Vehicle Safety Recall Completion Rates

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Suggested APA Format Citation:

Office of Defects Investigations. (2025, January). *Vehicle safety recall completion rates* (Report No. DOT HS 813 687). National Highway Traffic Safety Administration.

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Technical Report Documentation Page

1. Report No. DOT HS 813 687	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Vehicle Safety Recall Completion Rates		5. Report Date January 2025	
		6. Performing Organization Code	
7. Author Office of Defects Investigations		8. Performing Organization Report No.	
9. Performing Organization Name and Address Office of Defects Investigations National Highway Traffic Safety Administration 1200 New Jersey Avenue SE Washington, DC 20590		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address National Highway Traffic Safety Administration 1200 New Jersey Avenue SE Washington, DC 20590		13. Type of Report and Period Covered	
		14. Sponsoring Agency Code	
15. Supplementary Notes			

16. Abstract

This report builds on the foundation established by the three congressional reports required under the Fixing America's Surface Transportation Act (FAST Act), enacted in 2015. Section 24104 of the FAST Act mandated biennial analyses of vehicle safety recall completion rates, culminating in the submission of the final required report in compliance with this directive in 2020. These reports incorporated the recommendations of the 2018 U.S. Department of Transportation's Office of Inspector General to adopt a risk-based process for monitoring recall performance and collaborating with manufacturers to address underperforming recalls. NHTSA routinely updates the predictive model to enhance its utility as a tool for identifying trends and risk factors. Through this approach, NHTSA aims to strengthen accountability and ultimately reduce the number of defective or noncompliant vehicles on the road, aligning with NHTSA's mission to protect the public on our Nation's roadways.

17. Key Words FAST Act, recalls	18. Distribution Statement Document is available to the public from the DOT, BTS, National Transportation Library, Repository & Open Science Access Portal, https://rosap.ntl.bts.gov.

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 42	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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Introduction

This report builds on the foundation established by the three congressional reports required under the Fixing America's Surface Transportation Act (FAST Act), enacted in 2015. Section 24104 of the FAST Act mandated biennial analyses of vehicle safety recall completion rates, culminating in the submission of the final required report in compliance with this directive in 2020 (National Highway Traffic Safety Administration, 2021). These reports incorporated the recommendations of the 2018 U.S. Department of Transportation's Office of Inspector General (OIG) to adopt a risk-based process for monitoring recall performance and collaborating with manufacturers to address underperforming recalls.

This supplemental report reflects the NHTSA's continued commitment to transparency and accessibility regarding recall performance by providing updated analyses and expanding the application of predictive modeling. By leveraging improvements to this model and incorporating larger datasets, NHTSA can enhance the model's fit and predictive accuracy. As the dataset increases, the model benefits from more improved training, better representation of recall characteristics, and reduced variance. By leveraging improvements to this model, NHTSA can better identify underperforming, high-risk recalls[1] and continue working collaboratively with manufacturers to improve recall campaign performance.

NHTSA routinely updates the predictive model to enhance its utility as a tool for identifying trends and risk factors. Through this approach, NHTSA aims to strengthen accountability and ultimately reduce the number of defective or noncompliant vehicles on the road, aligning with NHTSA's mission to protect the public on our Nation's roadways.

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[1] Recalls were defined as high risk if they included at least one of the following: 1) Over 150,000 light vehicles; 2) Air bags; 3) Remedies involving Over-the-Air updates; 4) School buses, child safety seats, or sub-components of Occupant Safety Systems; 5) New technology; 6) Risk of death, park it/do not drive consumer advisories, regional, re-recalls, and scope expansion; or 7) Alternative propulsion-types (e.g., EV, hydrogen).

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Background

The National Highway Traffic Safety Administration works each day to oversee the implementation of motor vehicle safety recalls in accordance with the National Traffic and Motor Vehicle Safety Act ("the Safety Act"), 49 U.S.C. Chapter 301. Motor vehicle safety recalls are conducted when either NHTSA or manufacturers of motor vehicles or motor vehicle equipment determine that a safety defect is present in the manufacturer's product or that the product does not conform to an applicable Federal motor vehicle safety standard (FMVSS).[2] When a manufacturer issues a safety recall, 49 CFR Parts 573 and 577 require, among other things, the manufacturer to complete the following.

a. Notify [NHTSA] with a Part 573 Defect or Noncompliance Information Report which identifies the recalled product, summarizes the safety problem, and details the manufacturer's plans to offer a free remedy.
b. Notify owners and purchasers, by First Class mail of the recall and the available free remedy to address the safety risk. The notification required by § 577.5 shall:
c. Be furnished no later than 60 days from the date the manufacturer files its defect or noncompliance information report under Part 573.
d. If the final remedy for the defect or noncompliance is not available at the time of notification, the manufacturer shall issue an interim remedy notification and shall issue a second notification within a reasonable time and in accordance with the requirements of this part once that final remedy is available.
e. Report to [NHTSA] the number of recalled products that have been remedied by the manufacturer for eight consecutive quarters, followed by [3] years of annual reports.

    The quarterly and annual reports include counts for how many vehicles were remedied; how many were inspected but no remedy was required; and how many were exported, stolen, scrapped, or the owner could not be reached (e.g., undeliverable mail).

NHTSA's Office of Defects Investigation's (ODI) Recall Management Division (RMD) manages the oversight of this safety recall process, including the recall reports filed by manufacturers, review of the recall notices sent to owners, review of the remedy provided by the manufacturers for the recall, and the overall completion rate of the recall (i.e., the percentage of affected vehicles or items of equipment that have been repaired). In 2023 RMD processed 1,000 recalls that included over 39 million vehicles and items of motor vehicle equipment. While RMD routinely processes over 1,000 new recalls each year, staff also manage recalls from prior years, ensuring that manufacturers file quarterly and annual completion reports in a timely and accurate manner.

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[2] 49 U.S.C. § 30118 also authorizes the Secretary of Transportation to decide when a motor vehicle or motor vehicle equipment contains a safety defect or a noncompliance with a Federal motor vehicle safety standard.

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Methodology, Data Constraints, and Other Considerations

NHTSA's methodology for the scope and limitations of this report is as follows:

Scope of This Report

NHTSA categorizes light vehicles into three major categories: Light Trucks, Multipurpose Passenger Vehicles (MPV) such as SUVs and minivans, and passenger cars. For each category, NHTSA examined the number of vehicles that were reported as being remedied. Excluded from this report are recalls that include a combination of both light- and heavy-duty vehicles, as it is not possible to separate the light-vehicle remedy rates from the heavy-duty remedy rates.[3]

For this report, NHTSA examined recalls issued from 2010 to 2022 in which the manufacturer reported the recall's completion status for at least five quarters after the remedy program became available (as of November 2024). Only the fifth reporting quarter rate was analyzed even if more recent quarterly reports were available. However, if the recall reached 100 percent completion prior to the fifth quarter, then that quarterly report was used in the calculations. This refinement serves to control for variability in the length of reporting periods among manufacturers, as some companies continue to submit well after the minimum regulatory requirement. Recalls that had not reached this fifth-quarter maturation point—including recalls filed in calendar years 2023 and 2024—were not included because these recalls could similarly be misrepresented by the completion methodology.

Calculating Recall Completion Rates

NHTSA uses a standard formula for measuring completion rate for each recall campaign. This formula is the number of vehicles reported as remedied (including vehicles reported as inspected but not requiring remedy and vehicles returned to inventory) divided by the total number of vehicles involved in the recall (less any vehicles reported as being exported, stolen, scrapped, or unavailable for other legitimate reasons). NHTSA's completion rate formula is:

Recall Completion Rate =

$$\left(\frac{Count\ of\ Vehicles\ Remedied}{Count\ of\ Vehicles\ in\ Recall - Vehicles\ Exported, Stolen, Scrapped, Other} \right) * 100$$

This report will reference the annual completion rate, a volume-based weighted metric where recalls affecting more vehicles have a greater influence on the completion rate. An alternative metric is the unweighted average completion rate, in which all recalls are treated equally, regardless of the number of vehicles affected. For example, Fiat Chrysler Automobiles (FCA) achieved 100 percent completion rate on a 2020 recall of roughly 700 vehicles and 86 percent completion rate on a 2020 recall of roughly 3,000 vehicles. The weighted average completion rate of these two recalls would be 89 percent. As the population size for light-vehicle recalls can vary widely, this report presents the weighted metric to present a more accurate representation of remedy completion rates.

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[3] Factors No. 4 and No. 5 enumerated in the section on limitations of the data provide additional details about this limitation.

Limitations of the Data

This report compares recall completion rates across various factors. However, NHTSA notes that the findings provide only a partial picture. NHTSA understands a myriad of factors affect recall completion rates and many of these factors are intangible, difficult (if not impossible) to measure quantitatively, or not available to NHTSA. Accordingly, this report provides metrics and analysis based on data NHTSA receives and maintains, but the following caveats should be noted.

- *No demographic information*: Owner demographics, including socioeconomic factors and location of residence, as well as each owner's subjective assessment of risk, are believed to play a significant role in recall completion. However, this data is not a statutory requirement in the Motor Vehicle Safety Act.

- *Limited verification of manufacturer-supplied figures*: NHTSA is unable to verify the number of remedied vehicles reported by manufacturers with the limited data available to it. It should be noted that manufacturers are not required to provide that level of granularity to their completion reports. Likewise, NHTSA cannot independently verify the number of vehicles reported by manufacturers as exported, stolen, scrapped, or otherwise legitimately deducted from the number of vehicles recalled.

- *Initial parts shortages and restrictions*: Delays in the design, manufacturing, or supply of remedy parts can affect the availability of a recall remedy, particularly when a manufacturer first launches a remedy program. As discussed below, recall completion rates appear to be significantly affected by delays in availability of a recall remedy. However, NHTSA is unable to definitively determine whether certain types of delays, such as phased launches or full remedy unavailability, have a greater impact on completion rates.

- Vehicle owners' frustrations or apathy after encountering unavailable remedies may contribute to lower recall participation. For instance, during the Takata air bag recalls some manufacturers implemented phased launches or delayed remedy availability due to lack of available parts. However, given the dearth of available data, NHTSA cannot reliably assess whether phased launches uniquely affect completion rates differently from other types of remedy delays, nor can it quantify the extent of any such impact.

- *No detailed model year breakdown*: As discussed below, recall completion rates appear to be significantly affected by the age of the vehicles involved. However, NHTSA only receives data for the total number of vehicles affected and repaired for a given recall without any breakdown for vehicle age. A recall affecting 100,000 model year 2014 and 2015 vehicles might include 99,000 model year 2014 vehicles and 1,000 model year 2015 vehicles, or vice versa. Without that breakdown, NHTSA is unable to determine how many vehicles of each model year had been remedied, and thus is limited in its ability to measure the precise effect that vehicle age has on recall completion rates.

- *No detailed model breakdown*: A safety recall can include a variety of models. However, as with model years, manufacturers are not required to report their recall populations providing this level of granularity. For example, a Ford recall for 1 million vehicles might include the Ford Transit and the Ford Mustang. However, the specific number of affected Transits versus Mustangs are not statutorily required to be provided to NHTSA. Similarly, when the manufacturer submits its quarterly completion reports, it would not

be clear how many Transits were remedied versus the number of Mustangs remedied. Additionally, the type of vehicle may affect completion rates. A Transit might be used for on-the-job requirements, whereas a Mustang might only be driven for recreational purposes.

- *No measure of severity*: NHTSA does not categorize recalls according to the degree of risk they pose. Although all recalls address safety risks, vehicle owners might be less motivated to seek a remedy for a matter they perceive to be "low-risk." In this analysis, NHTSA attempts to control for severity by examining recalls with descriptions that mention a vehicle crash or fire, or cases in which the manufacturer issues a consumer advisory. But this control is imperfect. These terms may not necessarily be used in only the most high-risk recalls, or they may be used when describing recalls that vehicle owners may not perceive to be particularly high-risk. For example, the word "crash" might be included in the recall description for an incorrect tire pressure label because overinflated tires could explode and cause a crash. Nonetheless, some owners might not perceive the risk of an incorrect label as severe enough to warrant obtaining the remedy.

- *No measure of cost*: Vehicle owners may be more likely to take advantage of free repairs for issues they perceive would be costly under normal repair circumstances. However, NHTSA does not have data indicating how much each recall remedy costs (or is perceived by owners to cost).

- *Limited time period*: The analysis in this report is based on recalls that were issued from 2010 to 2022. To the extent that the recalls undertaken during this time period were not representative or materially different in other time periods, a randomized analysis of these recalls is not applicable.

What Can and Cannot Be Concluded From This Analysis

The analysis found in this report is presented in two parts. The section covering annual recall completion rates presents "raw data" on which no statistical modeling has been performed. Subsequent sections covering potential factor identification, model fit, and findings present results from a statistical model.

Using the raw data, NHTSA can draw some tentative conclusions, but these should be viewed cautiously. For example, Figure 1 indicates that some manufacturers tend to have higher average recall completion rates. However, this may be misleading because manufacturers issued different types of recalls between 2010 and 2022. Similarly, some manufacturers more frequently have recalls with delayed remedy launches than others. Some manufacturers had multiple recalls involving older vehicles, while some manufacturers had recalls for newer vehicles.

NHTSA developed a statistical model for its predictive analytics capabilities, but those results are constrained by the information available to it. As noted above, NHTSA lacks data on many factors that may affect recall completion rates to varying degrees. For example, a large manufacturer might have a higher recall completion rate than a smaller manufacturer for a given recall. While true, the difference might be explained by information not available to NHTSA, such as the demographics of vehicle owners of that manufacturer, the perceived risk of the defects or instances of noncompliance, or the manufacturer's relationships with their respective dealer franchises. The performance differential could also be affected by the recalls issued from 2010 to 2022. If NHTSA fit the same model to an earlier or later period of light-vehicle recalls,

the difference in recall completion rates between a large manufacturer and a smaller manufacturer could potentially increase or decrease—or disappear entirely.

Moreover, it is difficult for NHTSA to conclude that any manufacturer truly performed "better" than any other manufacturer. The figures that appear to support any such conclusion could potentially be explained by data not available in this analysis.

Annual Recall Completion Rates

Manufacturers are required to report to NHTSA the number of recalled products that have been remedied; how many were inspected but no remedy was required; and how many were exported, stolen, scrapped, or the owner could not be reached (e.g., undeliverable mail). Using these reports, NHTSA calculates the annual completion rate. This next section describes the weighted annual recall completion rates by each of the three factors found to have a statistical impact on recall completion rates:

- The recalling manufacturer,
- the age of the oldest affected vehicle, and
- the length of time between the Part 573 report and remedy availability.

Annual Rates by Manufacturer

Appendix A details the annual recall completion rates, by manufacturer, for light-vehicle recalls issued from 2010 to 2022. Thirteen major manufacturers are detailed in the table in Appendix A. Nearly all light vehicles recalled from 2010 to 2022 were recalled by the major vehicle manufacturers that support NHTSA's VIN Look-Up Tool found on www.NHTSA.gov/recalls.[4] Annual recall completion rates, calculated using the weighted average, for these manufacturers are provided in the following figures.

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[4] The 73 manufacturers that support NHTSA's VIN Look-Up Tool are listed here: https://vinrcl.safercar.gov/vin/.
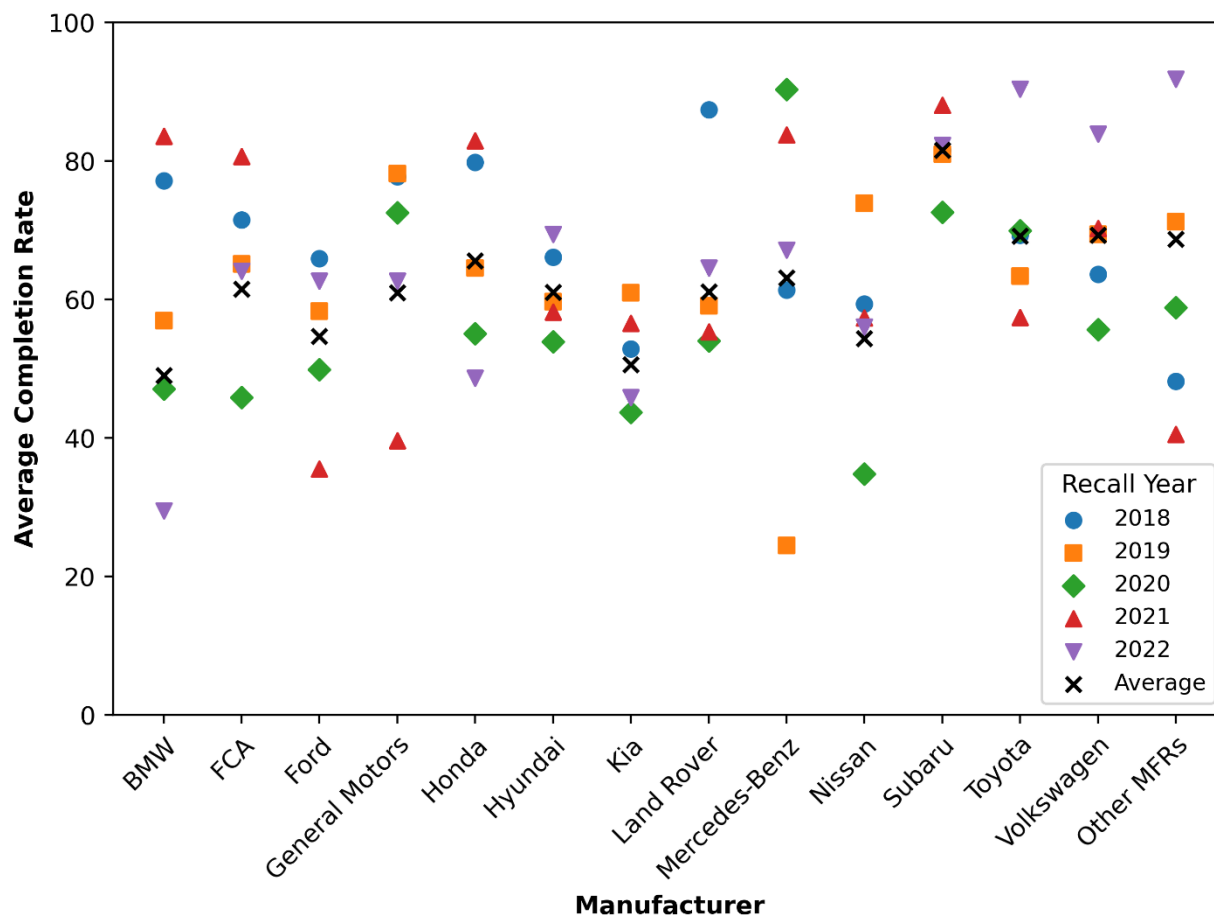
Figure 1. Recall completion rates by major light-vehicle manufacturers, 2018-2022 (5Q Recalls)

Figure 1 displays the manufacturers of light vehicles and the ranges of their weighted annual recall completion rates for recalls from 2018 to 2022.[5] The weighted average for each manufacturer is included in Figure 1 to provide a more balanced indicator of performance over the 5-year period. For the major manufacturers shown in the figure, the combined weighted average annual completion rate is 62.1 percent, meaning more than 62 percent of all light vehicles recalled were remedied. Across the 5-year span, Subaru consistently has higher completion rates than other manufacturers, with a weighted average completion rate above 80 percent. While BMW has the lowest weighted average completion rate (49.0%) across all 5 years, the single lowest completion rate for any given year was for Mercedes-Benz vehicles in 2019 with 24.5 percent.

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[5] Figure 1 does not imply any relationship between years.

Figure 2. Non-Takata vs Takata-only average recall completion rates by manufacturer, 2010-2022 (5Q Recalls)
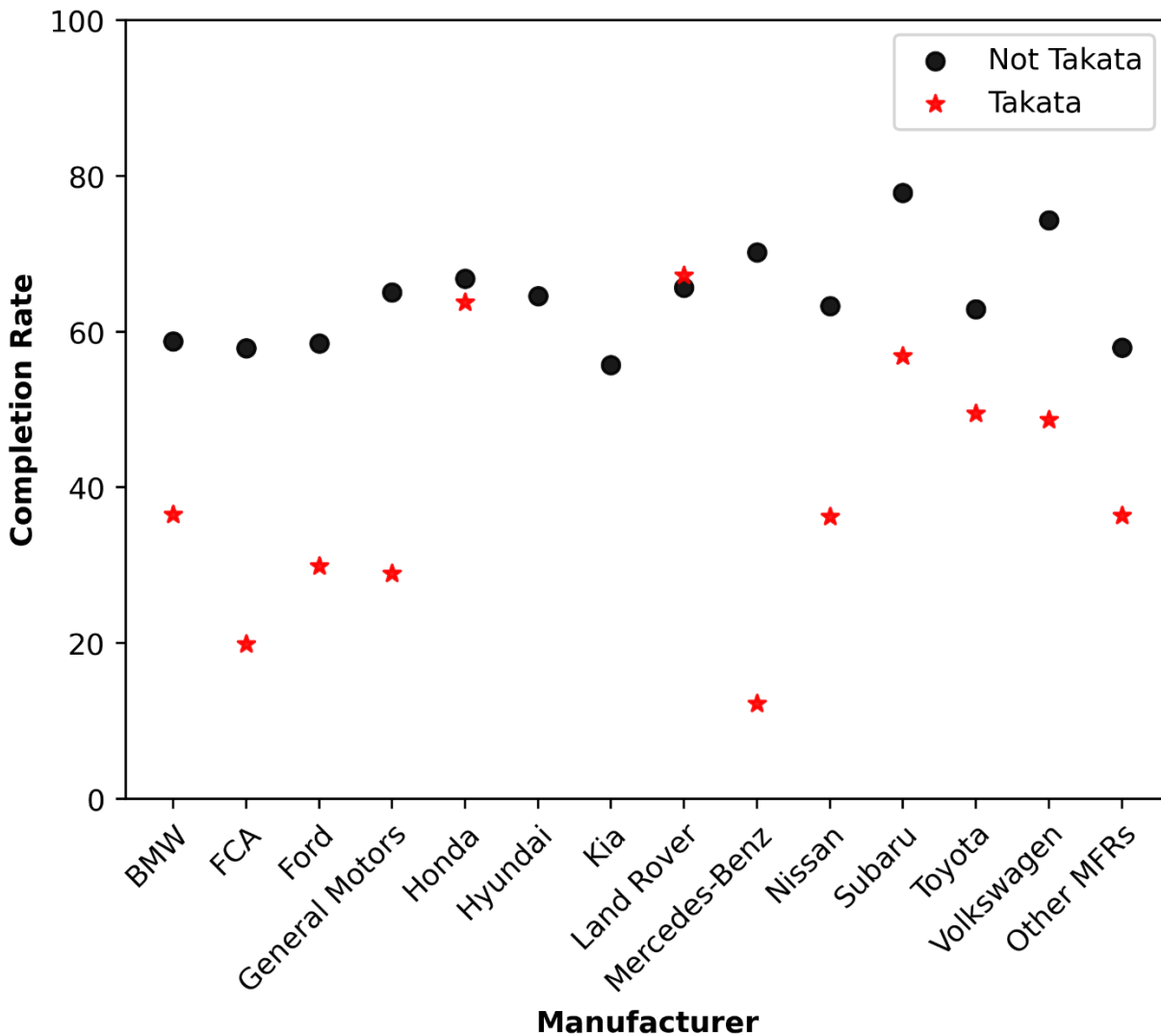
As shown in Figure 2, the massive Takata air bag recalls had an impact on the completion averages for many major manufacturer recall rates. All major manufacturers except for Land Rover, that had Takata recalls had lower weighted average completion rates for these vehicles than each of their other recalled vehicles respectively. Due to the size of the Takata recalls and the collective manufacturer recall programs, replacement parts supply was a significant challenge. NHTSA therefore created a first-of-its-kind Coordinated Remedy Program (CRO) to prioritize the parts supply and organize a recall schedule based on risk, including vehicle age and exposure to sustained heat and humidity. Since 2018 Takata air bag recall completion rates have improved significantly, driven by the implementation of the CRO requirements and a substantial increase in outreach efforts and repair incentives.

As discussed above, the age of a vehicle at time of recall is a statistically significant and well-known predictor of whether a recalled vehicle is remedied. Unsurprisingly, the high-volume Takata recalls—covering vehicles up to 20 years old at the time—launched during this period have significantly lowered the average recall completion rates (NHTSA, n.d.). Moreover, those

that remain unrepaired consist primarily of older vehicles, with a weighted average model year of 2007 (Buretta, 2020.).

Figure 2 shows the weighted average across the thirteen-year span, for non-Takata campaigns and for Takata-only campaigns.[6] The adverse impact can be seen more readily when analyzing the rates by year and manufacturer. For example, Mercedes-Benz had a weighted average completion rate of 70.2 percent for non-Takata recalls but only a 12.2 percent completion rate for Takata related recalls. A similar effect is seen for most but not all manufactures affected by Takata recalls. As shown in Figure 2, for Honda and Land Rover, the disparity between Takata completion rates and non-Takata campaign completion rates is much less pronounced.

Annual Rates by Model Year and Age of the Oldest Vehicle

Appendix B details the weighted annual recall completion rates, by model year, for light-vehicle recalls issued between years 2018 and 2022. The summary shows a general trend in which newer model year vehicles are more likely to be remedied than vehicles from older model years.[7] For example, the only time that NHTSA observes recall rates less than 20 percent is when the age of the oldest vehicle affected is older than 2006.

Table 1 summarizes the weighted average recall completion rates by vehicle model year, limiting to 2015 as the oldest model year, for all light-vehicle manufacturers. NHTSA consistently sees increases in recall completion rates for newer vehicles.

Table 1. Recall completion rates by vehicle model year, 2018-2022 (5Q recalls)

Oldest Model Year	Recall Year				
	2018	**2019**	**2020**	**2021**	**2022**
2015	74.6%	71.8%	71.8%	51.0%	42.1%
2016	77.3%	75.1%	66.0%	59.2%	54.3%
2017	85.5%	82.6%	72.3%	68.8%	72.8%
2018	90.2%	87.6%	82.9%	75.9%	74.1%
2019	92.2%	90.3%	84.8%	75.7%	80.1%
2020		90.4%	86.6%	79.1%	74.4%
2021			93.8%	83.7%	78.7%
2022				85.1%	82.9%
2023					84.9%

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[6] Some manufacturers did not have any mature Takata recalls, either because their recalls had not yet reached the fifth quarter of reporting or because the manufacturers were not part of the Takata recall.

[7] When a recall included two or more model years, NHTSA used the age of the oldest vehicle in the recall for the model year categorization displayed in Table 1 and Table 4. Boxes displaying as blank did not involve any model year vehicles in a recall that year.

NHTSA and industry research show that vehicle age is the predominant factor in low recall completion rates, and the ability to distinguish between newer and older vehicles in light-vehicle recalls is important (NHTSA, 2022; U.S. Government Accountability Office, 2024; Alliance for Automotive Innovation, 2024). One potential explanation for the disparity in recall completion rates between older and newer vehicles is the presence of new vehicle warranty programs. Newer vehicles generally return to franchised dealers for regular vehicle service and maintenance, warranty repairs, trade-ins, and off-lease events. In addition, franchised dealers have a relationship and contact information from the original purchaser to better facilitate the completion of a vehicle recall remedy. As vehicles age, the inverse is true—that is, vehicles depreciate, change owners, and return to franchised dealers for service less frequently. These characteristics are seen in analysis of completion percentages. Newer vehicles have historically had high completion rates, generally around 87 percent, which decline as vehicles age. Table 2 shows the same model year weighted average completion rate data but grouped in ranges by the age of the oldest vehicle at the time of the recall.

Table 2. Recall completion rates by age of oldest vehicle, 2018-2022 (5Q recalls)

Oldest Vehicle Age Range	Recall Year					
	2018	**2019**	**2020**	**2021**	**2022**	**Total**
0-3	88.9%	87.1%	83.6%	79.8%	81.0%	84.1%
4-9	65.7%	66.0%	54.4%	60.9%	66.2%	62.6%
10+	40.4%	45.7%	26.6%	26.8%	31.4%	34.2%

Annual Rates by Time Between Part 573 Report and Remedy Availability

This report compares recall completion rates among several variables, including the length of time between the manufacturer notifying NHTSA of the safety defect or noncompliance through filing the Part 573 report and the date that a manufacturer notifies owners that a remedy is available.

Figure 3 provides weighted average recall completion rates by length of time between the Part 573 report and the remedy availability. Typically, as the length of time for owners to be notified of the availability of the final remedy increases, the weighted average recall completion rate falls. In general, recalls in which the manufacturer notifies owners of an available remedy within 60 days can expect a weighted completion rate of roughly 67 percent. While those that do not have a remedy available until 1 year after the Part 573 report can expect weight completion rates of roughly 45 percent.
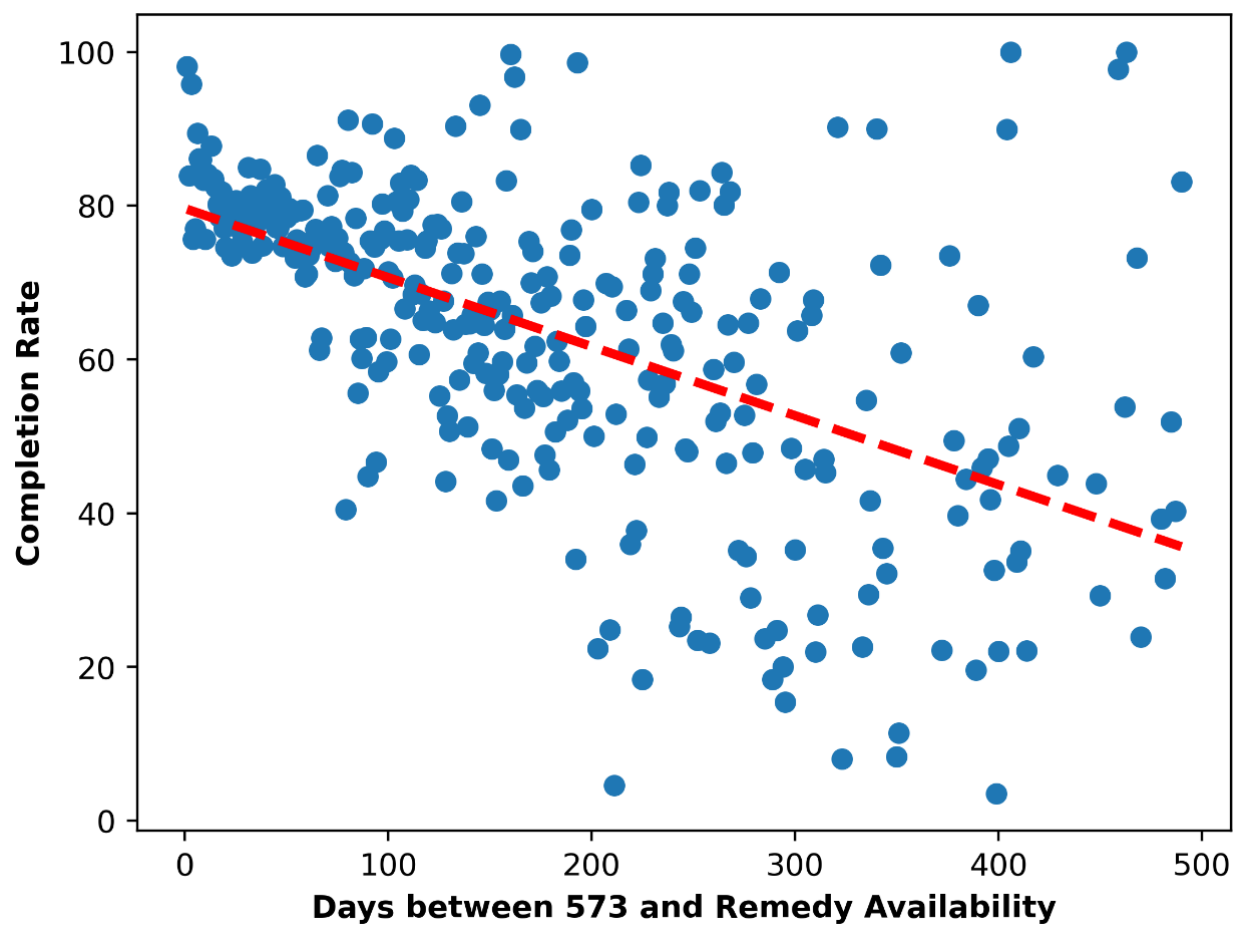
Figure 3. Recall completion rates by time between Part 573 report and remedy availability, 2010-2022

Recall Completion Trends and Significant Factors

This report analyzes recall completion rates with respect to two objectives:

1. To identify factors that have a statistical impact on recall completion rates; and

2. To produce a prediction model for future recall completion rates.

The results of this analysis are presented below.

Data Used

To generate as accurate a statistical model as possible, NHTSA used data from 3,297 mature light-vehicle recalls that were initiated from 2010 to 2022.

Approximately 55 percent of the recalls analyzed in this report included vehicles of more than one model year.[8] As noted above, NHTSA does not receive a detailed itemization of recalled vehicles by model year, only an overall total. For recalls that included vehicles in two or more model years, only the oldest model year was considered in development of the model.

Exploratory Analysis and Data Visualization

First, an exploratory analysis was conducted on the 3,297 light-vehicle recalls conducted from 2010 to 2022. Figure 4 shows an overview of which manufacturers issued the most recalls in this time period. The manufacturers identified in Figure 4 represent the largest light-vehicle manufacturers by total number of recalls from 2010 to 2022.

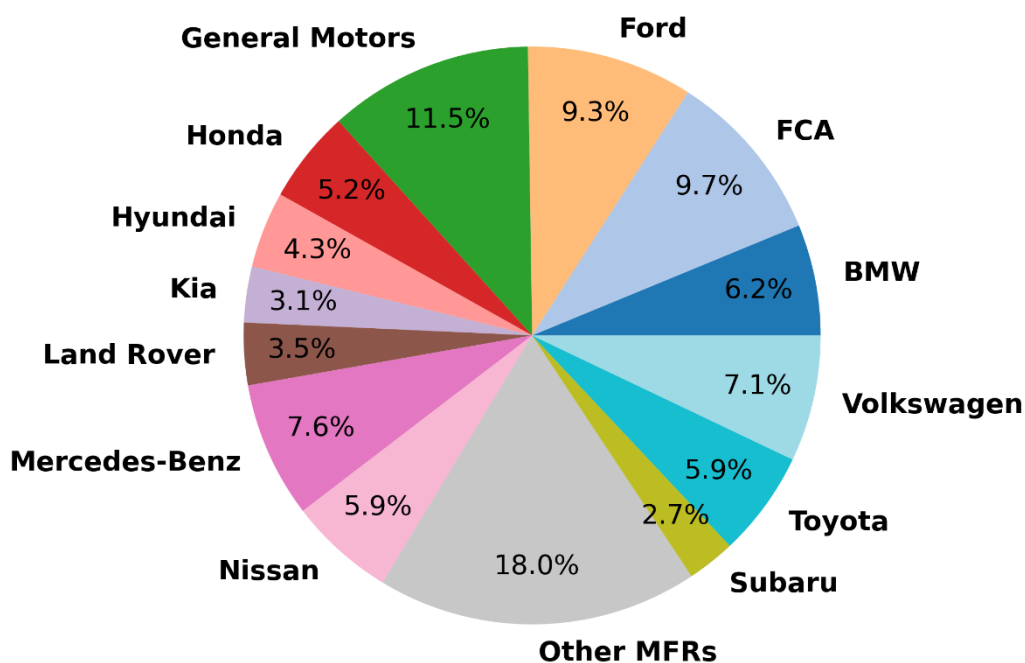

Figure 4. Distribution of vehicle recalls by manufacturer, 2010-2022 (5Q recalls)

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[8] Because NHTSA lacks a breakdown of the number of affected vehicles by model year, NHTSA cannot compute the average vehicle age among affected vehicles.

Although not shown in Figure 4, there is considerable variation in the size of recalls. More than a quarter of the recalls include less than 600 vehicles each, while a quarter of the recalls include more than 59,000 vehicles each. The largest recall had over 5 million vehicles affected. Additionally, Figure 4 does not consider the overall U.S. market share of each manufacturer, which may partially explain the numbers of vehicles recalled.
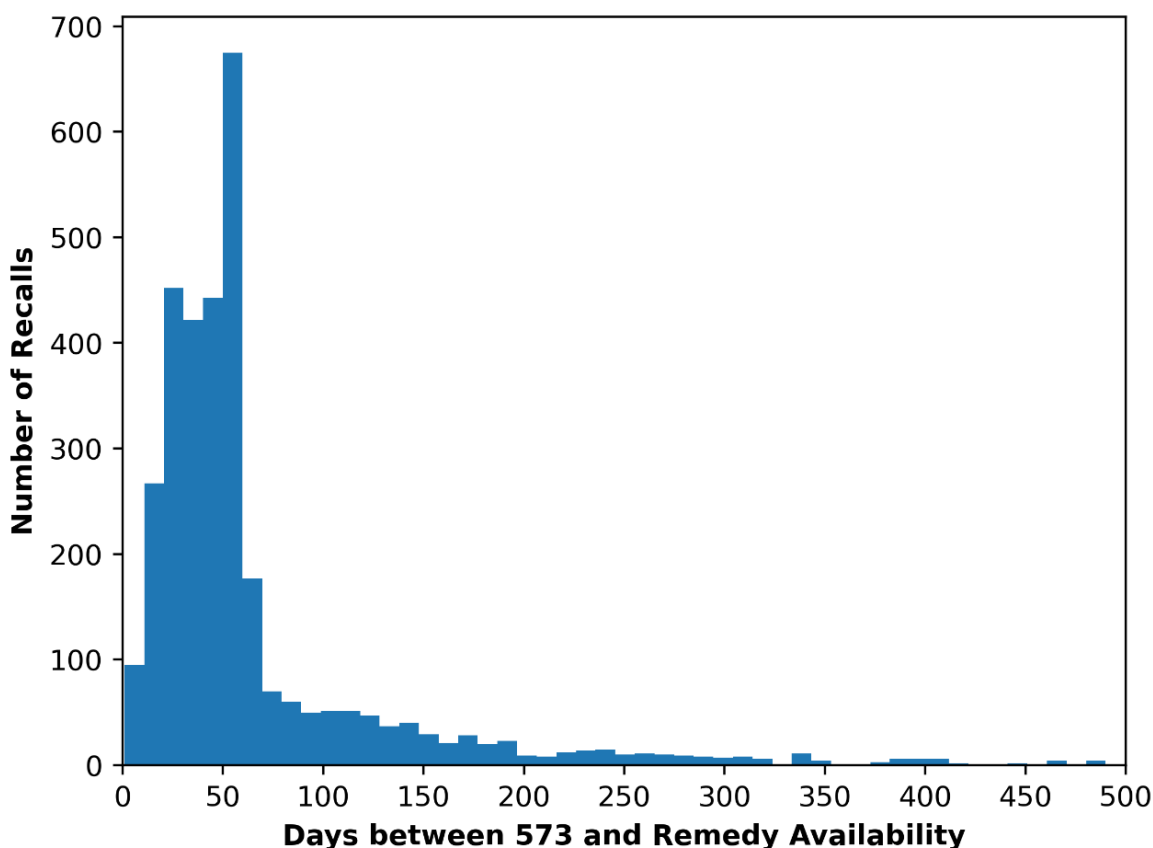

Figure 5. Number of days between Part 573 Report and remedy availability, 2010-2022 (5Q recalls)

Figure 5 shows the distribution of the length of time between these two dates for recalls from 2010 to 2022. As mentioned above, manufacturers are required to notify owners within 60 days that either an interim or a final remedy is available, in accordance with § 577.5. In most recalls, manufacturers notify owners that a final remedy is available within 60 days. Despite this trend, there are certain recalls whose time difference exceeds this threshold, with some extending over a year and up to 911 days. NHTSA observes this extended time difference to have a significant impact on recall rates, which will be discussed in more detail in subsequent sections.

Figure 6 (shown below) depicts how vehicle age (based on the oldest vehicle involved in a given recall) correlates with recall completion rates. The bubbles presented in Figure 6 are scaled according to the number of vehicles involved in the recall. Apart from BMW, Kia, Land Rover, and Volkswagen, all manufacturers conducted at least one recall involving more than 1 million vehicles from 2010 to 2022. Figure 6 shows a general downward trend in recall completion rates as the age of the recalled vehicles increases. Generally, recalls involving newer vehicles have higher recall completion rates than recalls involving older vehicles.
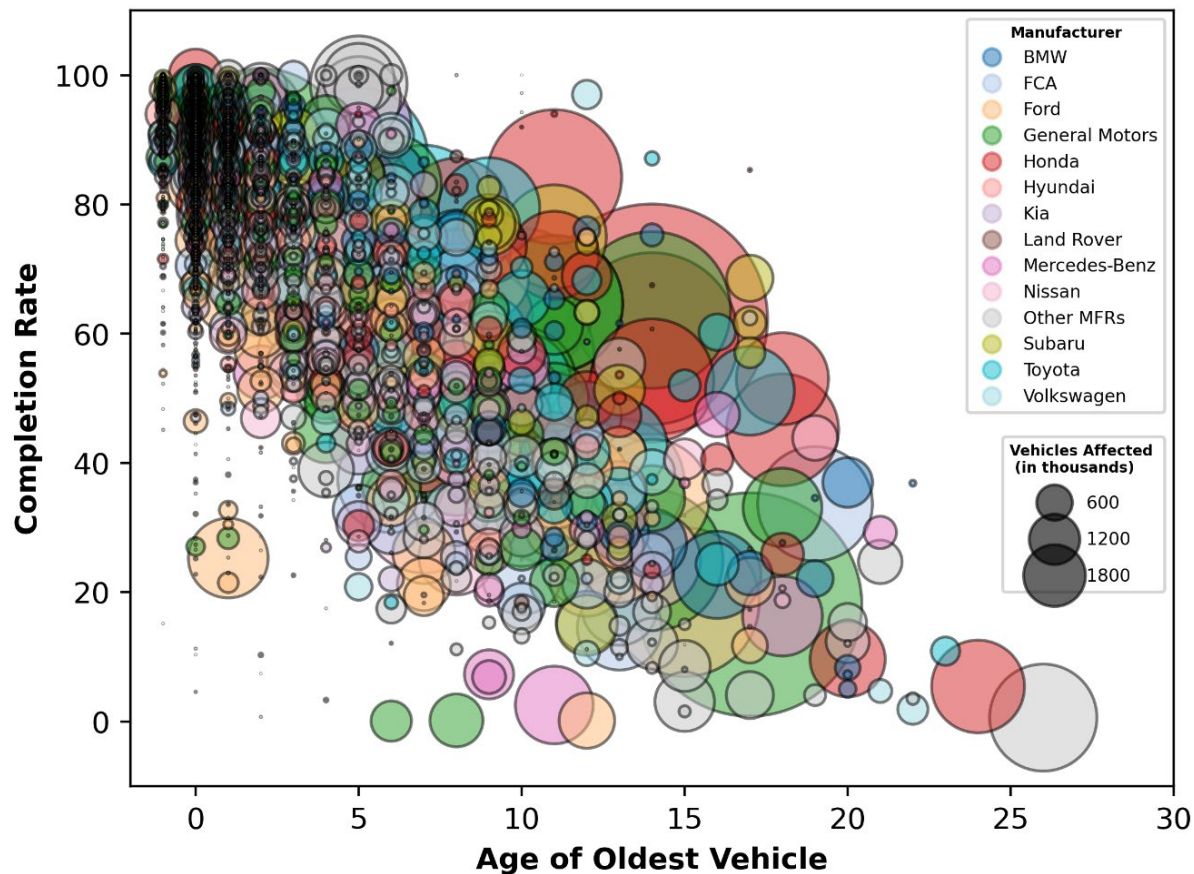
Figure 6. Recall completion rates by age of oldest vehicle and manufacturer, 2010-2022 (5Q recalls)

Of the 3,297 recalls examined in creating this model:

- 2,515 recalls (76%) were for vehicles 4 years older or less when the recall was issued.

- 552 of these (22% of 2,515) had completion rates less than 75 percent.

As noted above, recalls involving newer vehicles should have a relatively high recall completion rate, so it bears noting which recalls underperformed. As more data becomes available, NHTSA can better identify underperforming, high-risk recalls and continue working collaboratively with manufacturers to improve recall campaign performance.

NHTSA understands that there are a variety of factors such as the vehicle owner having a recent relationship with a dealer or the vehicle being under warranty that could influence newer vehicles having higher completion rates; however, NHTSA does not have data to quantify the exact contributing factors.

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Potential Factor Identification and Model Introduction

When examining the variables associated with safety recalls, NHTSA considered 13 factors for potential inclusion in the model:

1. The manufacturer;

2. The age of the oldest affected vehicle;

3. The vehicle type involved (i.e. light or heavy vehicle);

4. The component category;

5. The consumer advisory issued, if applicable;

6. The recall safety risk description includes the word "crash;"

7. The recall safety risk description includes the word "fire;"

8. The recall safety risk description includes the word "death;"

9. The recall safety risk description includes the word "injury;"

10. The recall safety risk description includes the word "serious;"

11. The year the recall was initiated;

12. The number of vehicles affected by the recall; and

13. The time elapsed between the Part 573 report and the date manufacturers notify owners that a remedy is available.

NHTSA considered several families of statistical models and a variety of machine-learning models to estimate recall completion rates. As a first step, NHTSA used models such as "random forests," which provide feature importance metrics, to select the most predictive input features. This analysis revealed three key predictors of recall completion rates: the age of the oldest affected vehicle, the manufacturer, and the time elapsed between the initial Part 573 report and the availability of the remedy.

Using these three features, NHTSA trained a range of models, including linear regression, ridge regression, random forest, support vector machine, gradient boosted regression, bayesian ridge regression, stochastic gradient descent, and logistic regression. Through five-fold cross-validation, the gradient boosted regression model emerged as the most accurate. This ensemble model combines several weak decision tree models to improve prediction accuracy. Details about this model can be found in the documentation for the Python machine learning package scikit-learn (Pedregosa et al., 2011).

NHTSA used the gradient boosted regression model as the predictive model for assessing the relative impact of each factor and projecting recall completion rates for future recalls. All 336,077,985 vehicles involved in recalls from 2010 to 2022 time frame contributed equally to the model.

Model Fit With Recall Completion Rates

Figure 7 illustrates the model. Every data point indicates a separate recall. The figure shows that NHTSA's model generally fits the data, but it is not a perfect predictor of recall completion rates due to the limited data that NHTSA is able to collect, as discussed above, and the inherently imperfect nature of modeling. When the 3,297 light-vehicle recalls from 2010 to 2022 were analyzed, the model predicted the correct completion rate for approximately 61 percent of those recalls, within plus or minus 10 percentage points. The model fits best for the "major" manufacturers, such as those found on NHTSA's VIN Look-Up Tool. For these major manufacturers, the model correctly predicted 65 percent of recall completion rates within plus or minus 10 percentage points. On the other hand, many of the recalls where the predicted completion rates were off by more than 10 percentage points involved smaller manufacturers (labeled as "Other MFRs" in Figure 7).
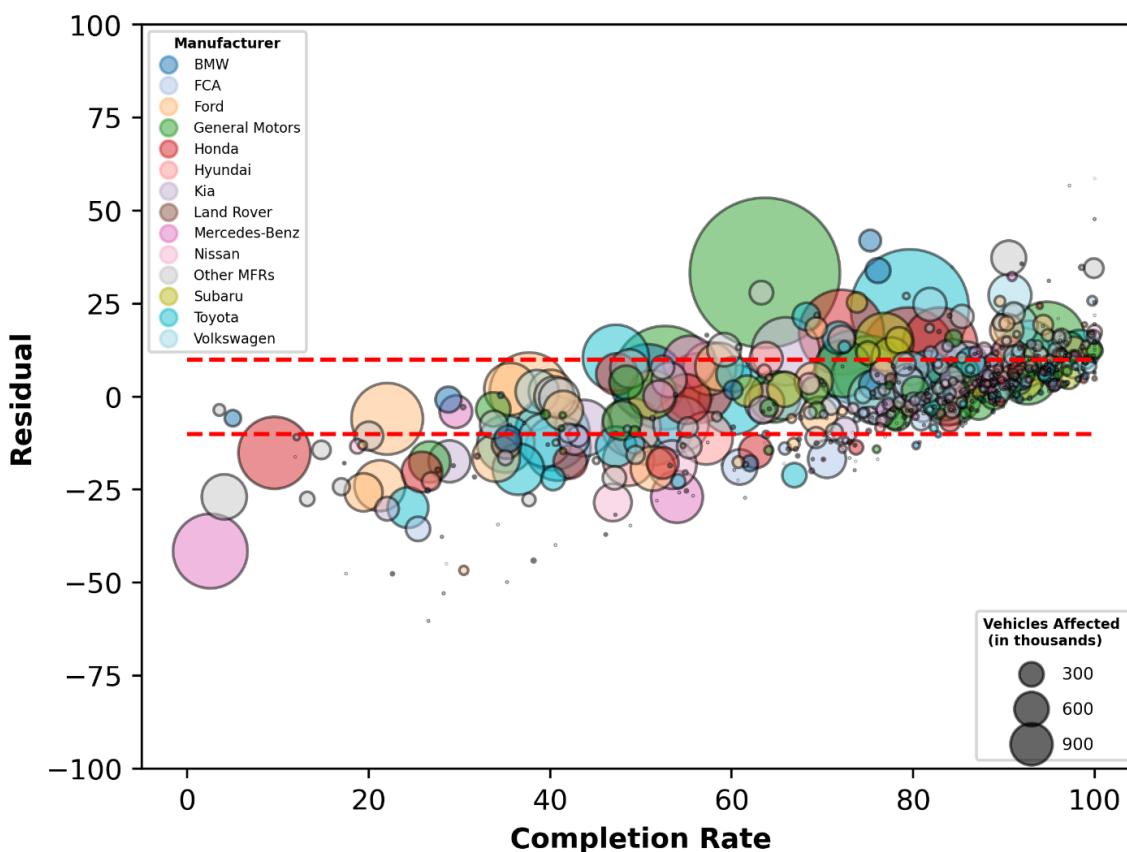
Figure 7. Model fit at predicting recall completion rates, 2010-2022 (5Q recalls)

Model Results and Most Significant Factors

NHTSA's model involves only three factors – age of the oldest vehicle, time between the initial Part 573 report and when the remedy is available, and manufacturer filing the recall. Using these three variables, there are 3,024 different input combinations to the model to predict the recall completion rate. NHTSA evaluates each of the input combinations to develop a lookup table for the model that can easily be used to identify underperforming recalls in the future.

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Summary of Findings

Based on the recall completion analysis and the statistical analysis that controlled for certain factors, NHTSA has made the following findings.

- Some 61 percent of vehicles recalled by major light-vehicle manufacturers from 2010 to 2022 were remedied by the fifth quarter of the recall. The lowest annual recall completion rate for the group during this period was 52 percent in 2015, and the highest annual recall completion rate was 69 percent in 2022.

- The age of the recalled vehicle plays a significant role in recall completion. Recalls for newer vehicles tend to have higher completion rates than recalls for older vehicles.

- Delays in availability of a recall remedy, as determined by the length in time between the manufacturer notifying NHTSA of the safety defect or noncompliance through filing the Part 573 report and the date that a manufacturer notifies owners that a remedy is available, plays a significant role in recall completion. Recalls in which the manufacturer has a final remedy available sooner tend to have higher completion rates than recalls that experience delays in remedy launch.

- NHTSA's model predicts 61 percent of recall completion rates accurately within a 10-percentage-point margin of error and predicts 65 percent of rates accurately for the major manufacturers examined in this analysis. This suggests that other factors relevant to recall completion rates are present but not identifiable with the available data.

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Actions to Improve Recall Completion Rates

NHTSA strives each day to improve the safety recall process and to ensure as many owners as possible seek remedies for recalled vehicles. More specifically, NHTSA is taking these actions or is evaluating these options.

- Further refinement of the predictive model guided by the statistical analysis in this report, particularly the significant findings noted above. This modeling, in conjunction with other analysis tools, will allow NHTSA to better identify, with more expediency and accuracy, under-performing recalls and to work with manufacturers to improve their rates. It will also allow for identification of better performing recalls and closer examination of the reason(s) for their relative higher completion rates as compared to peer recalls. As the volume of recalls within the predictive model increases, the accuracy of the model will improve and continue to identify recall types with comparably lower completion rates.

- Continued facilitation of sharing of information, such as best practices and lessons learned, for improving recalls completion. The continued oversight of the Takata recalls and the first-of-its kind coordinated remedy approach, is expected to continue to inform the agency, and then by extension, various automotive manufacturers and equipment suppliers that conduct or are otherwise directly involved in the execution of safety recalls. NHTSA will continue identifying opportunities to share information with manufacturers regarding recall best practices.

- Communications outreach such as NHTSA's SaferCar app allows for more public exposure of the continuing need to have recall-affected vehicles repaired. Additionally, NHTSA intends to continue to collaborate with manufacturers to ensure that existing consumer outreach methods and messages are effective and meet the needs of owners of affected vehicles.

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Appendix A: Annual Recall Completion Rates by Vehicle Manufacturer

The table below provides the weighted annual recall completion rate for manufacturers recalling light vehicles between 2010 and 2022. This table includes companies that modify new motor vehicles before their first retail sale (vehicle alterers), certain manufacturer distributors, and some low-volume, specialty manufacturers (such as limousine builders or electric vehicle manufacturers).

Table 3. Recall completion rates by vehicle manufacturer, 2010-2022 (5Q recalls)

Manufacturer	Recall Year												
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
BMW	78.8%	52.8%	75.1%	77.0%	40.6%	36.9%	46.4%	48.8%	77.1%	56.9%	47.0%	83.6%	29.5%
FCA	68.3%	73.8%	44.9%	51.1%	58.6%	49.4%	55.0%	61.0%	71.5%	65.1%	45.9%	80.6%	64.0%
Ford	39.6%	41.7%	52.7%	70.3%	62.8%	56.1%	50.2%	42.1%	65.9%	58.3%	49.8%	35.5%	62.6%
GeneralMotors	69.1%	91.1%	74.4%	78.0%	55.7%	49.8%	82.7%	70.0%	77.7%	78.2%	72.5%	39.6%	62.6%
Honda	63.4%	74.0%	53.6%	68.1%	60.6%	61.6%	69.3%	75.6%	79.8%	64.5%	55.0%	82.9%	48.6%
Hyundai	94.1%	57.6%	66.2%	60.7%	67.9%	68.1%	67.5%	69.4%	66.1%	59.6%	53.9%	58.1%	69.4%
Kia	85.4%	50.3%	48.8%	63.5%	66.6%	71.3%	52.7%	63.2%	52.8%	60.9%	43.7%	56.5%	45.8%
LandRover	93.5%	87.6%	85.3%	77.2%	76.4%	63.5%	71.4%	81.4%	87.4%	59.1%	54.0%	55.3%	64.5%
Mercedes-Benz	90.8%	31.6%	87.9%	88.3%	68.0%	75.9%	18.8%	75.3%	61.3%	24.5%	90.3%	83.7%	67.1%
Nissan	47.7%	53.2%	82.0%	82.1%	82.5%	50.6%	70.8%	62.6%	59.3%	73.9%	34.8%	57.3%	56.0%
Subaru	88.5%	67.9%	69.5%	66.5%	52.9%	29.0%	58.3%	69.8%	81.5%	80.9%	72.6%	88.0%	82.2%
Toyota	72.6%	66.5%	62.1%	54.6%	58.6%	41.5%	51.7%	53.0%	69.2%	63.4%	69.9%	57.4%	90.3%
Volkswagen	76.5%	93.8%	91.8%	87.8%	76.1%	79.2%	54.3%	74.5%	63.6%	69.4%	55.6%	70.3%	83.9%
Other MFRs	70.7%	64.7%	41.9%	48.1%	44.7%	15.6%	59.1%	44.9%	48.1%	71.2%	58.8%	40.5%	91.8%

Appendix B: Annual Recall Completion Rates by Vehicle Model Year

The table below details the weighted annual recall completion rates, by model year, for light-vehicle recalls issued from 2018 to 2022. The summary shows a general trend in which newer model year vehicles are more likely to be remedied than vehicles from older model years. For example, the only time that NHTSA observes recall rates less than 20 percent is when the age of the oldest vehicle affected is older than 2006. NHTSA consistently sees increases in recall completion rates for newer vehicles.

Table 4. Recall completion rates by vehicle model year, 2018-2022 (5Q recalls)

Oldest Model Year	Recall Year				
	2018	**2019**	**2020**	**2021**	**2022**
1996			5.4%		
1997			10.9%		
1998			2.1%		
1999		7.3%		36.9%	
2000		22.4%	18.0%	4.7%	
2001	85.3%	40.9%	36.6%	13.7%	26.3%
2002	60.2%	51.2%	25.8%		
2003	20.4%	29.1%	64.2%	18.8%	
2004	32.8%			6.9%	
2005	10.0%	41.4%			62.4%
2006	61.2%	25.3%	35.0%	18.5%	29.0%
2007	42.7%	70.1%	29.8%	27.1%	31.8%
2008	38.5%	74.3%	37.3%	57.6%	21.2%
2009	55.8%		68.6%	36.6%	62.5%
2010	69.7%	69.0%	41.9%	38.5%	27.3%
2011	62.4%	53.2%	52.2%	34.1%	
2012	68.2%	60.3%	53.5%	36.7%	45.0%
2013	63.4%	58.9%	53.2%	48.4%	44.8%
2014	72.8%	73.8%	51.2%	72.2%	45.4%
2015	71.0%	74.1%	59.5%	45.6%	37.6%
2016	85.9%	76.1%	70.1%	68.8%	58.4%

Oldest Model Year	Recall Year				
	2018	**2019**	**2020**	**2021**	**2022**
2017	83.9%	82.1%	81.3%	68.4%	86.0%
2018	92.0%	85.5%	83.2%	80.1%	70.0%
2019	91.6%	91.4%	82.9%	73.1%	82.1%
2020		91.0%	86.8%	77.9%	81.6%
2021			97.3%	86.4%	80.6%
2022				85.3%	78.0%
2023					87.8%

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