.5793	-0.1460	10.77	0.0010
2017 BMW M240 I 2dr	1	-0.2836	-24.7%	0.1094	-0.4981	-0.0690	6.71	0.0096
2017 BMW M240 I convertible	1	-0.2598	-22.9%	0.1253	-0.5054	-0.0142	4.30	0.0381
2017 BMW M240 XI 2dr 4WD	1	-0.1290	-12.1%	0.1112	-0.3470	0.0889	1.35	0.2460

Appendix: Illustrative regression results — collision frequency

Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
2017 BMW M240 Xi convertible 4WD	1	-0.2587	-22.8%	0.1434	-0.5399	0.0223	3.25	0.0713
2015 BMW M3 4dr	1	-0.2629	-23.1%	0.0878	-0.4350	-0.0907	8.96	0.0028
2016 BMW M3 4dr	1	-0.1955	-17.8%	0.0891	-0.3702	-0.0208	4.81	0.0282
2017 BMW M3 4dr	1	-0.1575	-14.6%	0.0920	-0.3379	0.0227	2.93	0.0868
2013 BMW M3/M3 Ci 2dr	1	-0.5161	-40.3%	0.0892	-0.6911	-0.3411	33.42	<0.0001
2013 BMW M3/M3 Ci convertible	1	-0.5581	-42.8%	0.1005	-0.7553	-0.3610	30.79	<0.0001
2015 BMW M4 2dr	1	-0.1123	-10.6%	0.0845	-0.2781	0.0533	1.77	0.1839
2016 BMW M4 2dr	1	-0.1579	-14.6%	0.0881	-0.3308	0.0148	3.21	0.0732
2017 BMW M4 2dr	1	0.0057	0.6%	0.0995	-0.1893	0.2009	0.00	0.9538
2015 BMW M4 convertible	1	-0.1984	-18.0%	0.0916	-0.3780	-0.0188	4.69	0.0303
2016 BMW M4 convertible	1	-0.1979	-18.0%	0.0953	-0.3847	-0.0111	4.31	0.0378
2017 BMW M4 convertible	1	-0.1072	-10.2%	0.1282	-0.3586	0.1441	0.70	0.4032
2016 BMW M4 GTS Coupe 2dr	1	-1.8607	-84.4%	0.4145	-2.6733	-1.0481	20.14	<0.0001
2013 BMW M5 4dr	1	-0.1819	-16.6%	0.0988	-0.3756	0.0118	3.39	0.0657
2014 BMW M5 4dr	1	-0.2091	-18.9%	0.0918	-0.3891	-0.0292	5.19	0.0227
2015 BMW M5 4dr	1	-0.1647	-15.2%	0.0997	-0.3602	0.0308	2.73	0.0987
2016 BMW M5 4dr	1	-0.0314	-3.1%	0.1071	-0.2413	0.1785	0.09	0.7693
2013 BMW M6 2dr	1	-0.1802	-16.5%	0.1672	-0.5079	0.1475	1.16	0.2812
2014 BMW M6 2dr	1	-0.1214	-11.4%	0.1161	-0.3491	0.1062	1.09	0.2958
2015 BMW M6 2dr	1	-0.2201	-19.8%	0.1620	-0.5377	0.0974	1.85	0.1742
2016 BMW M6 2dr	1	-0.0551	-5.4%	0.1575	-0.3639	0.2536	0.12	0.7263
2017 BMW M6 2dr	1	0.2650	30.3%	0.2058	-0.1383	0.6684	1.66	0.1979
2013 BMW M6 convertible	1	-0.5797	-44.0%	0.2435	-1.0571	-0.1024	5.67	0.0173
2014 BMW M6 convertible	1	-0.4129	-33.8%	0.1192	-0.6466	-0.1792	11.99	0.0005
2015 BMW M6 convertible	1	-0.1597	-14.8%	0.1426	-0.4392	0.1198	1.25	0.2627
2016 BMW M6 convertible	1	-0.0263	-2.6%	0.1484	-0.3172	0.2645	0.03	0.8591
2017 BMW M6 convertible	1	-0.2743	-24.0%	0.2558	-0.7758	0.2271	1.15	0.2837
2014 BMW M6 Gran Coupe 5dr	1	-0.0350	-3.4%	0.0991	-0.2294	0.1592	0.13	0.7234
2015 BMW M6 Gran Coupe 5dr	1	0.0322	3.3%	0.1120	-0.1874	0.2519	0.08	0.7736
2016 BMW M6 Gran Coupe 5dr	1	-0.0122	-1.2%	0.1238	-0.2549	0.2305	0.01	0.9214
2017 BMW M6 Gran Coupe 5dr	1	-0.1036	-9.8%	0.1855	-0.4672	0.2599	0.31	0.5764
2017 BMW M760 Xi 4dr 4WD	1	0.0622	6.4%	0.3136	-0.5526	0.6770	0.04	0.8428
2013 BMW X1 4dr	1	-0.4346	-35.2%	0.0849	-0.6012	-0.2680	26.16	<0.0001
2014 BMW X1 4dr	1	-0.4696	-37.5%	0.0840	-0.6344	-0.3049	31.22	<0.0001
2015 BMW X1 4dr	1	-0.4150	-34.0%	0.0845	-0.5808	-0.2492	24.07	<0.0001
2017 BMW X1 4dr	1	-0.4490	-36.2%	0.0892	-0.6239	-0.2742	25.34	<0.0001
2013 BMW X1 4dr 4WD	1	-0.4273	-34.8%	0.0834	-0.5908	-0.2639	26.26	<0.0001
2014 BMW X1 4dr 4WD	1	-0.4656	-37.2%	0.0831	-0.6286	-0.3027	31.38	<0.0001
2015 BMW X1 4dr 4WD	1	-0.4691	-37.4%	0.0835	-0.6328	-0.3053	31.53	<0.0001
2016 BMW X1 4dr 4WD	1	-0.4468	-36.0%	0.0836	-0.6108	-0.2828	28.53	<0.0001
2017 BMW X1 4dr 4WD	1	-0.4537	-36.5%	0.0845	-0.6195	-0.2880	28.80	<0.0001
2015 BMW X3 4dr	1	-0.4666	-37.3%	0.0943	-0.6516	-0.2816	24.45	<0.0001
2016 BMW X3 4dr	1	-0.4090	-33.6%	0.0909	-0.5872	-0.2307	20.23	<0.0001

Appendix: Illustrative regression results — collision frequency

Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
2017 BMW X3 4dr	1	-0.3900	-32.3%	0.0849	-0.5564	-0.2235	21.09	<0.0001
2013 BMW X3 4dr 4WD	1	-0.4614	-37.0%	0.0824	-0.6229	-0.2999	31.35	<0.0001
2014 BMW X3 4dr 4WD	1	-0.4506	-36.3%	0.0824	-0.6122	-0.2891	29.89	<0.0001
2015 BMW X3 4dr 4WD	1	-0.4200	-34.3%	0.0829	-0.5826	-0.2574	25.64	<0.0001
2016 BMW X3 4dr 4WD	1	-0.4372	-35.4%	0.0827	-0.5994	-0.2750	27.93	<0.0001
2017 BMW X3 4dr 4WD	1	-0.4099	-33.6%	0.0829	-0.5724	-0.2474	24.45	<0.0001
2015 BMW X4 4dr 4WD	1	-0.2683	-23.5%	0.0858	-0.4366	-0.1000	9.76	0.0018
2016 BMW X4 4dr 4WD	1	-0.2451	-21.7%	0.0857	-0.4132	-0.0771	8.18	0.0042
2017 BMW X4 4dr 4WD	1	-0.3100	-26.7%	0.0911	-0.4886	-0.1314	11.58	0.0007
2014 BMW X5 4dr	1	-0.3989	-32.9%	0.0861	-0.5677	-0.2301	21.46	<0.0001
2015 BMW X5 4dr	1	-0.3908	-32.3%	0.0860	-0.5594	-0.2222	20.64	<0.0001
2016 BMW X5 4dr	1	-0.3482	-29.4%	0.0866	-0.5180	-0.1784	16.16	0.0001
2017 BMW X5 4dr	1	-0.4165	-34.1%	0.0864	-0.5860	-0.2470	23.19	<0.0001
2013 BMW X5 4dr 4WD	1	-0.3550	-29.9%	0.0822	-0.5162	-0.1938	18.64	<0.0001
2014 BMW X5 4dr 4WD	1	-0.3736	-31.2%	0.0826	-0.5356	-0.2116	20.43	<0.0001
2015 BMW X5 4dr 4WD	1	-0.3669	-30.7%	0.0822	-0.5282	-0.2057	19.90	<0.0001
2016 BMW X5 4dr 4WD	1	-0.3558	-29.9%	0.0826	-0.5179	-0.1938	18.52	<0.0001
2017 BMW X5 4dr 4WD	1	-0.3683	-30.8%	0.0832	-0.5313	-0.2052	19.59	<0.0001
2013 BMW X5 M 4dr 4WD	1	-0.3506	-29.6%	0.1021	-0.5509	-0.1503	11.77	0.0006
2015 BMW X5 M 4dr 4WD	1	-0.1359	-12.7%	0.1127	-0.3570	0.0851	1.45	0.2281
2016 BMW X5 M 4dr 4WD	1	-0.2962	-25.6%	0.1010	-0.4943	-0.0980	8.59	0.0034
2017 BMW X5 M 4dr 4WD	1	-0.1920	-17.5%	0.1099	-0.4075	0.0234	3.05	0.0806
2015 BMW X6 4dr	1	-0.1830	-16.7%	0.1203	-0.4189	0.0528	2.31	0.1284
2016 BMW X6 4dr	1	-0.0900	-8.6%	0.0989	-0.2839	0.1038	0.83	0.3628
2017 BMW X6 4dr	1	-0.1653	-15.2%	0.1182	-0.3970	0.0663	1.96	0.1619
2013 BMW X6 4dr 4WD	1	-0.1139	-10.8%	0.0844	-0.2794	0.0514	1.82	0.1770
2014 BMW X6 4dr 4WD	1	-0.1349	-12.6%	0.0851	-0.3017	0.0318	2.51	0.1129
2015 BMW X6 4dr 4WD	1	-0.1555	-14.4%	0.0862	-0.3247	0.0135	3.25	0.0714
2016 BMW X6 4dr 4WD	1	-0.1644	-15.2%	0.0859	-0.3328	0.0039	3.66	0.0556
2017 BMW X6 4dr 4WD	1	-0.0291	-2.9%	0.0898	-0.2052	0.1468	0.11	0.7452
2013 BMW X6 M 4dr 4WD	1	-0.1732	-15.9%	0.1165	-0.4016	0.0551	2.21	0.1371
2014 BMW X6 M 4dr 4WD	1	-0.1763	-16.2%	0.1096	-0.3912	0.0386	2.58	0.1079
2015 BMW X6 M 4dr 4WD	1	0.0186	1.9%	0.1145	-0.2058	0.2431	0.03	0.8707
2017 BMW X6 M 4dr 4WD	1	-0.0667	-6.5%	0.1270	-0.3157	0.1823	0.28	0.5995
2013 Mini Cooper Clubman 2dr	1	-0.6189	-46.1%	0.0861	-0.7878	-0.4501	51.62	<0.0001
2014 Mini Cooper Clubman 2dr	1	-0.5758	-43.8%	0.0888	-0.7500	-0.4016	41.97	<0.0001
2016 Mini Cooper Clubman station wagon	1	-0.3856	-32.0%	0.0872	-0.5565	-0.2146	19.55	<0.0001
2017 Mini Cooper Clubman station wagon	1	-0.3047	-26.3%	0.0923	-0.4858	-0.1236	10.88	0.0010
2017 Mini Cooper Clubman station wagon 4WD	1	-0.3178	-27.2%	0.0874	-0.4892	-0.1463	13.19	0.0003
2013 Mini Cooper convertible	1	-0.7083	-50.8%	0.0868	-0.8786	-0.5380	66.47	<0.0001
2014 Mini Cooper convertible	1	-0.6940	-50.0%	0.0893	-0.8690	-0.5189	60.38	<0.0001
2015 Mini Cooper convertible	1	-0.7073	-50.7%	0.0902	-0.8842	-0.5303	61.39	<0.0001

Appendix: Illustrative regression results — collision frequency

Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
2016 Mini Cooper convertible	1	-0.4825	-38.3%	0.0924	-0.6637	-0.3014	27.27	<0.0001
2017 Mini Cooper convertible	1	-0.5370	-41.6%	0.0916	-0.7167	-0.3574	34.32	<0.0001
2013 Mini Cooper Coupe 2dr	1	-0.5560	-42.7%	0.0892	-0.7309	-0.3811	38.85	<0.0001
2014 Mini Cooper Coupe 2dr	1	-0.6876	-49.7%	0.1030	-0.8895	-0.4857	44.57	<0.0001
2015 Mini Cooper Coupe 2dr	1	-0.4038	-33.2%	0.1184	-0.6360	-0.1716	11.62	0.0007
2013 Mini Cooper Hardtop 2dr	1	-0.5517	-42.4%	0.0825	-0.7135	-0.3899	44.66	<0.0001
2014 Mini Cooper Hardtop 2dr	1	-0.4802	-38.1%	0.0838	-0.6446	-0.3158	32.78	<0.0001
2015 Mini Cooper Hardtop 2dr	1	-0.4460	-36.0%	0.0830	-0.6086	-0.2833	28.88	<0.0001
2016 Mini Cooper Hardtop 2dr	1	-0.4540	-36.5%	0.0852	-0.6211	-0.2869	28.35	<0.0001
2017 Mini Cooper Hardtop 2dr	1	-0.4252	-34.6%	0.0864	-0.5946	-0.2558	24.21	<0.0001
2015 Mini Cooper Hardtop 4dr	1	-0.3885	-32.2%	0.0838	-0.5528	-0.2243	21.49	<0.0001
2016 Mini Cooper Hardtop 4dr	1	-0.3593	-30.2%	0.0846	-0.5251	-0.1934	18.03	<0.0001
2017 Mini Cooper Hardtop 4dr	1	-0.3420	-29.0%	0.0879	-0.5143	-0.1696	15.13	0.0001
2013 Mini Cooper Roadster convertible	1	-0.7163	-51.1%	0.0892	-0.8911	-0.5414	64.45	<0.0001
2014 Mini Cooper Roadster convertible	1	-0.8019	-55.2%	0.0997	-0.9974	-0.6064	64.63	<0.0001
2015 Mini Cooper Roadster convertible	1	-0.6497	-47.8%	0.1043	-0.8542	-0.4452	38.79	<0.0001
2013 Mini Countryman station wagon	1	-0.6887	-49.8%	0.0844	-0.8542	-0.5232	66.55	<0.0001
2014 Mini Countryman station wagon	1	-0.6365	-47.1%	0.0839	-0.8010	-0.4721	57.55	<0.0001
2015 Mini Countryman station wagon	1	-0.6250	-46.5%	0.0850	-0.7917	-0.4584	54.03	<0.0001
2016 Mini Countryman station wagon	1	-0.6069	-45.5%	0.0872	-0.7780	-0.4359	48.37	<0.0001
2017 Mini Countryman station wagon	1	-0.6131	-45.8%	0.0993	-0.8079	-0.4184	38.08	<0.0001
2013 Mini Countryman station wagon 4WD	1	-0.6641	-48.5%	0.0855	-0.8317	-0.4964	60.28	<0.0001
2014 Mini Countryman station wagon 4WD	1	-0.6232	-46.4%	0.0851	-0.7900	-0.4564	53.62	<0.0001
2015 Mini Countryman station wagon 4WD	1	-0.6500	-47.8%	0.0858	-0.8183	-0.4817	57.33	<0.0001
2016 Mini Countryman station wagon 4WD	1	-0.6109	-45.7%	0.0864	-0.7805	-0.4414	49.91	<0.0001
2017 Mini Countryman station wagon 4WD	1	-0.5423	-41.9%	0.0922	-0.7231	-0.3614	34.54	<0.0001
2016 BMW X6 M 4dr 4WD	0	0	0	0	0	0		
Rated driver age group 14–24	1	0.2332	26.3%	0.0070	0.2194	0.2470	1100.30	<0.0001
25–29	1	0.2174	24.3%	0.0063	0.2050	0.2299	1176.86	<0.0001
30–39	1	0.0763	7.9%	0.0046	0.0672	0.0854	269.15	<0.0001
50–59	1	-0.0733	-7.1%	0.0046	-0.0825	-0.0642	249.34	<0.0001
60–64	1	-0.1190	-11.2%	0.0065	-0.1318	-0.1062	331.27	<0.0001
65–69	1	-0.1043	-9.9%	0.0073	-0.1187	-0.0899	202.51	<0.0001
70+	1	0.0137	1.4%	0.0068	0.0003	0.0272	4.02	0.0449
Unknown	1	-0.0492	-4.8%	0.0086	-0.0662	-0.0322	32.16	<0.0001
40–49	0	0	0	0	0	0		
Rated driver gender Male	1	-0.0366	-3.6%	0.0031	-0.0428	-0.0304	133.54	<0.0001
Unknown	1	-0.1403	-13.1%	0.0124	-0.1646	-0.1160	128.13	<0.0001
Female	0	0	0	0	0	0		

Appendix: Illustrative regression results — collision frequency

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Rated driver marital status	Single	1	0.2242	25.1%	0.0034	0.2174	0.2311	4123.42	<0.0001
	Unknown	1	0.1171	12.4%	0.0116	0.0943	0.1399	101.33	<0.0001
	Married	0	0	0	0	0	0		
Risk	Nonstandard	1	0.2889	33.5%	0.0071	0.2748	0.3029	1621.48	<0.0001
	Standard	0	0	0	0	0	0		
State	Alabama	1	-0.0078	-0.8%	0.0190	-0.0451	0.0294	0.17	0.6803
	Alaska	1	0.2883	33.4%	0.0363	0.2170	0.3596	62.82	<0.0001
	Arizona	1	0.0359	3.7%	0.0130	0.0102	0.0615	7.53	0.0061
	Arkansas	1	0.0015	0.2%	0.0325	-0.0623	0.0654	0.00	0.9614
	California	1	0.3134	36.8%	0.0061	0.3014	0.3254	2612.17	<0.0001
	Colorado	1	0.0396	4.0%	0.0129	0.0142	0.0649	9.41	0.0022
	Connecticut	1	0.0038	0.4%	0.0129	-0.0215	0.0291	0.09	0.7683
	Delaware	1	0.0415	4.2%	0.0282	-0.0138	0.0969	2.16	0.1418
	Dist of Columbia	1	0.3481	41.6%	0.0208	0.3073	0.3889	279.79	<0.0001
	Florida	1	-0.0505	-4.9%	0.0072	-0.0647	-0.0364	49.04	<0.0001
	Georgia	1	-0.0020	-0.2%	0.0099	-0.0215	0.0175	0.04	0.8396
	Hawaii	1	0.2194	24.5%	0.0194	0.1812	0.2576	126.69	<0.0001
	Idaho	1	-0.1522	-14.1%	0.0470	-0.2444	-0.0600	10.48	0.0012
	Illinois	1	-0.0116	-1.2%	0.0102	-0.0317	0.0083	1.31	0.2524
	Indiana	1	-0.0230	-2.3%	0.0193	-0.0609	0.0148	1.43	0.2325
	Iowa	1	-0.1457	-13.6%	0.0333	-0.2112	-0.0803	19.07	<0.0001
	Kansas	1	-0.0545	-5.3%	0.0278	-0.1091	0.0001	3.82	0.0505
	Kentucky	1	-0.2164	-19.5%	0.0261	-0.2677	-0.1650	68.26	<0.0001
	Louisiana	1	0.1308	14.0%	0.0175	0.0963	0.1652	55.29	<0.0001
	Maine	1	0.0222	2.2%	0.0461	-0.0681	0.1126	0.23	0.6292
	Maryland	1	0.1569	17.0%	0.0108	0.1357	0.1781	209.81	<0.0001
	Massachusetts	1	0.5509	73.5%	0.0109	0.5293	0.5724	2514.46	<0.0001
	Michigan	1	0.3355	39.9%	0.0146	0.3068	0.3643	523.61	<0.0001
	Minnesota	1	-0.1263	-11.9%	0.0168	-0.1593	-0.0932	56.05	<0.0001
	Mississippi	1	0.0547	5.6%	0.0328	-0.0097	0.1191	2.77	0.0960
	Missouri	1	-0.0447	-4.4%	0.0194	-0.0828	-0.0067	5.32	0.0211
	Montana	1	0.0494	5.1%	0.0835	-0.1142	0.2132	0.35	0.5536
	Nebraska	1	-0.1060	-10.1%	0.0382	-0.1809	-0.0311	7.70	0.0055
	Nevada	1	0.1621	17.6%	0.0163	0.1301	0.1941	98.75	<0.0001
	New Hampshire	1	0.1690	18.4%	0.0230	0.1239	0.2141	53.94	<0.0001
	New Jersey	1	0.0275	2.8%	0.0084	0.0109	0.0440	10.58	0.0011
	New Mexico	1	0.1096	11.6%	0.0267	0.0571	0.1621	16.77	<0.0001
New York	1	0.2589	29.6%	0.0075	0.2441	0.2737	1177.18	<0.0001	
North Carolina	1	-0.1975	-17.9%	0.0124	-0.2218	-0.1731	252.81	<0.0001	
North Dakota	1	0.0476	4.9%	0.1014	-0.1510	0.2464	0.22	0.6384	
Ohio	1	-0.1511	-14.0%	0.0137	-0.1779	-0.1242	121.42	<0.0001	
Oklahoma	1	-0.0267	-2.6%	0.0237	-0.0732	0.0197	1.27	0.2596	
Oregon	1	-0.0133	-1.3%	0.0159	-0.0447	0.0179	0.70	0.4023	
Pennsylvania	1	0.1572	17.0%	0.0095	0.1386	0.1759	273.54	<0.0001	

Appendix: Illustrative regression results — collision frequency

Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	P-value
Rhode Island	1	0.1377	14.8%	0.0248	0.0890	0.1863	30.76	<0.0001
South Carolina	1	-0.1706	-15.7%	0.0170	-0.2041	-0.1372	99.91	<0.0001
South Dakota	1	-0.1622	-15.0%	0.0772	-0.3137	-0.0108	4.41	0.0357
Tennessee	1	-0.0094	-0.9%	0.0160	-0.0409	0.0221	0.34	0.5590
Utah	1	-0.1438	-13.4%	0.0262	-0.1953	-0.0924	30.02	<0.0001
Vermont	1	-0.0449	-4.4%	0.0475	-0.1380	0.0482	0.89	0.3446
Virginia	1	0.0684	7.1%	0.0103	0.0481	0.0886	43.91	<0.0001
Washington	1	0.0320	3.3%	0.0121	0.0082	0.0557	7.00	0.0082
West Virginia	1	-0.0074	-0.7%	0.0431	-0.0919	0.0770	0.03	0.8621
Wisconsin	1	-0.1041	-9.9%	0.0220	-0.1473	-0.0610	22.43	<0.0001
Wyoming	1	-0.1197	-11.3%	0.0835	-0.2835	0.0439	2.06	0.1515
Texas	0	0	0	0	0	0		
Deductible range								
0–250	1	0.0967	10.2%	0.0042	0.0884	0.1051	516.35	<0.0001
501–1000	1	-0.2009	-18.2%	0.0036	-0.2080	-0.1939	3115.40	<0.0001
1001+	1	-0.6066	-45.5%	0.0148	-0.6357	-0.5776	1676.86	<0.0001
251–500	0	0	0	0	0	0		
Registered vehicle density								
0–99	1	-0.2128	-19.2%	0.0070	-0.2267	-0.1990	905.34	<0.0001
100–499	1	-0.1567	-14.5%	0.0041	-0.1648	-0.1487	1457.35	<0.0001
500+	0	0	0	0	0	0		
Forward Alerts package	1	0.0207	2.1%	0.0262	-0.0306	0.0721	0.63	0.4282
Forward Alerts/Automatic Braking package	1	-0.0548	-5.3%	0.0117	-0.0779	-0.0317	21.66	<0.0001
Driving Assistance package	1	-0.0600	-5.8%	0.0436	-0.1456	0.0255	1.89	0.1692
Driving Assistance Plus package	1	-0.0758	-7.3%	0.0169	-0.1091	-0.0425	19.93	<0.0001
Blind spot detection	1	-0.0088	-0.9%	0.0114	-0.0313	0.0135	0.60	0.4389
High-beam assistant	1	0.0138	1.4%	0.0061	0.0017	0.0259	5.01	0.0252
Adaptive headlights	1	-0.0130	-1.3%	0.0057	-0.0242	-0.0018	5.19	0.0227
Night Vision package	1	-0.0680	-6.6%	0.0270	-0.1210	-0.0149	6.31	0.0120
Park distance control	1	-0.0044	-0.4%	0.0078	-0.0198	0.0109	0.32	0.5720
Rearview camera and park distance control	1	-0.0080	-0.8%	0.0044	-0.0166	0.0005	3.33	0.0680
Surround View package	1	0.0095	1.0%	0.0115	-0.0131	0.0322	0.68	0.4088
Parking Assistant package	1	0.0251	2.5%	0.0120	0.0014	0.0487	4.33	0.0375
Parking Assistant Plus package	1	-0.0978	-9.3%	0.0281	-0.1530	-0.0426	12.07	0.0005



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