# 2010 Mazda 3 Adaptive Front Lighting System

▸ **Summary**

Several studies by the Highway Loss Data Institute (HLDI) have shown that some curve-adaptive, or steerable, lighting systems are associated with reductions in insurance losses. While these analyses controlled for potential confounding factors, a key limitation of these studies was that information on the time of crash was not available. Consequently, the estimated reductions represented the gross effect of the light systems on all claims regardless of the time of day.

The purpose of this study is to evaluate collision and property damage liability (PDL) claims data for the 2010 Mazda 3 by the time of crash to see if vehicles equipped with Mazda's adaptive lighting system are associated with fewer nighttime claims compared to those without. The figure below shows the estimated effect of the adaptive lighting system by the time of crash on collision and PDL claim frequencies. For both collision and PDL, Mazda's adaptive lighting systems are associated with statistically significant reductions in nighttime claim frequency of 10 and 15 percent, respectively. Changes in daytime claim frequency were not statistically significant.

Effect of Adaptive Front Lighting System on collision and PDL claim frequency by time of day
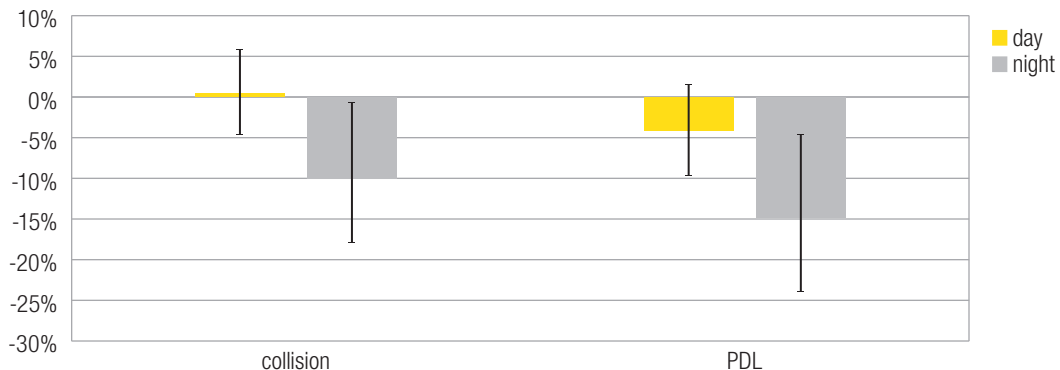
▸ Introduction

The Highway Loss Data Institute (HLDI) has conducted several studies that examined the relationship between collision avoidance systems and insurance losses. Four of these studies included evaluations of adaptive lighting systems (HLDI, 2011, 2016a, 2016c, 2016d). In those studies, after controlling for all of the demographic and geographic variables available to HLDI, as well as for other collision avoidance systems available in the vehicle study population, some adaptive lighting systems were associated with reductions in collision and property damage liability (PDL) claim frequencies. The PDL estimate ranged from a 1 percent disbenefit for Acura vehicles to a 9 percent benefit for Volvo vehicles and a weighted average benefit of 4 percent as shown in **Figure 1**.

Figure 1: Effect of adaptive lighting systems on physical damage claim frequencies by manufacturer
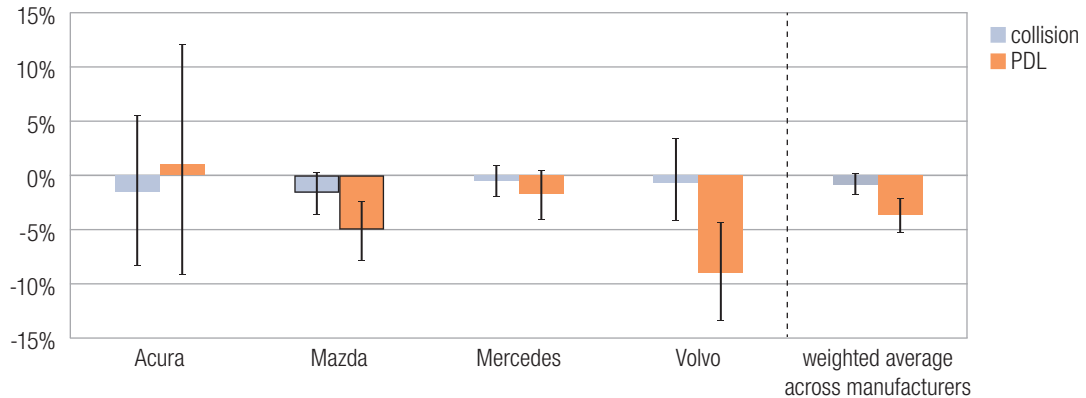
However, information on the time of crash was unavailable in these studies. Consequently, the estimated reductions represented the gross effect of the light systems on all claims regardless of the time of crash. It stands to reason that except during inclement weather, headlights are not typically used during daytime hours so any benefits observed in these studies would be attributable to reductions in nighttime crashes. The current study investigates this by evaluating collision and PDL claims data by the time of crash for the 2010 Mazda 3. The 2010 Mazda 3 was selected due to the available exposure and because there were no other collision avoidance systems available on this vehicle that might confound with the effect of the adaptive lighting system.

▸ Methods

Vehicle Information

Adaptive Front Lighting System (AFLS) is Mazda's term for headlamps that respond to driver steering. The system uses sensors to measure vehicle speed and steering angle while small electric motors turn the headlights accordingly to facilitate vision around a curve at night. It is functional after the headlights have been turned on at vehicle speeds above 2 mph. The adaptive lighting can be deactivated by the driver and will be in the previous on/off setting at the next ignition cycle. The adaptive lighting lamps on the 2010 Mazda 3 are high intensity discharge (HID), whereas the base lighting system uses halogen lamps.

AFLS is offered as optional equipment on the 2010 Mazda 3. The presence or absence of this feature is not discernible from the information encoded in the vehicle identification number (VIN), but rather, this must be determined from build information maintained by the manufacturer. Mazda supplied HLDI with the VINs for any vehicles that were equipped with AFLS. Vehicles of the same model year and series not identified by Mazda were assumed not to have AFLS and served as the control vehicles in the analysis. Electronic stability control was standard on most vehicles but optional on one trim level of the 2010 Mazda 3, so this trim level was excluded from the analysis. No other collision avoidance features are available on the 2010 Mazda 3. The high-performance version of the Mazda 3, the Speed3, was also excluded from the analysis. This resulted in 110,252 years of collision exposure for the 2010 Mazda 3.

Insurance data

Automobile insurance covers damages to vehicles and property as well as injuries to people involved in 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 and collision coverages. Exposure is measured in insured vehicle years. An insured vehicle year is one vehicle insured for 1 year, two vehicles for 6 months, etc.

Collision coverage insures against vehicle damage to an at-fault driver's vehicle sustained in a crash with an object or other vehicle; this coverage is common to all 50 states. PDL coverage insures against vehicle damage that at-fault drivers cause to other people's vehicle 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).

The time of crash is typically not included in the data provided to HLDI by its data suppliers. In order to perform this study, data suppliers were asked to provide time of crash information for all claims associated with the 2010 Mazda 3. This included claims for calendar years 2009–13. Twenty-seven companies supplied HLDI with information on the time of crash. In 2014, several of these insurers began regularly providing HLDI with data on the time of crash. As a result, this study includes data from the 27 insurers that provided time of crash information on 2010 Mazda 3 and includes calendar years 2009–16. These companies make up 97 percent of the total exposure for the 2010 Mazda 3 in the HLDI database.

Some of the reported crash times occurred in the data far more often than probable and may reflect coding of an unknown time of crash. This data included the times 00:00, 00:01, 12:00, and 12:01. This phenomenon is discussed in greater detail in **Appendix B**.

Figure 2 shows that the time of crash was known for 57 percent of the collision claims from these 27 companies while 43 percent had no time of crash information available. A key assumption in the design of this study was that the time of crash being known for a claim was independent of whether or not the vehicle was equipped with AFLS. **Figure 3** illustrates that the AFLS feature does not bias whether the time of crash is known, as the distribution of collision claims with known and unknown time of crash is similar for vehicles with and without AFLS. The distribution of claims with known and unknown time of crash was similar for PDL claims.

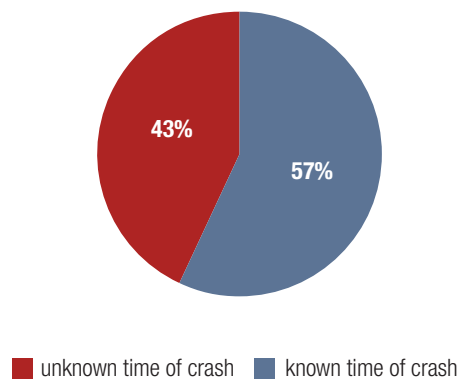**Figure 2: Collision claims with known time of crash**

43% 57%

■ unknown time of crash ■ known time of crash

Figure 3: AFLS and non-AFLS collision claims with known time of crash

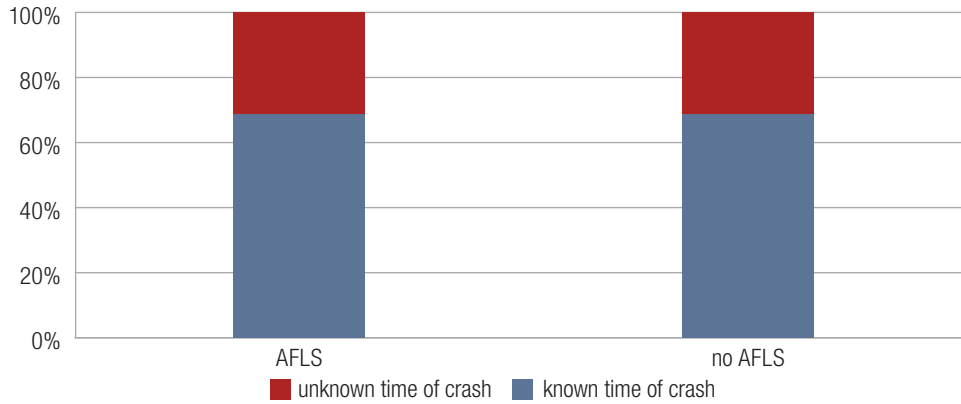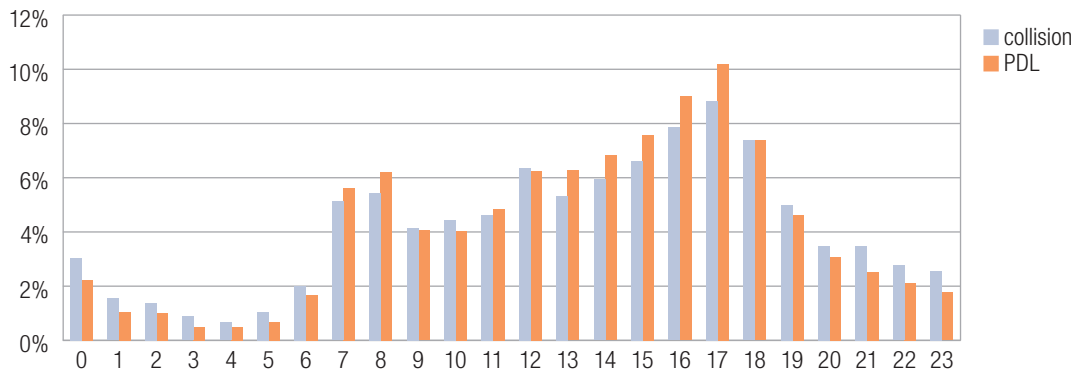■ unknown time of crash ■ known time of crash

Figure 4 shows the distribution of collision and PDL claims with known time of crash by the hour of day. The fewest number of claims stemmed from crashes occurring during the early morning hours between 1 a.m. and 5 a.m. The number of claims increased sharply between 7 a.m. and 8 a.m., the morning rush hour, and again at noon. The evening rush hour, between 4 p.m. and 6 p.m., had the highest number of claims. A larger proportion of PDL claims occurred during rush hour, as would be expected given that PDL claims tend to be from multiple-vehicle crashes and traffic is highest at these times.

Figure 4: Distribution of collision and PDL claims by hour


■ collision ■ PDL

Sunrise/Sunset Data

Claims with known time of crash were categorized as occurring either during nighttime, daytime or twilight. Nighttime was chosen to be 1 hour after sunset to 1 hour before sunrise based on the definition of astronomical twilight. According to the U.S. Naval Observatory (2016) website, "Astronomical twilight is defined to begin in the morning and to end in the evening when the center of the Sun is geometrically 18 degrees below the horizon. Before the beginning of astronomical twilight in the morning and after the end of astronomical twilight in the evening, scattered light from the Sun is less than that from starlight and other natural sources. For a considerable interval after the beginning of morning twilight and before the end of evening twilight, sky illumination is so faint that it is practically imperceptible." Since the earth rotates 15 degrees per hour (360 degrees/24 hours), the hours classified as nighttime are sufficiently dark to necessitate the use of headlights. Twilight was categorized at the hour before sunrise and the hour after sunset, with daytime comprising the time between sunrise and sunset.

Data on sunrise and sunset were obtained from the U.S. Naval Observatory. These data were obtained for each day of the year for 2013 and then applied to all of the calendar years in this study. The data were collected at the state level. In order to get state level data, a specific city had to be selected. For each state, the state capital was used for the city selection. Sunrise and sunset times were adjusted for daylight saving time at the calendar year level. Hawaii and Arizona do not observe daylight saving time, so no adjustment was made for those states. Using this methodology, 69 percent of the collision claims with known crash times were classified as day claims, whereas 23 percent were classified as night claims and 8 percent as twilight claims, as shown in **Figure 5**. For PDL, a higher proportion of claims, 75 percent, occurred during the day, with only 17 percent of claims occurring at night. This is consistent with the majority of PDL claims arising from multiple-vehicle crashes and typically increased amounts of traffic during the daytime hours.

Figure 5: Collision and PDL claims with known time of crash by time of day

collision   PDL
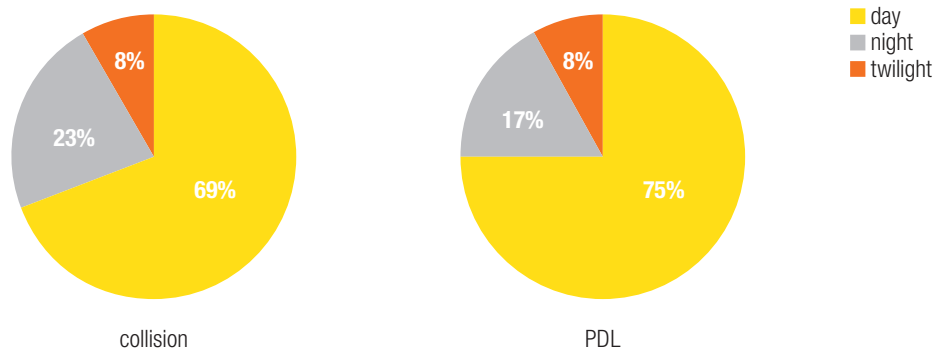
Statistical Methods

Regression analysis was used to quantify the effect of AFLS while controlling for other covariates. The covariates included calendar year, garaging state, vehicle density (number of registered vehicles per square mile), rated driver age group, rated driver gender, rated driver marital status, deductible range, risk, and vehicle series. AFLS was included as a binary variable indicating whether this safety feature was present or not.

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.

For space reasons, only the estimates for the AFLS are shown on the following pages. To illustrate the analyses, however, **Appendix A** contains full model results for the collision claim frequencies. To further simplify the presentation here, the exponent of the parameter estimate was calculated, 1 was subtracted, and the result multiplied by 100. The resulting number corresponds to the effect of the feature on that loss measure. For example, the estimate of the effect of adaptive lighting on collision claim frequency was -0.012; thus, vehicles with adaptive lighting are expected to have 1 percent fewer collision claims than vehicles without adaptive lighting ((exp(-0.012) -1)*100 = -1).

▸ Results

Figure 6 compares the overall effect, regardless of time of day, of AFLS on collision and PDL claim frequencies for all claims and just those with a known crash time. The vertical I-bars indicate the 95 percent confidence limits of the estimates. The estimated frequency benefit of AFLS for claims with a known crash time is consistent with the effect for all claims. This indicates that evaluating the subset of claims where the time of crash is known does not bias the overall effectiveness of AFLS.

Figure 6: Effect of AFLS on collision and PDL claim frequency for all claims and claims with known time of crash
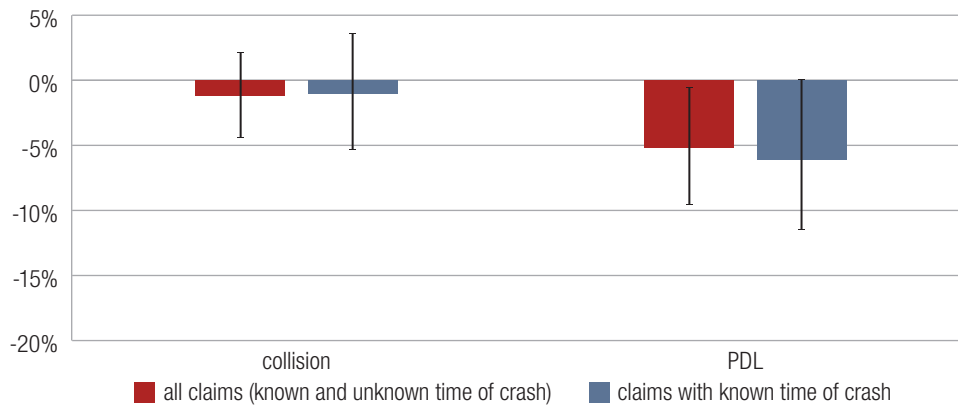
Results by time of day are summarized in **Table 1**. The upper and lower bounds represent the 95 percent confidence limits of the estimates. AFLS was associated with statistically significant reductions in nighttime claim frequency of 10 percent for collision and 15 percent for PDL. Daytime collision claim frequency showed no meaningful difference, while daytime PDL claim frequency showed a 4 percent reduction but was not statistically significant. Twilight claim frequency was higher by 12 percent for collision but lower by 5 percent for PDL. However, these estimates were not significant with large confidence bounds, as the data are thin with twilight only comprising 2 hours of the day.

Table 1: Change in insurance losses for Adaptive Front Lighting System by time of day										
		Lower bound	Frequency	Upper bound	Lower bound	Severity	Upper bound	Lower bound	Overall Losses	Upper bound
Collision	Day	-5%	0%	6%	-4%	2%	8%	-5%	3%	11%
	Night	-18%	**-10%**	-1%	-11%	-2%	8%	-23%	-12%	1%
	Twilight	-4%	12%	30%	-10%	7%	26%	-5%	19%	50%
PDL	Day	-11%	-4%	3%	-11%	-4%	2%	-17%	-8%	1%
	Night	-27%	**-15%**	0%	-33%	**-22%**	-9%	-47%	**-33%**	-17%
	Twilight	-24%	-5%	19%	-23%	-3%	21%	-34%	-8%	26%

Claim severity estimates were not statistically significant with the exception of the nighttime PDL result, where AFLS was associated with a 22 percent reduction. Consequently, nighttime overall losses for PDL showed a statistically significant reduction of 33 percent. Other overall loss results were not statistically significant. **Figures 7 and 8** illustrate these results graphically for collision and PDL, respectively.

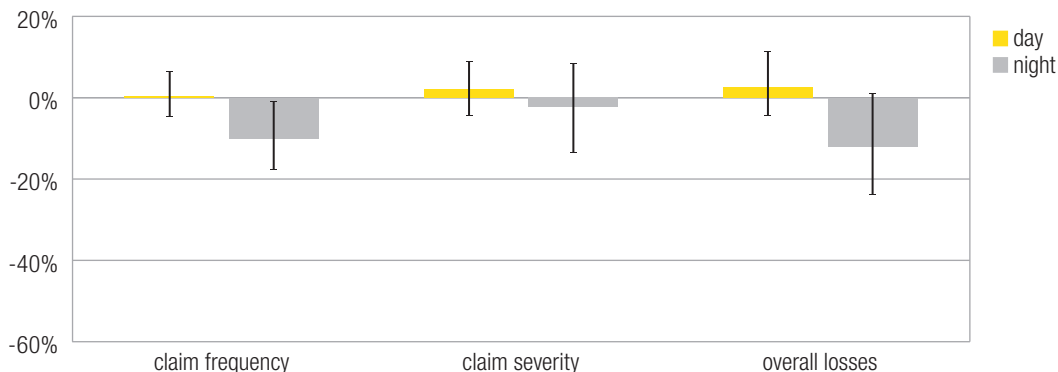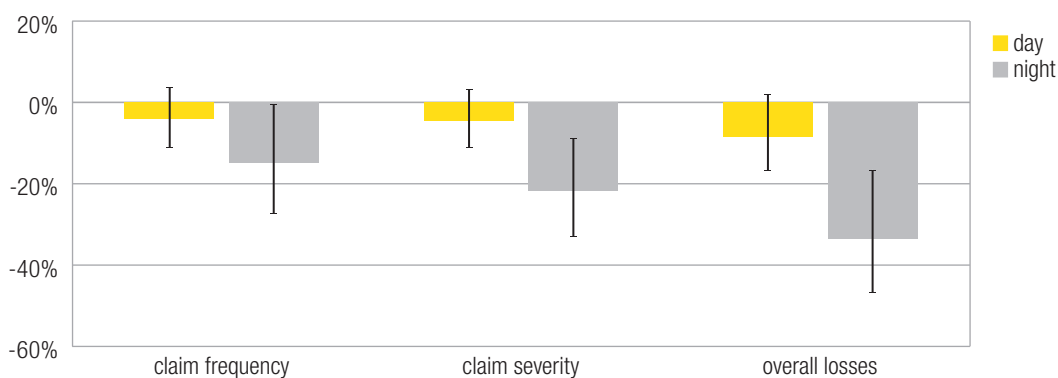**Figure 7: Effect of AFLS on collision losses**

Figure 8: Effect of AFLS on PDL losses

Discussion

Initial expectations for curve-adaptive headlights were that these systems would be of primary benefit on curved roads at night. Crashes in such situations are predominantly single-vehicle crashes, which is why early results for these systems that showed a stronger overall benefit for PDL claims compared with collision claims were surprising. However, recent research by the Insurance Institute for Highway Safety (IIHS) indicates that improved lighting systems can provide nighttime benefits beyond just on curved roads.

A 2014 IIHS study found that on the 2013 Mazda 3, HID headlights had an advantage over halogen lights (IIHS, 2014). In addition, with the curve-adaptive lights, drivers on a curved road were better able to spot hard-to-see targets, as much as 15 feet sooner at 30 mph, compared with regular headlights. More recently, IIHS has begun testing and rating different headlight systems. These tests have shown a wide range of results in the visibility and performance of different headlight systems (IIHS, 2016). While the research shows some advantages for curve-adaptive and HID headlights, these features do not guarantee good headlight performance. In general, systems that provided ample illumination on both curved and straight roads without excessive glare for oncoming drivers performed better.

The results of the current study are in agreement with the original HLDI studies on vehicles with adaptive lighting systems and the more recent IIHS research. While the overall estimate showed no significant collision benefit, a time of day analysis of Mazda's AFLS, which uses HID lamps, indicates a strong and statistically significant reduction in both collision and PDL claims stemming from nighttime crashes. During the day, when headlights typically would not be in use, there was no statistically significant difference in either collision or PDL claim frequencies. Nighttime PDL claim severity also is down by a significant 22 percent for vehicles with AFLS. This could be an indication that the improved visibility at night not only helps to avoid crashes but also may make crashes that still occur less severe. Overall, these results suggest that Mazda's AFLS is providing improved illumination for drivers at night and consequently reducing nighttime crashes.

▶ Limitations

There are limitations to the data used in this analysis. At the time of a crash, the status of the adaptive lights was not known. The adaptive lights can be deactivated by the driver and there is no way to know how many, if any, of the drivers in these vehicles had turned off the system prior to the crash. 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 such as point of impact and transmission status. The adaptive headlights studied in this report target certain crash types. For example, they would not be expected to mitigate collisions that occur when the vehicle is backing up. All collisions, regardless of the ability of a feature to mitigate or prevent them, are included in the analysis.

Mazda 3's with adaptive headlights cost significantly more compared to those without. The adaptive lighting system is only available on the s Grand Touring trim level whose MSRP was 13 percent higher than the next trim level, the s Sport. The type of person who is willing to pay such a large additional cost for an otherwise inexpensive car may be different from the person who is not. While the analysis controls for several driver characteristics, there may be other uncontrolled attributes associated with people who select these features.

This analysis assumes that crashes occur in the garaging state provided by the insurer for the associated VIN. The actual location of the crash is unknown. In addition, although most states lie within a single time zone, there are some states spread across multiple time zones. For most of these states, the majority of the geographic area of the state lies within a single time zone (see nationalatlas.gov for a map of the time zones). This analysis does not apply an adjustment to the sunrise/sunset times for crashes where the garaging ZIP code is in a different time zone from the state capital. The time of day for crashes that occur in these areas or in a state different from the garaging state may be misclassified.

▸ Appendix A: Illustrative regression results

Appendix A: Illustrative regression results - collision frequency								
Parameter		Degrees of freedom	Estimate	Effect	Standard Error	Wald 95% Confidence Limits		Chi-Square	P-value
Intercept		1	-7.8555		0.0402	-7.9343	-7.7766	38105.1	<0.0001
Calendar Year	2009	1	-0.0865	-1.4%	0.0505	-0.1856	0.0125	2.93	0.0868
	2010	1	-0.0105	6.4%	0.0293	-0.0678	0.0468	0.13	0.7195
	2011	1	-0.0190	5.5%	0.0275	-0.0730	0.0350	0.47	0.4911
	2012	1	-0.1005	-2.7%	0.0280	-0.1554	-0.0455	12.84	0.0003
	2013	1	-0.0729	8.8%	0.0278	-0.1273	-0.0184	6.88	0.0087
	2014	1	0.0114	7.6%	0.0274	-0.0422	0.0650	0.17	0.6779
	2016	1	-0.0406	3.3%	0.0412	-0.1214	0.0402	0.97	0.3246
	2015	0	0	0	0	0	0		
State	Alaska	1	-0.0882	-8.4%	0.1944	-0.4692	0.2929	0.21	0.6502
	Alabama	1	-0.0929	-8.9%	0.0961	-0.2813	0.0956	0.93	0.3340
	Arkansas	1	0.0806	8.4%	0.1331	-0.1802	0.3415	0.37	0.5447
	Arizona	1	-0.0650	-6.3%	0.0612	-0.1851	0.0550	1.13	0.2882
	Colorado	1	-0.0017	-0.2%	0.0635	-0.1262	0.1227	0.00	0.9782
	Connecticut	1	0.0079	0.8%	0.0623	-0.1142	0.1299	0.02	0.8992
	District of Columbia	1	-0.2295	-20.5%	0.1143	-0.4535	-0.0056	4.03	0.0446
	Delaware	1	-0.0849	-8.1%	0.1002	-0.2814	0.1116	0.72	0.3971
	Florida	1	-0.0909	-8.7%	0.0386	-0.1666	-0.0153	5.55	0.0185
	Georgia	1	-0.1275	-12.0%	0.0538	-0.2330	-0.0219	5.60	0.0179
	Hawaii	1	-0.1974	-17.9%	0.1012	-0.3958	0.0009	3.81	0.0511
	Iowa	1	0.0818	8.5%	0.1274	-0.1680	0.3316	0.41	0.5209
	Idaho	1	-0.2521	-22.3%	0.1817	-0.6082	0.1040	1.93	0.1653
	Illinois	1	-0.0794	-7.6%	0.0459	-0.1694	0.0106	2.99	0.0840
	Indiana	1	0.0689	7.1%	0.0746	-0.0772	0.2150	0.85	0.3554
	Kansas	1	-0.0250	-2.5%	0.0970	-0.2152	0.1652	0.07	0.7966
	Kentucky	1	-0.0860	-8.2%	0.0797	-0.2422	0.0702	1.16	0.2805
	Louisiana	1	0.0084	0.8%	0.0894	-0.1668	0.1836	0.01	0.9253
	Maryland	1	-0.2053	-18.6%	0.0450	-0.2934	-0.1172	20.87	<0.0001
	Maine	1	-0.0078	-0.8%	0.1531	-0.3080	0.2923	0.00	0.9592
	Michigan	1	0.2203	24.6%	0.0498	0.1228	0.3178	19.60	<0.0001
	Minnesota	1	-0.0398	-3.9%	0.0608	-0.1590	0.0795	0.43	0.5133
	Missouri	1	-0.0711	-6.9%	0.0772	-0.2223	0.0802	0.85	0.3571
	Mississippi	1	-0.3806	-31.7%	0.2198	-0.8115	0.0503	3.00	0.0834
	Montana	1	-0.2007	-18.2%	0.2910	-0.7709	0.3696	0.48	0.4904
	North Carolina	1	-0.0933	-8.9%	0.0609	-0.2126	0.0261	2.35	0.1256
	North Dakota	1	-0.5185	-40.5%	0.3352	-1.1756	0.1385	2.39	0.1219
	Nebraska	1	-0.1124	-10.6%	0.1271	-0.3615	0.1367	0.78	0.3764
	New Hampshire	1	0.0667	6.9%	0.1014	-0.1320	0.2654	0.43	0.5107
	New Jersey	1	-0.0484	-4.7%	0.0399	-0.1265	0.0298	1.47	0.2254
	New Hampshire	1	-0.0034	-0.3%	0.1106	-0.2202	0.2134	0.00	0.9754
	Nevada	1	-0.0051	-0.5%	0.0952	-0.1916	0.1815	0.00	0.9575
	New York	1	-0.0922	-8.8%	0.0364	-0.1636	-0.0208	6.40	0.0114

Appendix A: Illustrative regression results - collision frequency

Parameter		Degrees of freedom	Estimate	Effect	Standard Error	Wald 95% Confidence Limits		Chi-Square	P-value
	Ohio	1	-0.0936	-8.9%	0.0458	-0.1834	-0.0038	4.18	0.0410
	Oklahoma	1	-0.0343	-3.4%	0.1023	-0.2347	0.1662	0.11	0.7376
	Oregon	1	-0.1060	-10.1%	0.0672	-0.2378	0.0257	2.49	0.1148
	Pennsylvania	1	-0.0357	-3.5%	0.0352	-0.1048	0.0333	1.03	0.3103
	Rhode Island	1	-0.0438	-4.3%	0.1155	-0.2703	0.1826	0.14	0.7044
	South Carolina	1	-0.0491	-4.8%	0.0884	-0.2222	0.1241	0.31	0.5787
	South Dakota	1	-0.4918	-38.8%	0.4096	-1.2945	0.3110	1.44	0.2299
	Tennessee	1	0.0158	1.6%	0.0687	-0.1189	0.1504	0.05	0.8181
	Texas	1	-0.1177	-11.1%	0.0354	-0.1872	-0.0483	11.04	0.0009
	Utah	1	-0.0729	-7.0%	0.0772	-0.2242	0.0785	0.89	0.3453
	Virginia	1	-0.1381	-12.9%	0.0408	-0.2182	-0.0581	11.45	0.0007
	Vermont	1	-0.1761	-16.1%	0.2200	-0.6073	0.2550	0.64	0.4234
	Washington	1	-0.1282	-12.0%	0.0483	-0.2228	-0.0337	7.06	0.0079
	Wisconsin	1	0.0484	5.0%	0.0824	-0.1132	0.2100	0.34	0.5570
	West Virginia	1	-0.0671	-6.5%	0.1712	-0.4027	0.2684	0.15	0.6950
	Wyoming	1	0.3387	40.3%	0.3038	-0.2568	0.9341	1.24	0.2649
	California	0	0	0	0	0	0		
Rated driver gender	Male	1	-0.0121	-1.2%	0.0177	-0.0467	0.0226	0.47	0.4941
	Unknown	1	-0.0620	-6.0%	0.0698	-0.1988	0.0747	0.79	0.3740
	Female	0	0	0	0	0	0		
Rated driver marital status	Single	1	0.0769	8.0%	0.0199	0.0378	0.1160	14.85	0.0001
	Unknown	1	0.0548	5.6%	0.0690	-0.0805	0.1902	0.63	0.4270
	Married	0	0	0	0	0	0		
Risk	Nonstandard	1	0.0857	8.9%	0.0235	0.0396	0.1318	13.26	0.0003
	Standard	0	0	0	0	0	0		
Registered vehicle density	0–99	1	-0.0006	-0.1%	0.0318	-0.0629	0.0617	0.00	0.9849
	100–499	1	-0.0090	-0.9%	0.0197	-0.0476	0.0295	0.21	0.6453
	500+	0	0	0	0	0	0		
Rated driver age	14–20	1	0.1982	21.9%	0.0387	0.1223	0.2741	26.2	<0.0001
	21–24	1	0.1132	12.0%	0.0288	0.0567	0.1697	15.4	<0.0001
	25–39	1	0.0028	0.3%	0.0190	-0.0345	0.0401	0.02	0.8840
	65+	1	-0.0117	-1.2%	0.0363	-0.0828	0.0594	0.10	0.7467
	Unknown	1	0.0646	6.7%	0.0397	-0.0132	0.1423	2.65	0.1036
	40–64	0	0	0	0	0	0		
Deductible range	0–250	1	0.1867	20.5%	0.0292	0.1296	0.2439	41.03	<0.0001
	1001+	1	-0.3134	-26.9%	0.1526	-0.6124	-0.0144	4.22	0.0400
	251–500	1	0.1326	14.2%	0.0245	0.0847	0.1806	29.40	<0.0001
	501–1000	0	0	0	0	0	0		
Vehicle series	2010 3 4dr	1	-0.0096	-1.0%	0.0159	-0.0408	0.0215	0.37	0.5445
	2010 3 Station Wagon	0	0	0	0	0	0		
Adaptive Front Lighting System		1	-0.0118	-1.2%	0.0169	-0.0449	0.0212	0.49	0.4837


► Appendix B: Time of claim analysis

Close inspection of the time of crash information revealed that some of the reported crash times, in particular, the times of 00:00, 00:01, 12:00 and 12:01 occurred in the data far more often than probable. One hypothesis was that midnight or noon (or both) was used as a default hour when the actual time of the crash was not known. For example, one data supplier had almost 70 percent of midnight claims recorded as occurring at "00:01." For all other hours in the day, less than 1 percent of claims are recorded as occurring on the first minute of the hour. Similarly, other companies have a high proportion of claims reported exactly at midnight or noon (i.e., "00:00" or "12:00").

To correct for this problem, a separate time of day study (HLDI, 2016b) dropped all times with minutes of 00 or 01 from the dataset. This approach excluded the bad data with a minimum of bias. However, this also resulted in approximately one-third of the claims with a known crash time being excluded, some of which may have had valid crash times. This method was appropriate for that study as the primary focus was the hourly distribution of collision claims. Leaving those claims in the dataset would have disproportionately skewed the distribution towards the midnight and noon hours.

For the purposes of this study, the hourly distribution was not as important as whether or not the crash occurred at nighttime, when the headlights would be turned on, or during the day, when the headlights typically would be off. In addition, not all claims with a reported crash time of noon or midnight will be invalid, and excluding one-third of the 2010 Mazda 3 data would result in a much more limited dataset. Therefore, the primary results in this study include all of the claims with crash times as reported by the insurers. This appendix includes a supplementary analysis to verify whether excluding claims with minutes of 00 or 01 substantively affects the results. Any claim where the minutes of the crash time are 00 or 01 are treated as if the crash time is unknown. **Figures B6–B8** correspond to the same numbered figures in the primary report but with these claims treated as having unknown crash times.

Figure B6 shows that the estimated benefit of AFLS is larger for both collision and PDL when only looking at claims with known time of crash (00 and 01 minutes excluded). In particular, the PDL benefit is 9 percent for claims with known time of crash versus 5 percent for all claims. While this difference is not statistically significant, as the confidence bounds overlap, this could indicate that excluding claims with 00 or 01 minutes may bias the overall estimated effect of AFLS.

Figure B6: Effect of AFLS on collision and PDL claim frequency for all claims and claims with known time of crash, 00 and 01 minute claims treated as unknown

Legend:
- ■ all claims (known and unknown time of crash)
- ■ claims with known time of crash
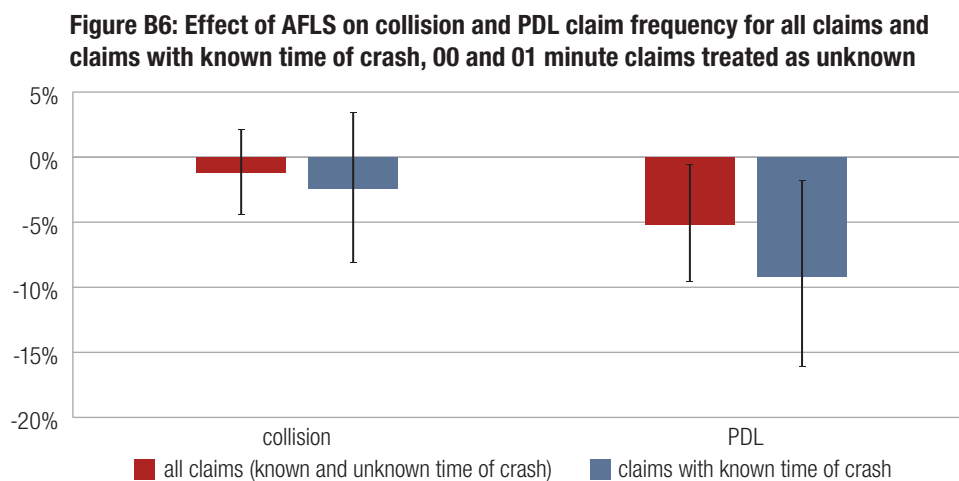
Figures B7 and B8 show the estimated effect of AFLS on collision and PDL insurance losses for day and night. AFLS are still associated with reductions in nighttime claim frequencies for both collision and PDL, but these results are no longer statistically significant. Nighttime PDL claim severity remains statistically significant with a 28 percent reduction. Daytime claim frequency for collision indicates no substantive change; PDL shows a 7 percent reduction, although this result is not statistically significant. Overall, these results are comparable with those using all claims with known crash times, as shown in **Figures 7 and 8**. Therefore, the overall conclusions of this study do not change if crash times with 00 or 01 minutes are excluded from the analysis.

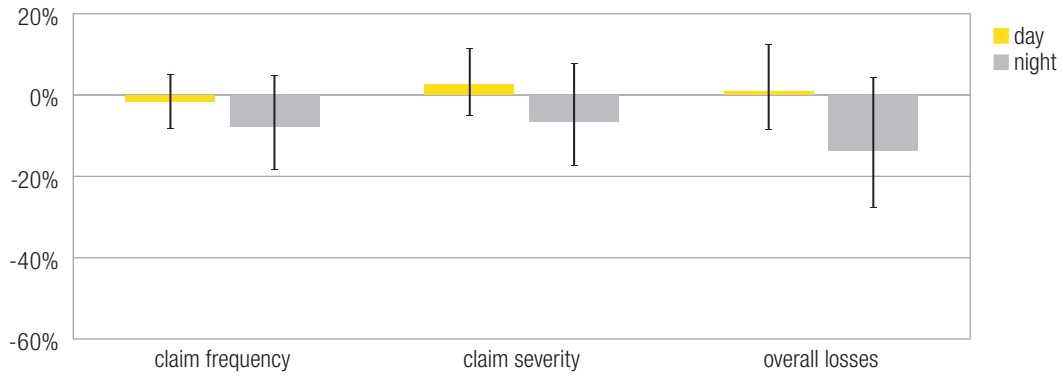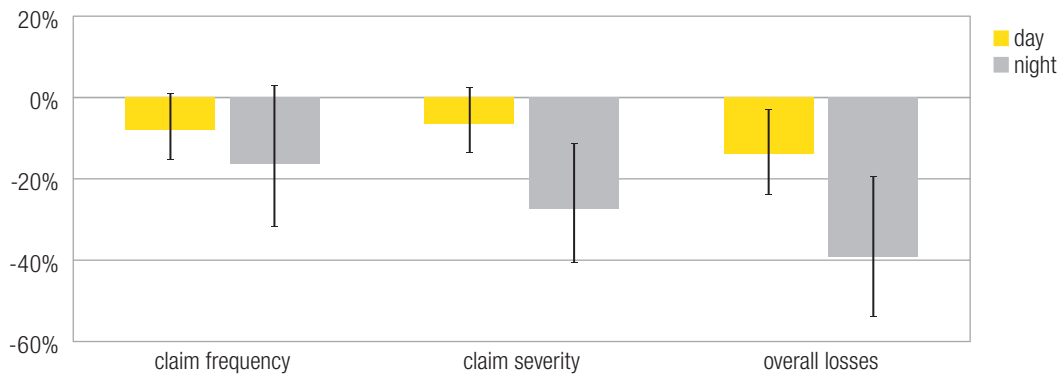**Figure B7: Effect of AFLS on collision losses, 00 and 01 minute claims excluded**

Figure B8: Effect of AFLS on PDL losses, 00 and 01 minute claims excluded

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