AUTOMOTIVE DEFECT & RECALL REPORT

2021

STOUT

TABLE OF CONTENTS

01

INTRODUCTION

Stout's 2021 Automotive Defect & Recall Report marks the seventh iteration of the automotive industry's most comprehensive analysis of component defect trends. The information in this report is curated from a wide array of national and international sources; it explores component defect and recall-related activity in the automotive industry with a specific focus on component defect risks and trends, trends in recall completion percentage activity, efforts to improve methods of consumer outreach, and forward-looking indicators of recall risk. This report serves as an update from prior years' reports and includes recall activity from 2020 as well as additional insights and trends not included in past iterations.

02

KEY CONSIDERATIONS IN ANALYSIS OF AUTOMOTIVE RECALL

Automotive recalls affect many stakeholders including vehicle owners, vehicle manufacturers ("OEM"), vehicle parts suppliers, insurers, franchised dealers, and government regulators.[1] Although vehicle safety is a key consideration for each stakeholder, each may also have other priorities, contributions, and interests. For example, vehicle owners weigh the perceived safety risk against the inconvenience of a repair. OEMs, suppliers, and insurers are concerned with the risk and cost of recalls, while government regulators are concerned with ensuring compliance with the Motor Vehicle Safety Act and maximizing recall completion percentages.

A key element in Stout's automotive recall analysis is the realization of the nuance within the available data based on the many differences among the vehicles, their likely owners, and the manufacturers that recall those vehicles. The identification of relevant segments based on vehicle age, defective component, supplier identification, and root cause is a critical element of Stout's analysis. In addition to performing quantitative analysis, Stout also considers the relevant qualitative aspects of each recall.

The year 2020 was a unique one for the automotive industry, with plant closures and global supply chain disruptions as a result of the COVID-19 pandemic that also contributed to the lowest volume of new vehicle sales since 2012. Vehicle injuries from crashes and collisions increased in 2020, although the total number of miles driven decreased.[2] Despite all the disruption surrounding the industry, recalls remained close to peak levels.

24

MILLION VEHICLES RECALLED IN 2020

EXCLUDING THE TAKATA RECALLS

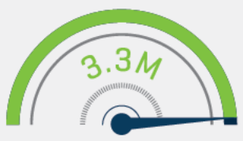
03

RECENT TRENDS IN AUTOMOTIVE RECALLS

The total number of light vehicles recalled in the U.S. in 2020 was 27.8 million, down 400,000 (1.4%) from 28.2 million in 2019, excluding the Takata recalls.[3] Further, individual light vehicle recall campaigns remained close to record highs, with 303 unique campaigns, also excluding the Takata recalls.

LARGEST AND SMALLEST RECALL CAMPAIGNS OF 2020:

LARGEST



VEHICLES RECALLED BY TOYOTA
(COMBINED BETWEEN MULTIPLE CAMPAIGNS)

SMALLEST

7 SINGLE VEHICLE RECALLS

The largest recall in 2020 was a combination of two recalls by the same manufacturer under two separate campaigns but due to the same defect. In total, 36 vehicle models across multiple model years were recalled. This is the first time in a few years that the largest recall of the year was not remedied with a software update. Further, 2020 also witnessed seven recalls involving just a single vehicle in each recall.

FIVE NON-TAKATA CAMPAIGNS IN 2020 AFFECTED MORE THAN 1 MILLION VEHICLES (41% OF VEHICLES AFFECTED FROM NON-TAKATA RECALL CAMPAIGNS):

TOYOTA FUEL PUMP

The low-pressure fuel pump inside the fuel tank may fail (3.3 million vehicles combined between multiple campaigns).

TOYOTA AIRBAGS

The airbag electronic control unit (ECU) may malfunction, possibly disabling the deployment of the airbags and/or seat belt pretensioners (2.9 million vehicles)•.

FORD DOOR LATCH

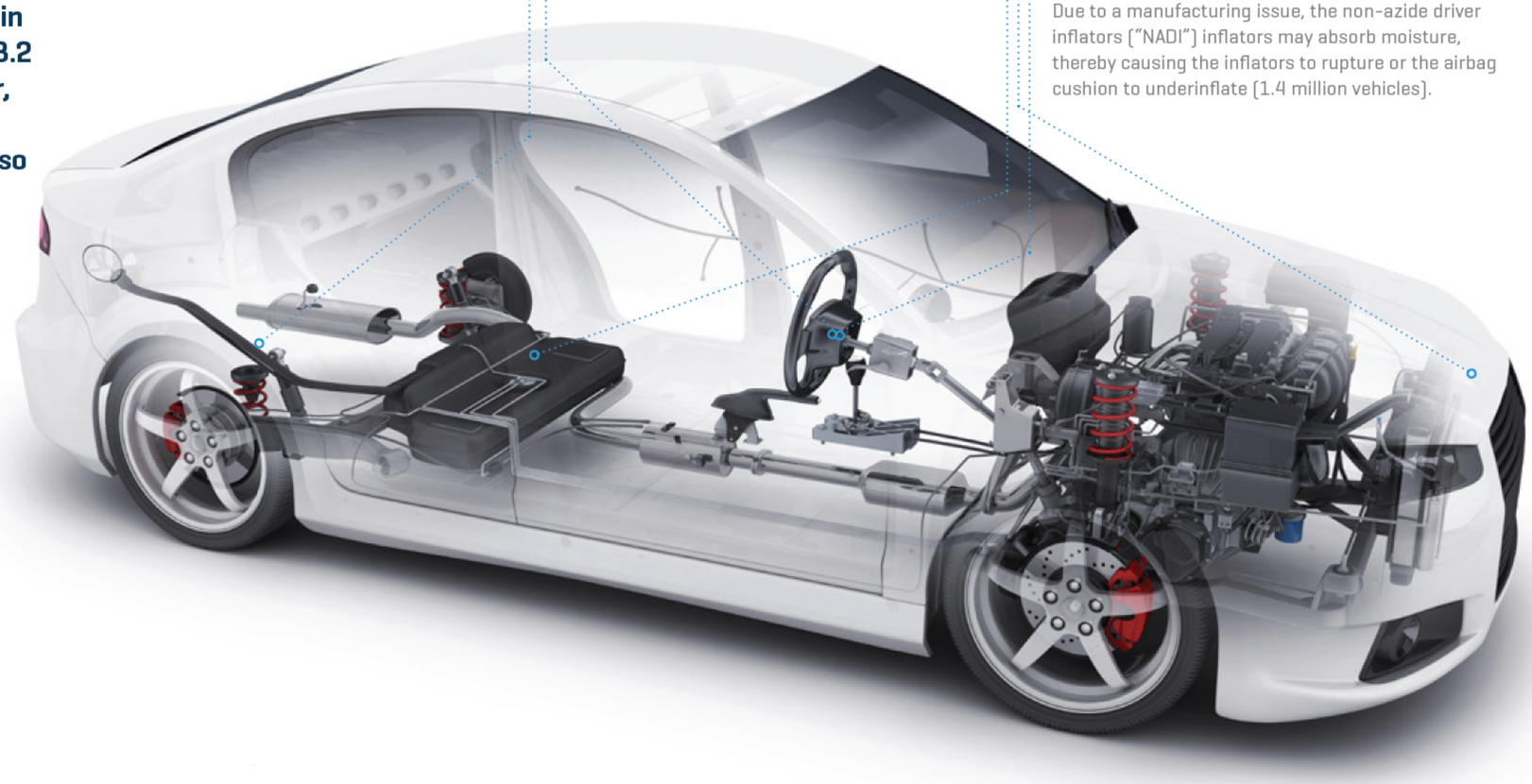
Previous recall—a component within the door latches may break, thereby making the doors difficult to latch and/or leading the driver or a passenger to believe that a door is securely closed when, in fact, it is not (2.1 million vehicles).

NISSAN HOOD LATCH

If the primary hood latch is inadvertently released, there is an increased likelihood that the secondary hood latch may corrode over time (1.8 million vehicles).

HONDA AIRBAGS

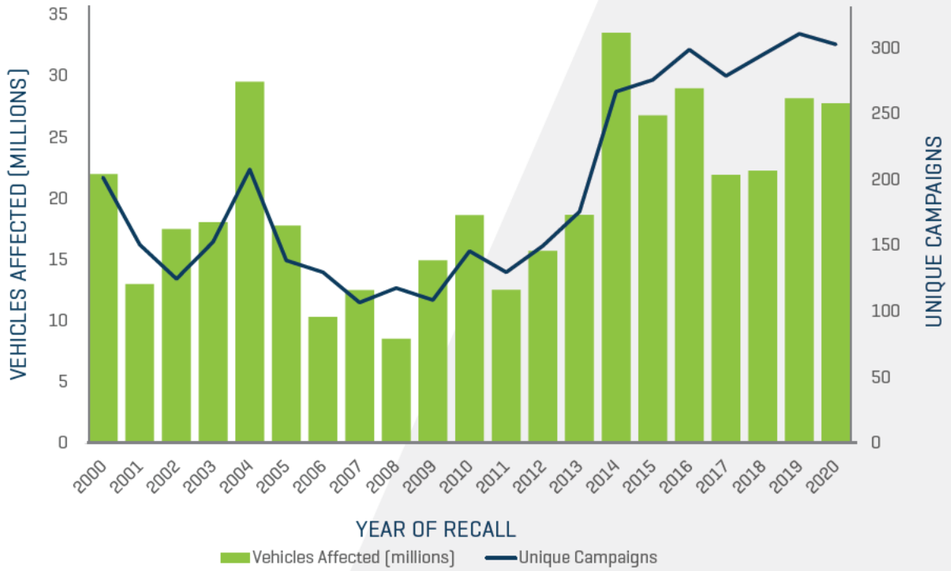
Due to a manufacturing issue, the non-azide driver inflators ("NADI") inflators may absorb moisture, thereby causing the inflators to rupture or the airbag cushion to underinflate (1.4 million vehicles).



TRENDS IN RECALL CAMPAIGNS

Figure 1 shows that the number of unique recall campaigns, exclusive of the General Motors (GM) ignition switch and Takata recalls, has increased over the last five years from less than 150 per year in the mid-2000s to over 300 for the last two years. The number of vehicles affected by these recalls have increased from 12–15 million per year to approximately 28 million in 2019 and 2020.

FIGURE 1 / UNIQUE CAMPAIGNS AND VEHICLES AFFECTED BY YEAR



In addition to a higher volume of recall campaigns in 2019 and 2020, there has been an increase in recall campaigns with higher numbers of affected vehicles. Figure 2 illustrates that in the last two years, there have been over 50 campaigns each year, with over 100,000 vehicles affected (this has not been the case since 2014).

Further, Figure 2 illustrates that smaller recall campaigns, where less than 10,000 affected vehicles were recalled, also increased in 2020 to a record high of 65% of all recall campaigns, thereby continuing a five-year trend of an increasing proportion of smaller recalls.

FIGURE 2 / PERCENTAGE OF UNIQUE CAMPAIGNS BY SIZE OF RECALL AND YEAR

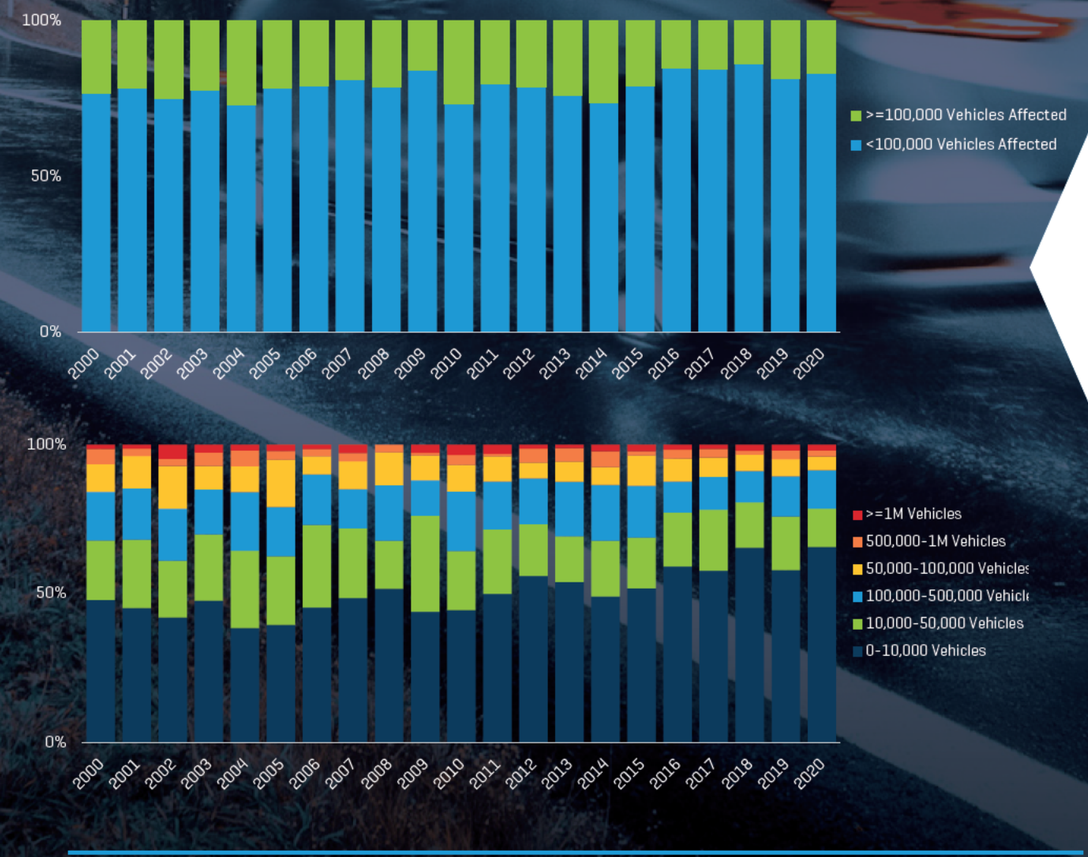


FIGURE 3 / UNIQUE CAMPAIGNS AND VEHICLES AFFECTED BY YEAR FOR OLDER VEHICLE RECALLS

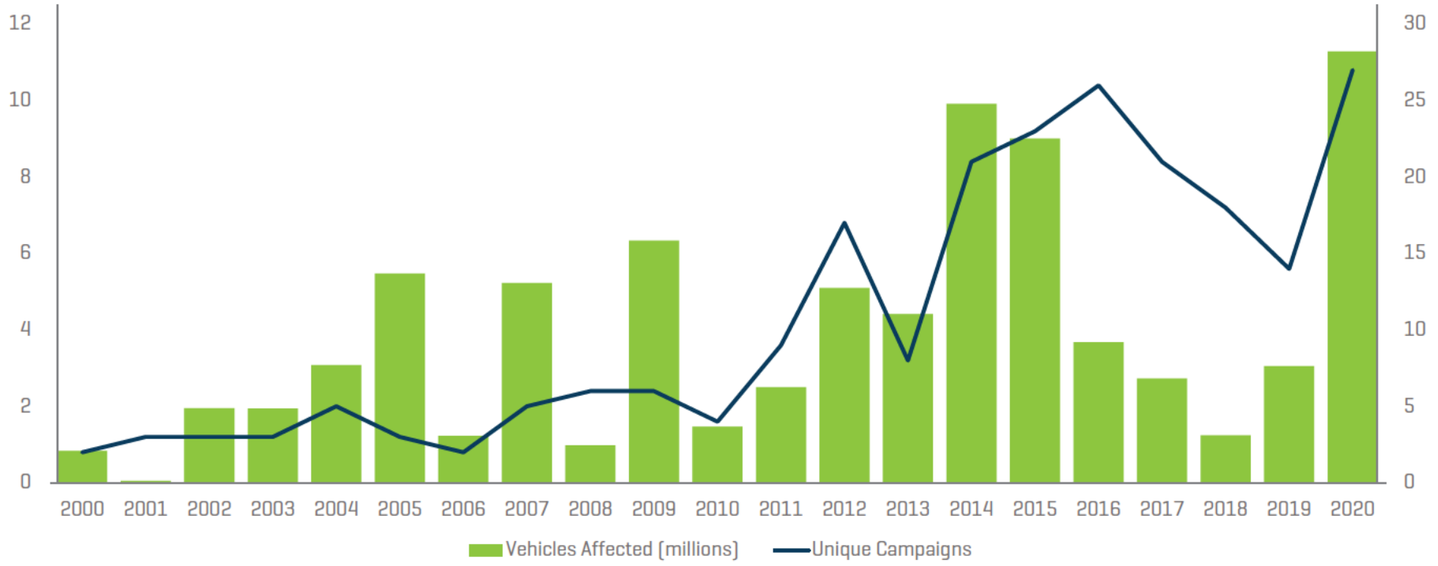


Figure 3 depicts a reversal of a five-year trend in 2020 of a declining proportion of older vehicle (eight years or older) recalls. Almost half of the older vehicle campaigns and 60% of the vehicles affected are airbag recalls, even after excluding Takata's coordinated remedy recall campaigns.

Further, four campaigns encompassing 1.7 million vehicles relate to Takata non-azide driver inflators ("NADI") recalls, which is a different propellant than what was recalled as part of Takata's coordinated remedy.

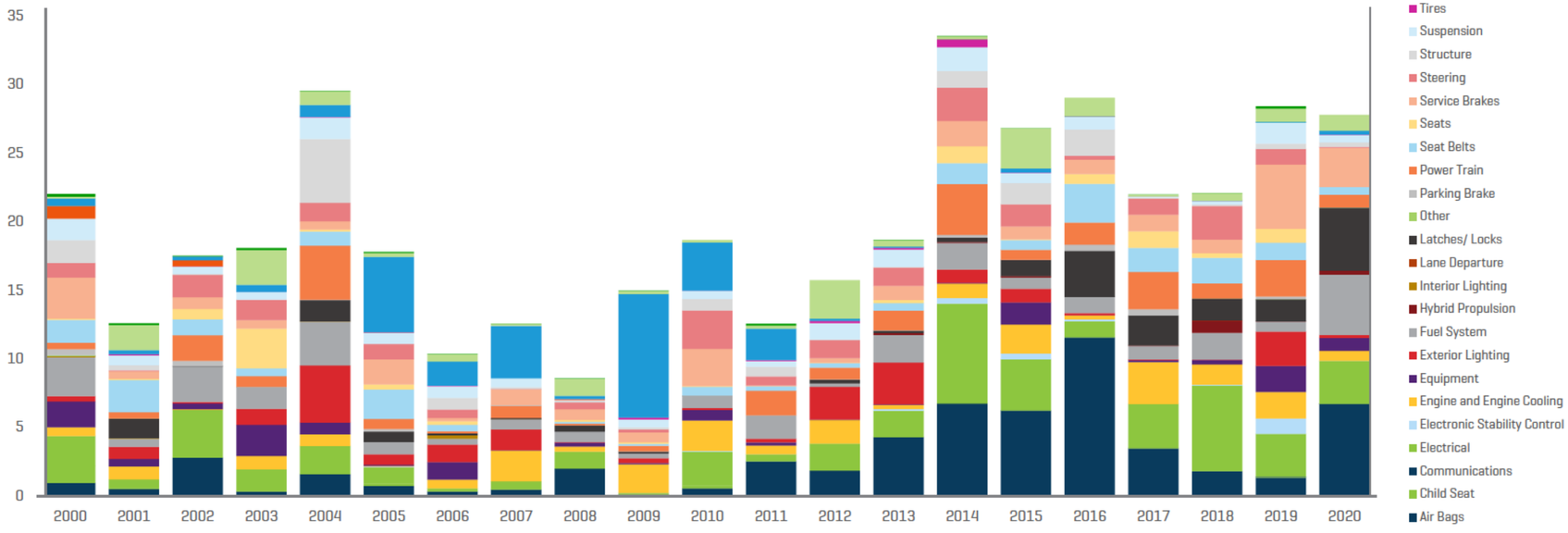
Further, three campaigns for 880,000 vehicles relate to an issue with the remedy of a vehicle that was affected by a campaign associated with Takata Coordinated Remedy, such as improperly folded airbags or an incomplete inspection. One campaign relates to airbag ruptures unrelated to Takata and phase-stabilized ammonium nitrate propellant (PSAN) and one recall relates to a manufacturing defect involving desiccated PSAN.

AFFECTED COMPONENTS

Figure 4 presents a consolidation in the classification of defective components in 2020, with 80% of recalled vehicles in the U.S. classified as being in just four of the component groupings used by NHTSA—airbags, fuel system, latches/locks, and brakes.

This level of consolidation has never been witnessed in prior years but is something to watch for in future periods, as this may signify higher levels of recall risk for certain components.

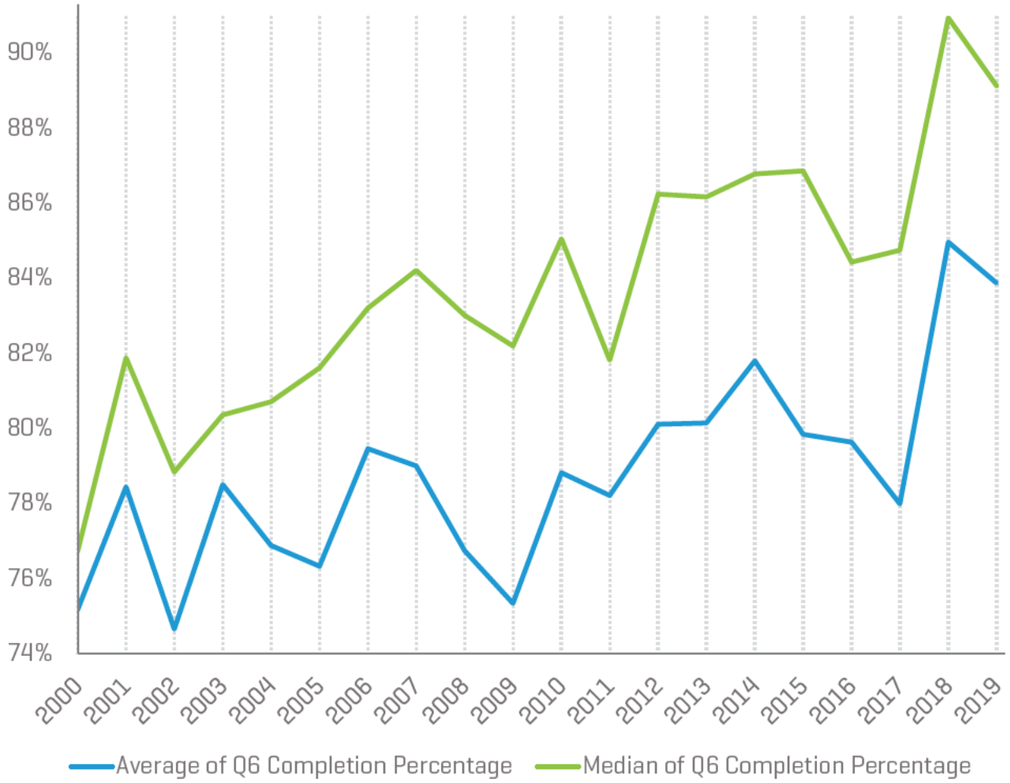
FIGURE 4 / VEHICLES AFFECTED BY COMPONENT AND YEAR



COMPLETION PERCENTAGES

Figure 5 indicates that completion percentages, measured after six quarters from recall remedy launch, have generally been increasing over the last two decades, with the average completion percentages peaking at 83.5% in 2018. This is primarily the result of a continuing trend of smaller and younger vehicle recalls. In 2019, the recall completion percentages decreased from the 2018 peak likely as a result of emergency orders, shelter-in-place orders, and business closures related to COVID-19 as well as a shift in vehicle owner perceptions and priorities caused by the pandemic.

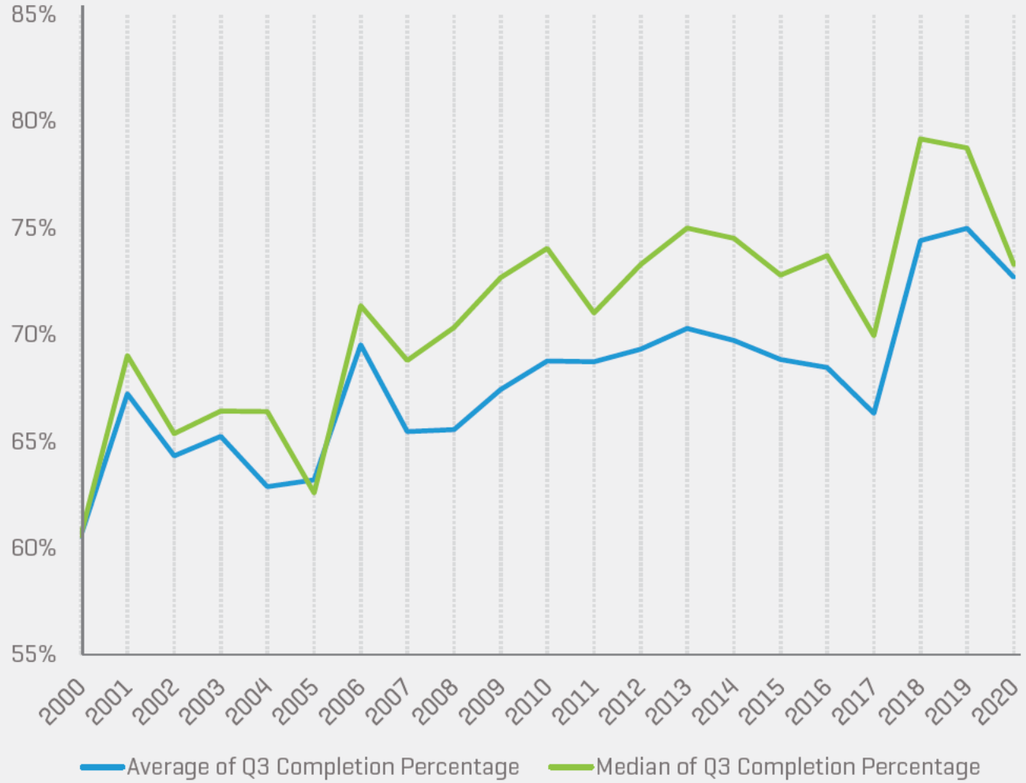
FIGURE 5 / OVERALL MEDIAN AND AVERAGE COMPLETION PERCENTAGE AFTER SIX QUARTERS FROM LAUUNCH BY YEAR



COVID-19 has influenced a measurable drop in recall completion percentages.

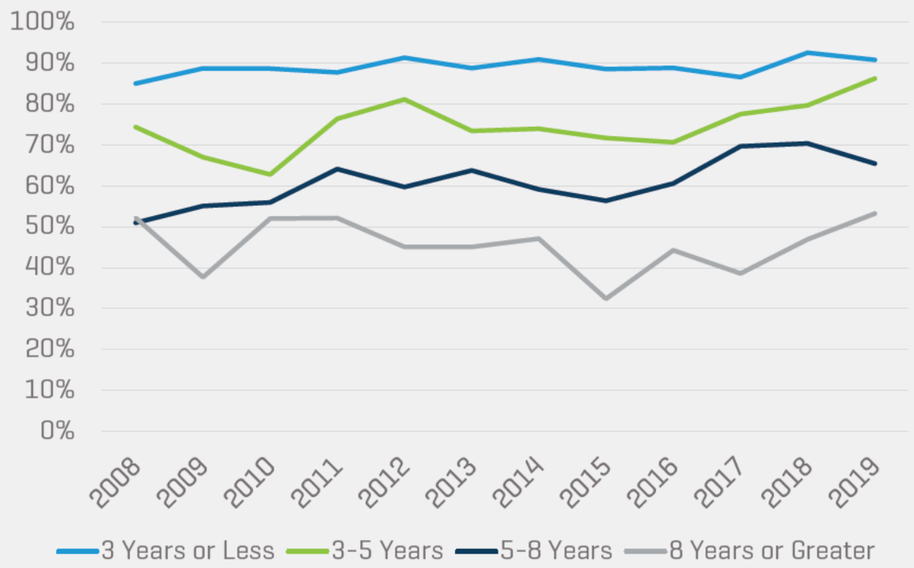
The overall trend in completion percentages are generally observable after the first three quarters after the launch of a campaign. However, this method predicted that completion percentages in 2019 would remain at near-record highs from 2018, which did not hold true likely because of pandemic-related restrictions during the final quarters of these campaigns. Figure 6 illustrates the first three quarters of 2020 recall campaign completions. These are campaigns that would have launched in the first half of 2020 which got off to a slower start in the first three quarters of launch as the pandemic was beginning.

FIGURE 6 / QUARTER THREE MEDIAN AND AVERAGE COMPLETION PERCENTAGE BY YEAR



Vehicle age remains one of the most influential factors for recall completion percentages. Figure 7 depicts recall completion percentages, after six quarters, for new vehicles (three years old or less), moderately new vehicles (three to five years old), moderately old vehicles (five to eight years old), and older vehicle recalls (over eight years old). Over the last three years, recall completion percentages of new vehicles (three years old or less) has been converging with moderately new vehicles (three to five years old) as has moderately old vehicles (five to eight years old) with older vehicle recalls (over eight years old). The convergence between younger and moderately old vehicle recalls could be possibly explained by declining U.S. vehicle sales, as owners are holding onto their vehicles for longer than they had in the past. Consequently, the average age of U.S. vehicles on U.S. roadways has risen to over 12 years.[6] Many owners holding onto their old vehicles likely still maintain a franchised dealer relationship, which positively influences the likelihood of a recall repair and results in completion percentages similar to that of the newest vehicles. The completion percentages for older vehicle recalls has continued to increase to above 50%, which has not been evident for almost 10 years before this and is likely the influence of recall administration innovations, many of which have been identified in the Takata recalls. However, the gap between the recall completion percentages of young and old vehicles continues to widen.

FIGURE 7 / QUARTER SIX MEDIAN COMPLETION PERCENTAGE BY VEHICLE AGE GROUP



TAKATA RECALLS

The term of the Independent Monitor of Takata airbag Coordinated Remedy Program ended [illegible] the Monitor identified that Priority Groups 1–10 collectively reported a completion percentage of 79%, which is significantly higher than comparable completion percentages of similarly aged vehicles. To achieve these completion percentages, the OEMs used numerous recall completion strategies to accelerate Takata recall repairs that had previously not been used in automotive recalls. The key elements cited by the Monitor as fundamental elements responsible for accelerating recall completion percentages related to advanced data analytics and proactive recall engagement to locate affected vehicle owners and motivate them to repair defective Takata airbag inflators. Another fundamental engine of this transformation was the first-of-its-kind public and private partnership between NHTSA, the Monitor, and affected vehicle manufacturers, which was expanded to include state departments of motor vehicles, local governments, and other third-party stakeholders with an interest in vehicle safety and a commitment to collaboration.

The Monitor's report also cited that over 11 million airbag inflators remained unrepaired or accounted for at the end of the Monitorship; this number did not include an additional six million GM vehicles that NHTSA determined must be added to the Coordinated Remedy.

To repair the remaining affected inflators, the Monitor highlighted the importance of:

- The development of more sophisticated data strategies
- Targeted communications eliminating all repair obstacles
- Maximizing the potential of franchised dealers
- Further engaging various stakeholders to assist with recall outreach and strategies

In addition to the vehicles included in the Takata Coordinated Remedy that contained frontal non-desiccated PSAN inflators, additional inflators manufactured by Takata have recently come under recall. These inflators include those manufactured with NADI propellants and certain desiccated PSAN inflators.

SUPPLIER IDENTIFICATION

For each recall initiated, OEMs are required to submit a § 573 notification that serves as a report to the U.S. Department of Transportation, National Highway Traffic Safety Administration that a defect related to motor vehicle safety or noncompliance with Federal Motor Vehicle Safety Standards exists.

Required sections of Part 573 letters include the following:

- MANUFACTURER, DESIGNATED AGENT AND OTHER CHAIN OF DISTRIBUTION INFORMATION
- IDENTIFICATION OF THE RECALL POPULATION AND ITS SIZE
- DESCRIPTION OF THE DEFECT OR NONCOMPLIANCE AND CHRONOLOGY OF EVENTS
- MANUFACTURER OF DEFECTIVE COMPONENT
- THE REMEDY PROGRAM AND ITS SCHEDULE

Identification of a supplier by an OEM in a §573 letter indicates that the supplier played a role in the fabrication of a defective or non-complying motor vehicle component. The identification does not necessarily mean that the supplier in question is entirely, or even partially, at fault for the defect, but only that the supplier was involved in the manufacture of the component. This involvement indicates the potential for involvement in a future cost recovery action.

The overall root cause of the recall, classified by Stout as likely due to assembly-related defects (defects that occur due to an error at an OEM assembly facility), likely due to design-related defects (defects that result in vehicle components ability to withstand vehicle field conditions), and likely due to manufacturing-related defects (defects that are the result of errors at a supplier's manufacturing facility).

We see a continuation in decline of assembly-related defects in 2020. Figure 7 presents the number of recall campaigns that are likely due to assembly-related defects and the proportions of which a supplier was identified in a §573 letter. In 2020, there were 56 unique campaigns (18% of non-Takata campaigns) that Stout identified as likely assembly-related, which were a reduction from 114 at the peak in 2014. Further, 70% of the likely assembly-related vehicles affected in 2020 were from just three campaigns. Two of the three recalls were the result of torque issues used for fasteners and the third was the result of a lubricant used during assembly that was incompatible with the driveshaft's protective coating that caused degradation when exposed to road salt.

Figure 8 depicts the number of recall campaigns that are likely design-related defects and the proportion in which a supplier was identified in a §573 letter. The overall vehicle recalls that are likely design-related decreased in 2020 as did the proportion of supplier identification in this category.

The trend in these recalls over the last three years shows an elevated number of recalls in this category. OEMs and suppliers should watch this trend, as design-related defects generally affect larger volumes of vehicles and are, therefore, more costly, as the defect is common in vehicles across numerous model years and platforms, including vehicle platforms produced in different countries. For example, in 2020, five of the six recalls with over one million affected units was classified by Stout as likely design-related. The only one that was not involved vehicle model years from 1996 to 2001, where traceability may have played a role in the recall size.

Figure 9 presents the number of recall campaigns that are likely due to manufacturing-related defects and the proportions of these recalls in which a supplier was identified in a §573 letter. In 2020, we witnessed a slight decrease in the overall number of manufacturing-related defects and a distribution by component similar to that of all recalls. However, we are generally seeing an increased number of manufacturing defects since 2014. This is important for suppliers, as they consider recall risk assessments and the development of recall risk mitigation strategies and protocols. In addition, the shutdowns associated with COVID-19 and the associated PPAP process and calibrations required once manufacturing resumed could further exacerbate these risks.

FIGURE 7 / UNIQUE CAMPAIGNS BY SUPPLIER IDENTIFICATION AND YEAR FOR DEFECTS LIKELY ASSEMBLY RELATED

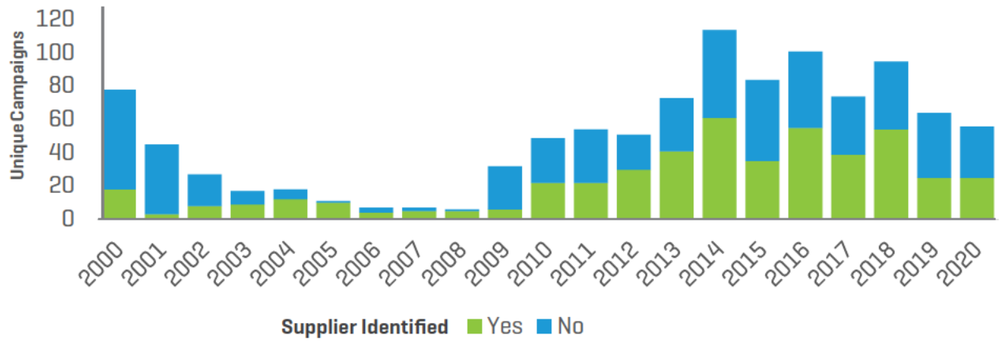


FIGURE 8 / UNIQUE CAMPAIGNS BY SUPPLIER IDENTIFICATION AND YEAR FOR DEFECTS LIKELY DESIGN RELATED

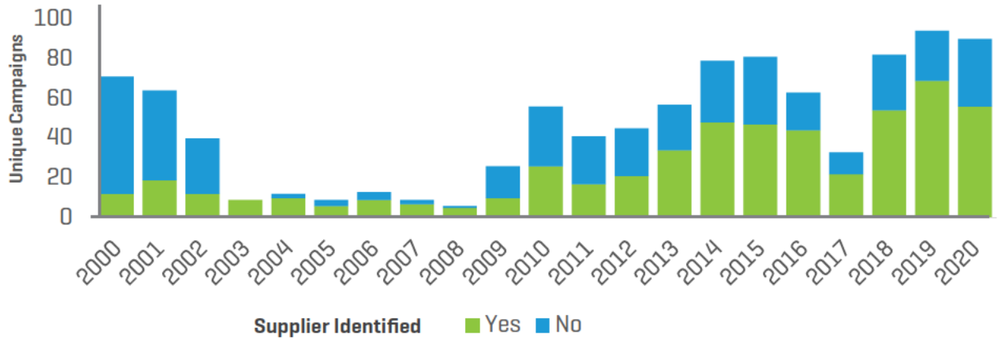
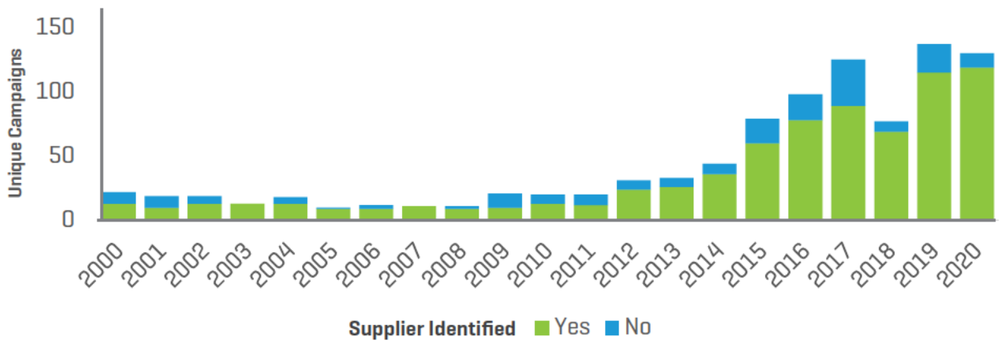


FIGURE 9 / UNIQUE CAMPAIGNS BY SUPPLIER IDENTIFICATION AND YEAR FOR DEFECTS LIKELY MANUFACTURING RELATED



04 REGULATORY CONSIDERATIONS

In the U.S., automobile recalls are initiated for vehicles that do not comply with the Federal Motor Vehicle Safety Standards (FMVSS), the enforcement of such recalls being the prerogative of NHTSA. Announcements of changes in the FMVSS as well as investigations, enforcement actions, and the granting or denying of certain petitions provide insight into emerging areas of automobile recall in the U.S.

UPDATES TO FEDERAL MOTOR VEHICLE SAFETY STANDARDS

Technological innovation in the automobile industry continues to be the focus of NHTSA's rulemaking. In 2020, NHTSA sought comments for at least seven proposed rulemakings.

- NHTSA requested comments regarding the development of a safety framework for automated driving systems. The purpose of the framework would be to "define, assess, and manage the safety of automated driving performance," as well as allow for further development and innovation of automated driving system technology.[8]
- NHTSA suggested changes to regulatory text regarding crashworthiness standards for vehicles with automated driving systems and without traditional manual controls that are necessary for human drivers. This would ensure that vehicles with different designs and features are appropriately considered during testing as well as confirming compliance with FMVSS.[9]
- In response to a public comment from 2017 to amend test procedures for air brakes and occupant crash protection, NHTSA requested comments for all testing procedures that could be replaced, repealed, or modified.[10]
- Modifications were made to the FAST Act, which required NHTSA to exempt a limited number of replicable vehicles manufactured/imported by low-volume vehicle manufacturers from FMVSS. Therefore, this required NHTSA to develop new requirements involving registration, annual reports, consumer disclosures, and labeling.[11]
- NHTSA plans to update the child restraint systems listed in the occupant crash protection FMVSS. This would "ensure that the child restraint systems used by NHTSA to test advanced airbags are representative of the current child restraint system fleet, and would make it easier for vehicle manufacturers and test laboratories to acquire CRSs for testing purposes."[12]
- NHTSA reestablished "that the FMVSS test conditions and procedures apply to NHTSA's compliance testing and that manufacturers are not required to ensure that their vehicles are designed in such a manner," but instead "ensure that the vehicles are capable of being tested," which supersedes all prior statements made by NHTSA.[13]
- NHTSA plans to collect information from entities that have tested vehicles with automated driving systems for NHTSA's Automated Vehicle Transparency and Engagement for Safe Testing (AVTEST) program.[14]

INVESTIGATIONS

Investigations conducted by NHTSA's Office of Defects Investigation (ODI) provide insight into potential defects that the agency considers to be a risk to the motoring public. OEMs and suppliers can review these investigations and the reasons why investigations were escalated or resolved to refine internal testing and quality control initiatives based on the concerns, or lack thereof, that arise from these investigations. At the close of 2020, NHTSA's ODI had 48 open defect investigations. Eighteen of these were categorized as Engineering Analyses and 30 Preliminary Evaluations. Engineering analyses tended to be open for longer periods of time, with 15 of the Engineering Analyses open for over one year, with the oldest having been open for 14 years. Further, 15 preliminary evaluations were open for over one year, with the oldest having been open for a little over four years.

Airbags (4) and Steering (5) were the most investigated component groups of open Engineering Analyses and Suspension (4), Power Train (4) and Engine / Engine Cooling (3) were the most common open investigations for Preliminary Evaluations in 2020. Further, ODI closed 12 defect investigations in 2020, one Engineering Analysis involving Visibility and 11 Preliminary Evaluations. Two of the Preliminary Evaluations were upgraded to Engineering Analyses, six resulted in recalls, and three did not require further escalation.

ENFORCEMENT ACTIONS

In 2020, NHTSA announced three consent orders involving three vehicle manufacturers: two light vehicle manufacturers and one heavy vehicle manufacturer. Both enforcement actions involving the light vehicle manufacturers resulted from inaccurate reporting regarding existing recalls. These enforcement actions were intended to send a signal to OEMs to review processes used to report and communicate vehicle recalls to NHTSA and vehicle owners and an evaluation of the risk of non-compliance with reporting requirements. The consent orders included a $210 million fine, improvement of safety practices (such as new safety offices, testing facilities, and data analytics), and incorporation of independent third-party auditors that report to NHTSA.

The consent order related to the heavy vehicle manufacturer was the result of failing to recall vehicles in a timely manner and complying with reporting requirements. The consent order included up to a $30 million fine and the requirement to improve safety practices through data analytics, IT systems, and employee training

$450 MILLION

TOTAL FINES LEVIED BY NHTSA IN 2020 IN RELATION TO THREE CONSENT ORDERS

MOTOR VEHICLE DEFECT PETITIONS

In 2020, NHTSA denied six motor vehicle defect petitions (MVDP) and did not grant any MVDP.

AFFECTED VEHICLE	DATE OF PETITION	ALLEGED DEFECT
2005 Toyota Prius	January 2013	**Steering Wheel**: Separation of the intermediate shaft assembly and the steering column assembly
2008 Chevrolet Impala	November 2013	**Steering Wheel**: Separation of the intermediate shaft assembly and the steering column assembly
2008 Nissan Sentra	September 2015	**Brake System**: Brake master cylinder leak/ Investigation of two prior recalls involving brake master cylinder leaks
2004 Isuzu Rodeo	May 2018	**Fuel Tank**: Detachment of fuel tank due to rust
2019 Volkswagen GTI	August 2019	**Transmission**: Stalling when vehicle prepares for a stop or turn
2013 Mercedes-Benz E350	April 2020	**Brake System**: Corrosion in rear brake lines

In two of the denials, NHTSA differentiates between a defect and normal wear and tear of the vehicle and its components. With regard to the detachment of a fuel tank due to rust, NHTSA noted, "The damage that may result in tank retention concerns appears to occur progressively over many years with ample opportunity for detection and repair." In another petition regarding a brake master cylinder leak, NHTSA noted, "Master cylinders are generally expected to experience wear and display a finite service life." These differentiations suggest that NHTSA may consider certain components to have a finite service life where degradation of a component is distinct from a defect of that component. However, NHTSA indicates in the fuel tank example that there is "ample opportunity for detection and repair," which is an important reference for when the service life of other complex components is considered. For example, currently there is no defined service period for airbags in the automotive industry.

6
MVDPs
DENIED IN 2020

PETITIONS FOR INCONSEQUENTIAL NONCOMPLIANCE

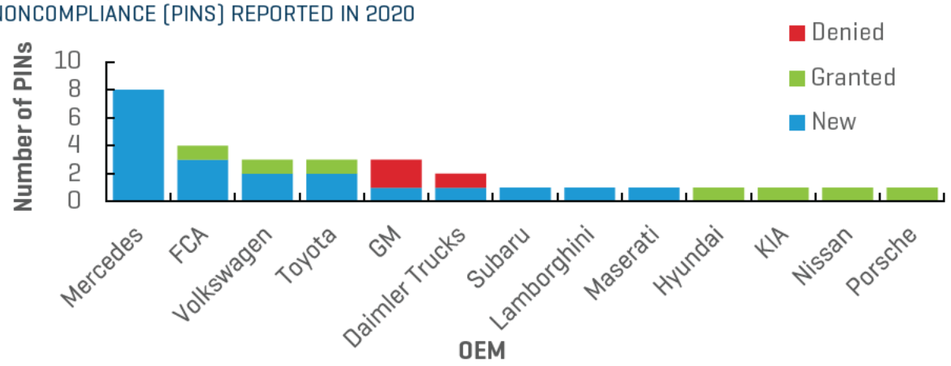
Figure 10 presents the number of new Petitions for Inconsequential Noncompliance (PINs) filed as well as those that were granted or denied in 2020.

In 2020, 20 PINs were reported on the Federal Registrar, 7 were granted, 3 were denied, and 10 are pending. The three denials included two by GM and one by Daimler Trucks. GM submitted a PIN related to Takata inflators in its GMT 900 vehicles. NHTSA concluded, "The 'unique' inflator design differences and vehicle features to which GM points are unpersuasive. The use of thinner wafers is not unique to GMT900 inflators—other Takata inflator variants with 8-mm wafers have experienced ruptures and abnormally high pressures during ballistic testing—and the results of the OATK Aging Study and testing data obtained on field aged inflators, at most, show that GMT900 inflators age more slowly than the worst performing inflator variants. Moreover, four GMT900 inflators have experienced abnormally high peak pressures consistent with propellant degradation."

In another GM PIN relating to seat belt assembly load-limiting torso bars not meeting 12 mm diameters, GM petitioned that crash testing it performed on the subject vehicles were "substantially similar" to compliant vehicles. NHTSA concluded that "In summary, we are not convinced that the crash test data provided in the GM submission is sufficient to show that the smaller torsion bar placed in the subject vehicles would be inconsequential to safety." "More generally, GM's assessment also ignores the crucial role that the static testing requirements of FMVSS No. 209 play in acting as a safety backstop for crash scenarios that are not accounted for in dynamic tests such as those conducted by GM." In this petition denial, NHTSA emphasizes the importance it gives FMVSS No. 209 and/or the importance of considering all standards and metrics when petitioning for inconsequentiality.

Further, Daimler Trucks submitted a PIN related to brake light activation with automatic traction control. Daimler Trucks petitioned, "ATC events occur during low traction conditions such as snow, ice, and mud. The duration of the event can be very short and may not even be noticed by the following driver. If brake light illumination for an ATC event is noticed, it would help to provide early warning of an adverse road condition ahead and encourage the following driver to slow down." NHTSA concluded, "Illumination of the stop lamps during a traction control event is an impairment of the stop lamp function. The safety risk occurs when the stop lamps are activated and other road users expect that the motion of the vehicle is being retarded, but the vehicle is not slowing, thereby potentially confusing or misleading road users by the introduction of a nonstandard signal." In this petition denial, NHTSA highlights that the safety risk relates to the motion of the vehicle and the expectations of other road users regarding the motion of the vehicle. In light of new technologies, such as autonomous vehicles, this finding is all the more interesting. This petition suggests that the expectations of road users will likely inform the manner in which NHTSA considers safety risk.

FIGURE 10 / PETITIONS FOR INCONSEQUENTIAL NONCOMPLIANCE (PINS) REPORTED IN 2020



05

RECALL REMEDY TIMES

Stout analyzes recall remedy times in the U.S. as an important element of the total cost of an automotive recall. Stout identified dealer repair bulletins for 188 U.S. recall campaigns filed in 2020, excluding campaigns classified as software defect, software remedy, or software integration. Many recall campaigns contained multiple labor codes. Certain campaigns contained labor codes that were combined with one or more labor code, thereby creating an additive effect, while other campaigns contained repair times that were mutually exclusive for different vehicles or inspection results. Stout coded each recall campaign to identify the maximum labor time allotted per campaign. For example, if one vehicle model had a one-hour labor time and another vehicle model had a 1.5-hour labor time, then 1.5 hours was used for purposes of this analysis. If an inspection procedure was 0.2 hours and a repair procedure was 1.0 hour, depending on the result of the inspection, 1.2 hours was used in the analysis.

Consistent with prior years, Stout's analysis found that most recall campaigns involve a remedy time of under three hours but significant variability of allotted labor times across recall campaigns and components. Figure 11 shows the high, low, and average recall remedy time by component as well as the number of campaigns in each component grouping. There is significant variation in labor times for some components as seen on the left side Figure 11. For example, Engine and Engine Cooling labor times range from 0.5 hours to nearly 18 hours, which is primarily due to the complexity and diversity of the repairs across vehicle types. However, it is important to note that the average labor time only reflects 3.6 hours out of the total seven associated recall campaigns for this component. This trend is consistent across other components such as Fuel System, Steering, Power Train, airbags, Suspension, Electrical, Visibility and Seats. Despite the observed variation in labor times, and recalls with long labor times, all components have an average labor time closer to the bottom end of the range indicating that the longer repair times are less common.

Figure 12 presents the same data as Figure 11, but limits the data to remove statistical outliers measured by recall campaigns with a standard deviation greater than +/- 1. When these statistical outliers are removed, tighter ranges of labor time are observed, with the average labor times more consistently landing closer to the middle of labor time ranges.

Figure 13 depicts recall labor times expanded to years 2016–2020, and statistical outlies are removed from the analysis. In this view of the data, smaller labor ranges and lower average labor times are generally observed. The effect of lowering the average labor time by the inclusion of more data points in the analysis suggests that most recalls have shorter labor times, generally under two hours

FIGURE 11 / LABOR TIMES BY COMPONENT – 2020

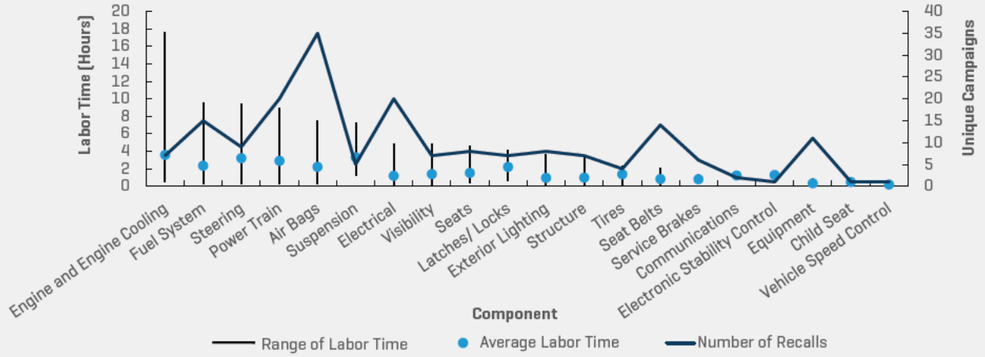


FIGURE 12 / LABOR TIMES BY COMPONENT – 2020 (WITH STATISTICAL OUTLIERS REMOVED)

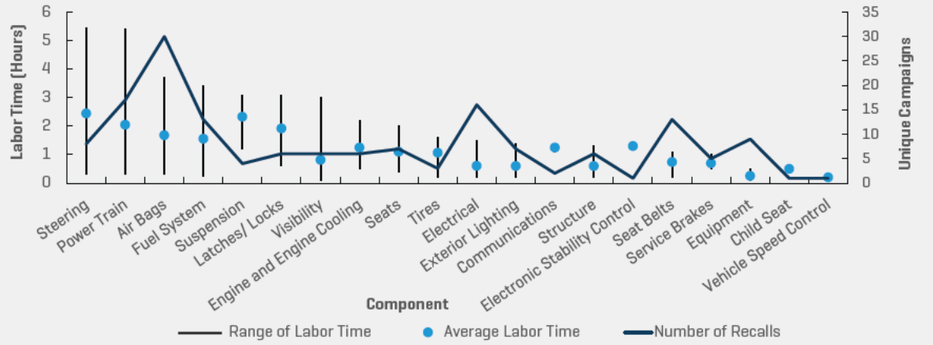
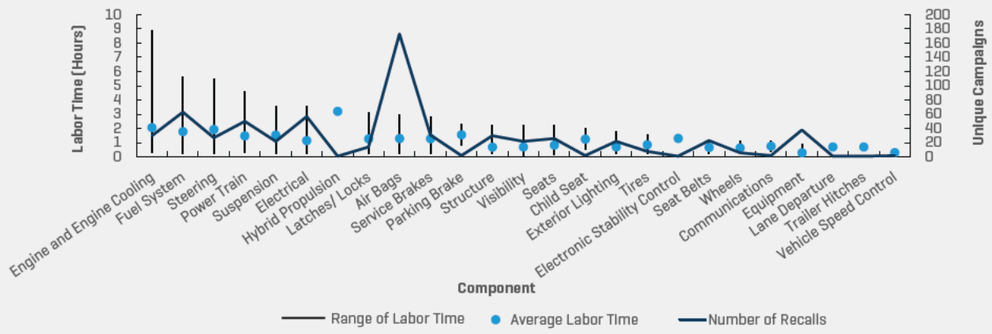


FIGURE 13 / LABOR TIMES BY COMPONENT – 2016-2020



06 ELECTRIC VEHICLE BATTERY DEFECTS

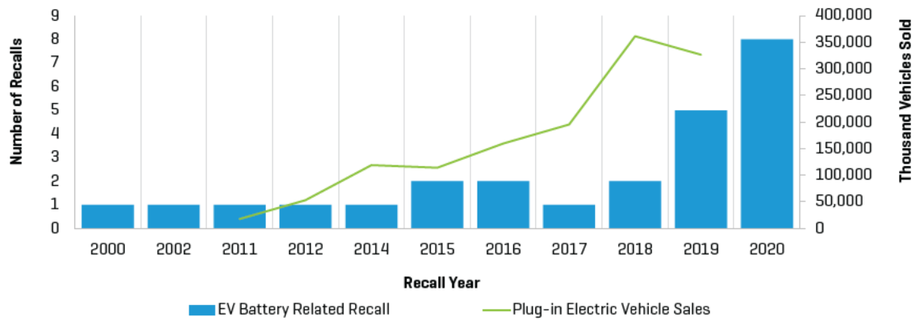
Stout recognized an increasing trend in electric vehicle (EV) battery recalls in the last several years and conducted separate analyses of these defects. Stout isolated recalls, initiated from 2000 to 2020, identified as having defects in the battery pack module, battery management system, converters and inverters, fail safe systems, and high voltage charging systems.

The number of EV battery recalls in the U.S. appears to be generally correlated with electric vehicle sales in the U.S., thereby indicating that as sales increased recall activity also increased. From 2000 to 2014, one electric vehicle battery recall or less was identified per year. This increased to approximately two recalls per year between 2015 and 2018. In 2019, five EV battery recalls were initiated, which further increased to eight in 2020.

The nature of EV battery defects changed over the analysis period, with the earlier recalls generally not relating to the battery themselves, but instead related to the fail-safes around high voltage systems, moisture intrusion, and placement issues. In 2019, Stout observed similar defects, and this became more frequent as sales increased. However, in 2020, more defects directly related to the EV battery were initiated, comprising what appear to be both manufacturing and design defects. The manufacturing defects consisted of defects in the welding that attach individual cells together as well as debris contamination within the cells. The design defects relate to overloaded systems that have resulted in vehicle fires or the loss of drive power.

Across all periods analyzed, recalls related to EV batteries have generally occurred in vehicles that were one or two years old at the time of recall. Because EV production is relatively small and known defects are identified early, EV battery recalls tend to be small and generally contain only a few hundred to a few thousand units. However, incident rates are rising as production is increasing and incidents commonly occur across global platforms. In other words, recall actions initiated in the U.S. commonly mirror those in foreign jurisdictions. Moreover, in 2020, the first recall related to an EV battery was influenced by a NHTSA investigation suggesting increased awareness by NHTSA, as EV production has increased and defects manifest. EV battery recalls can be very costly if the remedy involves the replacement of the battery pack. For example, the GM Bolt recall expansion is estimated to cost an additional $1 billion to the $800 million already estimated for the original recall population,[15] and the Hyundai Kona battery recall is estimated to cost approximately $900 million.[16]

FIGURE 14 / BATTERY-RELATED RECALLS VS. ELECTRIC VEHICLE SALES



"The GM Bolt recall expansion is estimated to cost an additional **$1 billion** to the **$800 million** already estimated for the original recall population, and the Hyundai Kona battery recall is estimated to cost approximately **$900 million**."

07 ELECTRONIC COMPONENT DEFECTS

Today's cars, SUVs, and light trucks contain more advanced electronic safety and convenience content than ever before, powering premier features throughout the vehicle. These features have led to the continued expansion of software in vehicles – as well as opportunities to repair vehicles without costly replacement components. These trends continued in 2020 but were complicated by pandemic related semiconductor shortages and other supply chain disruptions, the consequences of which are not yet fully known. Therefore, Stout's analysis of electronic component defects is key to identifying and understanding these nascent trends and to help the industry plan for the future.

Stout's analysis of integrated automotive electronic components examines how software and non-software-related failure modes contribute to the risks and costs of defects and recalls. Stout utilizes a variety of source materials for its analysis, including NHTSA recall data, -§573 letters, quarterly completion reports, and technical service bulletins (TSBs). Then, Stout categorizes electronic components into four primary groups based on defect and remedy descriptions. These groups are enumerated below:

- Integrated Electronic Components (IECs): Encompasses the failure of electrical components due to physical defects, including defects related to water intrusion, wiring failure, etc. (these defects are not caused or fixed by software)
- Software Defect: Includes the failure of components related to a defect in operating software
- Software Integration: Failure that results from software interfacing with other components or systems in a vehicle
- Software Remedy: Failure is not clearly caused by a software defect, but a software flash or replacement is identified as the appropriate defect remedy

As Figure 15 indicates, the overall number of recalls of electronic components and related failure modes declined slightly in 2020, after having reached a peak in 2019. This year, we observed declines in most categories of electronic component defects, with a slight increase in the number of software defects.

Figure 16 indicates that the proportion of software-based defects—that is, software defects, software integration, and software remedy—increased for the fourth consecutive year, while IEC-related defects continued to decline. The increase in software-based defects highlights opportunities for OEMs and suppliers to employ modifications to vehicle systems, such as software updates and calibration adjustments, to remedy defects that would previously have required the repair or replacement of vehicle components. The increase in the number of software-based defects, particularly software remedies, is a trend that we expect will continue in the years to come.

Approximately 10 million vehicles were recalled for electronic component defects in 2020, as depicted in Figure 17, which represents a decrease of 30% from 2019. This was proportionately larger than the decline in the number of vehicles affected by recalls observed industrywide and represents the lowest number of vehicles affected by electronic component defects since 2017. Moreover, fewer vehicles were involved in software remedy campaigns in 2020 than in prior years.

Figure 18 illustrates that 2020 was the third year in which there was an increase in the absolute and proportionate number of vehicles affected by IEC-related defects, which may reflect the failure of aging electronic components.

FIGURE 15 / RECALL CAMPAIGNS BY ELECTRONIC COMPONENTS AND YEAR

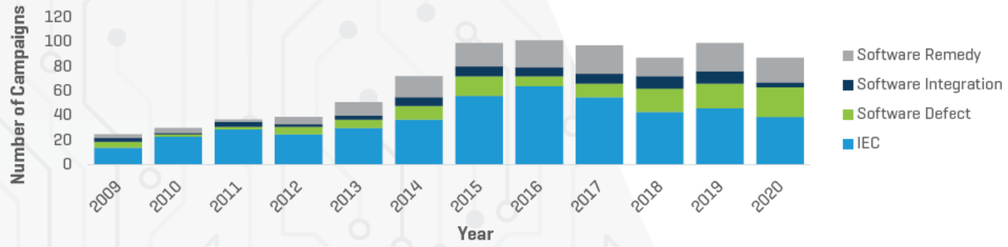


FIGURE 16 / PERCENTAGE OF RECALL CAMPAIGNS BY ELECTRONIC COMPONENTS AND YEAR

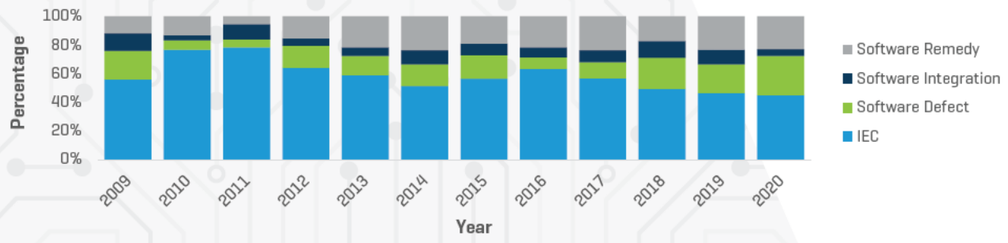


FIGURE 17 / VEHICLES AFFECTED BY ELECTRONIC COMPONENTS AND YEAR

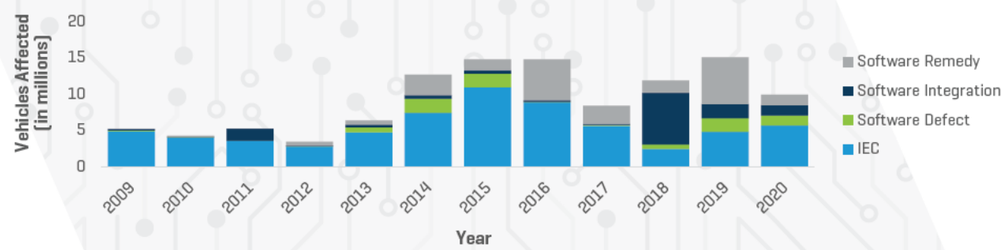
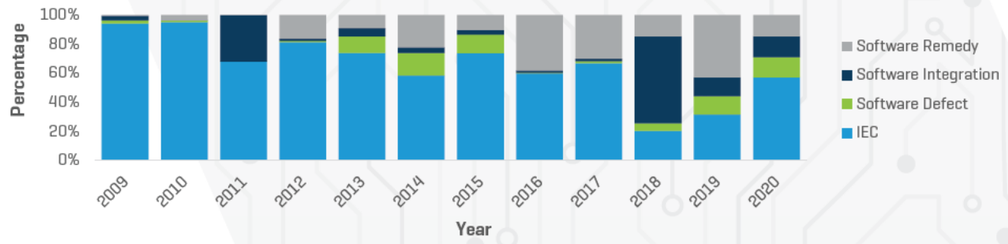


FIGURE 18 / PERCENTAGE OF VEHICLES AFFECTED BY ELECTRONIC COMPONENTS AND YEAR



COMPONENT TRENDS: REARVIEW AND BACK-UP CAMERA RECALLS

One notable trend in 2020 was the continued expansion of rearview and back-up camera recalls. There were 14 recalls of these components in 2020, which affected almost 3.1 million vehicles, almost 80% of which involved software-based defects, which include 737,000 vehicles recalled because of software errors causing disruptions between integrated components that impact the rearview camera, 608,000 vehicles recalled due to incorrect software in the instrument control panel, and 500,000 vehicles recalled due to incorrect central network software, each of these defects highlighting the vulnerability of integrated systems Indeed, this was the largest number of vehicles affected by such recalls, as these components became required equipment on vehicles manufactured for sale in the U.S. in 2018. Similar recalls were observed across multiple jurisdictions globally.

Coinciding with requirements that new vehicles produced in the U.S. contain rearview and back-up cameras, the number of recalls of these components increase dramatically; this phenomenon reflects both the number of vehicles equipped with these systems as well as the regulatory focus on their operation, as they have become safety-critical systems. Accordingly, manufacturers of rearview camera equipment have faced a changing risk profile related to these components as they transitioned from driver-convenience features to safety-critical equipment.

The trend of rearview camera recalls could provide an instructive framework for evaluating the risks of other components that may become standard safety equipment in the future. We reviewed this trend for other components that have also become mandatory safety equipment—airbags, electronic stability control, and anti-lock brakes.

AIRBAGS

Airbags had been standard equipment in vehicles for many years before becoming required safety equipment in vehicles manufactured and sold in the U.S. in 1998.[17] Following this requirement, there has been a significant increase in the number of airbag recalls and vehicles affected, as seen in Figure 20. The time period depicted in the analysis excludes the period of time that reflects the impact of the Takata recalls.

ELECTRONIC STABILITY CONTROL

Light vehicles were equipped with electronic stability control systems for many years prior to becoming required safety equipment on September 1, 2012[18]; such vehicles experienced only limited recall activity during that time. In the years following the implementation of the new regulation, Stout observed a substantial increase in the number and size of recalls that involved electronic stability control, and is depicted in Figure 20.

ANTI-LOCK BRAKES

The use of anti-lock brakes on passenger vehicles was widespread prior to becoming a required safety equipment as of September 1, 2012.[19] Figure 22 presents the frequency and severity of these recalls, thereby indicating the variability in the incidence of these recalls prior to NHTSA's requirement, with a steady increase in anti-lock brake recalls following the regulation. Prior to the NHTSA requirement, there was one large recall of 1.3 million vehicles due to corrosion in the ABS system resulting from environmental conditions and several recalls related to a variety of issues in 2007.

Among the components studied, we observed a similar pattern of increased frequency and severity of recall activity among required safety components as has recently emerged for rearview and back-up cameras. Indeed, in each example, the greatest number of recalled vehicles was observed following a regulatory requirement.

While this analysis presents the relationship between a component's status as required safety equipment and its susceptibility to recall, there are other factors that may further influence this analysis and must be considered, such as the age of the components and technologies, number of vehicles equipped with these components prior to becoming safety-critical, evolving complexity of systems over time, and other changes in the regulatory environment. Nevertheless, this analysis may provide an instructive framework for evaluating risks of other components transitioning to becoming safety-critical and may be instructive for newer safety systems, such as lane-keeping assist, forward collision avoidance, and automatic braking.

FIGURE 19 / NUMBER OF VEHICLES AFFECTED AND UNIQUE CAMPAIGNS, BEFORE AND AFTER REARVIEW AND BACKUP CAMERA REQUIREMENT

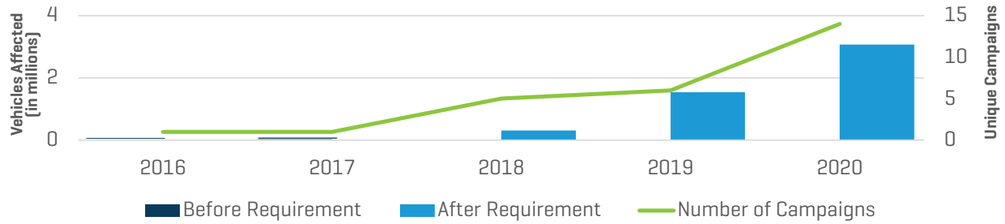


FIGURE 20 / NUMBER OF VEHICLES AFFECTED AND UNIQUE CAMPAIGNS, BEFORE AND AFTER AIRBAG REQUIREMENT

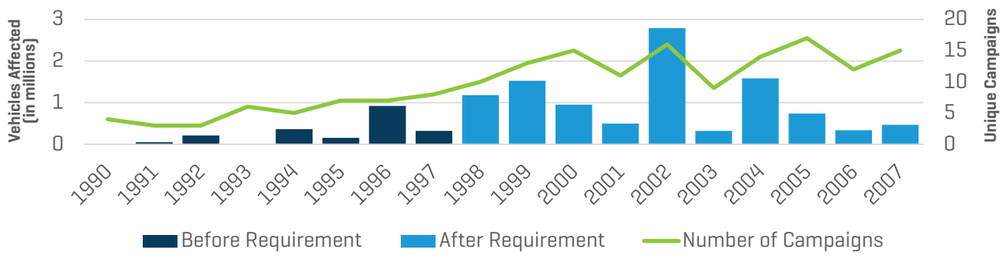


FIGURE 21 / NUMBER OF VEHICLES AFFECTED AND UNIQUE CAMPAIGNS, BEFORE AND AFTER ELECTRONIC STABILITY CONTROL REQUIREMENT

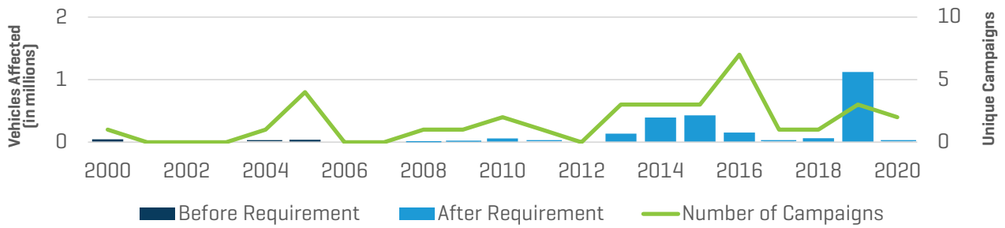
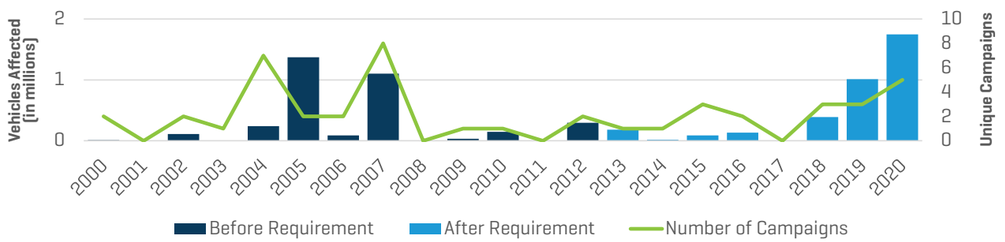


FIGURE 22 / NUMBER OF VEHICLES AFFECTED AND UNIQUE CAMPAIGNS, BEFORE AND AFTER ANTI-LOCK BRAKES REQUIREMENT



REARVIEW & BACK-UP CAMERA REMEDIES

In addition to analyzing the incidence of rearview and back-up camera recalls, Stout has also studied the nature of their remedies, providing insight into the potential costs of those repairs. For all recall repairs, the average remedy time was relatively short – less than one hour. The average repair time for software remedies, 0.8 hours, is lower than the average 1.0 hour repair time for IEC related defects. The longest recall for a rearview and backup camera recall was 3.0 hours.

The majority of rearview and back-up camera recalls studied were remedied with a software update, with only 22% requiring repair or replacement of equipment, including rearview mirrors, audio display units, or rearview cameras. Two of the recalls involving software remedies received remedies over-the-air (OTA), representing a notable proportion of all OTA recall remedies delivered to date. While most rearview and back-up camera recalls received software remedies, the availability of these remedies may change as the components continue to age.

<1 HOUR

AVERAGE REMEDY TIME FOR ALL RECALL REPAIRS

DEFECT INVESTIGATIONS AND ELECTRONIC COMPONENT DEFECTS

Potential failures and safety concerns have been the subject of defect investigations conducted by NHTSA. In addition to signaling potential future recalls, these defect investigations provide valuable technical insights into the nature of current electronic component defects, which is valuable to the analysis of future issues. A 2020 defect investigation of technology-related defects initiated by NHTSA provides insight into potential shifts in the age of vehicles affected by electronic component defects (emphasis added by Stout):

*"On June 22, 2020, the Office of Defects Investigations (ODI) opened Preliminary Evaluation PE20-010 to investigate incidents of media control unit (MCU) failures resulting in loss of rearview camera .... **flash devices have a finite lifespan based upon the number of program/erase (P/E) cycles**. The subject MCU allegedly fails prematurely due to memory wear-out of the eMMC NAND flash ... The data show **failure rates over 30 percent in certain build months and accelerating failure trends after 3 to 4 years-in-service**... **With this failure mode, the only recovery available is a replacement of the eMMC device, achieved by physical part replacement of either the MCU assembly or visual control module subcomponent**...There are precedents for addressing defects that result in loss of either backup camera, defogging, or turn signal functions under safety recalls. Tesla has implemented certain over-the-air or OTA updates to subject vehicles to mitigate the effects of MCU failure. These updates include firmware changes to reduce memory usage of the subject memory card, improve eMMC error correction and storage management strategies, changing the control logic for turn signal activation, and defaulting the HVAC system to Auto (71.6F) for drives after MCU failure to address windshield defogging. **Tesla indicated that the MCU failures are likely to continue to occur in subject vehicles as vehicles continue to operate and use available memory in the 8GB eMMC NAND flash memory until 100% of units have failed**..."*

This investigation provides insight into the changes in the age of vehicles affected by electronic component defects and the potential remedies available. After a review, the vehicle manufacturer determined that as a result of finite memory available in certain components, 100% of these components will fail, as available memory is consumed with failures accelerating within 3–4 years of service. While some storage management and other mitigation efforts could be deployed with software updates, ultimately, these failures would require physical replacement of the components.

NOTABLE SOFTWARE REMEDY TRENDS: EXPANSION OF OTA

While it is more frequently observed for non-safety related field actions, the availability of OTA remedies for safety recalls have been previously infrequent, with only two such remedies offered prior to 2020. However, five such remedies were available in 2020, thereby marking an impressive expansion of OTA remedies afor safety recalls. In addition to safety recalls, we observed 15 technical service bulletins in 2020 that indicated the use of OTA remedies and suggested more widespread use of OTA remedy delivery for non-safety defects.

The 2020 recalls utilizing OTA remedy delivery have achieved high completion percentages by most measures, but the disparity in completion progress in these recalls reveal that barriers to completion remain.

OTA REMEDY	COMPLETION RATE	REMEDY REQUIREMENT
20V-191	95.4% completion in Q3	Requires owner to select Update Now when prompted on radio display
20V-440	79.2% completion in Q2	Must be connected to a Wi-Fi network, requires navigation through menu prompts to identify software update and installation
20V-461	84.7% completion in Q2	Owner required to accepted applicable terms and conditions, vehicle not operable during installation
20V-489	85.1% completion in Q1	Owner required to accepted applicable terms and conditions, vehicle not operable during installation
20V-609	99.8% completion in Q2	Update included in firmware releases with push notifications provided to the vehicle and mobile app; owners can initiate updates from mobile app.

08 EMISSIONS RECALLS

Much attention is given to recalls and other responses to defects involving safety issues; however, significant regulatory action is taken in relation to defects that result in increased emissions.

In 2015, Volkswagen recalled almost 550,000 diesel vehicles in the U.S. in connection with revelations regarding emissions defeat devices installed in 2.0L and 3.0L vehicles.[20] In 2019, FCA (Fiat Chrysler Automobiles, now Stellanits) announced that it was recalling over 860,000 vehicles as a result of in-use emissions investigations, which have led to requiring the replacement of catalytic converters in the vehicles.[21] This recall by FCA is in addition to the automaker's 2017 recall of over 100,000 diesel vehicles equipped with emissions-defeat software.[22]

On March 9, 2021, a settlement was entered between Daimler AG and Mercedes-Benz USA, LLC, and the Department of Justice, the U.S. Environmental Protection Agency (EPA), and California Air Resources Board to resolve violations of the Clean Air Act and California law related to cheating on emissions tests and the failure to disclose unlawful defeat devices in 250,000 diesel vehicles leased or sold in the U.S. Daimler AG and Mercedes-Benz USA, LLC agreed to recall and repair the affected vehicles, offer an extended warranty on those vehicles, and pay a civil penalty of $875 million.[23]

Like vehicle safety regulations, many different countries and other jurisdictions—including individual states within the U.S.—maintain their own individual regulations in addressing motor vehicle tailpipe emissions. This can lead to varying emissions requirements in the different markets in which OEM's sell their vehicles and even variation within single countries.

In this regard, Stout analyzed EPA vehicle emissions recall data. Through requests under the Freedom of Information Act (FOIA), Stout collected data related to emissions defect reports, recall reports, and recall completion maintained by the EPA related to light vehicles. In this section, Stout presents its findings and shares unique insights related to the nature of emissions-related defects.

EPA COMPLIANCE ACTIVITIES[24]

1963 CLEAN AIR ACT

1975 ENERGY POLICY AND CONSERVATION ACT

2005 ENERGY POLICY ACT

2007 ENERGY INDEPENDENCE AND SECURITY ACT

The EPA derives its authority to regulate vehicles, fuels, and engines from statutes enacted by Congress. Through these acts, the EPA is responsible for emissions compliance oversight from initial product design to performance in the field.

The EPA can require automakers to recall and repair affected vehicles if it determines a substantial number in a category or class do not meet emissions standards while in use. However, emissions defects in emissions-related components may not always result in a recall if those defects do not increase emissions.

The EPA's Office of Transportation Air Quality (OTAQ) considers defect and recall reporting to be critical components of compliance for the light-duty vehicle sector. These programs are considered critical to the enforcement of the EPA's air quality regulations for the light-duty because:

- Light-duty emissions standards are the most stringent.
- Light-duty vehicles have sophisticated and complex emissions control systems, increasing opportunities for defects to occur.
- Dealership infrastructure conveys information to consumers and repairs vehicles.
- Manufacturers are required to report emissions related defects to the EPA.

Stout's analysis has focused on the EPA's regulations pertaining specifically to light-duty vehicles.

DEFECT REPORTS

An emissions-related defect is a defect in design, materials, or workmanship in a device, system, or assembly as described in a vehicle's application for certification that was previously approved by the EPA. Vehicle manufacturers are required to notify the EPA of emissions-related defects in 25 or more vehicles in the same class and category. These notices can result in a recall, but may not if the defect in an emissions-related component does not result in an increase in emissions.[25]

Because issues revealed in defect reports may not result in recalls if they do not lead to an increase in emissions, they provide an interesting insight into emissions defects for OEMs and suppliers. Defect reports can provide an indication of nascent defects and those at the margins of emissions regulations. Understanding the risks indicated by defect reports not only provides an advanced notice of issues that may ultimately result in recalls, but can also help to highlight the boundary between minor defects and major recalls.

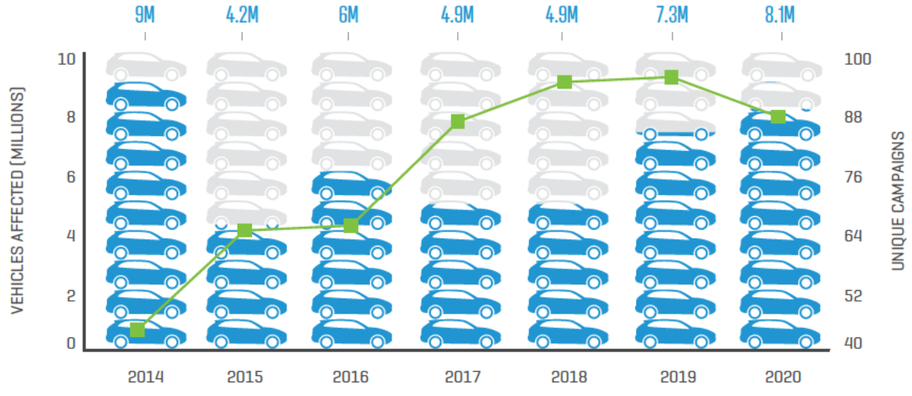
EMISSIONS RECALLS

Like safety recalls, emissions recalls may be initiated on a voluntary or mandatory basis. For both, vehicle manufacturers are required to submit a recall plan for remedying defects, as well as quarterly progress reports. Vehicle manufacturers are also required to notify vehicle owners of the non-conformity and provide instructions for obtaining a remedy.[26]

As evident from Figure 23, the greatest number of recalled vehicles during the period studied by Stout was observed in 2014, when approximately nine million vehicles were involved in emissions recalls. In addition, we observed a steady increase in the number of vehicles affected each year since 2018, reaching 8.1 million vehicles involved in recalls in 2020. The relatively high number of vehicles affected by emissions recalls in 2020 was influenced by two individual recalls that involved over one million units each.

The annual number of vehicles affected in the other years analyzed between 2015–2019 ranged between 4.2 million and 7.3 million vehicles. During this period, we observed both the largest recall that affected 1.9 million vehicles and the smallest recall that affected only three vehicles.

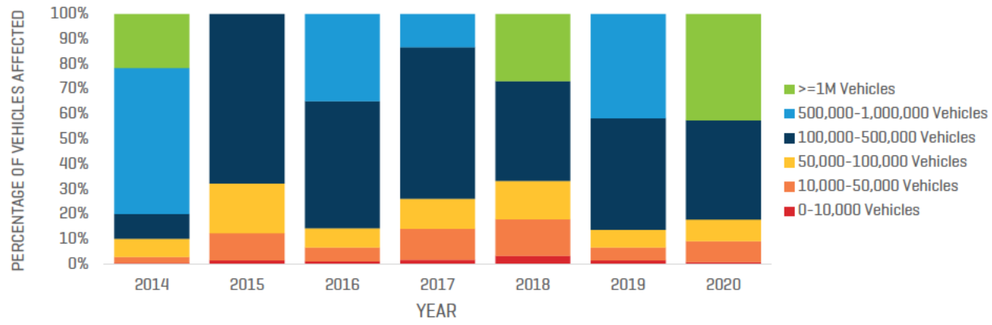
FIGURE 23 / UNIQUE EMISSIONS RECALL CAMPAIGNS & VEHICLES AFFECTED BY YEAR



In addition to the increase in the number of vehicles affected by emissions recalls since the low in 2015, Figure 20 depicts an increasing number of recall campaigns through 2019, notably in the wake of the Volkswagen diesel Clean Air Act violations, thereby indicating enhanced compliance oversight. The number of individual emissions recall campaigns declined slightly in 2020 in contrast to the increasing number of vehicles involved in recalls.

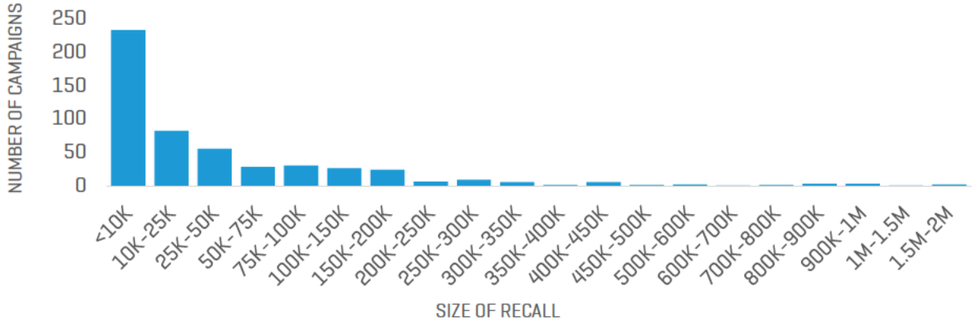
Further, the relationship between the number of emissions campaigns and the vehicles affected suggests decreases in the size of emissions recall campaigns between 2015 and 2019, a trend which was reversed in 2020. Indeed, Figure 24 indicates a significant proportion of vehicles affected by emissions recalls in 2020 were involved in recalls of over one million units. Despite the reversal, in 2020, approximately 60% of emissions recall campaigns affected fewer than 500,000 vehicles.

FIGURE 24 / PERCENTAGE OF VEHICLES AFFECTED BY YEAR AND SIZE OF RECALL



Over the entire period 2014–2019, as depicted in Figure 25, most emissions recalls involve fewer than 10,000 vehicles, and very few vehicle campaigns involve over 200,000 vehicles. This pattern is similar to what has been observed in the distribution of safety recall sizes. In the case of emissions recalls, the EPA's data indicates specific tracing of individual test groups, thereby allowing manufacturers to focus on recall populations. Stout has also observed that the majority of emissions recalls involve vehicles that are three years old or younger at the time of recall, which also limits the total recall population.

FIGURE 25 / UNIQUE CAMPAIGNS BY SIZE OF RECALL



EMISSIONS RECALLS COMPLETION PERCENTAGES

Vehicle manufacturers are required to submit six consecutive quarters of recall remedy data to the EPA that indicates the number of vehicles 1) involved in the action, 2) inspected and repaired, and 3) those not available for repair. This remedy data was provided to Stout along with the defect and recall reports requested in its FOIA request to the EPA. Stout analyzed the EPA's remedy information to understand average and sixth quarter completion percentages and quarterly completion progress for emissions recalls. Stout further refined its analysis by the ages of vehicles involved in emissions recalls to understand how this factor impacts the emissions recall completion percentages. This information can help OEMs and suppliers plan for the impacts of emissions recalls as well as devise strategies for improving recall completion percentages.

76%

OVERALL AVERAGE COMPLETION RATE FOR EMISSIONS RECALLS, 2014-2019

As depicted in Figure 26, the average completion percentage for emissions recalls ranged from approximately 67%–82% between 2014 and 2019; the overall average during this period is approximately 76%, which is slightly below the average for safety recalls during this period. Further, completion percentages for emissions recalls declined in 2019, likely due to challenges resulting from the COVID-19 pandemic, which is similar to the impact described above for safety recalls.

Figure 26 depicts the median completion percentage for emissions recalls from 2014 to 2019, which ranges from 77%–85%. The trend in emissions recalls median completion percentages follows the average and declines in 2019.

Further, the relationship between emissions recall completion percentages and vehicle age is similar to what Stout has observed for safety recalls—specifically, completion percentages decline as vehicle age increases. Figure 27 presents average and median completion percentages for vehicles that are three years old and younger. The average and median completion percentages for vehicles in this age group are greater than the overall average and median, which is consistent with our observations for safety recalls. Overall, the completion percentage trends for the three-years and younger cohort follows those of emissions recalls.

As shown in Figure 28, emissions recall completion percentages for the 3- to 5-year age group are significantly lower than the three-year and younger group and emissions recalls overall. Emissions recall completion percentages for this vehicle age group have been steadily improving since the lows of 2017 and are approaching the overall average of 79%.

As depicted in Figure 29, the average and median completion percentages drop appreciably for vehicles that are 5–8 years old at the time of recall as compared to other vehicle age cohorts.

Further, although emissions recalls and safety recalls exhibit more similarities than differences, it is important to consider that the differences between these recalls can impact recall completion performance. For example, the emissions testing requirements of numerous states may accelerate the completion of emissions recall repairs if such repairs remedy a condition required for vehicle owners to receive an emissions certification. In addition, these testing requirements create a point-of-contact for owners of older vehicles and may encourage them to repair faulty emissions conditions and have recall repairs performed. Any requirement that older vehicles to be tested must also receive state emissions certification may also help overcome the challenges that are often encountered when attempting to reach out to the owners of older vehicles.

FIGURE 26 / AVERAGE AND MEDIAN COMPLETION PERCENTAGES BY YEAR

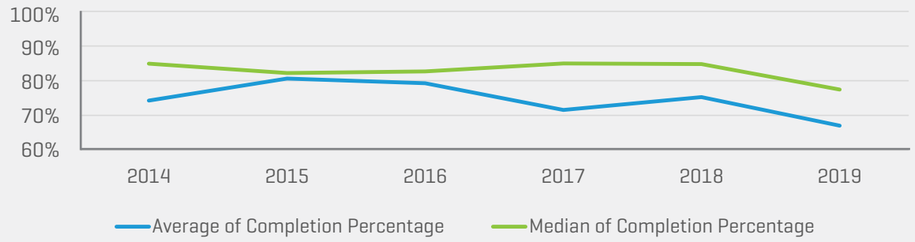


FIGURE 27 / AVERAGE AND MEDIAN COMPLETION PERCENTAGES, VEHICLES 3 YEARS OLD AND YOUNGER

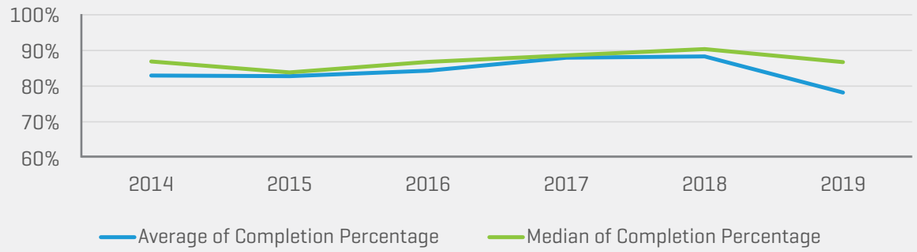


FIGURE 28 / AVERAGE AND MEDIAN COMPLETION PERCENTAGES, VEHICLES 3- TO 5-YEARS OLD

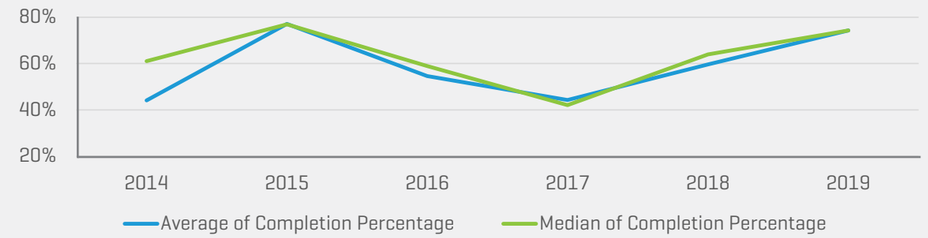
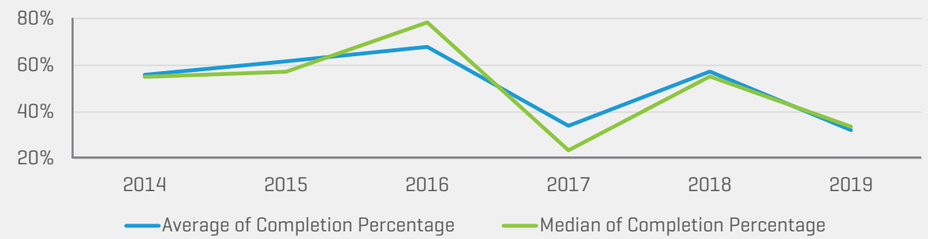


FIGURE 29 / AVERAGE AND MEDIAN COMPLETION PERCENTAGES, VEHICLES 5- TO 8-YEARS OLD



09 RECREATIONAL VEHICLE RECALLS

In 2020, Stout expanded our analyses of light vehicle recalls to include recreational vehicles (RV) in 2020. The RV industry came into focus as the traditional leisure, hospitality, and travel industries experienced pandemic-related disruption. Many expect 2021 to be a year of tremendous growth for the RV industry in the U.S. as society emerges from the pandemic.

The combination of pent-up demand, increasing consumer confidence, limited options for international travel, and the desire to vacation in a controlled environment will likely drive numerous families towards RVs t his summer. According to the Recreational Vehicle Industry Association (RVIA), other factors underlying the expected growth include an increased interest in the outdoors, greater flexibility with work and school, and desire to travel with family.[27] As a result of this increased interest, the RV industry expects 2021 to be a year of record shipments of RVs, ranging from 565,000 to 586,000 units, which is up 30% from 2020 and 14% from the previous sales record set in 2017.[28]

This growth in the RV industry comes at a time when the shifting demographics towards younger RV owners was already spurring growth. A recent RV industry study found that RV ownership is at a record high of 11.2 million households, up 26% from 8.9 million households in 2011.[29] This growth is largely attributed to baby boomers, who are all now over the age of 50 and have higher levels of disposable income and longevity than did previous generations.[30]

Millennials, occasionally described as the "experience-driven generation," have also taken an interest in RVs in recent years.[31] Millennials are often renters of RVs, as opposed to buyers, and represent the largest demographic group of RV renters.[32] Moreover, millennials represent an opportunity for the RV industry to build a consumer base outside of older demographics and retirees.

Given the observed growth of the RV industry, Stout was interested in defective emergence patterns in these vehicles, the nature and types of failures, and the impact of this on the safety of these vehicles. Stout's analysis of RV recall campaigns includes motorhomes, fifth-wheel trailers, campers, and travel trailers. Figure 30 depicts that the number of recall campaigns has increased since 2010, peaking at 190 campaigns in 2018. It must be noted that the number of RV recall campaigns is correlated with the trend of RV sales over time, which increased between 2012 and 2018 before undergoing two years of decline from 2019 to 2020.[33]

Campaigns involving RVs that are less than one year in age consistently represent 50%–70% of RV recall campaigns by year. This trend helps to explain the correlation between RV recall campaigns and RV sales: the most likely time an RV will be recalled is within the year in which it is sold. This trend suggests that there could be a record number of RV recalls in 2022, if expected record sales in 2021 come to fruition.

Figure 31 shows that on average of approximately 15%–30% of campaigns involve units between 1 and 4 years of age, 5%–10% involve units between 5 and 10 years of age, and only 1%–5% of campaigns involve units older than 10 years.

Figure 32 compares RV recall campaigns to light vehicle recall campaigns in terms of age of affected units and the size of the campaigns. Relative to the recalls of light vehicles, RV campaigns involve relatively newer vehicles. Over the period 2015–2020, 63% of RV campaigns involved units that were less than one year old, relative to 43% of campaigns for light vehicles. In contrast, only approximately 2% of RV campaigns involve units that are over 10 years old relative to almost 10% of light vehicle campaigns.

RV recall campaigns are far smaller than light vehicle campaigns. This is largely attributable to the annual sales of light vehicles in the U.S., which have ranged from 10 million to 17 million units over the past 10 years, while RV sales have ranged from 200,000 to 500,000 units.[34] For light vehicles, the largest group of recalls by size involve over 10,000 units, thereby representing 43% of campaigns during this period. The largest group for RV campaigns is under 100 units, thereby representing 42% of campaigns during this period.

"The most likely time an RV will be recalled is within the year in which it is sold. This trend suggests that there could be a **record number of RV recalls in 2022,** if expected record sales in 2021 come to fruition."

FIGURE 30 / RV SALES AND COUNT OF RV RECALL CAMPAIGNS BY YEAR

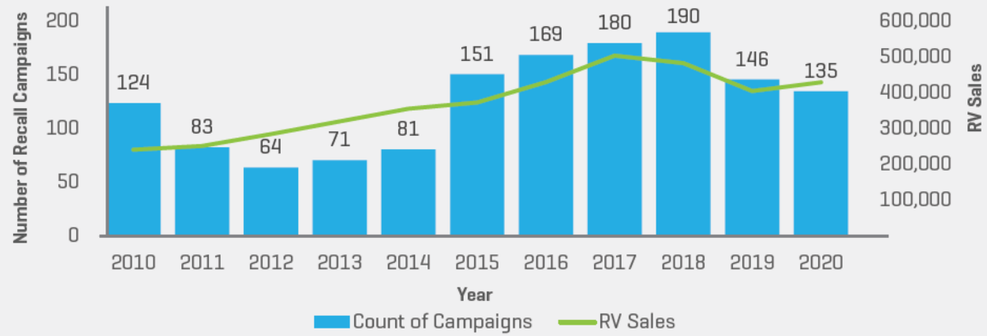


FIGURE 31 / PERCENTAGE OF UNIQUE CAMPAIGNS BY AGE OF VEHICLE AND YEAR

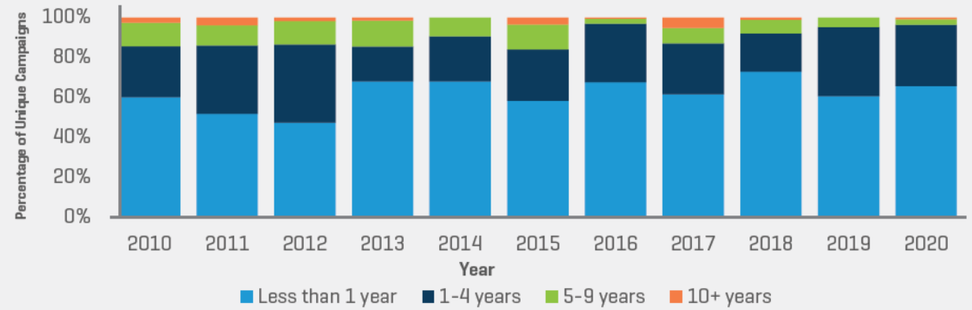
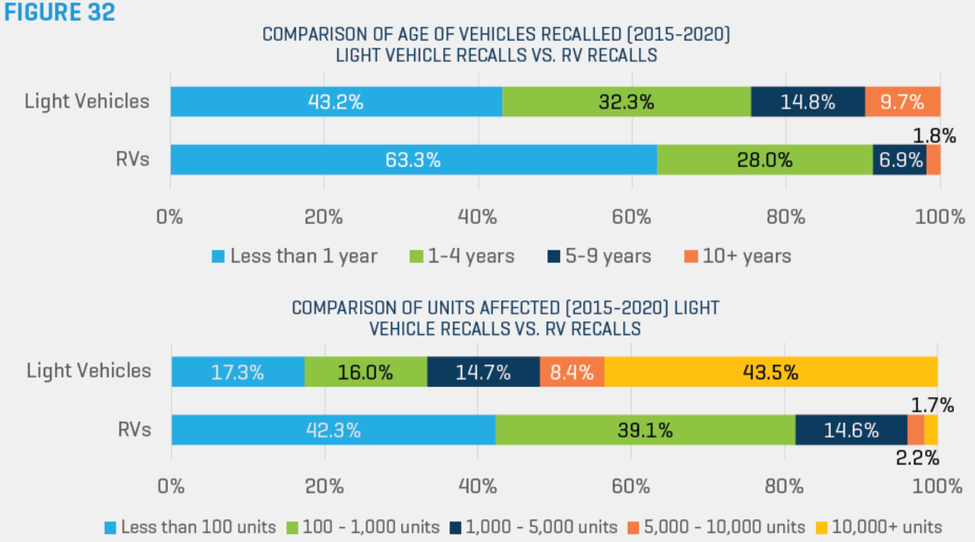


FIGURE 32



We also analyzed the components involved in RV recalls. Figure 33 depicts that of 148 RV campaigns in 2020, 49 (approximately one-third) are related to RV accessory defects, which are not applicable to light vehicles. A few examples of these accessory defects include those related to cooktops, fridges, beds, and propane lines.

Analysis of historical completion percentages suggests that campaigns for RV accessory defects have relatively lower completion percentages. For example, when analyzing campaigns that involve new units (less than one year old), those campaigns that involved propane-related equipment had average completion percentages of approximately 55%, which is lower than non-RV accessory defects, which ranged from 60% to 85%.

Figure 34 depicts that the median completion percentage for RV campaigns ranged from 55% to 65% in the period from 2015 to 2019, which is significantly lower than the range of light vehicle averages in recent years of between 80% and 90%. Similar to light vehicles, age is an influential factor in whether a recall will be completed. Similar to light vehicles, newer models have higher completion percentages.

The following factors are responsible for why RV recall completion percentages are lower:

- There are fewer RV dealerships as compared to light vehicle dealerships. This may increase the perceived inconvenience of bringing a recalled RV in for a service.
- The sporadic use of RVs (median use of an RV is 20 days per year)[35] may decrease the perceived safety risk related to recall campaigns.
- A large proportion of RV recalls related to accessory defects decrease the perceived safety risk related to these recall campaigns. Further, owners may take it upon themselves to remediate these defects themselves.
- Shorter warranty periods for RVs (generally 1–2 years for non-structural issues) may result in fewer RVs being serviced at dealers that are equipped to perform recall campaign procedures.

The RV industry and the factors contributing to RV recall completion percentages are rather different from that in the light vehicle industry. RV recalls have lower completion percentages than light vehicle recalls, despite the fact that RV recalls involve newer vehicles. This relationship contradicts the established trend of recalls involving newer vehicles, thereby resulting in higher completion percentages; therefore, this compounds the magnitude of the divergence of completion percentages of RVs and light vehicles. Further, this also exemplifies the need to analyze RV recalls with consideration of the characteristics which diverge from the existing knowledge of recall completion percentages of light vehicles. These characteristics include the smaller size of RV recalls and the high proportion of RV recalls involving RV accessories.

Increasing ownership and general interest in RVs places greater importance upon addressing the shortfalls of completion percentages for RV recall campaigns. This is particularly relevant to the expected record sales of RVs in 2021 that are likely to result in a record number of RV recalls in 2022.

FIGURE 33

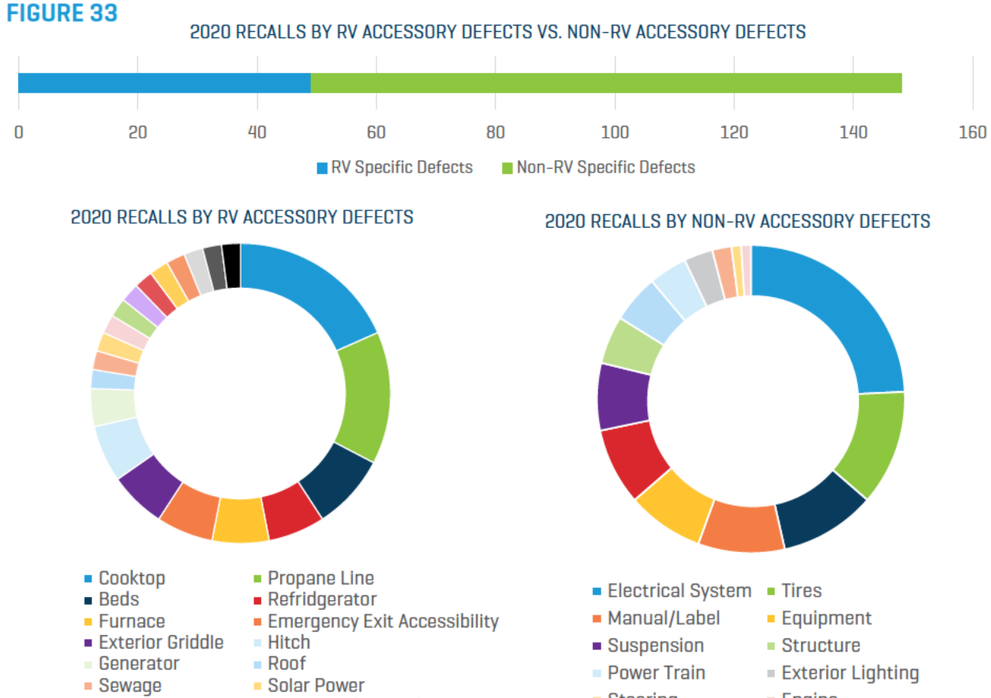


FIGURE 34

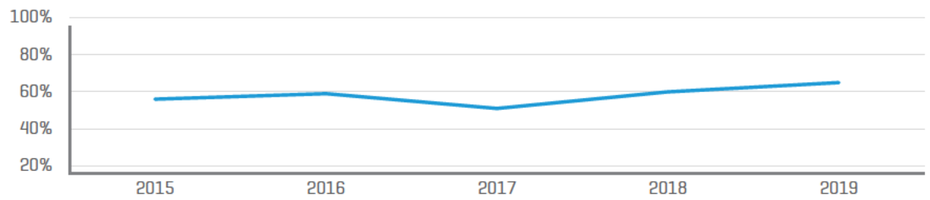
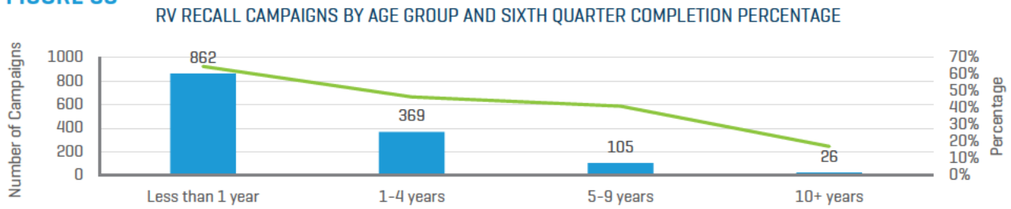


FIGURE 35



10 TECHNICAL SERVICE BULLETINS

Much focus is placed on the vehicle defects that result in recall. However, many more defects and technical issues do not raise safety concerns and result in notices to dealers and technicians, which affect millions of vehicles each year. These communications are memorialized as TSBs and represent a trove of data related to potential component defects that are collected and analyzed each year by Stout and provide insights into a broader set of component issues.

BACKGROUND OF TECHNICAL SERVICE BULLETINS

TSBs are regularly issued by OEMs to alert technicians at dealerships and independent repair shops, as well as the general public, to detailed diagnostic protocols and remedial procedures related to vehicle defects. These instructions are issued by OEMs based on internal testing and feedback from issues identified in the field. As such, defects addressed in TSBs may relate to isolated vehicle populations or require broader field service actions.

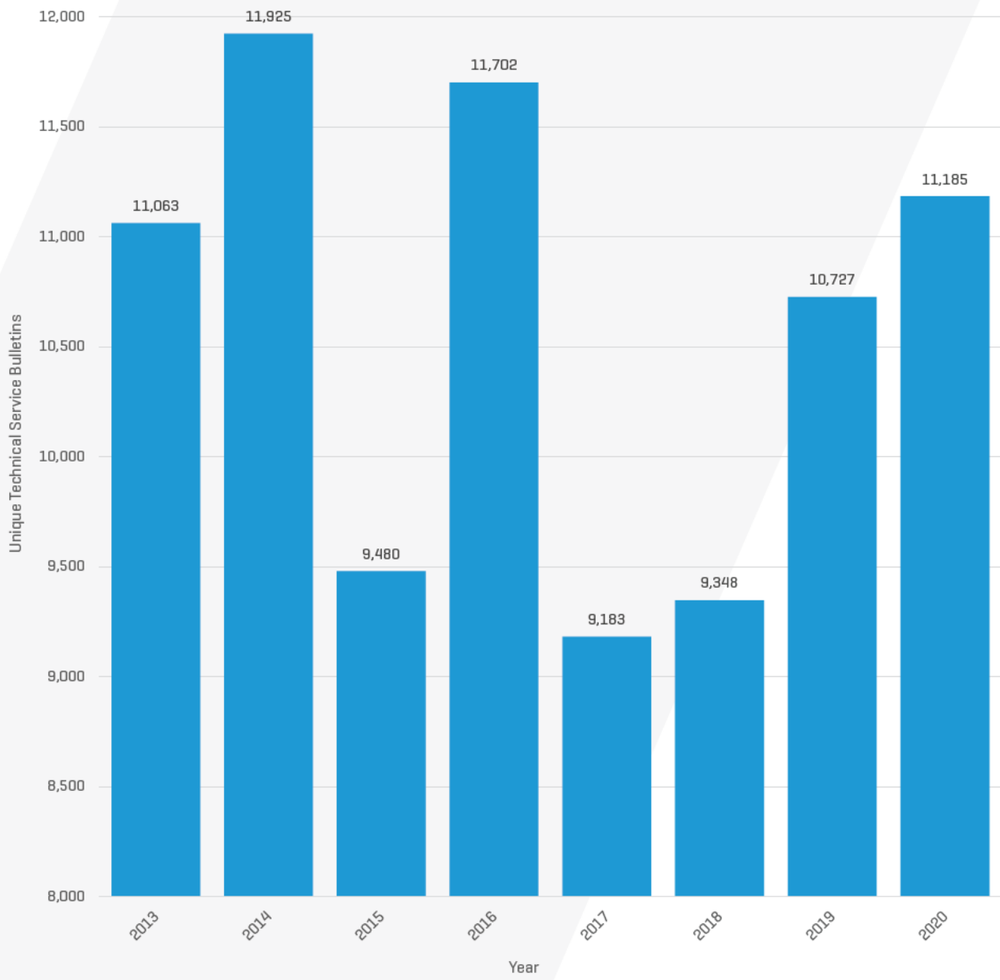
TSBs often include a description of the potential defect and resulting failure mode, prescribed set of diagnostic procedures for identifying the defect, and approved remedy procedures. While such information is certainly valuable to technicians who are not affiliated with franchised dealerships, TSBs often include specific labor operation procedures and approved repair materials and remedy times that govern the reimbursement of available dealers for work performed.

Each year, Stout analyzes TSBs to uncover additional insights related to those defects that do not rise to the level of safety recalls. Our analyses considers quantitative details from TSBs such as the incidence of defects, vehicle models, and model years affected, components involved, and approved diagnostic and remedy labor times. Our analysis of TSBs also considers qualitative insights from the review of individual TSBs, which enhance our understanding of the nuances of defect diagnosis and remedies and consider the relationships between issues identified in TSBs and those found in other sources of defect data.

TRENDS IN TECHNICAL SERVICE BULLETINS

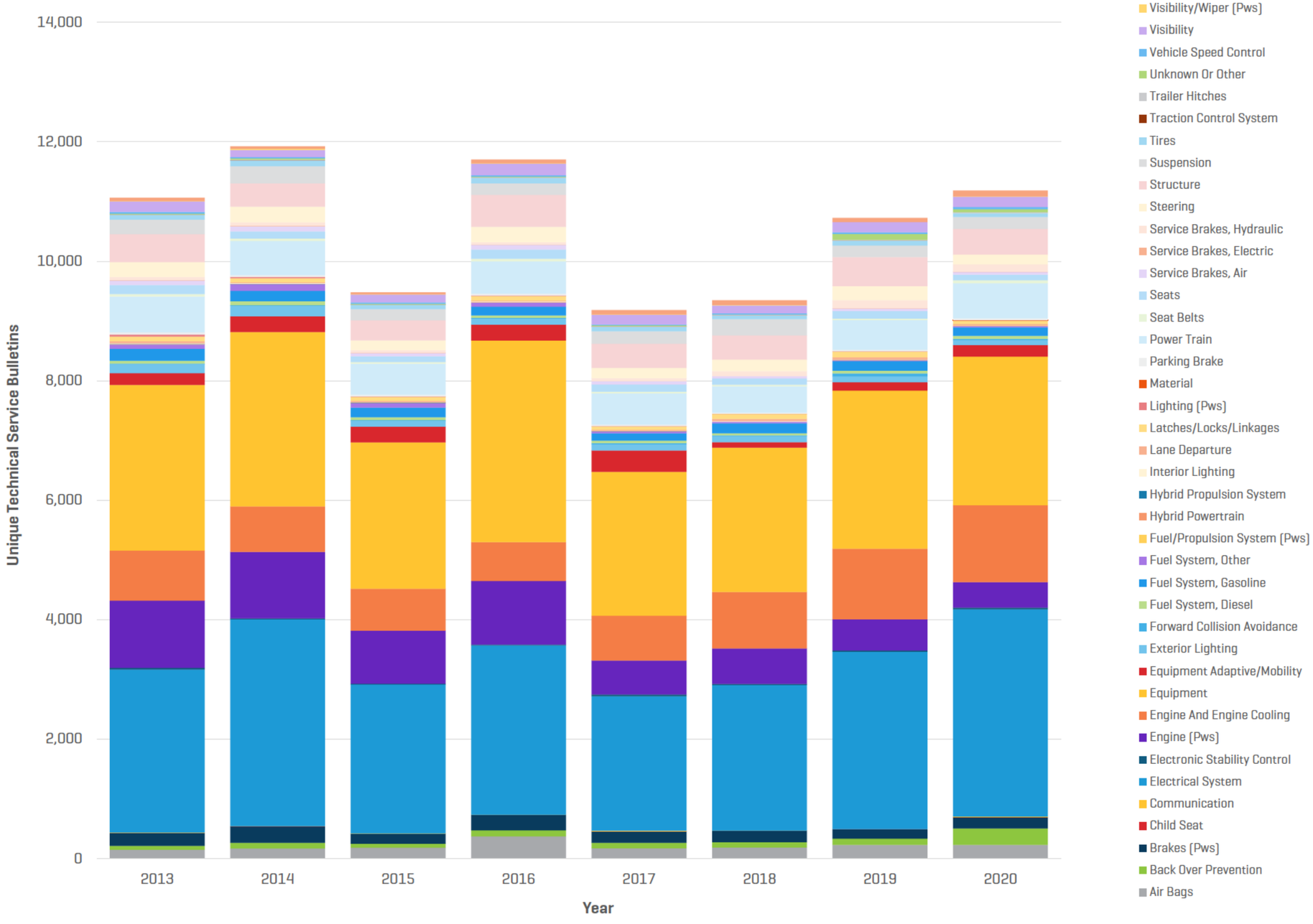
The number of individual TSBs far exceeds that of U.S. recalls each year. As previously discussed, the issues addressed by TSBs extend beyond those that result in safety recalls and, therefore, reflect a greater number of potential diagnostic and remedy concerns addressed by service bulletins. Figure 36 reveals a steady increase in the number of TSBs from 2017 to 2020, after having reached a peak in 2016; this recent trend is consistent with the overall growth in the number of light vehicle recalls over the same time period.

FIGURE 36 / COUNT OF TECHNICAL SERVICE BULLETINS BY YEAR



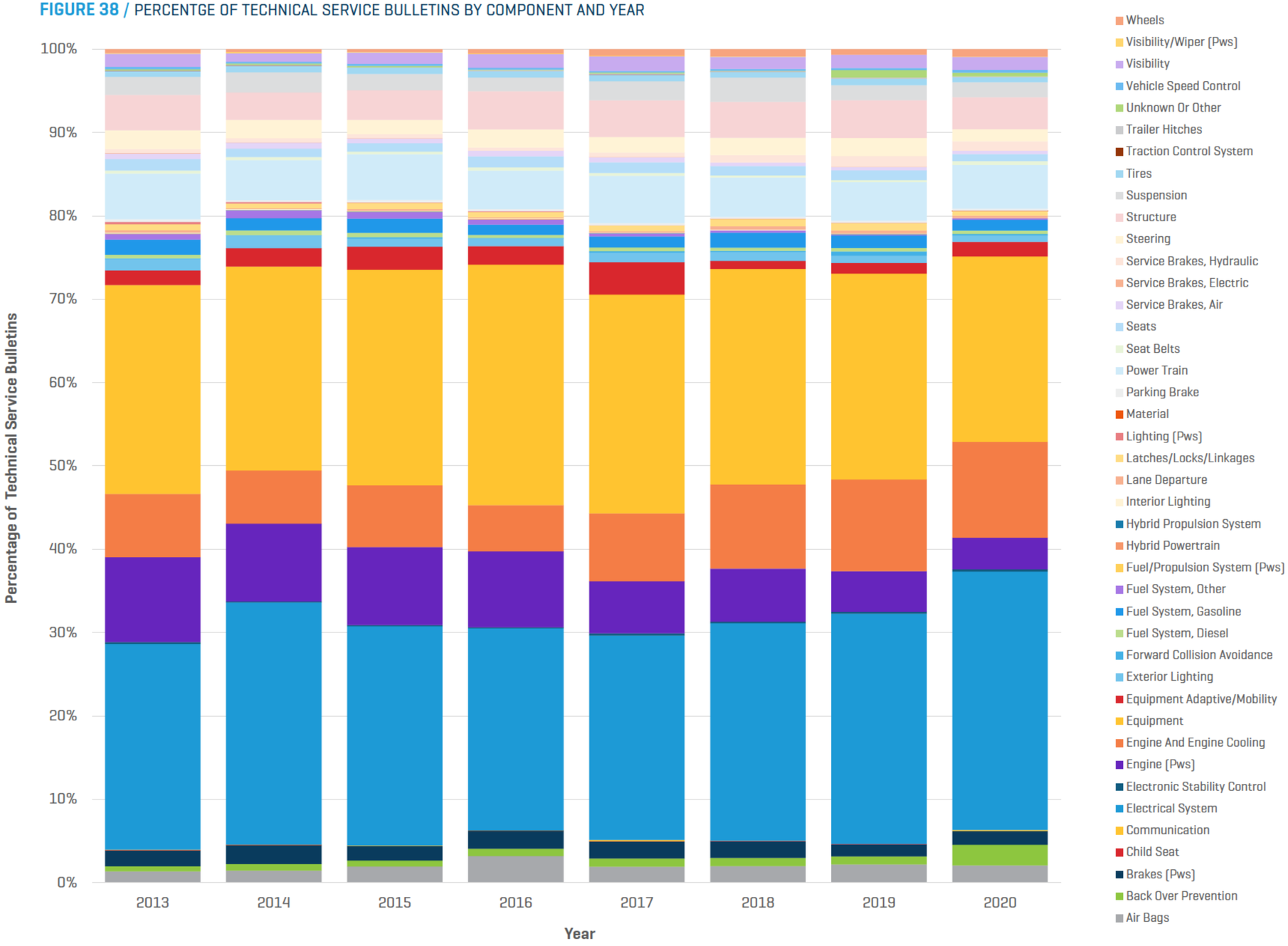
Figures 37 and 38 (following page) depict the incidence of TSBs by component, where we observe TSB trends similar to those in recalls. This pattern likely reflects the increased implementation and reliance on certain vehicle technologies. In 2020, we observed a doubling of the number of TSBs involving back-over prevention components. Based on our review of the service bulletins, it is evident that these issues do not necessarily result from the failures of back-over prevention systems that we observe in recalls but instead include false parking aid warnings, low chime volumes, systems that continuously beep, and inconsistent or inoperative warnings. We also observe a steady increase in the number of TSBs classified as Electrical System, including bulletins issued for batteries, software concerns, and certain engine issues.

FIGURE 37 / COUNT OF TECHNICAL SERVICE BULLETINS BY COMPONENT AND YEAR



While certain TSB component trends reflect those seen in recalls, we also observe component trends that differ between recalls and TSBs. Notably, issues involving airbag components have consistently represented a small proportion of TSBs—less than 2% in 2020, as compared to a much greater incidence of recalls involving these systems. Similarly, the proportion of electronic stability control recalls was almost seven-times greater in 2020 than the proportion of TSBs involving the same components. Indeed, this pattern exists for high-profile components that perform key vehicle safety functions, which may indicate that OEMs are more likely to initiate recalls sooner for such components instead of issuing multiple TSBs and field actions.

FIGURE 38 / PERCENTGE OF TECHNICAL SERVICE BULLETINS BY COMPONENT AND YEAR



11

INTERNATIONAL RECALLS

With the increases in the globalization and standardization of component production worldwide, the risk of multi-national recalls also increases. An analysis of international recall data and global trends can provide valuable insight for industry participants into what might lie ahead for the U.S. as well as how other jurisdictions may respond to component defects.

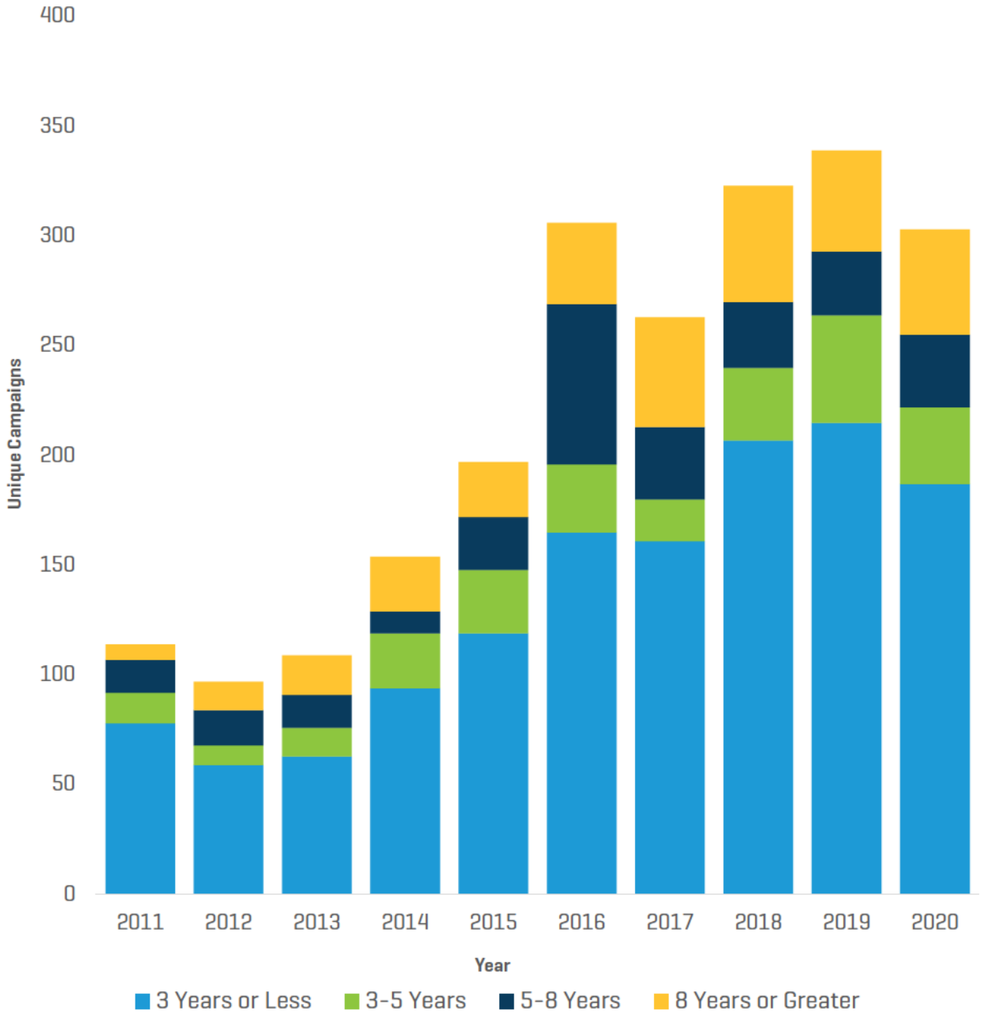
Stout identified, compiled, and translated data from many of the world's largest vehicle markets to conduct custom analysis that highlights pertinent trends and activity. Each year, Stout continues to add new global defect data to provide a more comprehensive understanding of global automotive component defect trends.

In its analysis, Stout observed that the majority of international component defect and recall activity in 2020 mirrored the activity in the U.S, with a decline in the number of campaigns from the peak in 2019. Specifically, Stout's analysis indicated a decline across all categories of components in each jurisdiction studied, thereby likely reflecting the impact of industry-wide pandemic disruptions. Stout also observed continued declines in recalls involving airbags in all locations studied, controlling for the decline in Takata inflator recall activity, thereby indicating a decline in identified component failures across the industry. These similarities are likely attributable to the continuing global standardization of component supply and production. In the following sections, we highlight key observations from our analysis of international recall data.

GERMANY

Figure 39 illustrates that Germany experienced a reduction in the number of unique campaigns in 2020, which were mostly driven by recalls involving newer vehicles—evident in the chart of those five-years and younger—while the number of German recall campaigns involving older vehicles remained consistent with the activity observed in prior years. A similar decline in the number of newer vehicle recalls in 2020 was observed in the U.S.

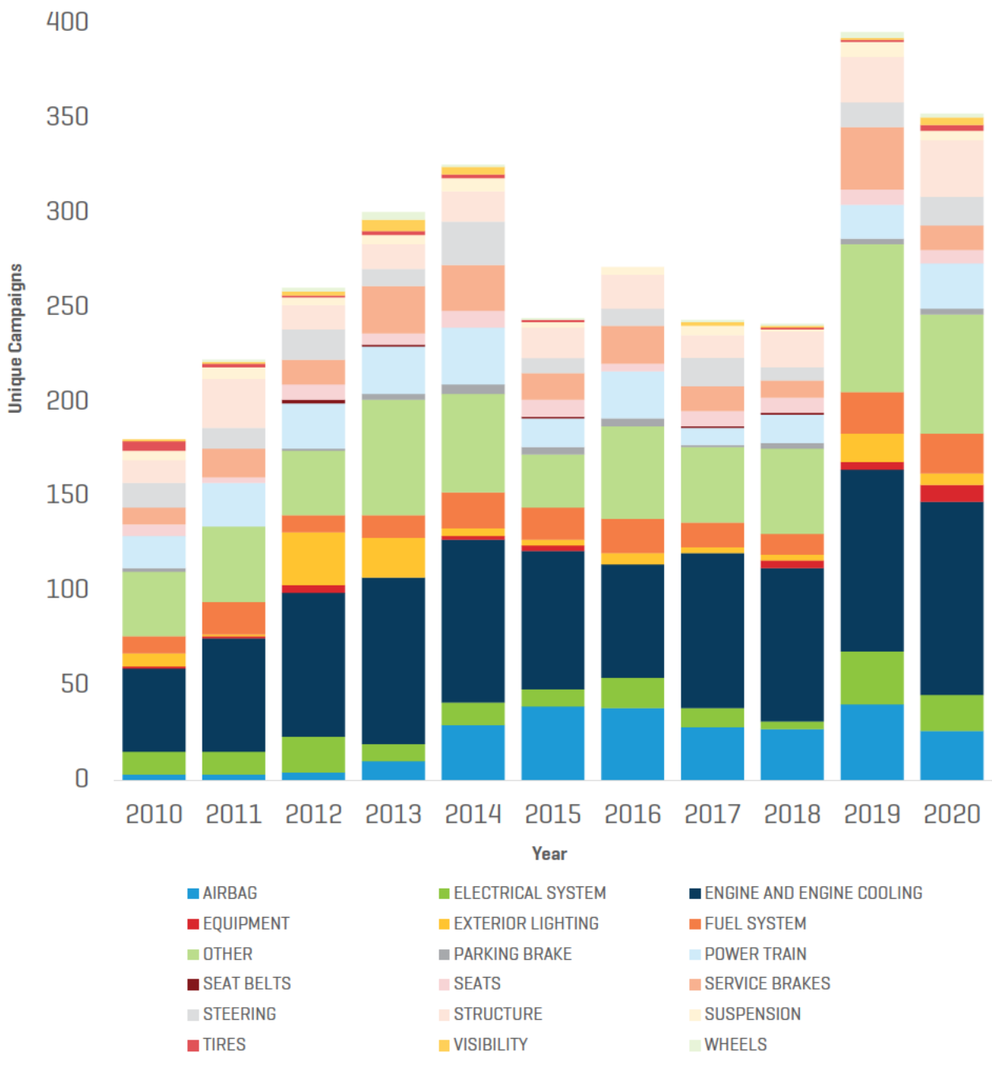
FIGURE 39 / COUNT OF GERMAN RECALL CAMPAIGNS BY VEHICLE AGE AND YEAR



JAPAN

Despite a similar reduction in the number of recall campaigns reported in 2020, as is evident in Figure 40, Japan experienced an increase in recalls involving fuel pumps, more than doubling from 7 to 15 recalls between 2019 and 2020. Two of the Japanese fuel pump recalls were the result of fuel pump impeller deformation, as was reported in the largest recall in the U.S. during this year. These recalls involved over 20,000 vehicles in Japan.

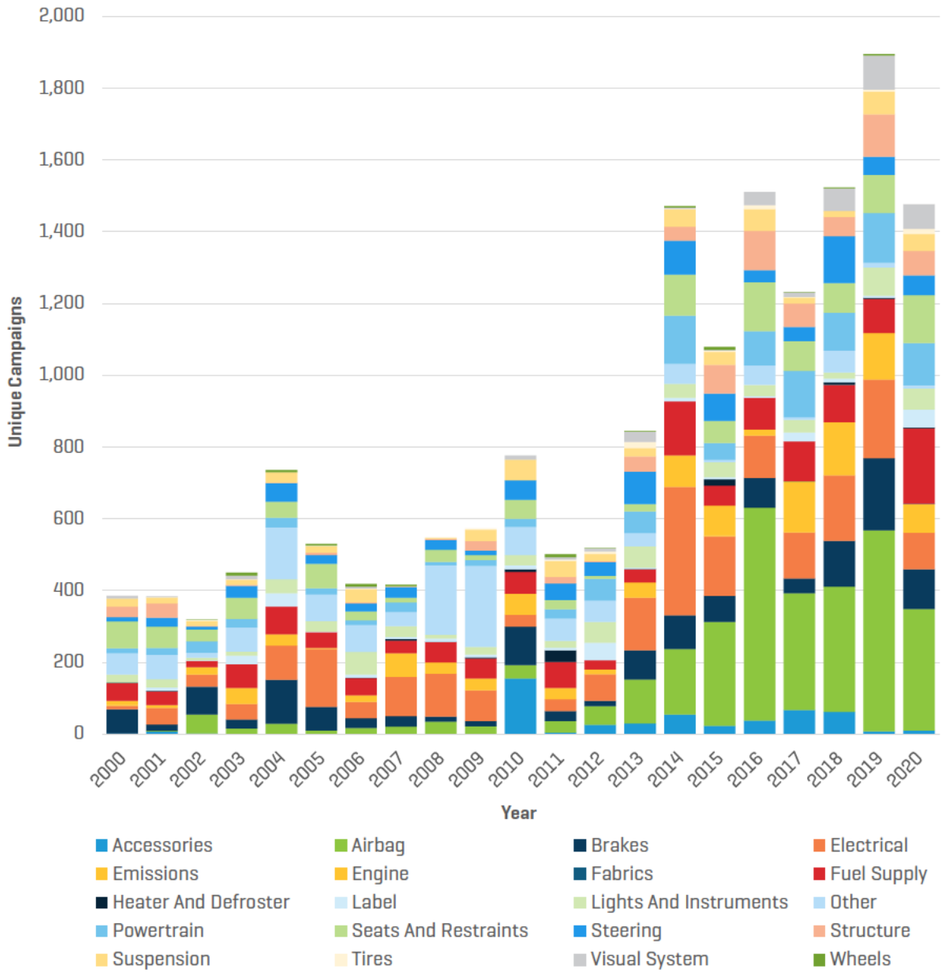
FIGURE 40 / COUNT OF JAPANESE RECALL CAMPAIGNS BY VEHICLE COMPONENT AND YEAR



CANADA

As observed in Figure 41, the number of Canadian recall campaigns declined to their lowest level since 2017, thereby indicating stable or declining activity in most component categories. The declining trend is particularly evident in recalls involving airbag, engine, and lights and instruments. Stout did observe an increase in Canadian recalls involving certain vehicle systems, like rearview cameras, which experienced similar activity in the U.S. in 2020. Rearview camera recalls increased from 7 to 13 recalls in 2020, affecting over 275,000 vehicles. Further, 10 of the Canadian rearview camera recalls involved software remedies, which is only slightly lower than the proportion of U.S. recalls of these component defects.

FIGURE 41 / COUNT OF CANADIAN RECALL CAMPAIGNS BY VEHICLE COMPONENT AND YEAR



12 CONCLUSION

The automotive industry continues to evolve as vehicles equipped with new technologies and materials are integrated to improve vehicle safety and performance. These innovations have introduced a host of innovative software, electronic components, and advanced materials that may yet interact in unforeseen or unexpected ways with other components and systems in vehicles, driver behaviors, and the driving environment. Supply challenges including labor disruptions and critical component shortages, which have become commonplace during the ongoing COVID-19 pandemic, have created uncertainty not seen before.

While defect trends associated with advanced automotive technologies are still emerging, new safety-critical components are increasingly involved in automotive recalls, a trend OEMs and suppliers may expect to continue as such technologies become commonplace. As an example, recalls of rearview-cameras, recently required in all new vehicles sold in the U.S., reached record levels in 2020 - a trend Stout expects to continue. Meanwhile, the development and implementation of innovative and convenient remedies provides more options than ever for OEMs to make recall repairs available to owners and convenient to complete, increasing completion percentages and lowering the costs of recall to OEMs and suppliers.

Any analysis of the risk of component defect must also recognize vehicle longevity and the aging of the current U.S. vehicle fleet. Vehicles are remaining on the road longer than ever, which provides opportunities for the emergence of latent defects in materials, design, and manufacturing, and exposure to environmental and operating conditions not previously experienced in past generations of vehicles. Failures in these populations of vehicles present unique challenges to OEMs and suppliers (as they tend to be larger recalls but also can be more difficult to detect), may include multiple vehicle models and model years, may involve repairs for which remedy parts are not readily available and may involve a variety of failure modes. These factors can complicate the root cause investigation and completion of repairs.

Given the risk of component defects and the challenges presented by complex new technologies and an aging vehicle fleet, it is more important than ever that automotive OEMs and suppliers look to all available sources of component defect data (internal and external) to understand emerging defect trends and proactively develop systems and processes to mitigate those risks and to identify opportunities to improve business intelligence regarding the risk of automotive component defects. Stout has developed the industry's most comprehensive repository of automotive component defect data, incorporating our unique industry expertise to provide meaningful interpretations of that data. Through the ongoing study of automotive component defect data and analysis of defect patterns and emerging trends, Stout provides unique insights to the industry which can be used to develop informed, thoughtful, and effective strategies to mitigate risks of automotive component defects and manage potential exposure to their consequences — all while enabling more informed business decisions in a highly competitive market.

WHAT WE DO

Stout professionals have provided consulting services and expert testimony for significant automotive industry warranty and recall programs and disputes.

On behalf of both OEMs and suppliers, Stout has analyzed:

- Warranty and recall data collection systems, warranty repair history, administrative processes and costs, recall risks and costs, component risk factors, recall completion rates, and other information
- Warranty and recall circumstances of many sizes and types – from the largest of recalls affecting millions of vehicles, to small recalls or extended warranty actions affecting several thousand vehicles – and everything in between

Our analyses are used to assist clients in understanding the risk and economic costs of warranty service repair, recall campaigns, and other actions for purposes of risk mitigation, improved business processes, customer and supplier negotiations, claim reassessment, or settlement and trial testimony.

We work closely with our clients to understand the risk and potential impacts associated with defects of automotive components, whether it is a customer service action, extended warranty offers, a voluntary recall or one required by NHTSA, or the other responses to warranty data, component defects, or customer complaints.

HOW WE DO IT

We take a collaborative approach leveraging our clients' knowledge, experience, and expertise – seeking to integrate cross-functional expertise from our clients with Stout's data and experience. To do this, we:

- Develop and use dozens data sets containing recall and other campaign defect data
- Use our expertise in understanding the wide variety of potential warranty and recall activities, and the costs associated with each
- Employ traditional and creative approaches in assessing risk from multiple perspectives, as appropriate
- Make use (wherever possible) of supplier and program-specific information to further refine and support our analysis
- Apply both quantitative and qualitative risk factors impacting warranty and recall risk, as warranty and recall risk is often nuanced and not easily represented by simple mathematical or actuarial calculations
- Identify likely warranty and recall scenarios and establish cost and risk parameters for each
- Work to develop risk mitigation strategies based on our work with the cross-functional teams of our clients (engineering, legal, insurance, risk management, sales, etc.)

ABOUT THE AUTHORS

NEIL STEINKAMP is a Managing Director at Stout. He is a leading expert in the field of automotive recall and defect analysis. His expertise includes strategic consulting regarding risk mitigation processes, intensive data analysis of structured and unstructured recall and defect data, analysis of recall costs and exposures, and assessments of factors impacting recall completion percentages. He has consulted with OEMs, suppliers, dealers, vendors, and their advisors.

Neil can be reached at **+1.646.807.4229** or **nsteinkamp@stout.com**

ROBERT LEVINE is a Director at Stout. His experience and expertise includes automotive warranty and recall data analytics, benchmarking, risk assessments, and recall cost analysis. He frequently consults with both OEMs and suppliers to assist in measuring the costs of a recall to the OEM, the internal systems for recall and warranty data collection and reporting, measurement and assessment of recall and product defect risks, and analysis of recall completion rates.

Robert can be reached at **+1.248.432.1294** or **rlevine@stout.com**

RAYMOND ROTH is a Director at Stout. He is a leading expert in the behavior of automotive recalls. His expertise includes strategic consulting using data driven techniques to identify barriers to recall completion and strategies to overcome those barriers as well as identification of component defect trends and benchmarks. He has consulted with OEMs, suppliers and dealers regarding strategic business initiatives.

Raymond can be reached at **+1.248.432.1337** or **rroth@stout.com**

ANSON SMUTS is a Manager at Stout. His expertise includes automotive warranty and recall data analytics and analysis of factors affecting recall completion percentages. He has consulted with OEMs and suppliers to assist in the evaluation of risks and measurement of exposure to recall and warranty costs.

Anson can be reached at **+1.248.432.1275** or **asmuts@stout.com**

ENDNOTES

[1] Other automotive stakeholders, such as vehicle auctions, independent repair facilities, independent dealers, and state and local governments are also indirectly impacted by recalls.

[2] https://www.nhtsa.gov/press-releases/2020-fatality-data-show-increased-traffic-fatalities-during-pandemic#:~:text=While%20Americans%20drove%20less%20in,36%2C096%20fatalities%20reported%20in%202019.

[3] For the purposes of this report, "Takata Recalls" are those recalls initiated and conducted in connection with the Coordinated Remedy Order issued by the National Highway Traffic Safety Administration ("NHTSA").

[4] NADI is an abbreviation for non-azide driver inflators, where non-azide is the inflator propellant used. This propellant is distinct for the phased-stabilized ammonium nitrate propellant that was used in vehicles subject to the Takata Coordinated Remedy order.

[5] Completion percentages after six quarters from recall remedy launch are not yet available for 2019 recall campaigns.

[6] https://www.wsj.com/articles/average-u-s-vehicle-age-hits-record-12-years-11623680640?mod=hp_lead_pos10

[7] https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/state_of_takata_air_bag_recalls_fourth_report.pdf

[8] https://www.federalregister.gov/documents/2020/12/03/2020-25930/framework-for-automated-driving-system-safety

[9] https://www.federalregister.gov/documents/2020/03/30/2020-05886/occupant-protection-for-automated-driving-systems

[10] https://www.federalregister.gov/documents/2020/12/10/2020-27001/federal-motor-vehicle-safety-standards-test-procedures

[11] https://www.federalregister.gov/documents/2020/01/07/2019-27211/replica-motor-vehicles-vehicle-identification-number-vin-requirements-manufacturer-identification

[12] https://www.federalregister.gov/documents/2020/10/29/2020-21476/federal-motor-vehicle-safety-standards-occupant-crash-protection

[13] https://www.federalregister.gov/documents/2020/12/21/2020-28107/notice-regarding-the-applicability-of-nhtsa-fmvss-test-procedures-to-certifying-manufacturers

[14] https://www.federalregister.gov/documents/2020/07/02/2020-14227/agency-information-collection-activities-notice-and-request-for-comment-automated-vehicle

[15] https://www.freep.com/story/money/cars/general-motors/2021/08/20/chevy-bolt-recall-2021-gm-fire-risk/8217053002/

[16] https://www.cnet.com/roadshow/news/hyundai-kona-electric-recall-battery-replacement/#:~:text=Putting%20in%20a%20new%20battery%20is%20a%20big%20deal.&text=Following%20a%20dotted%20series%20of,cost%20%24900%20million%20to%20execute

[17] https://www.nhtsa.gov/equipment/air-bags

[18] https://www.nhtsa.gov/sites/nhtsa.gov/files/fmvss/ESC_FR_03_2007_0.pdf

[19] https://www.nhtsa.gov/sites/nhtsa.gov/files/fmvss/ESC_FR_03_2007_0.pdf

[20] https://www.consumerreports.org/cro/cars/guide-to-the-volkswagen-dieselgate-emissions-recall-

[21] https://www.freep.com/story/money/cars/chrysler/2019/03/13/fca-recall-emissions/3149654002/

[22] https://www.consumerreports.org/pickup-trucks/fca-diesel-owners-to-get-money-and-fix-in-emissions-settlement/#:~:text=Owners%20of%20the%20roughly%20104%2C000,get%20an%20engine%20software%20update

[23] https://www.epa.gov/enforcement/daimler-ag-and-mercedes-benz-usa-llc-clean-air-act-civil-settlement

[24] EPA 2014–2017 Progress Report: Vehicle & Engine Compliance Activities

[25] EPA 2014–2017 Progress Report: Vehicle & Engine Compliance Activities

[26] EPA 2014–2017 Progress Report: Vehicle & Engine Compliance Activities

[27] https://www.rvia.org/sites/default/files/2021-05/RV_Summer_Travel_Infographic_Final_v2.jpg

[28] https://www.rvia.org/news-insights/rv-shipments-projected-eclipse-575000-units-2021-breaking-previous-record-14-percent

[29] https://www.gorving.com/newsroom/rv-industry-association-manufacturing-statistics

[30] IBISWorld, Recreational Vehicle Dealers in the US, March 2021

[31] IBISWorld, RV & Camper Van Rental, March 2020

[32] IBISWorld, RV & Camper Van Rental, March 2020

[33] RV sales data retrieved from the Recreational Vehicle Industry Association, https://www.rvia.org/historical-rv-data

[34] National Automobile Dealers Association, *NADA Data 2020 Report*.

[35] https://www.rvia.org/go-rving-rv-owner-demographic-profile

stout.com

Investment Banking | Transaction Advisory | Valuation Advisory | Disputes, Compliance, & Investigations