



Predicted availability of safety features on registered vehicles — a 2024 update

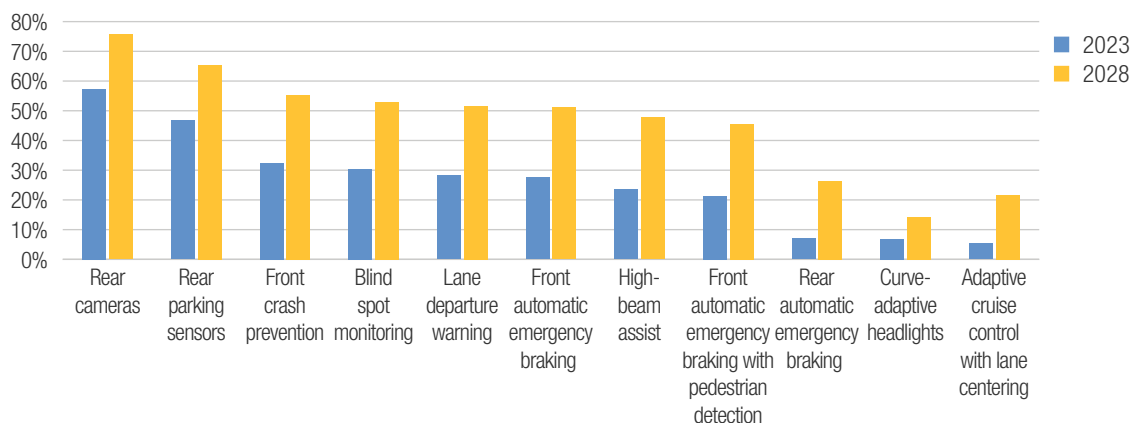
Highway Loss Data Institute (HLDI) studies have indicated that some collision avoidance systems, particularly front crash prevention systems, are reducing insurance claims. While some of the reductions are sizable, these systems were first introduced on only a small number of luxury vehicles. Consequently, the impact of these systems on all crashes has been limited.

Prior HLDI studies have shown that it typically takes decades after a feature is introduced for that feature to be installed on most vehicles on the road. This study updates the forecasted availability of collision avoidance features with the addition of three new features: front automatic emergency braking (AEB) with pedestrian detection, rear AEB, and high-beam assist.

The figure below shows the percentage of registered vehicles predicted to be equipped with safety features in calendar years 2023 and 2028. The presence of most systems is predicted to increase by more than 15 percentage points by 2028. However, curve-adaptive headlights are predicted to increase by only 7%.

Six features are predicted to be on more than half of the registered vehicle population by 2028. Rear cameras, which were mandated on new vehicles produced since May 1, 2018, are predicted to be on 76% of the registered vehicle fleet by 2028. Front AEB is predicted to increase from 28% of the registered vehicle population in 2023 to 51% in 2028. This projected increase is in part due to the auto industry’s voluntary commitment, brokered by the Insurance Institute for Highway Safety and the National Highway Traffic Safety Administration, to equip new vehicles with front AEB. Front crash prevention that warns and/or automatically brakes is predicted to achieve a 55% fleet penetration in 2028.

Predicted registered vehicles equipped with collision avoidance systems, 2023 and 2028 calendar years

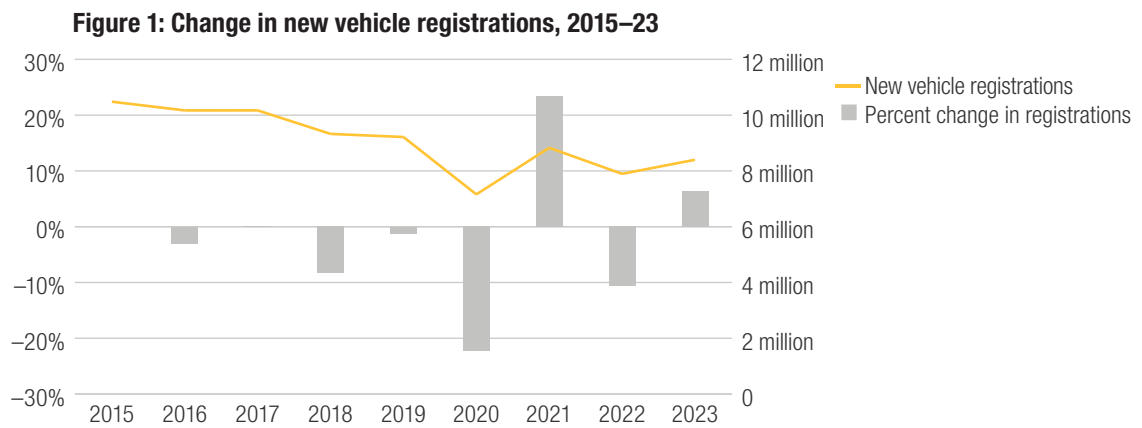


► Introduction

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

Prior Highway Loss Data Institute (HLDI) studies showed that it typically takes decades after introduction for most vehicles on the road to have a given feature (HLDI, 2012, 2014b, 2015, 2016, 2017, 2018, 2019b, 2020, 2021, 2022, 2023a). Most of the prior studies examined the prevalence of the features based on availability, meaning the feature was available as standard or optional equipment. The percentage of the vehicles equipped with an optional feature was unknown. Therefore, the optionally equipped percentage was estimated for each feature based on known take rates from some manufacturers. Using this information, the percentage of registered vehicles equipped with a certain feature, along with future predictions, could be better estimated.

The COVID-19 pandemic affected the economy, including new and used vehicle sales. Compared with 2019, the number of new vehicle registrations in 2020 fell 22%, which is much different from 2015–19. The U.S. economy was considered to have fully recovered by June 2021 (Siegel & Dam, 2021). As shown in **Figure 1**, new vehicle registrations rose 23% in 2021 compared with 2020 and totaled only 4% lower than the number registered in 2019. In 2022, new vehicle registrations dropped 11% compared with 2021 but were still 10% higher than the number of registrations in 2020. The number of new vehicle registrations rebounded in 2023, increasing 6% compared with 2022. Therefore, the number of future new vehicle registrations is based on the trend of the past 30 years, excluding the exceptional 2020 data.



► Methods

This study combines vehicle safety feature information from HLDI with vehicle registration data from S&P Global. For each of the features studied, there are three figures:

- The **first figure** for each feature illustrates the percentage of new vehicle series with that 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.
- The **second figure** for each feature illustrates the percentage of registered vehicles with that feature by calendar year. In this figure, each observation (model year, make, series) is weighted by the number of registered vehicles. This second figure also includes an “equipped” line that estimates the percentage of the vehicle fleet with the feature installed.
- The **third figure** for each feature illustrates its predicted availability, with the actual availability displayed for comparison. One set of lines represents predicted availability with the optional take rate considered, while the other set represents the estimate without including that rate. This figure provides 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 study: electronic stability control (ESC), front crash prevention systems that warn and those that automatically brake, front automatic emergency braking with pedestrian detection, adaptive cruise control with lane centering, lane departure warning, blind spot monitoring, curve-adaptive headlights, high-beam assist, rear parking sensors, rear cameras, and rear automatic emergency braking.

HLDI compiled the vehicle feature information by model year, make, and series, and mapped these three variables to the registration data from S&P Global. For each combination of model year, make, and series, one of three possible feature values is provided: “standard,” “optional,” or “not available.”

Registration counts belonging to either of the first two groups (standard and optional) are hereafter referred to as “available.” For example, in calendar year 2023, 20.6% of registered vehicles had front automatic emergency braking as standard equipment and another 15.7% had it as an option, so it is said that front automatic emergency braking was available in 36.3% of the 2023 registered vehicles.

The most recent S&P Global data available to HLDI cover calendar years 1976–2023. For each calendar year, multiple recent model years are used, ranging from 10 model years for calendar year 1976 to 40 model years for calendar year 2023. 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 are available, but the analysis was limited to 40 model years; this covered at least 95% of the overall fleet in calendar years during which safety features started to gain popularity. Some model years are present in earlier calendar years, age out of the data set, and then reenter when the data set is expanded. To increase the amount of usable data, missing values were extrapolated based on existing values. S&P Global 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 2009–23.

Approach used to estimate optionally equipped rates: This study estimates the optionally equipped rates for each of the features using HLDI feature data and Vehicle Identification Number (VIN) information from a limited number of manufacturers. Using HLDI’s vehicle information, vehicles registered in 2023 with optional features were identified. The equipped rates for individual features for a calendar year were estimated based on VIN data that HLDI previously received from 13 manufacturers. The equipped rate for each feature was estimated using several regression models that included some or all of the following variables: model year, size, class, and vehicle base price. Where possible, HLDI used the equipped rates from the participating manufacturers to estimate those for other vehicles of the same model year, size, class, and price. Where that level of detail was not available, the equipped rates were estimated with regression models according to the variables with known values. In the worst-case scenario, the estimated equipped rates were based exclusively on model year and vehicle price.

Once these estimated rates were assigned to the unknown values in the historical data, the optional and standard feature data from past years were used to estimate future equipped rates for each feature.

Approach used to estimate the number of new vehicles: New vehicles are defined as vehicles aged 0 and -1 years. For example, a 2012 model year vehicle in calendar year 2012 has a vehicle age of 0 years, while a 2013 vehicle in the same calendar year has an age of -1. Prior HLDI studies estimated the number of new vehicles in the first unknown year in the future by averaging the registrations for new vehicles for the last 5 known calendar years. However, because the COVID-19 pandemic affected new vehicle sales in 2020, the present study averaged the number of registrations for new vehicles in calendar years 2018-19 and 2021-23 to estimate the number of new vehicles in 2024. To predict new vehicle registrations for calendar years 2024-50, a 30-year past trend in new vehicle registrations was studied. During this period, new vehicle registrations increased by an average 0.7% per calendar year. New vehicle counts for 2024 and beyond were therefore calculated by adding 0.7% each year on a cumulative basis.

Approach used to estimate attrition rates: For a given model year, registration counts typically peak at age 1 and then decline over time. For example, in calendar year 2013 there were fewer model year 2008 registrations than there were in 2012. The rate at which registrations declined as a vehicle aged 1 year (i.e., as the vehicle aged from 1 to 2 years, 2 to 3 years, 3 to 4 years, etc.) was calculated for every model year/age change combination over the past 30 years of data. The average attrition rate for a given age change was then calculated and applied to future years (2024-50) and vehicles undergoing the same age change.

Additionally, to account for changes in attrition, a 30-year past trend was studied. During this period, attrition rates declined by an average of 0.19% per model year. Based on this, the attrition rate for each subsequent model year slowed by an additional 0.19%. In other words, the attrition rate for the 2026 model year was projected to be 0.19% less than the attrition rate for the 2025 model year, which was 0.19% less than the 2024 model year, and so on. 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's data for which 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 registrations with the feature available to the total registration count. The only two independent variables were calendar year and model year.

► Results

Figure 2: Percentage of new vehicle series with ESC by model year

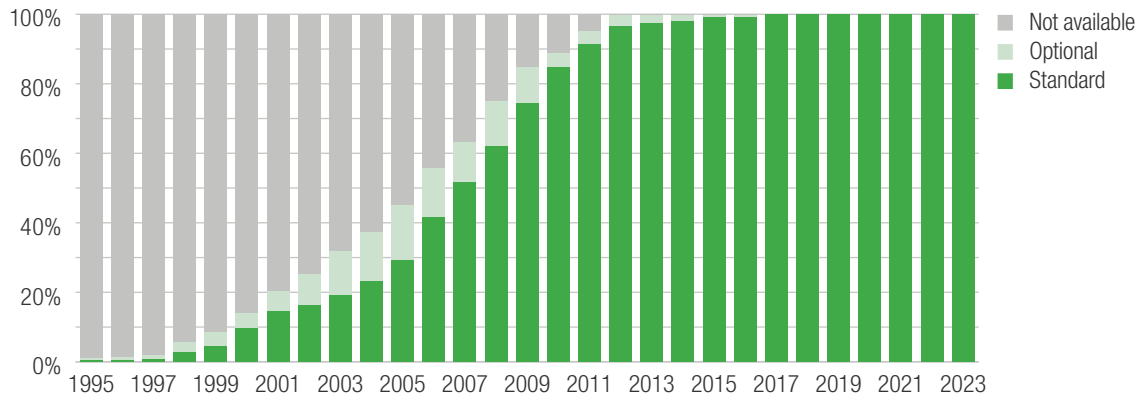


Figure 2 shows the percentage of new vehicle series with either standard or optional ESC by model year. ESC was introduced in model year 1995, and by the 2004 model year, it had become standard on 23% and optional on 14% of vehicle series. **ESC has been required on all light-duty vehicles beginning September 1, 2011.** From model year 2013 to 2016, the only vehicles that did not have standard ESC were very large pickup trucks weighing more than 10,000 pounds, which were not yet subject to the regulation. By the 2017 model year, all vehicle series had standard ESC.

Figure 3: Percentage of registered vehicles with ESC by calendar year

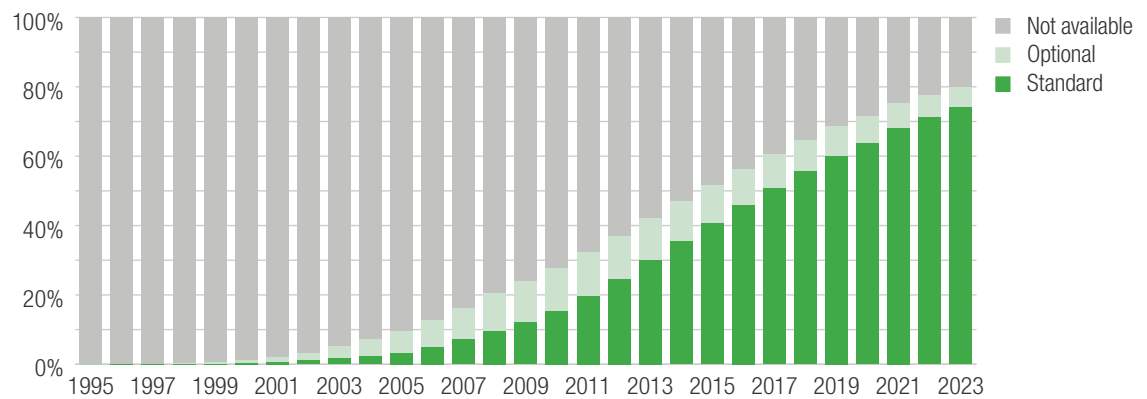


Figure 3 shows the percentage of registered vehicles with either standard or optional ESC by calendar year. By 2004, ESC had become standard on 2% and optional on 5% of registered vehicles. By 2023, ESC was standard or optional on 80% of registered vehicles. Data were not available to estimate the optionally equipped rate for ESC.

Figure 4: Predicted percentage of registered vehicles with ESC by calendar year

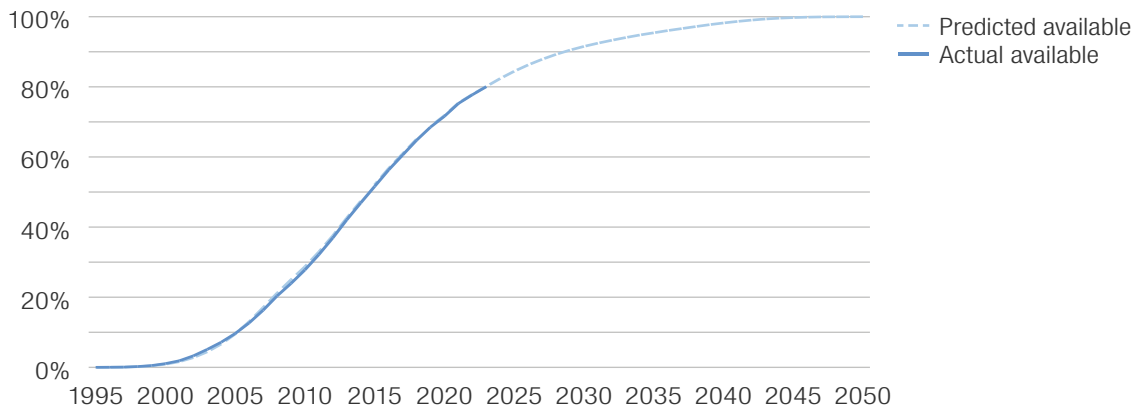


Figure 4 shows the predicted percentage of registered vehicles with either standard or optional (i.e., available) ESC by calendar year. It is predicted that ESC will be standard or optional on 95% of registered vehicles in 2034.

Front crash prevention systems

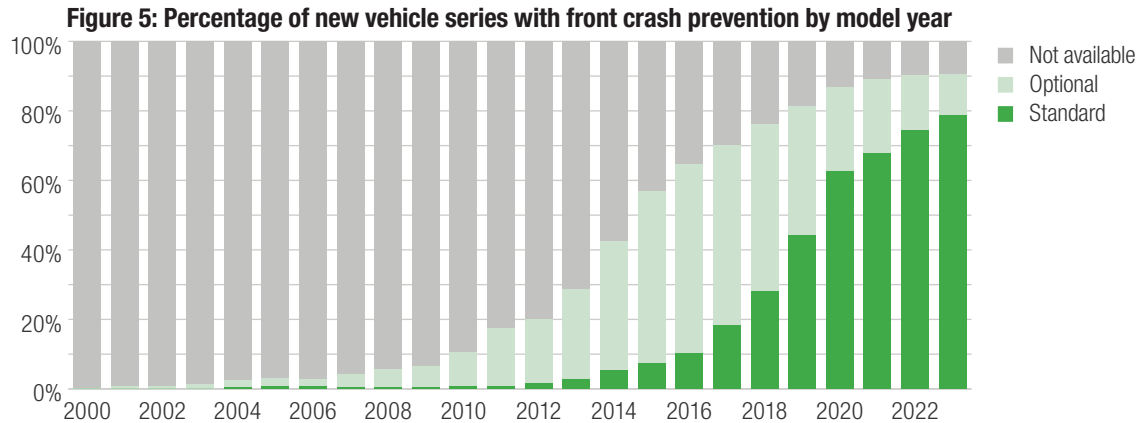


Figure 5 shows the percentage of new vehicle series with either standard or optional front crash prevention by model year. It includes vehicles that warn and/or automatically brake. Front crash prevention was introduced in model year 2000, and by the 2009 model year, it had become standard on 1% and optional on 6% of vehicle series. For the 2023 model year, front crash prevention was standard on 79% and optional on 12% of vehicle series.

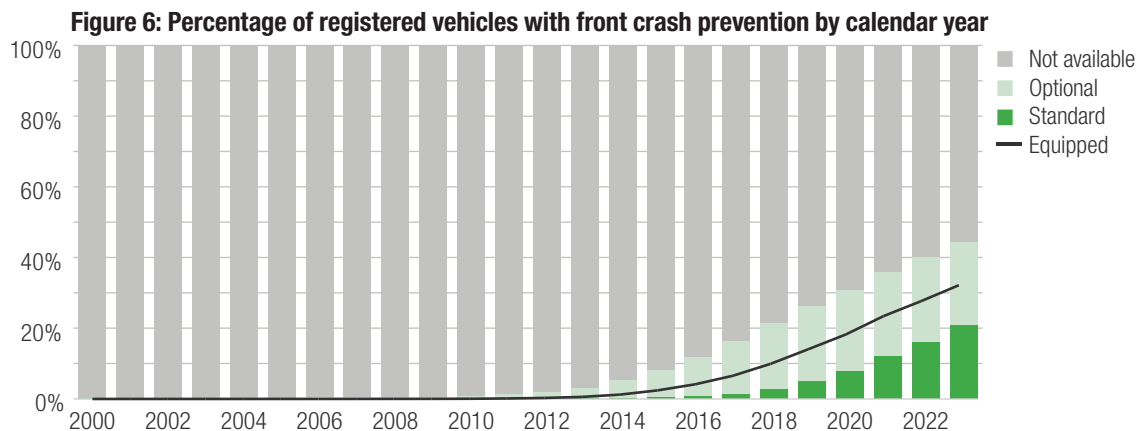


Figure 6 shows the percentage of registered vehicles with either standard or optional front crash prevention by calendar year. In 2009, front crash prevention was available on less than 1% of registered vehicles. By 2023, front crash prevention was standard or optional on 44% of registered vehicles, with about 32% of registered vehicles estimated to be equipped with the feature.

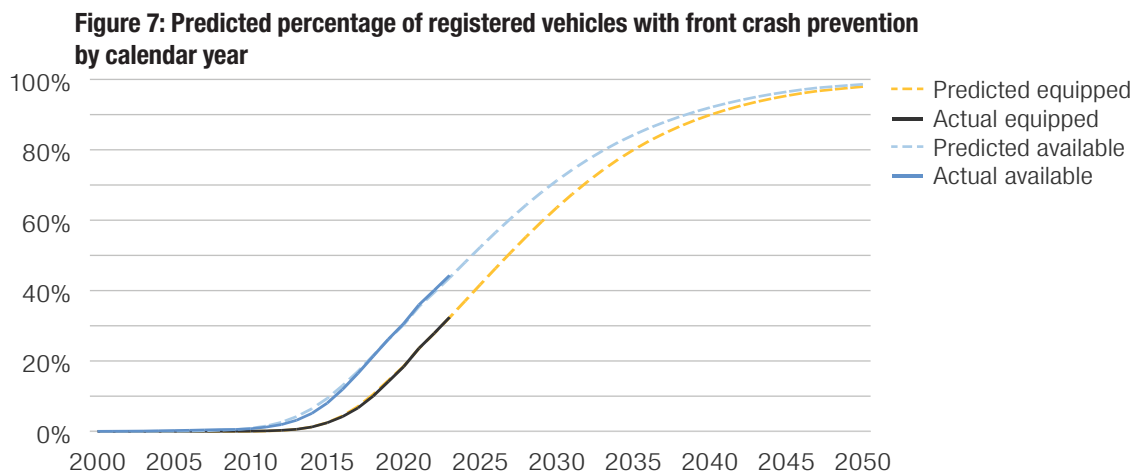


Figure 7 shows the predicted percentage of registered vehicles with front crash prevention by calendar year. It takes into account a 2022 voluntary commitment by many manufacturers to make front automatic emergency braking (AEB) standard on most of their vehicles by 2022. One set of predictions is for vehicles with front crash prevention available (standard or optional), and the other set of predictions is for vehicles equipped (either standard or optionally equipped) with the system. It is predicted that 95% of registered vehicles will be equipped with front crash prevention by 2044.

Figure 8: Percentage of new vehicle series with front automatic emergency braking by model year

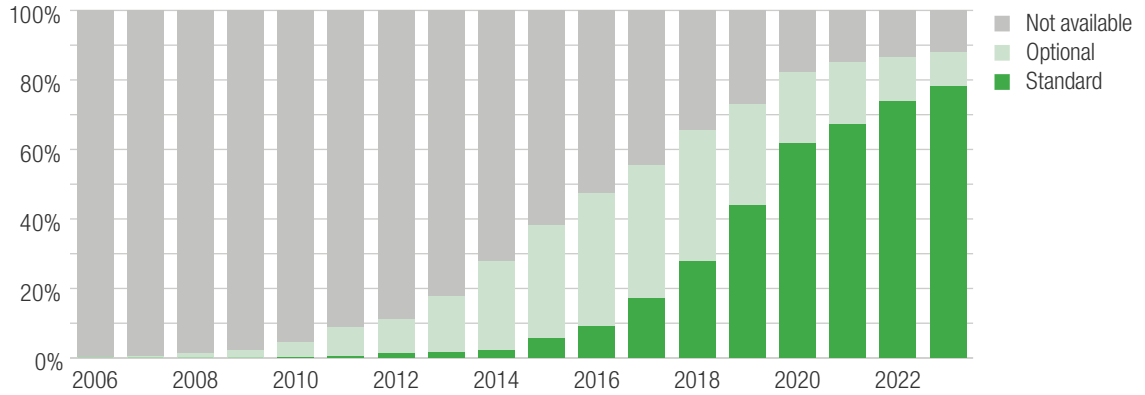


Figure 8 shows the percentage of new vehicle series with either standard or optional front AEB by model year. This system may also issue warnings. Front AEB was introduced in model year 2006, and by the 2015 model year, it had become standard on 6% and optional on 33% of vehicle series. For the 2023 model year, front AEB was standard on 78% and optional on 10% of vehicle series.

Figure 9: Percentage of registered vehicles with front automatic emergency braking by calendar year

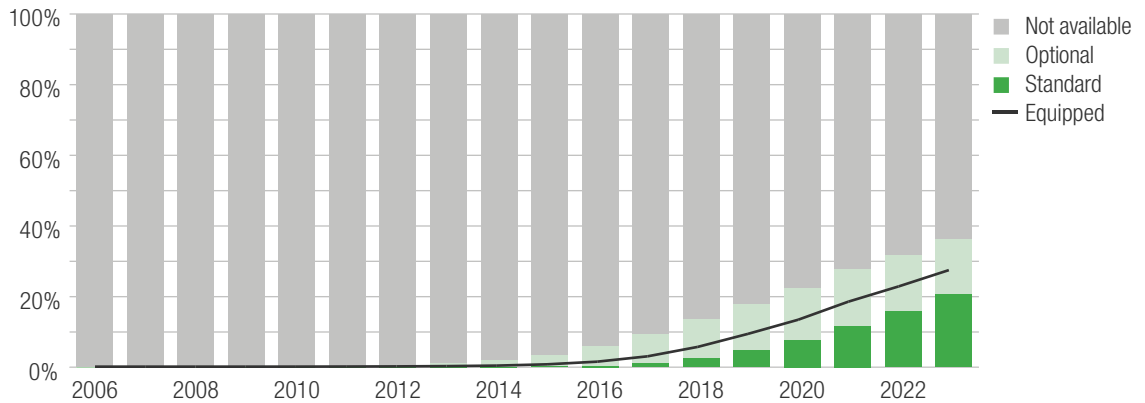


Figure 9 shows the percentage of registered vehicles with either standard or optional front AEB by calendar year. In 2015, front AEB was available on about 4% of registered vehicles. By 2023, front AEB was standard or optional on 36% of registered vehicles and estimated to be present on 28%.

Figure 10: Predicted percentage of registered vehicles with front automatic emergency braking by calendar year

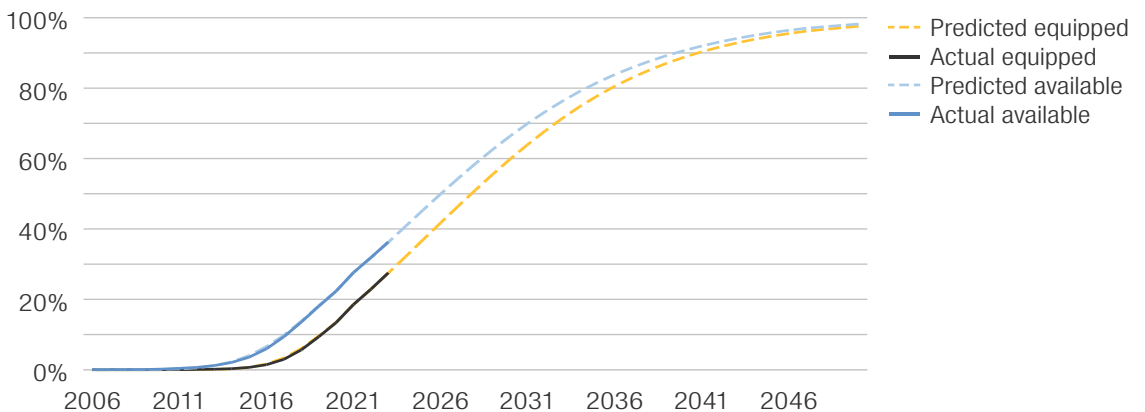


Figure 10 takes into account the 2022 voluntary commitment. It is predicted that 95% of registered vehicles will be equipped with that feature by 2045.

Figure 11: Percentage of new vehicle series with front automatic emergency braking with pedestrian detection by model year

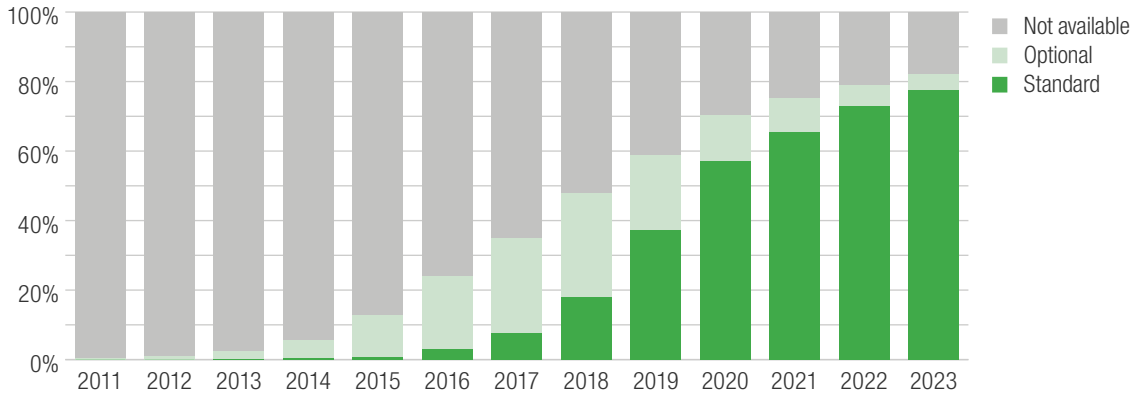


Figure 11 shows the percentage of new vehicle series with either standard or optional front AEB with pedestrian detection by model year. This system was introduced in model year 2011, and by the 2016 model year, it had become standard on 3% and optional on 21% of vehicle series. For the 2023 model year, front AEB with pedestrian detection was standard on 77% and optional on 5% of vehicle series.

Figure 12: Percentage of registered vehicles with front automatic emergency braking with pedestrian detection by calendar year

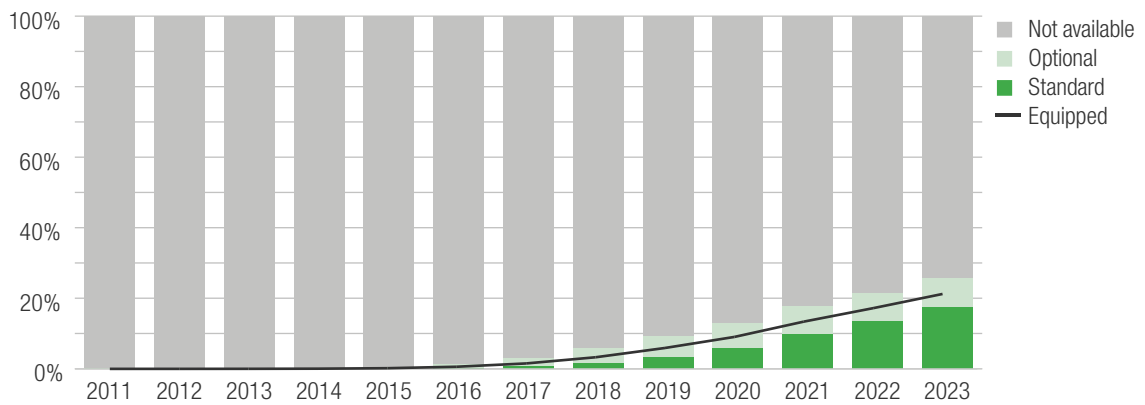


Figure 12 shows the percentage of registered vehicles with either standard or optional front AEB with pedestrian detection by calendar year. In 2016, front AEB with pedestrian detection was available on about 1% of registered vehicles. By 2023, it was standard or optional on 26% of registered vehicles, with about 21% of registered vehicles estimated to be equipped with the feature.

Figure 13: Predicted percentage of registered vehicles with front automatic emergency braking with pedestrian detection by calendar year

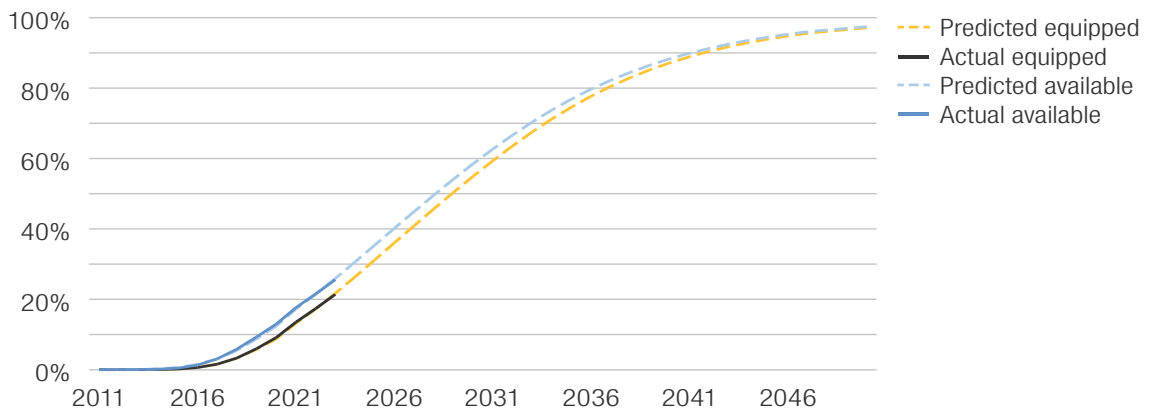


Figure 13 shows the predicted percentage of registered vehicles with front AEB with pedestrian detection by calendar year. It is predicted that 95% of registered vehicles will be equipped with that feature by 2046.

Figure 14: Percentage of new vehicle series with adaptive cruise control with lane centering by model year

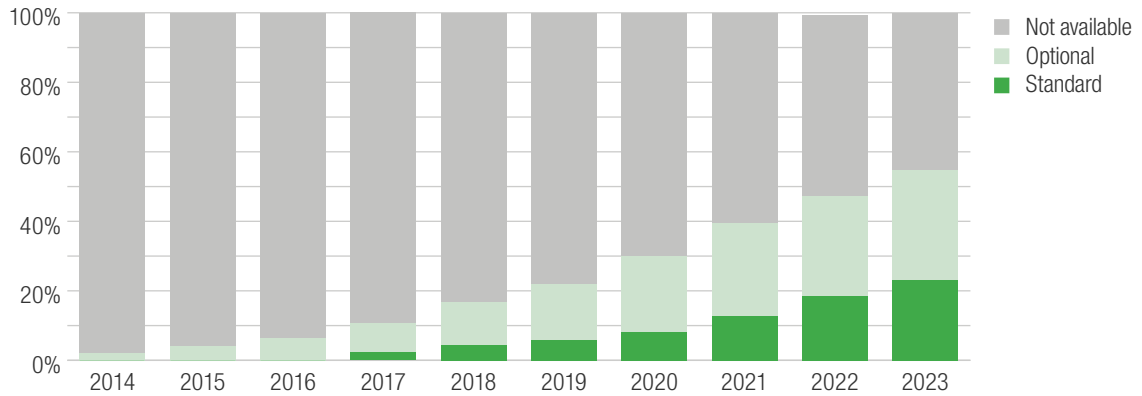


Figure 14 shows the percentage of new vehicle series with either standard or optional adaptive cruise control with lane centering by model year. This system includes adaptive cruise control with some form of steering-based lane keeping and with complete stop capability. Adaptive cruise control with lane centering was introduced in model year 2014, and by the 2017 model year, this feature had become standard on 2% and optional on 9% of vehicle series. For the 2023 model year, adaptive cruise control with lane centering was standard on 23% and optional on 31% of vehicle series.

Figure 15: Percentage of registered vehicles with adaptive cruise control with lane centering by calendar year

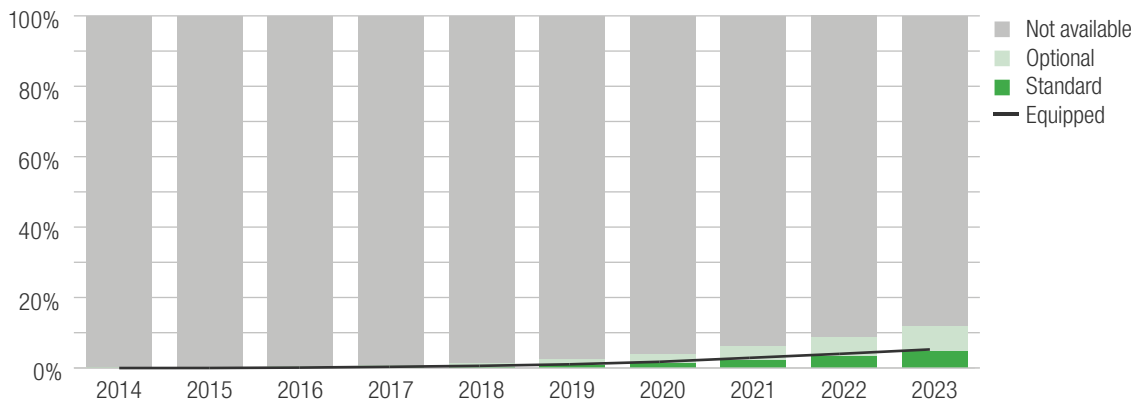


Figure 15 shows the percentage of registered vehicles with either standard or optional adaptive cruise control with lane centering by calendar year. In 2016, adaptive cruise control with lane centering was available on less than 1% of registered vehicles. By 2023, adaptive cruise control with lane centering was standard or optional on 12% of registered vehicles, but only 5% of them were estimated to be equipped with the feature.

Figure 16: Predicted percentage of registered vehicles with adaptive cruise control with lane centering by calendar year

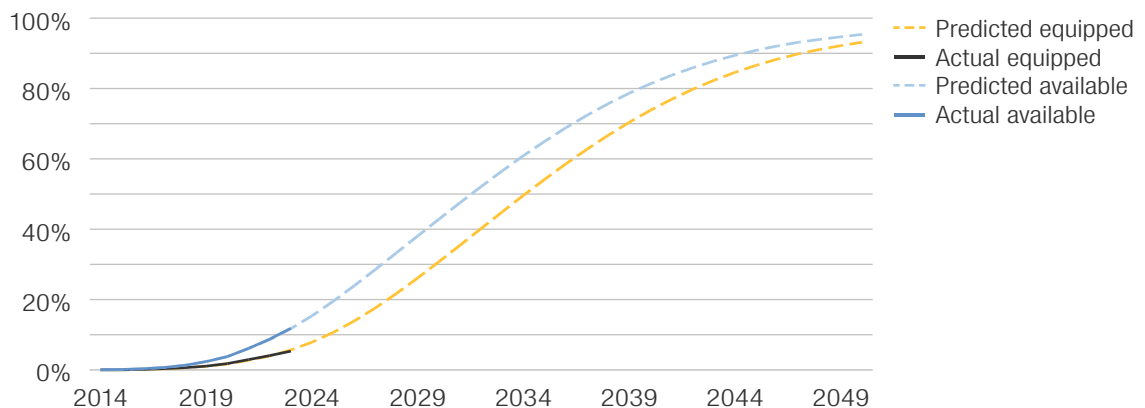


Figure 16 shows the predicted percentage of registered vehicles with adaptive cruise control with lane centering by calendar year. It is predicted that 95% of registered vehicles will be equipped with this feature sometime after 2050.

Side-assist systems

Figure 17: Percentage of new vehicle series with lane departure warning by model year

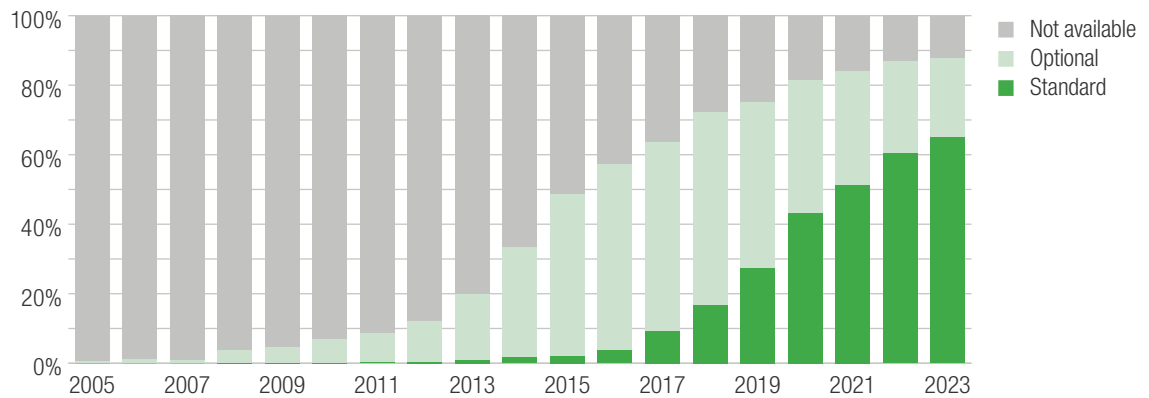


Figure 17 shows the percentage of new vehicle series with either standard or optional lane departure warning by model year. Both vehicles with systems that only warn drivers when they depart a lane and those with systems that both warn and provide lane keeping are included. Lane departure warning was introduced in model year 2005, and by the 2014 model year, it had become standard on about 2% and optional on 32% of vehicle series. For the 2023 model year, lane departure warning was standard on 65% and optional on 23% of vehicle series.

Figure 18: Percentage of registered vehicles with lane departure warning by calendar year

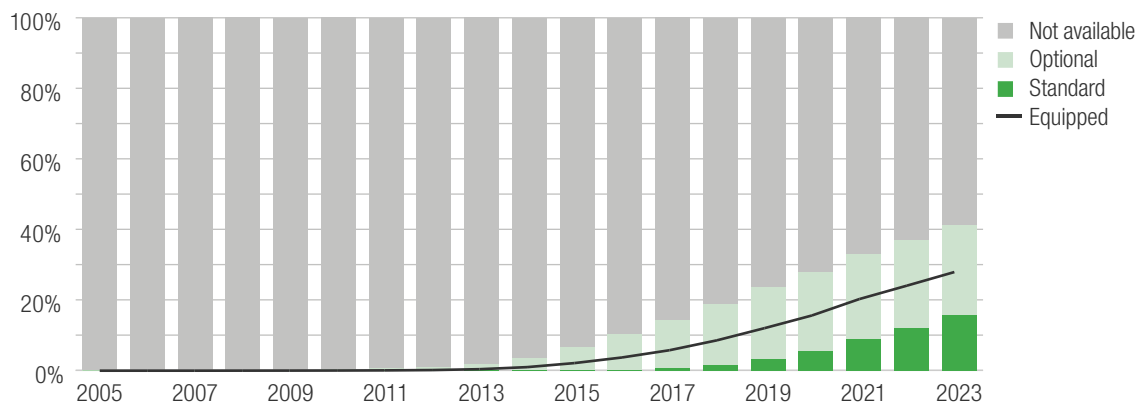


Figure 18 shows the percentage of registered vehicles with either standard or optional lane departure warning by calendar year. In 2014, lane departure warning was available on 4% of registered vehicles. By 2023, lane departure warning was standard or optional on 41% of registered vehicles, but only 28% of registered vehicles were estimated to be equipped with that feature.

Figure 19: Predicted percentage of registered vehicles with lane departure warning by calendar year

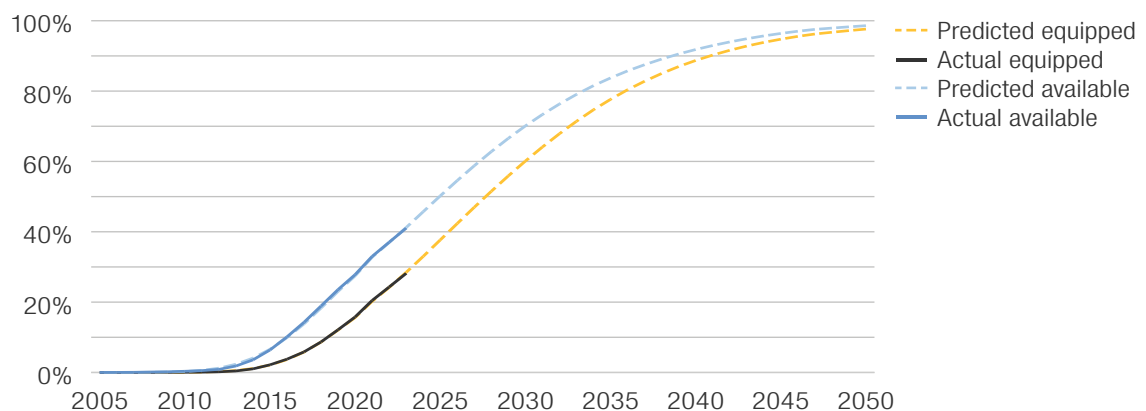


Figure 19 shows the predicted percentage of registered vehicles with lane departure warning by calendar year. It is predicted that 95% of registered vehicles will be equipped with lane departure warning in 2045.

Figure 20: Percentage of new vehicle series with blind spot monitoring by model year

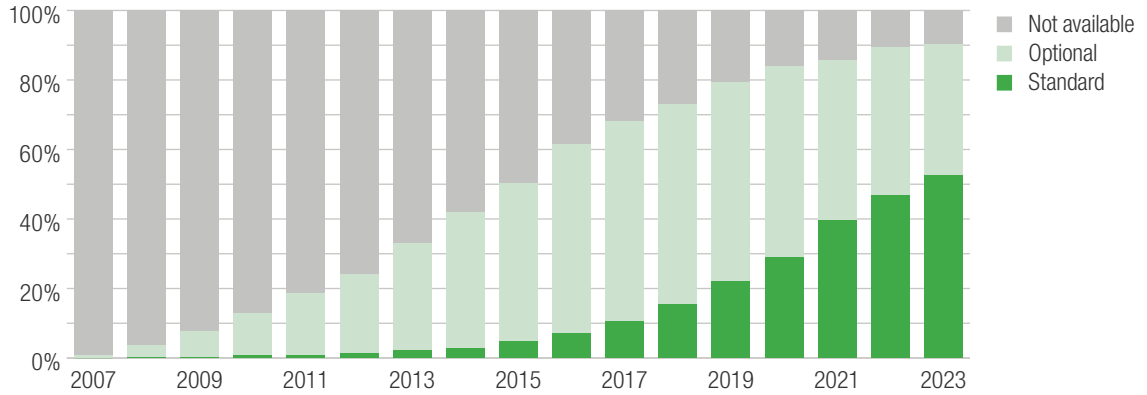


Figure 20 shows the percentage of new vehicle series with either standard or optional blind spot monitoring by model year. Blind spot monitoring was introduced in model year 2007, and by the 2016 model year, it had become standard on 7% and optional on 54% of vehicle series. For the 2023 model year, blind spot monitoring was standard on 52% and optional on 38% of vehicle series.

Figure 21: Percentage of registered vehicles with blind spot monitoring by calendar year

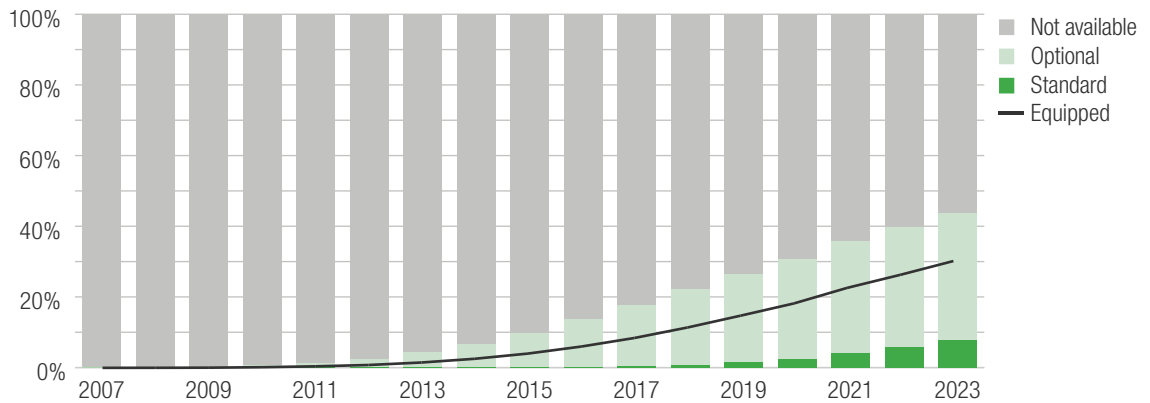


Figure 21 shows the percentage of registered vehicles with either standard or optional blind spot monitoring by calendar year. In 2016, blind spot monitoring was available on 14% of registered vehicles. By 2023, blind spot monitoring was standard or optional on 44% of registered vehicles, but only 30% of registered vehicles were estimated to be equipped with that feature.

Figure 22: Predicted percentage of registered vehicles with blind spot monitoring by calendar year

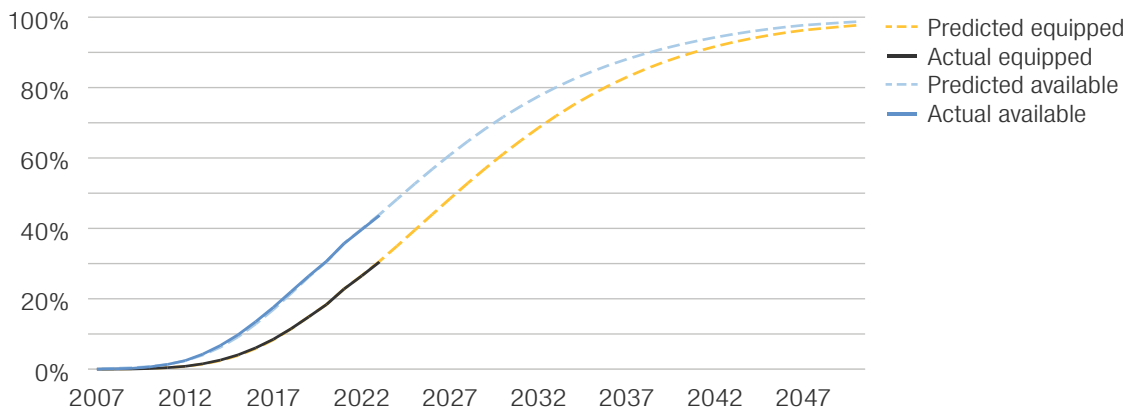


Figure 22 shows the predicted percentage of registered vehicles with blind spot monitoring by calendar year. It is predicted that 95% of registered vehicles will be equipped with blind spot monitoring in 2045.

Night-assist systems

Figure 23: Percentage of new vehicle series with curve-adaptive headlights by model year

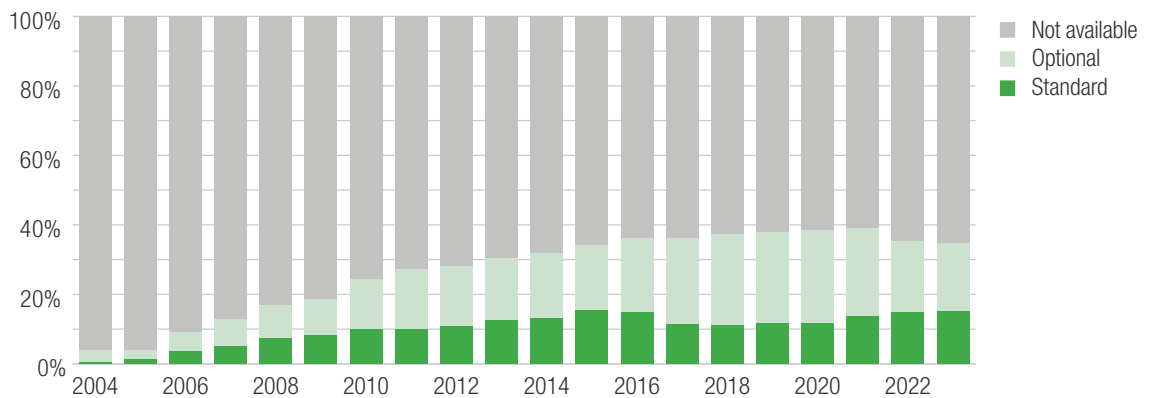


Figure 23 shows the percentage of new vehicle series with either standard or optional curve-adaptive headlights by model year. Curve-adaptive headlights were introduced in model year 2004, and by the 2013 model year, they had become standard on 13% and optional on 18% of vehicle series. The percentage of vehicle series with standard curve-adaptive headlights reached 15% in the 2015 model year and then declined through the model year 2020. However, starting in the 2021 model year, the percentage increased again. In model year 2023, curve-adaptive headlights were installed on 15% of vehicle series as standard equipment and in 20% of vehicle series as optional equipment.

Figure 24: Percentage of registered vehicles with curve-adaptive headlights by calendar year

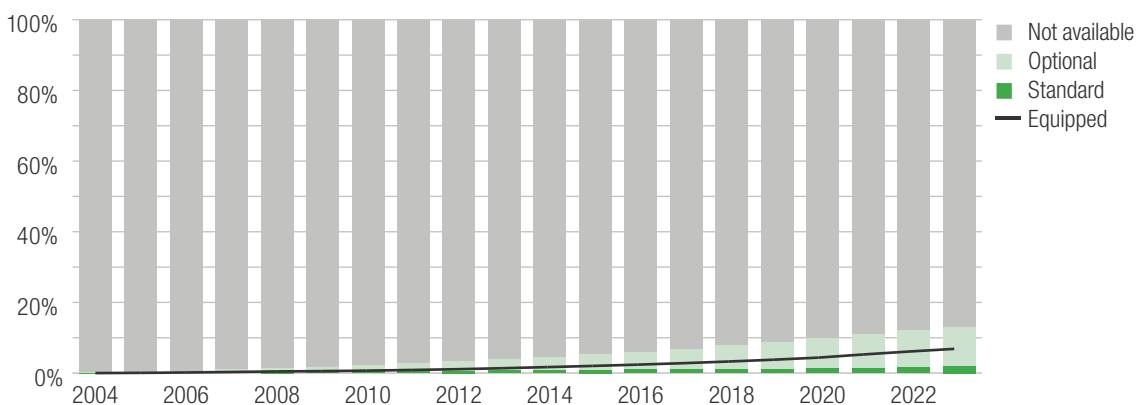


Figure 24 shows the percentage of registered vehicles with either standard or optional curve-adaptive headlights by calendar year. In 2013, curve-adaptive headlights were available on 4% of registered vehicles. By 2023, curve-adaptive headlights were standard or optional on 13% of registered vehicles, but only 7% of registered vehicles were estimated to be equipped with the feature.

Figure 25: Predicted percentage of registered vehicles with curve-adaptive headlights by calendar year

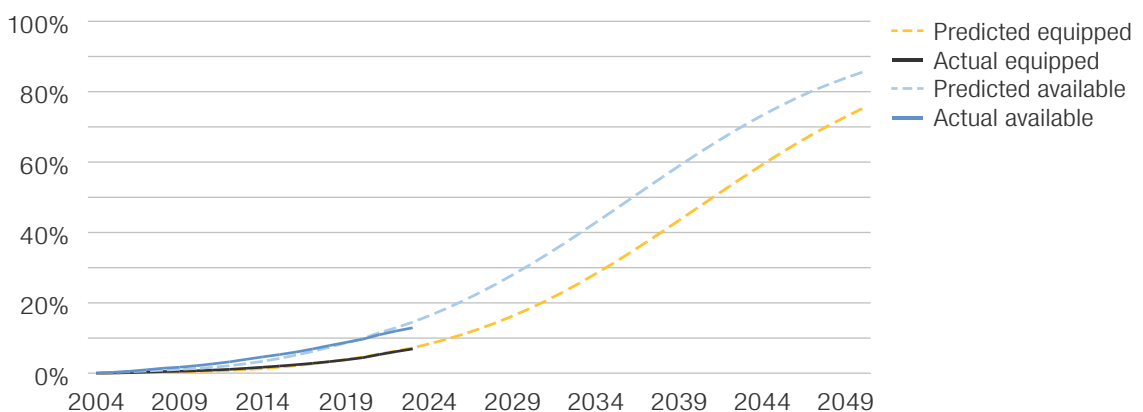


Figure 25 shows the predicted percentage of registered vehicles with curve-adaptive headlights by calendar year. It is predicted that 95% of registered vehicles will be equipped with curve-adaptive headlights sometime after 2050.

Figure 26: Percentage of new vehicle series with high-beam assist by model year

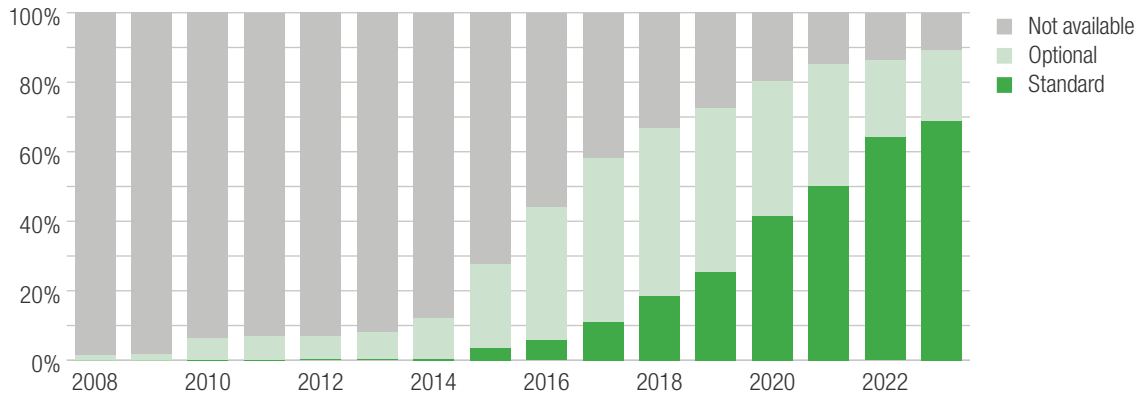


Figure 26 shows the percentage of new vehicle series with either standard or optional high-beam assist by model year. High-beam assist was introduced in model year 2008, and by the 2016 model year, it had become standard on 6% and optional on 38% of vehicle series. In model year 2023, high-beam assist was installed on 69% of vehicle series as standard equipment and 20% of vehicle series as optional equipment.

Figure 27: Percentage of registered vehicles with high-beam assist by calendar year

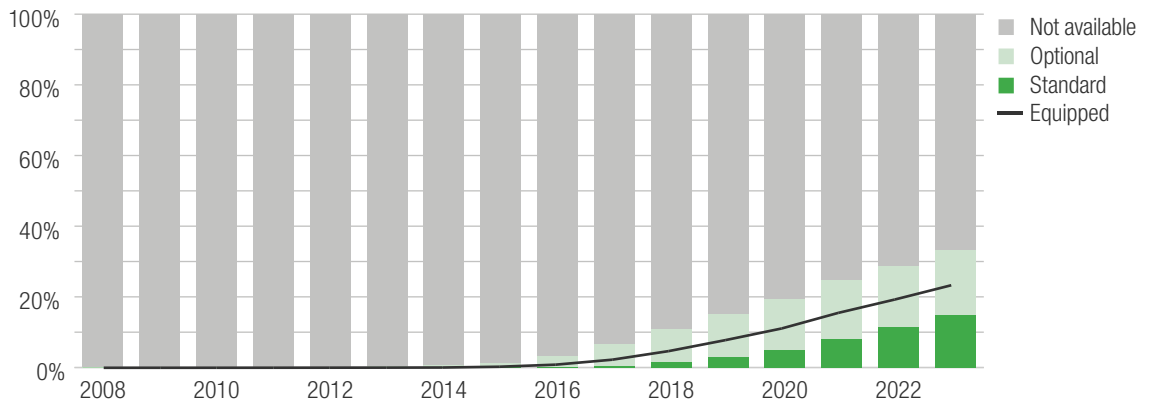


Figure 27 shows the percentage of registered vehicles with either standard or optional high-beam assist by calendar year. In 2015, high-beam assist was available on about 1% of registered vehicles. By 2023, high-beam assist was standard or optional on 33% of registered vehicles, and about 24% of registered vehicles were estimated to be equipped with the feature.

Figure 28: Predicted percentage of registered vehicles with high-beam assist by calendar year

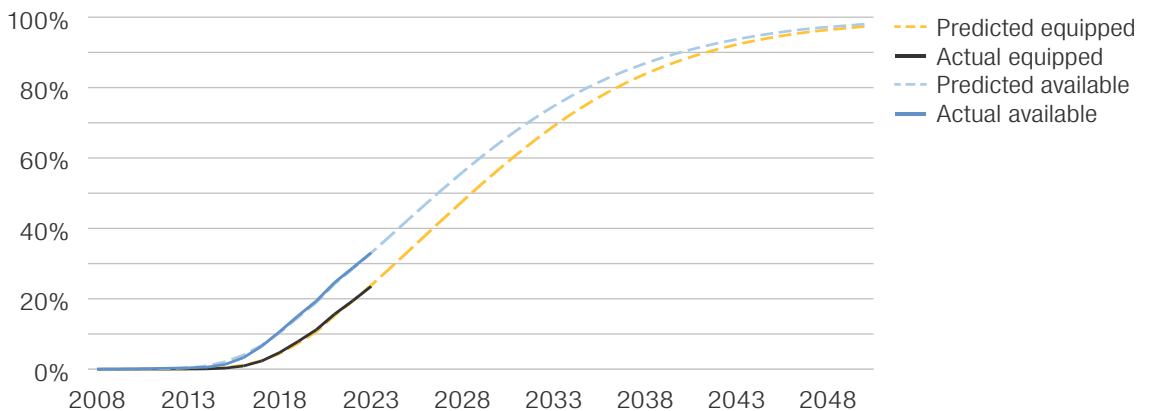


Figure 28 shows the predicted percentage of registered vehicles with high-beam assist by calendar year. It is predicted that 95% of registered vehicles will be equipped with high-beam assist in 2046.

Parking systems

Figure 29: Percentage of new vehicle series with rear parking sensors by model year

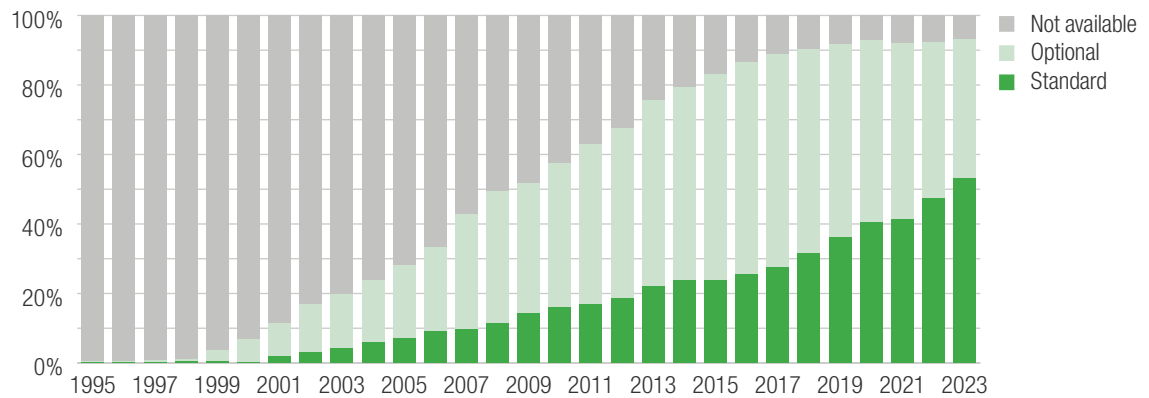


Figure 29 shows the percentage of new vehicle series with either standard or optional rear parking sensors by model year. Rear parking sensors were introduced in model year 1995, and by the 2004 model year, they had become standard on 6% and optional on 18% of vehicle series. For the 2023 model year, rear parking sensors were standard on 53% and optional on 40% of vehicle series.

Figure 30: Percentage of registered vehicles with rear parking sensors by calendar year

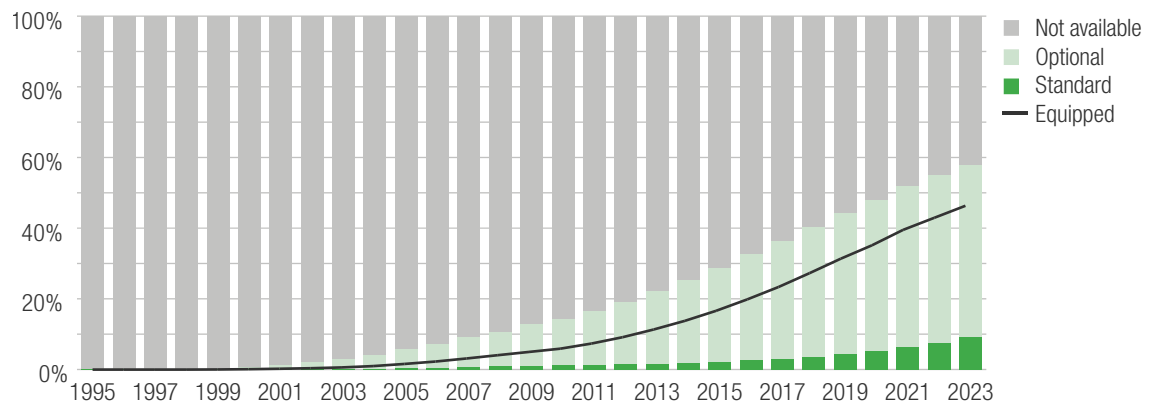


Figure 30 shows the percentage of registered vehicles with either standard or optional rear parking sensors by calendar year. In 2004, rear parking sensors had become standard on less than 1% and optional on 4% of registered vehicles. By 2023, rear parking sensors were standard or optional on 58% of registered vehicles, but only 47% of registered vehicles were estimated to be equipped with the feature.

Figure 31: Predicted percentage of registered vehicles with rear parking sensors by calendar year

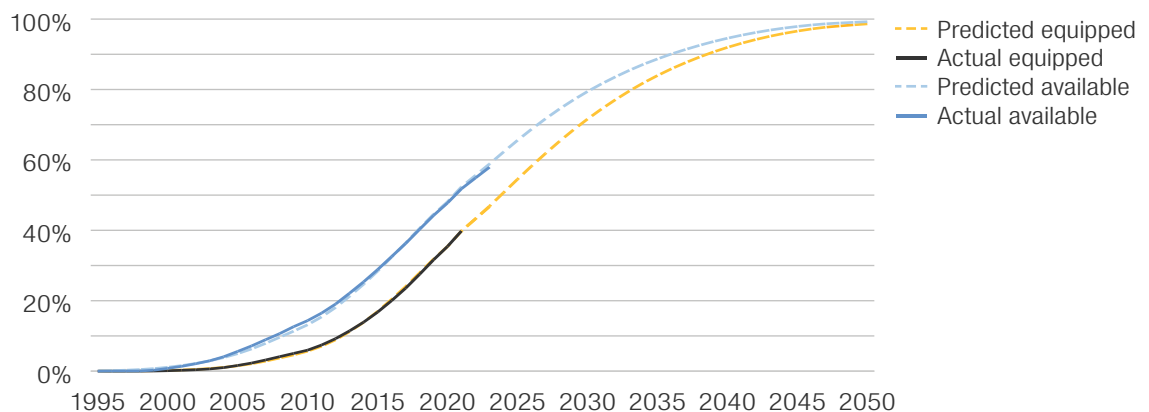


Figure 31 shows the predicted percentage of registered vehicles with rear parking sensors by calendar year. It is predicted that 95% of registered vehicles will be equipped with rear parking sensors in 2043.

Figure 32: Percentage of new vehicle series with rear cameras by model year

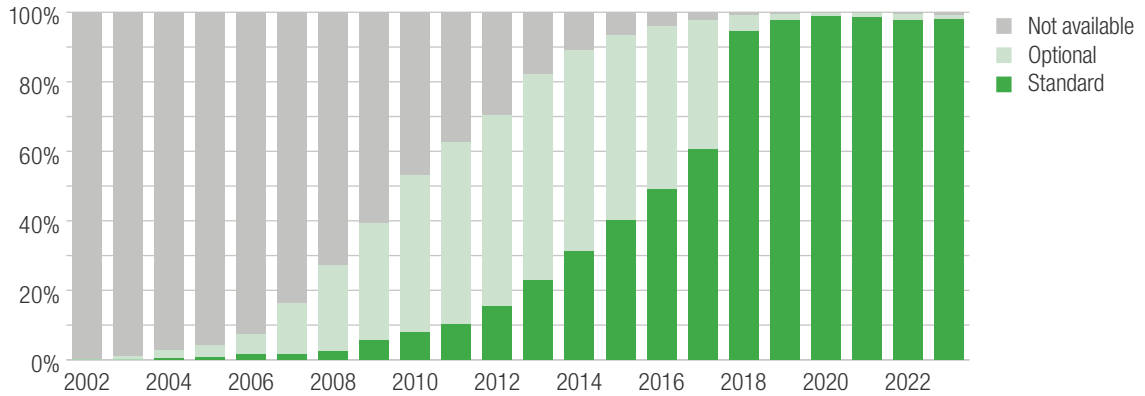


Figure 32 shows the percentage of new vehicle series with either standard or optional rear cameras by model year. Rear cameras were introduced in model year 2002, and by the 2011 model year, they had become standard on 10% and optional on 53% of vehicle series. **Rear cameras have been required on all new vehicles with a gross vehicle weight rating under 10,000 pounds produced since May 1, 2018.** For the 2023 model year, rear cameras were standard on 98% and optional on 1% of vehicle series.

Figure 33: Percentage of registered vehicles with rear cameras by calendar year

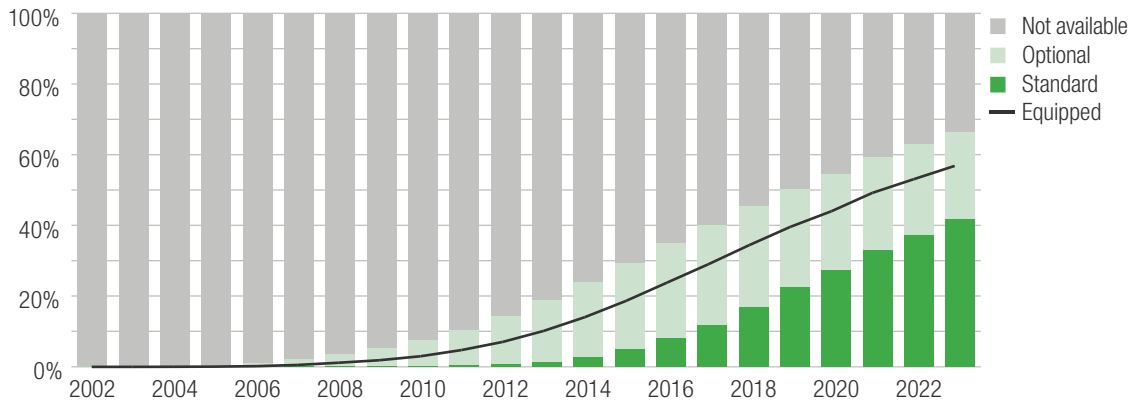


Figure 33 shows the percentage of registered vehicles with either standard or optional rear cameras by calendar year. In 2012, rear cameras were available on 14% of registered vehicles. By 2023, rear cameras were standard or optional on 66% of registered vehicles. It was estimated that 57% of registered vehicles were equipped with that feature.

Figure 34: Predicted percentage of registered vehicles with rear cameras by calendar year

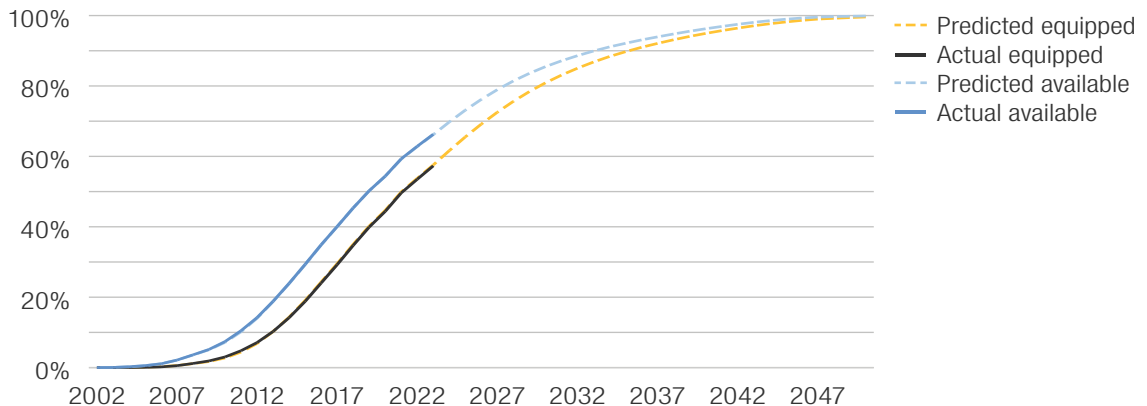


Figure 34, which takes into account the 2018 mandate, shows the predicted percentage of registered vehicles with rear cameras by calendar year. It is predicted that 95% of registered vehicles will be equipped with rear cameras in 2040.

Figure 35: Percentage of new vehicle series with rear automatic emergency braking by model year

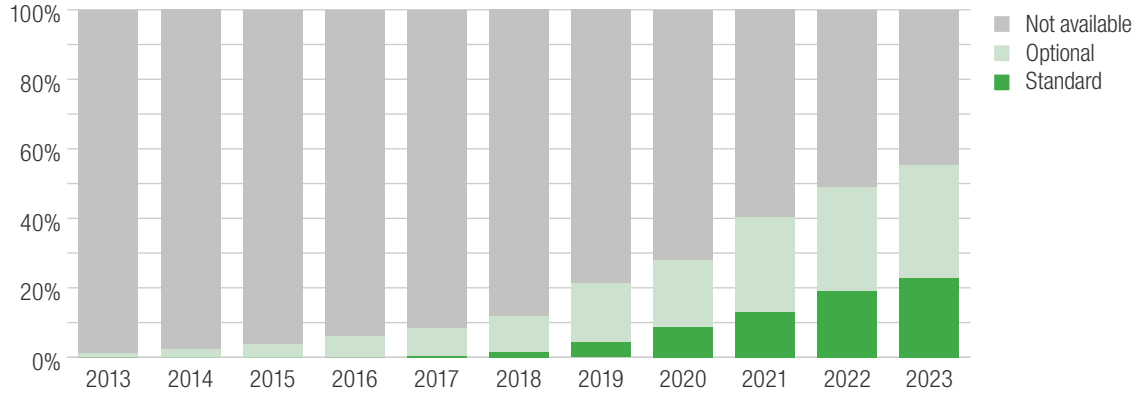


Figure 35 shows the percentage of new vehicle series with either standard or optional rear AEB by model year. Rear AEB was introduced in model year 2013, and by the 2018 model year, it had become standard on 2% and optional on 10% of vehicle series. For the 2023 model year, rear AEB was standard on 23% and optional on 32% of vehicle series.

Figure 36: Percentage of registered vehicles with rear automatic emergency braking by calendar year

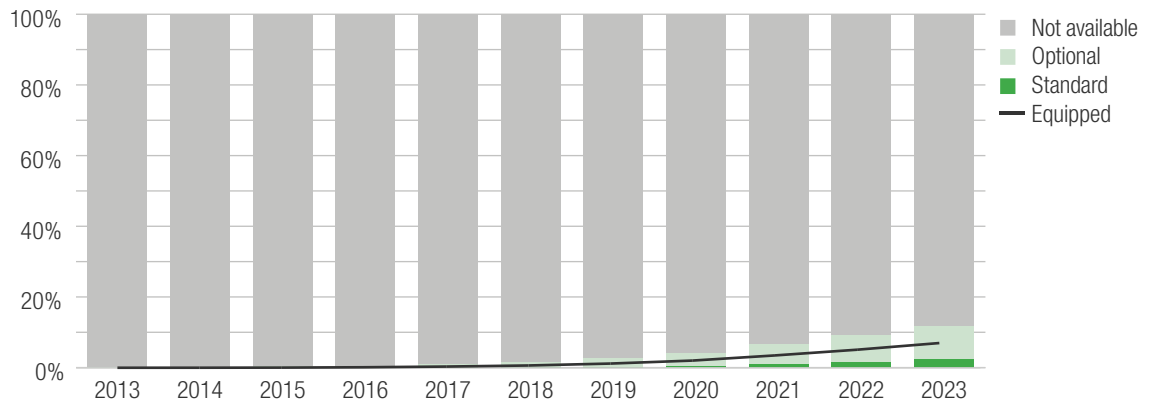


Figure 36 shows the percentage of registered vehicles with either standard or optional rear AEB by calendar year. In 2017, rear AEB had become available on 1% of registered vehicles. By 2023, rear AEB was standard or optional on 12% of registered vehicles, and 7% of registered vehicles were predicted to be equipped with the feature.

Figure 37: Predicted percentage of registered vehicles with rear automatic emergency braking by calendar year

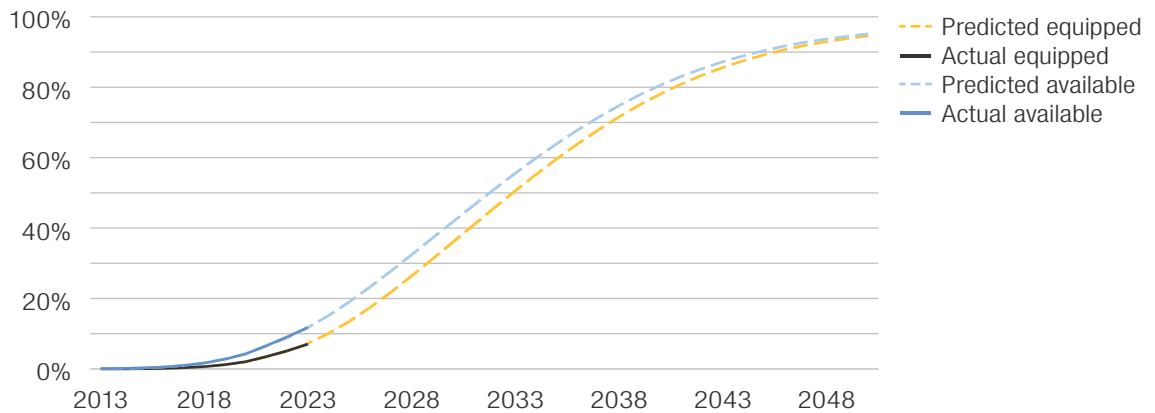


Figure 37 shows the predicted percentage of registered vehicles with rear AEB by calendar year. It is predicted that 95% of registered vehicles will be equipped with rear AEB in 2050.

Figure 38: Predicted registered vehicles equipped with collision avoidance systems, 2023 and 2028 calendar years

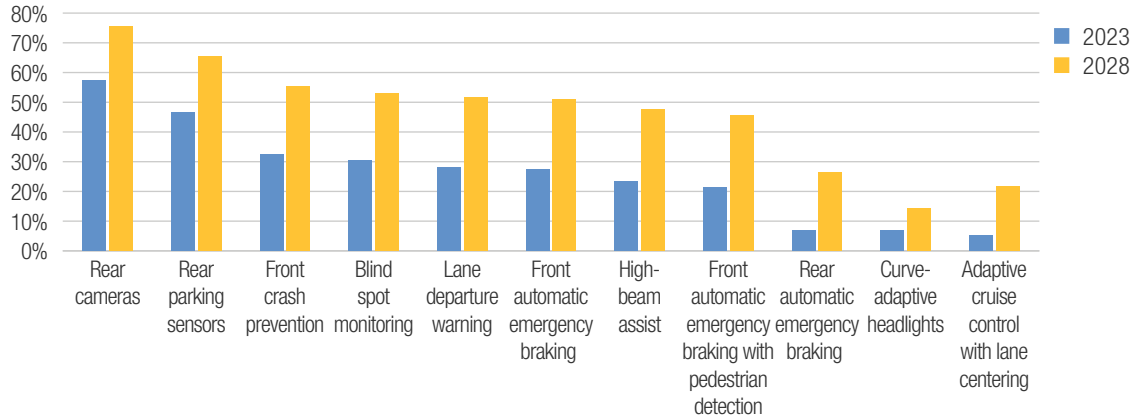


Figure 38 shows the percentage of registered vehicles estimated to be equipped with the features covered by this report in 2023 and 2028. The presence of all systems is estimated to increase by about 15 to 25 percentage points by 2028, except curve-adaptive headlights, which are estimated to only increase by 7%. Rear cameras and rear parking sensors are estimated to be equipped on 76% and 65%, respectively, of the registered vehicle population by 2028. Front AEB is estimated to increase from 28% of the registered vehicle population in 2023 to 51% in 2028. This projected increase can be attributed to a voluntary industry commitment brokered by the Insurance Institute for Highway Safety (IIHS) and the National Highway Traffic Safety Administration. Twenty automakers agreed to equip nearly all their vehicles with front AEB no later than the production year beginning September 1, 2022. Consequently, front crash prevention systems that warn or/and automatically brake are estimated to achieve a 55% fleet penetration by 2028.

► Discussion

It takes many years for new vehicle features to spread through the registered vehicle fleet, even when they are required by the government. Among the collision avoidance features discussed in this report, only rear cameras have been mandated, while many manufacturers agreed to voluntarily equip vehicles with front AEB by September 1, 2022.

With the exception of ESC, estimated take rates have been included for optional features. Although it is not known with absolute certainty how many of the optional features were purchased, estimates were made from VIN data supplied to HLDI from 13 manufacturers. These data provide a better estimate of the actual penetration of collision avoidance features in the vehicle fleet. Equipped rates varied considerably by feature. About 27.5% of the fleet was estimated to be equipped with front AEB, even though it was available on 36.3% of vehicles in the 2023 fleet (20.6% standard and 15.7% optional). Rear cameras, however, were estimated to be installed on 57.3% of the 2023 registered vehicle fleet (41.7% standard and 24.6% optional).

The percentage of new vehicle series with a given feature as standard has increased steadily since the introduction of the feature, except for curve-adaptive headlights, which were standard on fewer and fewer vehicles from model year 2015 to 2020. Consequently, curve-adaptive headlights may not reach 95% availability in the fleet as soon as the other features, if they ever become so prevalent. The headlight evaluation program from the Insurance Institute for Highway Safety has found that headlights can provide sufficient levels of lighting without adaptive technology. For example, many vehicles, such as the 2022 Honda Insight and the 2022 Genesis G90, with headlights that earn the highest rating of good from the IIHS evaluation have LED headlights that are not curve adaptive. This might have slowed the growth of adaptive headlights in the fleet.

Another feature predicted to reach 95% fleet penetration after 2050 is adaptive cruise control with lane centering, which provides some Level 2 driving automation capability. When introduced in the model year 2014, adaptive cruise control with lane centering was available on only a small number of vehicles. For the 2023 fleet, adaptive cruise control with lane centering was estimated to be available on 12% of vehicles, with 5% equipped with it. Although the percentage of new vehicle series with adaptive cruise control with lane centering as standard has increased since the feature's introduction, it will still take decades until a majority of vehicles on the road are equipped with it.

Front AEB with pedestrian detection was analyzed separately from regular front AEB because of increased concern about pedestrian safety. Front AEB with pedestrian detection was introduced in model year 2011 and was initially available only as optional equipment. It became standard on vehicles in model year 2013; in the 2013 fleet, the feature was available on only about 0.1% of registered vehicles. After a decade, nearly 26% of the 2023 registered vehicles had front AEB with pedestrian detection available, and 21% were estimated to be equipped with the feature. Based on the growth rate, it is predicted that 95% of registered vehicles will be equipped with front AEB with pedestrian detection by 2046.

Given the profound benefits of rear AEB on insurance losses (HLDI, 2023b), this bulletin studied rear AEB for the first time. Introduced in model year 2013, rear AEB was estimated to be available on 12% of the 2023 registered vehicles, with 7% equipped with it. As a result, rear AEB is predicted to achieve a 95% fleet penetration around 2050.

High-beam assist systems were also added to this bulletin for the first time. These systems provide better visibility at night and allow drivers to spot obstacles in time to avoid them. The percentage of registered vehicles with high-beam assist available has increased since this feature's introduction in 2008, reaching 33% in 2023, with 24% of registered vehicles equipped with them. It is predicted that 95% of registered vehicles will be equipped with high-beam assist in 2046.

Accounting for the optionally equipped vehicles in the analysis, we predict that features will reach half of the registered vehicle fleet 1 to 5 years later than estimates from projections that assume all vehicles with an optional system were actually equipped with that system.

A prior HLDI study (2019a) found that Honda and Subaru vehicles equipped with effective collision avoidance systems persisted longer in the vehicle fleet. Another HLDI report (2014a) found that ESC-equipped vehicles also last longer in the vehicle fleet than non-ESC-equipped vehicles. This could lead to a slowdown in the turnover of the fleet, as vehicles are lasting longer. However, a sensitivity analysis on changes in the rate of attrition found that small changes in the rate of attrition over time had minimal impact on results. Consequently, the potential longer life span for collision avoidance-equipped vehicles was not accounted for in the predictions.

The COVID-19 pandemic has introduced a great deal of uncertainty. It affected the economy, including new and used vehicle sales. Indeed, a sharp decrease in new vehicle sales was observed in 2020, but the U.S. economy was considered to be fully recovered as of June 2021 (Siegel & Dam, 2021). Accordingly, the 2020 registration data were not used to estimate the future in this study.

► Limitations

One limitation of the logistic model with a probit link is that it assumes a distribution with an asymptote of 100%, which it approaches slowly toward the end of the distribution. When a given feature's prevalence reaches 95%, the feature's growth substantially slows, and it takes a number of years to capture the remaining 5%. It is not known how this remaining small percentage will be captured because no feature has yet reached 100% prevalence. 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 project future data. It may be the case that 100% prevalence is never reached, as some people tend to keep old cars as collectable vehicles. The goal of this study was to estimate when each feature will be available for the vast majority of the fleet, not 100% of the fleet.

Additionally, the work presented here was based on data from a limited number of vehicle manufacturers. The estimates for the optionally equipped rates were the best estimates possible with the available data. Sensitivity analysis was conducted by excluding an individual manufacturer from the data set and using the remaining data for the analysis. For most safety features, the elimination resulted in only minimal changes in our feature-equipped estimates. However, for a few manufacturers, larger changes were observed. Additional data from manufacturers would likely result in better estimates.

Another limitation is that the prediction was based on the coarse calendar year/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 assumptions of 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 as reflected in the graphs, the model fits the existing data well, and therefore it is reasonable to believe that our predictions for the future fleet are the best possible given the limitations.

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