2010 Mazda Adaptive Front Lighting System time of day analysis

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ABSTRACT

Objective: Analysts evaluated insurance claims under collision and property damage liability (PDL) coverage for the 2010 Mazda 3 by time of the crash to see if vehicles equipped with Mazda's adaptive lighting system are associated with fewer nighttime claims compared to those without.

Methods: Mazda supplied the Highway Loss Data Institute (HLDI) with the vehicle identification numbers for 2010 Mazda 3 vehicles that were equipped with Adaptive Front Lighting System (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. The 2010 Mazda 3 was selected due to the available exposure (over 100,000 vehicle years insured) and because there were no other collision avoidance systems available on this vehicle that might confound with the effect of AFLS. HLDI data suppliers provided time of crash information for approximately 57% of claims associated with the 2010 Mazda 3. Using state-level data on sunrise and sunset times from the U.S. Naval Observatory, 69% of collision claims with known crash times were classified as day claims, whereas 23% were classified as night claims and 8% as twilight claims. For property damage liability, a higher proportion of claims (75%) occurred during the day, with only 17% of claims occurring at night. Regression analysis was used to quantify the effect of AFLS while controlling for other covariates, including calendar year, garaging state, vehicle density, age group, gender, marital status, deductible range, risk, and vehicle series. Claim frequency was modeled using a Poisson distribution. Separate models were constructed for the day and night analyses.

Results: For both collision and PDL, Mazda's Adaptive Front Lighting System was found to be associated with statistically significant reductions in nighttime claim frequency of 10% and 15%, respectively. During the day, when headlights typically would not be in use, there was no statistically significant difference in either collision or PDL claim frequencies.

Discussion: The Insurance Institute for Highway Safety (IIHS) has begun testing and rating the performance of automobile headlight systems. A primary motivation for evaluating headlight systems was research by HLDI indicating that some curve-adaptive, or steerable lighting systems were associated with reductions in insurance losses. While these analyses controlled for potential confounding factors, a key limitation 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.

This examination of insurance data by time of day revealed that Mazda's Adaptive Front Lighting System is associated with significant reductions in claim rates during nighttime conditions.

Conclusion: Mazda's Adaptive Front Lighting System is associated with a lower nighttime claim frequency than models with the base headlights. This confirms that the previously reported benefits of adaptive front lighting are due to improved illumination for drivers at night. Efforts to promote similar lighting systems will improve vehicle safety.

INTRODUCTION

Thirty percent of U.S. traffic fatalities involving passenger vehicles during 2014 occurred in dark and unlit conditions, while the most recent National Household Travel Survey indicates that only 10% of passenger vehicle miles traveled are driven between 9 p.m. and 6 a.m. (Insurance Institute for Highway Safety, 2016a). Poor driver visibility is likely to have contributed to such nighttime crashes, although other factors such as fatigue, impairment, and driving too fast for conditions have also been implicated in these crashes.

Several studies have attempted to investigate the relationship between lighting conditions and traffic crashes. Owens and Sivak (1996) found that both reduced visibility and drivers' consumption of alcohol played major roles in nighttime road fatalities, with low illumination associated primarily with collisions involving pedestrians and cyclists. Plainis et al. (2006) compared road injury data under dim and bright conditions for two EU countries and found low luminance likely to contribute to the disproportionate number of traffic injuries that occur after dark. Using the illumination provided by the different phases of the moon, Sivak et al. (2007) estimated 22% more fatalities on nights with a new moon versus a full moon.

A meta-analysis by Elvik (1995) found that public lighting could serve as an effective countermeasure to reduce nighttime crashes, particularly fatal ones. It stands to reason that efforts to improve driver visibility with advanced headlight technologies are another potential countermeasure that may work to reduce crashes in dark, unlit conditions.

The Highway Loss Data Institute has conducted several studies that examined the relationship between collision avoidance systems, including adaptive, or steerable, lighting systems, and insurance losses (HLDI, 2011, 2016a, 2016b, 2016c). In those studies, after controlling for 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 PDL claim frequencies. The PDL estimate ranged from a 1% disbenefit for Acura vehicles to a 9% benefit for Volvo vehicles and a weighted average benefit of 4% as shown in **Figure 1**.
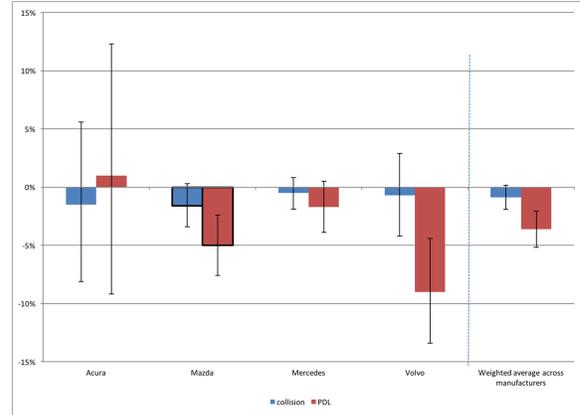
Figure 1. Effect of adaptive lighting systems on physical damage claim frequencies by manufacturer.

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.

This study evaluates claims data by the time of day the crashes occurred for the model year 2010 Mazda 3 to see if vehicles equipped with an adaptive lighting system from Mazda are less likely to have nighttime claims than those without.

METHODS

Vehicle Data
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. 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.

HLDI has data on the vehicles insured by its member companies including the length of time those vehicles were insured as well as any claims filed for that vehicle under collision or PDL coverage. Using this information, HLDI calculates collision or PDL claim frequency as the number of claims divided by exposure, where exposure is defined as the number of insured vehicle years. One insured vehicle year can represent one vehicle insured for one year, two vehicles insured for six months, etc. HLDI also receives the VINs of the vehicles on the insurance policy.

Information about the garaging ZIP code of the vehicle, deductible amount, and rated driver are also provided. Rated driver characteristics include age, gender, marital status, and insurance risk group. Insurance risk group is a binary variable indicating whether the rated driver is considered to have standard or higher insurance risk. The rated driver is the one who typically is considered to represent the greatest loss potential for the insured vehicle. In a household with multiple vehicles and/or drivers, the assignment of drivers to vehicles can vary by insurance company and by state. Although the actual driver operating the vehicle at the time of the claim is unknown, prior HLDI research has shown rated driver characteristics to be highly correlated with insurance losses (HLDI, 2014).

Time of Crash Data
The time of crash is not included in the data provided to HLDI by all of its data suppliers. For the purposes of this study, data suppliers were asked to provide time of crash information for collision and PDL claims associated with the 2010 Mazda 3. Time of crash information was provided for 57% and 56% of collision and PDL claims, respectively. A key assumption in the design of this study was that the time of crash being known for a claim was independent of whether the vehicle was equipped with AFLS. **Figure 2** illustrates that presence of 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.
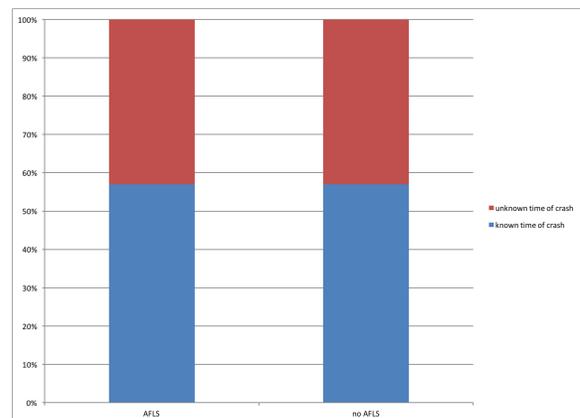
Figure 2. AFLS and Non-AFLS collision claims with known time of crash.

Figure 3 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.
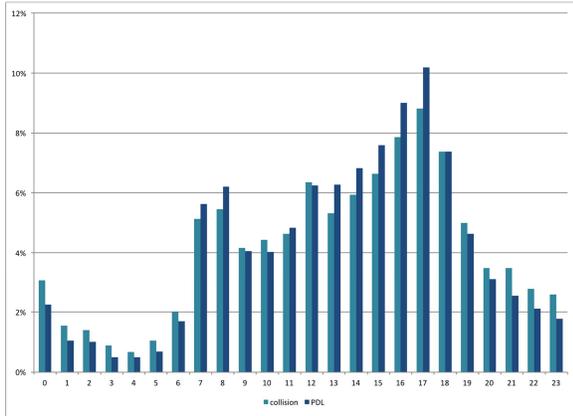

Figure 3. Distribution of collision and PDL claims by hour of day.

Claims with known time of crash were categorized as occurring either during nighttime, daytime, or twilight. Nighttime was chosen to be one hour after sunset to one hour before sunrise based on the definition of astronomical twilight. The U.S. Naval Observatory (2016) website states, "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 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% of the collision claims with known crash times

were classified as day claims, whereas 23% were classified as night claims and 8% as twilight claims, as shown in **Figure 4**. For PDL, a higher proportion of claims, 75%, occurred during the day, with only 17% of claims occurring at night. This is consistent with the majority of PDL claims arising from multiple-vehicle crashes and increased traffic during the daytime hours.
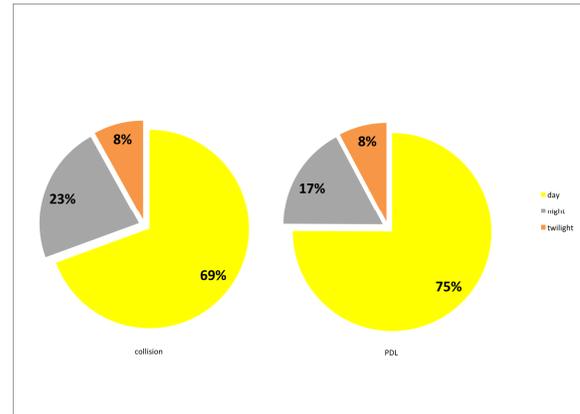

Figure 4. Collision and PDL claims with known time of crash by time of day.

Analysis 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 with a logarithmic link function. Separate regression analyses were conducted for daytime versus nighttime claims for both collision and PDL coverages.

RESULTS

Figure 5 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% 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.
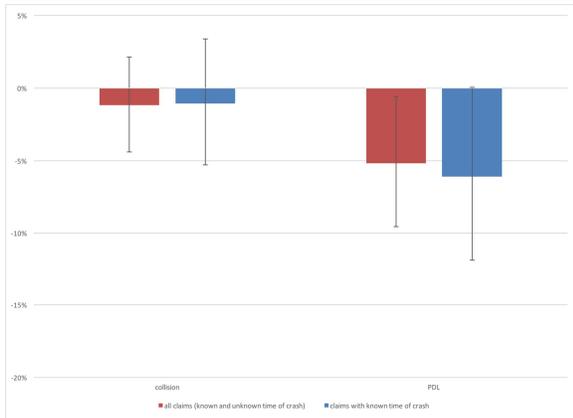
Figure 5. Effect of AFLS on collision and PDL claim frequency for all claims and claims with known time of crash.

Results by time of day for AFLS are summarized in **Figure 6**. The black error bars represent the 95% confidence limits of the estimates. AFLS was associated with statistically significant reductions in nighttime claim frequency of 10% for collision and 15% for PDL. Daytime collision claim frequency showed no meaningful difference, while daytime PDL claim frequency showed a 4% reduction but was not statistically significant. Although not displayed, twilight claim frequency was higher by 12% for collision but lower by 5% for PDL. However, these estimates were not significant and had large confidence bounds, as the data were thin with twilight only comprising two hours of the day.
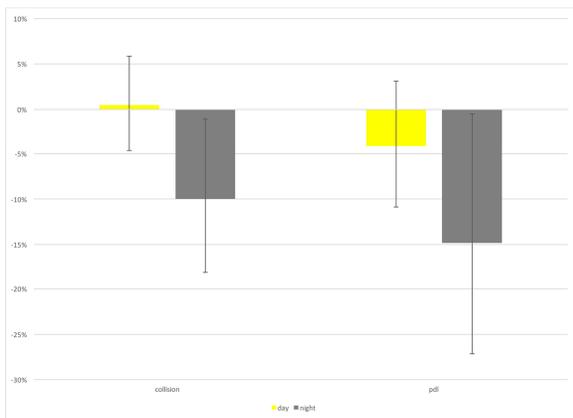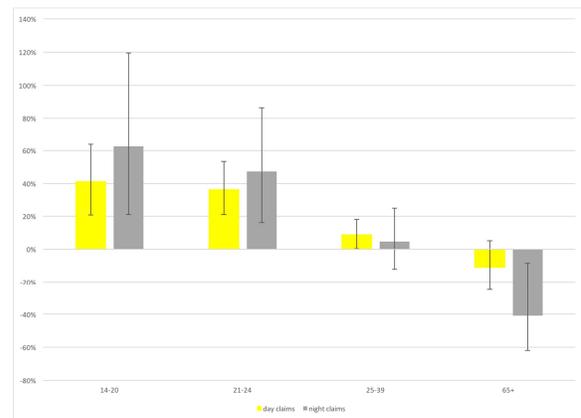

Figure 6. Effect of AFLS on collision and PDL claim frequency by time of day.

Estimates for some of the other covariates included in the model are shown in **figures 7-10**. **Figures 7 and 8** show the effect of rated driver age on collision and PDL claim frequency, respectively. Compared with rated drivers age 40-64, younger drivers have higher overall claim frequencies, with the largest difference occurring at night. Interestingly, for collision coverage, nighttime claim frequencies were highest for the 21-24 age group, although GDL laws restricting nighttime teen driving and alcohol are likely factors. Older drivers have the lowest nighttime claim frequencies, which may be a result of older drivers self-restricting their nighttime driving.
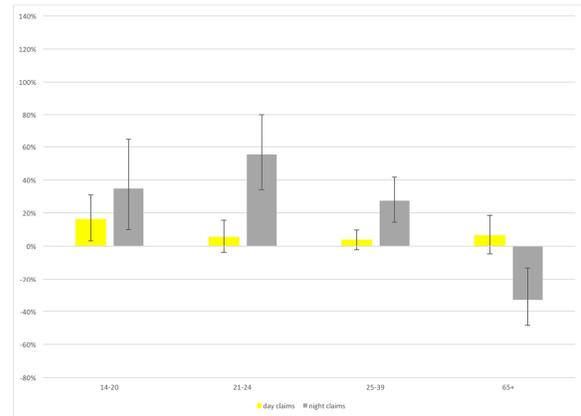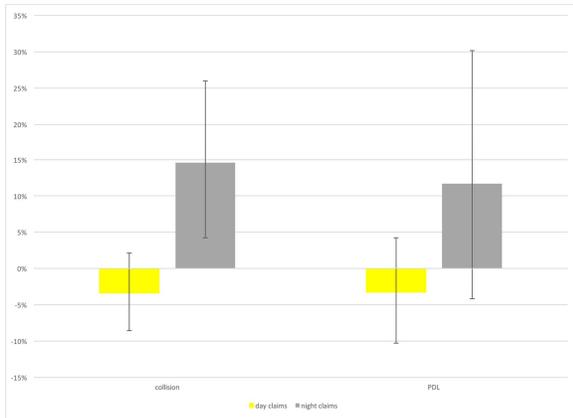

Figure 7. Estimated effect of rated driver age on collision claim frequency relative to 40-64 age group.
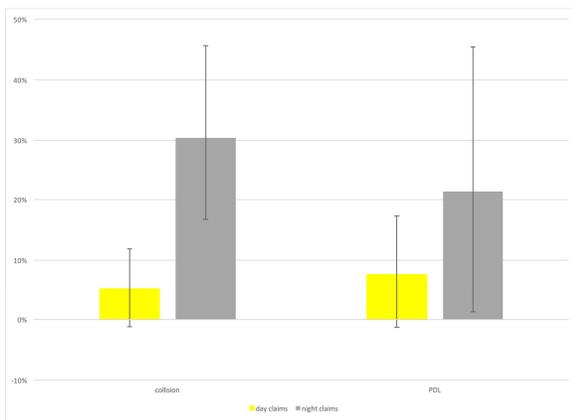

Figure 8. Estimated effect of rated driver age on PDL claim frequency relative to 40-64 age group.

The effects of rated driver gender and marital status on collision and PDL claim frequency are shown in **figures 9 and 10,** respectively. Male and single rated drivers also tend to have increased nighttime claim frequencies, compared with female and married rated drivers.

Figure 9. Estimated effect of male versus female rated driver gender on collision and PDL claim frequency.


Figure 10. Estimated effect of single versus married rated driver marital status on collision and PDL claim frequency.

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, the curve-adaptive headlights in the 2010 Mazda 3 also use HID lamps versus halogen lamps in the base model. 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.

Figure 11 compares the visibility performance of the 2013 Mazda 3 with adaptive HID headlights versus the base halogen headlights, following the IIHS headlight testing protocol (IIHS, 2016b). Under the IIHS headlight testing protocol, visibility performance is assessed as the distance at which 5 lux is reached and continuously maintained until the vehicle is at most 10 meters away, or 15 meters for the left edge of the straightaway. Tests were performed on a straightaway as well as 150- and 250-meter radius left and right curves using both high and low beams. The system was tested with the adaptive functionality of the system on (swiveling HID) as well as turned off (static HID). Except for the straightaway test with high beams enabled, the HID lights outperformed the halogen lights. In addition, on curved tests, enabling the adaptive functionality provided additional benefits, in some cases almost double the benefit of HID alone. Interestingly, on the 150-meter radius curve, the static HID lights provided left edge illumination at a greater distance than the swiveling HID. This could potentially be by design to reduce glare for oncoming drivers.
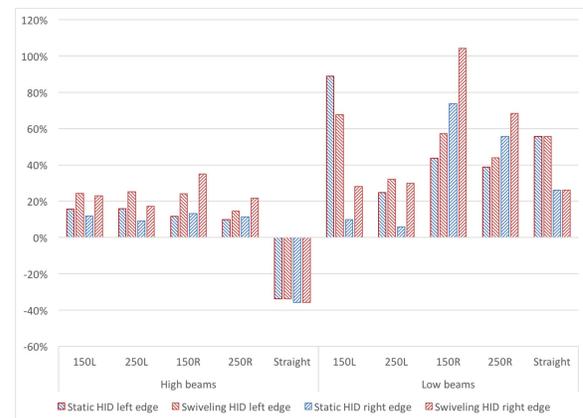
Figure 11. 5 lux distance relative to halogen for 2013 Mazda 3.

The IIHS has used this testing protocol to evaluate and rate different headlight systems. These tests have shown a wide range of results in the visibility and performance of different headlight systems (IIHS, 2016c). 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.

CONCLUSION

The results of the current study are in agreement with the original HLDI studies on vehicles with adaptive

lighting systems and the recent IIHS research. While the initial study that did not account for time of crash 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. Overall, these results suggest that advancements in headlighting technology can improve driver visibility at night and may serve as an effective countermeasure to help reduce 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 underestimate the true effectiveness of these systems.

Additionally, the data supplied to HLDI do 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 3s with adaptive headlights cost significantly more than those without. The adaptive lighting system is only available on the s Grand Touring trim level whose MSRP was 13% higher than the next trim level, the s Sport. The characteristics of consumers willing to pay such a large additional cost for an otherwise inexpensive car may differ from consumers who do not choose this equipment. 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.

Some of the reported crash times from certain data suppliers occurred in the data 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. Additional analyses were conducted excluding data from those companies where irregularities occurred, as well as excluding crash times with 00 or 01 minutes. The overall conclusions of this study did not change.

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