Predicted availability of safety features on registered vehicles — a 2016 update

Prior Highway Loss Data Institute (HLDI) studies have indicated that some collision avoidance systems are reducing insurance claims. In particular, claim frequency reductions were found across all of the crash-related coverages for most front crash prevention systems. Reductions in bodily injury liability claims indicate the front crash prevention systems are functioning as intended because the systems are designed to prevent or mitigate the severity of front-to-rear crashes, the type of crash that typically results in a bodily injury liability claim. Initial evaluations of forward collision warning systems estimated reductions in bodily injury liability claim frequencies of 4–25 percent. Benefits tend to be even greater for those systems that added autonomous braking. Systems that provided autonomous braking reduced bodily injury liability claim frequency by 14–32 percent. While the reductions are sizable, these systems were first introduced on a small number of luxury vehicles. Consequently, the impact of these systems on the population of all crashes has been limited. A voluntary commitment among many manufacturers will increase the number of vehicles on the road with standard autonomous braking systems. According to the terms of the commitment, manufacturers will equip nearly all of their new vehicles by 2022.

Sensing technologies are evolving. Early front crash prevention systems were radar based while newer systems use radar, lasers, cameras, and/or a fusion of different sensing technologies. As the sensing technologies have evolved, the price of the systems has dropped and, as a consequence, many non-luxury vehicles are now available with these technologies. For example, starting in 2013 the Honda Accord was offered with a camera-based front crash prevention system and lane departure system. A study of that system found reductions in claim frequencies across all of the crash-related coverages. The bodily injury liability reduction was a statistically significant 24 percent (2015a). The Honda Accord is one of the best-selling cars in the United States. Given the high sales volume of this vehicle, the effectiveness of the front crash prevention system on the Accord could have an impact on gross insurance losses.

Prior reports from HLDI (2012, 2014a, 2015b) showed that it typically takes decades after introduction before most vehicles on the road have a given feature. For example, absent a mandate it will not be until 2042 that 95 percent of all registered vehicles would be expected to have lane departure warning, which was rolled out in the United States in 2005. Adaptive headlights, which rolled out in the United States in 2004, could take even longer. If it continues to follow its current trajectory, adaptive headlights will not be available in 95 percent of registered vehicles until 2047. Federal mandates or other voluntary commitments would accelerate the fitment of these features. As shown below, a mandate for 2017 model vehicles could speed up the penetration of some features in the fleet by as much as 6 years.
Introduction

Given the potential and proven benefits of collision avoidance systems, it is almost certain that these systems will reduce the number of crashes and insurance claims. While estimating the efficacy of available systems is an important part of understanding the long-term impact of these systems, it is also important to understand the prevalence of these systems in the current fleet and to estimate their growth in the fleet over time. The purpose of this bulletin is to quantify the prevalence of vehicle features in the registered vehicle fleet, trace that prevalence from introduction through the most current registration data, and then to predict the prevalence in the future.

Methods

This bulletin combines vehicle feature information from the Highway Loss Data Institute (HLDI) with vehicle registration data from R.L. Polk and Company. For each feature studied there are three figures:

- The first figure illustrates the percentage of new vehicle series with a given feature by model year. In this figure, each new vehicle series (model year, make, series) is a single observation. The observations have not been weighted by insurance exposure or vehicle registration information. Using new vehicle series to illustrate how common a feature is can be deceiving because new safety features typically appear initially on luxury vehicles, which tend to be sold in lower volumes than non-luxury vehicles.

- The second figure for each feature illustrates the percentage of registered vehicles with a feature by calendar year. In this figure, each observation (model year, make, series) is weighted by the number of registered vehicles.

- The third figure for each feature illustrates the predicted availability for that feature. The actual availability is also displayed for comparison. This figure helps to provide insight into the time required for the presence of a feature to build in the registered vehicle fleet.

The following features are included in this bulletin: electronic stability control, rear parking sensors, front crash prevention systems that warn and those that autonomously brake, rear camera, adaptive front lighting systems, lane departure warning, blind spot monitor, and highway drive-ready. In order to be highway drive-ready, a vehicle had to have blind spot monitor, adaptive cruise control with full stop capability and some form of steering based lane keeping. The steering based lane keeping could be part of a lane departure prevention system, an adaptive cruise control system or stand-alone lane keeping.

Vehicle feature information was obtained by HLDI. The feature information is structured by model year, make, and series. The same three variables were mapped to the registration data from R.L. Polk. For each model year-make-series combination, one of three possible feature values are provided: "standard," “optional,” and “not available.”

Registration counts belonging to either of the first two groups are hereafter referred to as “available.” For example, in calendar year 2008, 9.7 percent of registered vehicles had standard ESC and another 10.8 percent had it as an option, so it is said that ESC was available in 20.5 percent of the 2008 registered vehicles.

The most recent R.L. Polk data available to HLDI contains calendar years 1976–2015. For each calendar year, a number of recent model years are used, ranging from 10 model years for calendar year 1976 to 40 model years for calendar year 2015. The number of model years included in each calendar year has increased over time. For calendar years 2009 and later, more than 50 of the most recent model years were available, but the analysis was limited to 40 model years. This covered at least 95 percent of the overall fleet in calendar years where safety features started to gain popularity. There are model years that are present in earlier calendar years, age out of the dataset, and then re-enter when the dataset was expanded. To increase the amount of usable data, missing values were extrapolated based on existing values. Polk has restated some of its data. In this report, original data were used from 1976 to 2008 while restated data were used for calendar years 2009–15.
Approach used to estimate the number of new vehicles: In order to estimate the number of new vehicles in 2016, registrations for new vehicles for the prior 5 calendar years (2011–15) were averaged. New vehicles are defined as vehicles aged 0 and -1. For example, a 2012 model year in calendar year 2012 would have a vehicle age of 0, while a 2013 vehicle in the same calendar year would be aged -1. To predict new vehicle registrations for calendar years 2017–50, a 30-year past trend in new vehicle registrations was studied. During this period, new vehicle registrations increased on average 2.1 percent per calendar year. New vehicle counts for 2017 and beyond were calculated by adding 2.1 percent to the prior year registration counts.

Approach used to estimate attrition rates: Attrition rates were calculated for each calendar/model year combinations through 2015 and applied to future years (2016–50) and vehicles of the same age. Additionally, to account for changes in attrition, a 30-year past trend was studied. During this time period, attrition rates declined on average 0.2 percent per calendar year. Based on this, the attrition was estimated to be slower by 3.8 percentage points (0.2% * (1+37)/2) on average in the future years (2016–50). Different attrition rates were explored and can be seen in the Appendix. For the next 20 years, there was little difference between the rates. The attrition assumptions will be monitored, refined, and modified as needed for future analysis.

The estimation procedure was conducted separately for each feature in the study. The procedure involved running a logistic regression model (assuming a binomial distribution with a probit link) on the past year data where feature prevalence is known and then applying the model estimates to predict the feature prevalence for future years.

The dependent variable in the model was the ratio of the registration count where the feature was available to the total registration count. The only two independent variables were calendar year and model year.
\section*{Results}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Percentage of new vehicle series with ESC}
\end{figure}

Figure 1 shows the percentage of vehicle series by model year with either standard or optional ESC. ESC was introduced in model year 1995 and by the 2004 model year had become standard on 23 percent and optional on 14 percent of vehicle series. For the 2015 model year, ESC was standard on 99 percent and optional on 1 percent of vehicle series. ESC has been required on all light duty vehicles beginning September 1, 2011. Starting in model year 2013, the only vehicles that do not have standard ESC are very large pickup trucks weighing more than 10,000 pounds and not subject to the regulation.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{Percentage of registered vehicles with ESC}
\end{figure}

Figure 2 shows the percentage of registered vehicles by calendar year with either standard or optional ESC. By 2004, ESC had become standard on 2 percent and optional on 5 percent of registered vehicles. By 2015, ESC was standard or optional on 52 percent of registered vehicles.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{Predicted percentage of registered vehicles with available ESC}
\end{figure}

Figure 3 shows the percentage of predicted registered vehicles by calendar year with either standard or optional ESC. It is predicted that ESC will be standard or optional on 95 percent of registered vehicles in 2033.
Figure 4 shows the percentage of vehicle series by model year with either standard or optional rear parking sensors. Rear parking sensors were introduced in model year 1995 and by the 2004 model year had become standard on 6 percent and optional on 18 percent of vehicle series. For the 2015 model year, rear parking sensors were standard on 24 percent and optional on 59 percent of vehicle series.

Figure 5 shows the percentage of registered vehicles by calendar year with either standard or optional rear parking sensors. By 2004, rear parking sensors had become standard on less than 1 percent and optional on 4 percent of registered vehicles. By 2015, rear parking sensors were standard or optional on 29 percent of registered vehicles.

Figure 6 shows the percentage of predicted registered vehicles by calendar year with either standard or optional rear parking sensors. It is predicted that rear parking sensors will be standard or optional on 95 percent of registered vehicles in 2038.
Figure 7 shows the percentage of vehicle series by model year with either standard or optional front crash prevention. Included vehicles consist of those that only warn and those that warn and autonomously brake. Front crash prevention was introduced in model year 2000 and by the 2006 model year had become standard on 1 percent and optional on 2 percent of vehicle series. For the 2015 model year, front crash prevention was standard on 6 percent and optional on 50 percent of vehicle series.

Figure 8 shows the percentage of registered vehicles by calendar year with either standard or optional front crash prevention. By 2006, front crash prevention had become standard on less than 1 percent and optional on less than 1 percent of registered vehicles. By 2015, front crash prevention was standard or optional on 8 percent of registered vehicles.

Figure 9 takes into account the 2022 voluntary commitment and shows the percentage of predicted registered vehicles by calendar year with either standard or optional front crash prevention. It is predicted that front crash prevention will be standard or optional on 95 percent of registered vehicles in 2042.
Figure 10: Percentage of new vehicle series with autonomous emergency braking

Figure 10 shows the percentage of vehicle series by model year with either standard or optional autonomous emergency braking. Autonomous emergency braking was introduced in model year 2006 and by the 2012 model year had become standard on less than 1 percent and optional on 11 percent of vehicle series. For the 2015 model year, autonomous emergency braking was standard on 4 percent and optional on 30 percent of vehicle series.

Figure 11: Percentage of registered vehicles with autonomous emergency braking

Figure 11 shows the percentage of registered vehicles by calendar year with either standard or optional autonomous emergency braking. By 2012, autonomous emergency braking had become standard on less than 1 percent and optional on 1 percent of registered vehicles. By 2015, front crash prevention was standard or optional on 3 percent of registered vehicles.

Figure 12: Predicted percentage of registered vehicles with available autonomous emergency braking (includes 2022 voluntary commitment)

Figure 12 takes into account the 2022 voluntary commitment and shows the percentage of predicted registered vehicles by calendar year with either standard or optional autonomous emergency braking. It is predicted that autonomous emergency braking will be standard or optional on 95 percent of registered vehicles in 2042.
Figure 13: Percentage of new vehicle series with rear camera

Figure 13 shows the percentage of vehicle series by model year with either standard or optional rear cameras. Rear cameras were introduced in model year 2002 and by the 2007 model year had become standard on 2 percent and optional on 14 percent of vehicle series. For the 2015 model year, rear cameras were standard on 39 percent and optional on 51 percent of vehicle series. Rear cameras will be required on all new vehicles starting May 1, 2018.

Figure 14: Percentage of registered vehicles with rear camera

Figure 14 shows the percentage of registered vehicles by calendar year with either standard or optional rear cameras. By 2007, rear cameras had become standard on less than 1 percent and optional on 2 percent of registered vehicles. By 2015, rear cameras were standard or optional on 29 percent of registered vehicles.

Figure 15: Predicted percentage of registered vehicles with available rear camera (includes 2018 mandate)

Figure 15 takes into account the 2018 mandate and shows the percentage of predicted registered vehicles by calendar year with either standard or optional rear cameras. It is predicted that rear cameras will be standard or optional on 95 percent of registered vehicles in 2037.
Figure 16: Percentage of new vehicle series with adaptive headlights

Figure 16 shows the percentage of vehicle series by model year with either standard or optional adaptive headlights. Adaptive headlights were introduced in model year 2004 and by the 2008 model year had become standard on 8 percent and optional on 12 percent of vehicle series. For the 2015 model year, adaptive headlights were standard on 16 percent and optional on 21 percent of vehicle series.

Figure 17: Percentage of registered vehicles with adaptive headlights

Figure 17 shows the percentage of registered vehicles by calendar year with either standard or optional adaptive headlights. By 2008, adaptive headlights had become standard on less than 1 percent and optional on 1 percent of registered vehicles. By 2015, adaptive headlights were standard or optional on 6 percent of registered vehicles.

Figure 18: Predicted percentage of registered vehicles with available adaptive headlights

Figure 18 shows the percentage of predicted registered vehicles by calendar year with either standard or optional adaptive headlights. It is predicted that adaptive headlights will be standard or optional on 95 percent of registered vehicles in 2047.
Figure 19 shows the percentage of vehicle series by model year with either standard or optional lane departure warning. Included vehicles consist of systems that only warn a driver when they depart a lane and systems that warn along with active lane keeping. Lane departure warning was introduced in model year 2005 and by the 2009 model year had become standard on less than 1 percent and optional on 4 percent of vehicle series. For the 2015 model year, lane departure warning was standard on 2 percent and optional on 46 percent of vehicle series.

Figure 20 shows the percentage of registered vehicles by calendar year with either standard or optional lane departure warning. By 2009, lane departure warning had become standard on less than 1 percent and optional on less than 1 percent of registered vehicles. By 2015, lane departure warning was standard or optional on 7 percent of registered vehicles.

Figure 21 shows the percentage of predicted registered vehicles by calendar year with either standard or optional lane departure warning. It is predicted that lane departure warning will be standard or optional on 95 percent of registered vehicles in 2042.
Figure 22 shows the percentage of vehicle series by model year with either standard or optional blind spot monitor. Blind spot monitor was introduced in model year 2006 and by the 2009 model year had become standard on less than 1 percent and optional on 8 percent of vehicle series. For the 2015 model year, blind spot monitor was standard on 5 percent and optional on 45 percent of vehicle series.

Figure 23 shows the percentage of registered vehicles by calendar year with either standard or optional blind spot monitor. By 2009, blind spot monitor had become standard on less than 1 percent and optional on less than 1 percent of registered vehicles. By 2015, blind spot monitor was standard or optional on 10 percent of registered vehicles.

Figure 24 shows the percentage of predicted registered vehicles by calendar year with either standard or optional blind spot monitor. It is predicted that blind spot monitor will be standard or optional on 95 percent of registered vehicles in 2041.
Driverless vehicles have captured the attention of media and on a daily basis news stories abound about such vehicles and their potential impact on personal transportation and segments of the economy related to transportation. Despite all of the attention, there are currently no driverless vehicles for sale in the U.S. to consumers. However, there are vehicles available from a few manufacturers that are capable of automatically controlling speed and following the road in limited conditions. Many implementations of this capability still require the driver to keep hands on the steering wheel. Other implementations permit the driver to let go of the steering wheel for short periods and very few allow this for indefinite periods even though all of the currently available systems are designed with the expectation that the driver is capable of retaking control nearly instantaneously. The purpose of this analysis is to illustrate the number of vehicles that have the minimum components necessary for limited self-driving. For the sake of discussion these vehicles will be called highway drive-ready. In order to be highway drive-ready, a vehicle had to have blind spot monitor, adaptive cruise control with full stop capability and some form of steering based lane keeping. The steering based lane keeping could be part of a lane departure prevention system, an adaptive cruise control system or standalone lane keeping. Figure 25 shows the percentage of vehicle series by model year with either standard or optional highway drive-ready. Highway drive-ready vehicles first appeared in model year 2012 and in four model years has become optional on 9 percent of vehicle series.

Figure 25: Percentage of highway drive-ready new vehicle series

Highway drive-ready vehicles first appeared in model year 2012 and in four model years has become optional on 9 percent of vehicle series.

Figure 26: Percentage of registered vehicles highway drive-ready

Figure 26 shows the percentage of registered vehicles by calendar year with either standard or optional highway drive. In 2012-15 highway drive was available on less than 1 percent of registered vehicles.

Figure 27: Predicted percentage of registered available vehicles that are highway drive-ready

Figure 27 shows the percentage of predicted registered vehicles by calendar year with either standard or optional highway drive. It is predicted that highway drive will be standard or optional on 95 percent of registered vehicles in 2043.
Figure 28 further illustrates that even when features are required, it still takes decades for the U.S. fleet to become 95 percent equipped. Feature X is a theoretical feature that is not available on model year 2015 vehicles but becomes standard on all 2016 model vehicles. This is an example of the fastest possible rollout of a standard feature. Under these assumptions it will still take approximately 25 years, or until 2041, until this newly introduced standard feature will be on 95 percent of the U.S. fleet.

**Figure 28: Predicted percentage of registered vehicles with feature X**

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**Discussion**

It takes a long time for new vehicle features to spread through the registered vehicle fleet. Even when features are required by the National Highway Transportation Administration, it takes many years for features to be available on all vehicles. ESC, for example, was first available to consumers in 1995 and shown to be effective in reducing insurance losses and deaths. It has been required on all light duty vehicles since September 1, 2011. However, even with that requirement in place for several years, only 52 percent of the vehicle fleet had this feature available in 2015. It will take until 2033 for 95 percent of the fleet to be equipped with ESC. Many collision avoidance features have been recently introduced to the fleet and to date only rear cameras have been mandated by NHTSA. Additionally, manufacturers are voluntarily equipping vehicles with autonomous braking by 2022. Figure 29 demonstrates the length of time it takes a feature to reach 95 percent of the fleet. Adaptive headlights, for example, will not reach 95 percent until 2047, and a 2017 mandate would only accelerate the time by 6 years. While these collision avoidance features may be reducing collisions and losses, it will be many years before vehicles fitted with them represent a significant portion of the vehicle fleet.

Additionally, a prior HLDI report on electronic stability control (ESC) found that ESC-equipped vehicles last longer in the vehicle fleet than non-ESC equipped vehicles (HLDI, 2014b). Vehicles equipped with other effective collision avoidance features could also allow vehicles to persist longer in the vehicle fleet, slowing fleet turnover. This could lead to a slowdown in the change of the fleet from one with few collision avoidance features to one with more features. The longer life span for ESC or collision avoidance-equipped vehicles was not accounted for in the predictions.

**Figure 29: Calendar year features reach 95% of registered vehicle fleet with and without hypothetical mandate**

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**Notes:**
- Rear camera mandate May 1, 2018
- Front crash voluntary commitment
Limitations

One limitation of the logistic model with a probit link is that it assumes a distribution with an asymptote of 100 percent, which it approaches slowly towards the end of the distribution. When a given feature's prevalence reaches 95 percent, its growth substantially slows and it takes a number of years to capture the remaining 5 percent. It is not known how this remaining small percentage will be captured since no feature has reached 100 percent prevalence yet. The model was carefully chosen to fit the existing (past year) data well, and there is no reason to believe that it does not adequately describe the future data. It may be the case that the full 100 percent prevalence is never reached, as some people tend to keep old cars as collectable vehicles. Even if so, the goal of the study was to estimate when each feature will be available for the vast majority of the fleet, not 100 percent of the fleet.

Another limitation is that the prediction was based on the coarse calendar/model year registration counts rather than stratified by make and series. However, the stratified approach would be difficult if not impossible to accomplish. The future is uncertain, and so is the future new model fleet. Even with the present approach, a bold assumption of stalled vehicle sales had to be made. Making further assumptions on which makes and series will be popular in the future or which manufacturers will introduce safety features more aggressively is beyond the scope of this analysis. However, as mentioned previously and reflected in the graphs, the model fits the existing data well, and consequently it is reasonable to believe that the predictions for the future fleet are the best possible.
Appendix Figure 1: Predicted percentage of registered vehicles with front crash prevention

Appendix Figure 2: Predicted percentage of registered vehicles with rear camera

Appendix Figure 3: Predicted percentage of registered vehicles with adaptive headlights
References


