Eastern Research Group, Inc.

FINAL

Evaluation of the Texas Vehicle Emissions Inspection and Maintenance Program in the Dallas-Fort Worth and Houston-Galveston-Brazoria Nonattainment Areas

Prepared for:

Texas Commission on Environmental Quality

Prepared by:

Eastern Research Group, Inc.

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EVALUATION OF THE TEXAS VEHICLE EMISSIONS INSPECTION AND MAINTENANCE PROGRAM IN THE DALLAS-FORT WORTH AND HOUSTON-GALVESTON-BRAZORIA NONATTAINMENT AREAS

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Executive Summary

This report documents the evaluation of the Texas Vehicle Emissions Inspection and Maintenance (I/M) program for the 2020 and 2021 biennial period. Eastern Research Group (ERG) performed this evaluation for the Texas Commission on Environmental Quality (TCEQ) using the Texas Information Management System (TIMS) database and Remote Sensing (RS) data from January 1, 2020, through December 31, 2021. A significant change occurred in the program since the last program evaluation. Beginning in January of 2020 tailpipe testing was eliminated; therefore, many analyses that were in past program evaluation reports are no longer necessary.

This evaluation generally follows the United States Environmental Protection Agency (EPA) draft guidance on using in-program data for the evaluation of the Texas I/M program performance [EPA, 2001] and the EPA guidance on the use of RS for the evaluation of I/M program performance [EPA, 2004].[1] This study focuses on program coverage, the inspection process, and the repair process. Additionally, program benefits were estimated on an annual basis. However, beginning January 1, 2020, tailpipe testing was no longer part of the I/M process as the program became On-board Diagnostics (OBD)-only, testing model year (MY) 1996 and newer vehicles. Therefore, many analyses that were in previous program evaluation reports are not presented in this report.

Overall, the results for the Texas I/M program were positive. However, ERG found that improvements could be made in a few areas, and a list of specific recommendations for improvements in the program is provided in the last section of this Executive Summary. Some of the suggestions will be helpful for future biennial evaluations and will make the results more reflective of overall program performance.

A. COVERAGE

The results of the coverage analysis using out-of-program RS data revealed a consistent, high rate of participation in the Texas I/M program.

Participation Rates (Section II.A) – The program participation rates were estimated by determining the fraction of vehicles seen on the road during RS studies that had recent records in the TIMS. This analysis found that in the Dallas-Fort Worth (DFW) program area, the participation rate was 91.2% in 2020 and 94.0% in 2021. In the Houston-Galveston-Brazoria (HGB) program area, the 2020 and 2021 participation rates were 92.4% and 94.0%, respectively. The overall program participation rates were 91.8% in 2020 and 94.0% in 2021.

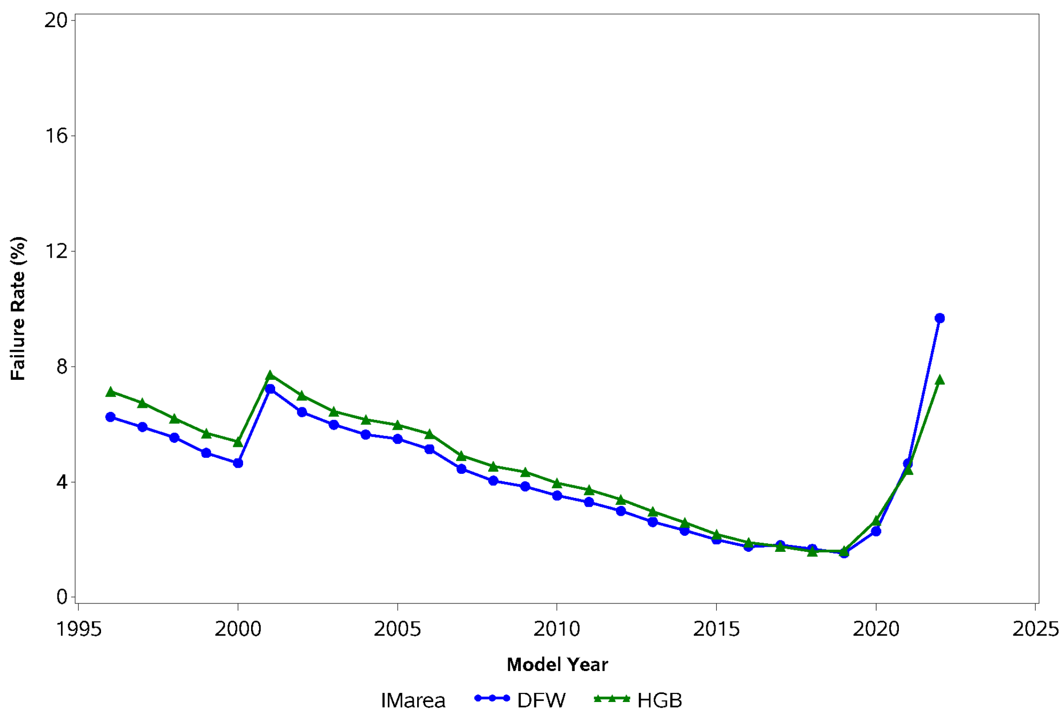
[1] Citations for references are given in Section 7.

B. INSPECTION

Appropriateness of Major TIMS Fields (Section III.A) – The TIMS was used to document the Texas I/M program inspection process. This analysis checked the major fields in the TIMS using a series of basic data checks to demonstrate the accuracy and completeness of the data in the TIMS. ERG produced frequency distributions of almost all database variables to examine field values for in-range values, out-of-range values, and missing values. The following summarizes the major findings of this analysis.

Inspection Statistics (Section III.B) – Analysis of the TIMS data indicated that during the evaluation period, over 18.8 million OBD tests were performed on 1996 and newer MY light-duty passenger cars and trucks, resulting in approximately 8 million unique vehicle OBD tests. The DFW and HGB program areas initial inspection rates were similar and are illustrated in the figure below.

Figure ES-1. Initial Inspection Failure Rates by, MY and I/M Program Area



Repeat I/M Failure Patterns (Section III.C) – ERG examined the TIMS data to determine the relative frequencies of the I/M pass/fail patterns during each vehicle's inspection cycle.

In 99.2% of the test sequences, a verified initial test or an initial test that could reasonably be assumed to be a true initial test was confirmed, and a final test certified.

OBD Inspection Analyzer Communication Performance (Section III.D) – Overall, OBD communication rates between vehicle computers and program analyzers were greater than 99%.

TIMS Handling of OBD Codes (Section III.E) – It appears that the OBD inspection logic used in Texas for light-duty gasoline-powered vehicles agrees with EPA policies. For the very few cases where this was found not to be true, ERG believes these instances were due solely to a minor oversight such as operator error or analyzers not having the latest software update for a brief period that resulted in a small percentage of errors.

C. REPAIR

Number and Types of Repairs (Section IV.A) – During the evaluation period, analysis of the TIMS data indicated that 95,218 repairs were made to vehicles to bring them into compliance with the Texas I/M program. The program requires reporting repair types according to five categories: fuel system, ignition electrical system, emissions system, engine mechanical, and miscellaneous. The fractions of total repairs in these five categories were approximately 39%, 8%, 16%, 1%, and 36%, respectively.

OBD Repair Effectiveness (Section IV.B) – ERG's analyses indicated approximately 81% of OBD tests that initially fail for an illuminated malfunction indicator light (MIL) with stored diagnostic trouble codes (DTCs) eventually receive a passing inspection. And within that cohort, 62.1% of the MIL-On failures passed with confirmed repairs and their monitors reset, and 17.5% passed after being repaired but without failure mode monitors reset. As seen in the earlier studies, when evaluating repairs by failure category (i.e., evaporative emissions control system, O_2 Sensor, Exhaust Gas Recirculation (EGR) System, air injection system, and catalytic converter), unset readiness monitors were seen to potentially "hide" malfunctions in 2% to 35% of "repaired" vehicles. This large range is consistent with the findings in previous program evaluation reports and reflects the uncertainty in identifying cases where unset readiness monitors are masking MIL illumination in repaired vehicles.

Average Repair Costs (Section IV.C) – The analysis of the TIMS repair cost data with repair costs of zero and greater than $2,000 removed indicate that Texas motorists spent approximately $5.6 million during this evaluation period performing 35,000 repairs so that they would be in compliance with the Texas I/M program. It should be noted that repair costs are hand-entered by the vehicle emissions inspectors, which can lead to transcription errors.

As in the previous studies, a large percentage (61.7%) of the repair costs in the TIMS were recorded as zero. Again, with zero repair costs and those over $2,000 removed, the median and mean repair costs ranged from $20 to $241 and $37 to $398.

D. I/M EMISSIONS BENEFITS

The annual emissions benefit of an I/M program (I/M benefit) can be measured by the decrease in emissions for the I/M fleet at the time of vehicle repairs. The annual I/M benefit was estimated by looking at before and after repair emissions and by pairing TIMS data with RS data.

Calculation of the Annual I/M Benefit using Comprehensive Method (Section V.B) – The analysis of RS data, which is out-of-program data, provides a different view of the annual I/M benefit of the Texas I/M program. The average RS emissions from 30 to 90 days before I/M inspections were compared to the average RS emissions from 1 to 90 days after the I/M inspections. About 96% of the vehicles measured by RS had I/M sequences produced by passing their initial inspections, while a little over 3% had a Fail-Pass I/M test sequence. Initial pass vehicles had RS emissions changes of +4.1% for hydrocarbon (HC), +6.4% increase for carbon monoxide (CO), and +3.4% increase for nitrogen oxides (NO_x), while the Fail-Pass vehicles had RS emissions changes of +0.6% for HC, -2.1% for CO, and a -4.5% increase for NO_x.

Remote Sensing Analysis of I/M and non-I/M Vehicles (Section V.C) – The vehicles observed by RS were divided into two groups: vehicles that have never been in the I/M program prior to the RS observation, and vehicles that have been in the I/M program prior to the RS observation. This provided a four-year period before the 2020/2021 analysis years, and a sufficiently large sample size to compare the I/M fleet to the no-I/M fleet. A slight HC benefit and a larger NO_x benefit were observed for the I/M fleet; however, the I/M CO fleet average was higher than that of the no-I/M fleet.

E. MEASURES FOR EVALUATING STATION PERFORMANCE

(Section VI) – This section strives to consolidate the analyses performed that pertain to the evaluation of station performance. Distinctions between errors of commission vs. errors of omission were also identified whenever possible, with the former viewed as more likely attempts at committing a fraudulent test, while the latter could be viewed somewhat more leniently. An example of an error of commission would be a Vehicle Identification Number (VIN) mismatch, where the electronic VIN (eVIN) does not correspond to the hand-entered VIN. In the benign case, the discrepancies are basically random. In a highly suspicious case, the exact same eVIN may be found in a large number of tests, which seems to indicate a clear case of attempted clean-scanning. An example of an error of omission metric is a zero-value repair cost, as this will not result in falsely passing or failing the I/M test. In all, there were nine error-of-commission metrics and three error-of-omission metrics developed, and station rankings were developed for the error of commission category.

F. RECOMMENDATIONS

As a result of performing this biennial evaluation of the Texas I/M program, ERG developed a list of recommendations the TCEQ may consider implementing. As in the earlier reports, the purpose of most of these recommendations is to improve the program, but some also are intended to improve future biennial I/M program evaluations. For each recommendation, ERG provided an importance rating of High **(***)**, Medium **(**)**, or Low **(*)**. These ratings are provided to assist the TCEQ in prioritizing efforts to improve the Texas I/M program.

TIMS Recommendations

TIMS Recommendation 1 (***): Increase number of repair categories. The TIMS repair data include only five different repair types, and these types are too general to permit a detailed analysis of the data. These types include fuel system, ignition/electrical system, emissions system, engine mechanical, and miscellaneous. "Miscellaneous" repairs make up almost 40% of the reported repairs. It is recommended that the TCEQ consider increasing the number of repair categories in the analyzer software and eliminating the "miscellaneous" category since that does not provide any useful information. Ideally, the repair choices that inspectors see and choose from would be only those that apply to the technology of the vehicle being inspected, although that does involve an increase in programming complexity. Another problem is that a large number of repairs with a cost of zero exist in the dataset, along with some extremely high (e.g., greater than $2,000) costs as well. The source of these errors is not clear, but the erroneous costs make it difficult to comprehensively assess costs across the entire dataset. It is possible that some zero cost repairs could be warranty repairs, so including a "Warranty" choice in the cost options could help track this.

OBD Recommendations

OBD Recommendation 1 (***): Investigate requiring a "set" status for certain monitors to prevent hiding malfunctions. Our analysis found that in 2% to 35% of instances when a vehicle received an initial fail for a certain monitored component, the retest OBD result, which follows a repair, could be hidden by an "unset" readiness status for that monitor. This opens the possibility that malfunctioning emissions control components could remain unrepaired even though the follow-up OBD test received a "pass." ERG recommends that the TCEQ investigate implementing a software change that would require certain monitors to have a "set" readiness status on an OBD retest that follows certain types of initial failures. This software change was also recommended in the previous program evaluation report.

OBD Recommendation 2 (***): Review the OBD exemption list. Review the current list of vehicles on the OBD readiness exemption list to ensure it is up to date. This may have been done recently, but the document does not indicate when the last update was performed.

OBD Recommendation 3 (***): Expand Trigger Reports. The TCEQ should work with the Texas Department of Public Safety (DPS) and expand the number and frequency of trigger reports.

OBD Recommendation 4 (*): Diesel OBD and Heavy-duty Gasoline OBD. Per the EPA guidance, Texas does not perform testing on OBD l heavy-duty; however, this topic continues to be discussed in the I/M community. California will begin implementing a heavy-duty diesel I/M program in January of 2023. ERG suggests the TCEQ stay abreast of any developments in this area.

OBD Recommendation 5 (*): Key-on-Engine-Running. The MIL Illumination Status appears to be well enforced as a condition for OBD failure as no inspections were recorded with a MIL Illumination Status of "N" and an overall OBD result of "P." However, the Key-On-Engine-Running (KOER) MIL Illumination Status is manually entered by the inspector, and the accuracy of this entry is not automatically enforced by the analyzer. Therefore, the TCEQ may want to consider a specification change where passing MIL Status would result in a passing OBD result despite a KOER result of fail.

OBD Recommendation 6 (*): Collect Additional OBD Data. The TCEQ may want to explore collecting additional OBD data that may now be available such as Permanent DTCs, Pending DTCs, Fuel Consumption, Run Time, and Traveled Distance.

RS Recommendations

Recommendation 1 (***): Volume of RS data collected in DFW and HGB. The Comprehensive RS Method has been used to evaluate the RS component of the I/M program, as discussed in Section V. This method has been used in previous program evaluation reports ERG has done for the TCEQ. The number of RS records collected each year increased through calendar year 2013 but has declined each year since then. In the 2018 report, there were 650,000 and 660,000 RS records for DFW and HGB, respectively, and in the 2020 report, those numbers are 409,000 and 344,000. For this 2022 report, 470,000 RS records were collected for DFW and 400,000 for HGB. As all vehicles now receive OBD inspections instead of tailpipe inspections, the RS records are the only data source available to track actual fleet emissions levels over time; therefore, maintaining a robust RS dataset, with a high volume of records, continues to be of great value for future program evaluations.

Recommendation 2 (**): Collect RS data in San Antonio. In the 2009 Report, ERG was able to use RS data from San Antonio to analyze the DFW/HGB RS fleet data using the Reference Method. The Reference Method for evaluating I/M programs compares RS readings from a non-I/M area like San Antonio to the RS readings from an I/M area to identify trends, benefits, and calculate effectiveness of implementing an I/M program. If possible, efforts should continue to obtain RS data from a non-I/M area for future evaluations.

Repair Tracking Recommendations

Regardless of how malfunctioning vehicle emission control systems are detected, improvements can be made to the system of recording the repairs that are made to vehicles. The repairs, not the inspections, keep vehicle emission control systems operating properly and, in turn, maintain low vehicle emissions.

Repair Tracking Recommendation 1 (***). Use a more detailed, but short list of repairs for I/M inspectors to choose from. Because all vehicles are now getting OBD tests, the repair groupings can be based on the DTC, and this would be a good opportunity to revamp the repair categories. Currently, the TIMS provides inspectors with five general repair categories for reporting I/M-induced repairs, and these categories appear to be too broad to be useful. ERG recommends the repair tracking system be redesigned so that it provides inspectors a list of the five to 10 most effective repairs for each vehicle technology. ERG performed a study in 2015 for the Maryland Department of the Environment that identified a list of legitimate repairs for a given OBD DTC [ERG 2015]. This approach would provide a convenient, short list of repairs for inspectors that would make the inspectors' task simpler while recording valuable repair information that is most important for the I/M program.

Providing more standardized menu options would also help improve the accuracy of these data by standardizing the entries as well as making it more onerous for the technician to enter incorrect data than to enter real data. If it becomes more difficult to input false data than the real data, then technicians would be motivated to be more accurate when completing these electronic entry forms.

Repair Tracking Recommendation 2 (***). Recording Repair Costs. A large number of repair costs are either zero or greater than $2,000. It might be worthwhile to consider a software change that would require the inspector to input repair information within set limits of price and from a menu selection of repair choices. For example, repair costs of zero would not be accepted, and any repairs above a certain threshold (e.g., $1,000), would have to be validated by re-entering the data.

I. INTRODUCTION

The purpose of this report is to fulfill a federal requirement to evaluate the effectiveness of the state's I/M program operating in the DFW and HGB areas. Title 40 Code of Federal Regulations (CFR) §51.353 (c), Network Type and Program Evaluation, requires all states subject to an enhanced I/M program to evaluate the effectiveness of their program and submit a program evaluation report to the EPA every two years. The last program evaluation report was issued on June 30, 2020. The DFW and HGB areas are evaluated because only the enhanced programs are required to be evaluated every two years. The Austin-Round Rock and El Paso programs are not enhanced programs; therefore, those programs are not part of this study.

The DFW and HGB enhanced I/M programs were implemented on May 1, 2002, by the TCEQ and the DPS. These programs incorporated vehicle emissions inspections using OBD computer testing and Acceleration Simulation Mode (ASM) dynamometer testing in Collin, Dallas, Denton, and Tarrant Counties of the DFW area and Harris County of the HGB area. In May 2003, the enhanced I/M program was expanded to include Ellis, Johnson, Kaufman, Parker, and Rockwall Counties of the DFW area, and Brazoria, Fort Bend, Galveston, and Montgomery Counties of the HGB area. On January 1, 2020, the tailpipe test was eliminated from the program and now only OBD testing is performed on MY 1996 and newer vehicles.

Beginning in 2004, the TCEQ contracted with ERG to research options for evaluating the DFW and HGB I/M programs, and ERG developed the Texas I/M Program Evaluation Plan [ERG, 2004]. This report detailed numerous potential methods and measures for evaluating the I/M program. Working closely with ERG, the TCEQ selected a set of measures that provide qualitative and quantitative assessments of the four major evaluation elements as described in the EPA's Guidance on Use of In-Program Data for Evaluation of I/M Program Performance, along with several measures that assess actual emissions benefits, as described in the Texas I/M Program Evaluation Plan and the EPA's Guidance on Use of Remote Sensing for Evaluation of I/M Program Performance. This evaluation is required to be conducted in accordance with the TCEQ-selected measures.

A. EVALUATION ANALYSIS APPROACH

The Clean Air Act requires that states evaluate their I/M programs every two years. The Sierra Method was initially used to evaluate the Texas I/M program in 2000 [ERG 2003], and later ERG used the updated EPA guidance [EPA 2001, EPA 2004] as a framework for an evaluation performed in 2006 [ERG 2006]. Since then, ERG performed evaluations in 2009 [ERG, 2009], 2012 [ERG 2012], 2014 [ERG 2014], 2016 [ERG 2016], 2018 [ERG 2018], and 2020 [ERG 2020] using the same approach as the 2006 Report.

This 2022 report follows the same general methodology, analyzing and evaluating data to assess program coverage, the vehicle inspection process, the vehicle repair process, program air quality benefits, and station performance. These areas were chosen to provide the most useful information at a reasonable cost as well as an objective assessment on the overall status of the Texas I/M program, with the intent of identifying both areas that may be improved and those that are performing well.

B. STRUCTURE OF THE REPORT

As previously stated, this report follows the same outline as past reports. Section II investigates coverage by comparing vehicle license plates read during RS measurements with the vehicles seen in the Texas I/M program TIMS database.

Section III investigates the inspection process in various ways using the TIMS data for the evaluation period, but now is only focused on OBD equipped vehicles. For example, TIMS data fields were checked for appropriateness, the various failure patterns were counted, and OBD communication rates and test outcomes were examined.

In Section IV, the TIMS data were analyzed with a focus on the repair data to examine the types of repairs, the cost of repairs, and the success of these repairs by analyzing the reported OBD readiness and diagnostic data.

Section V provides emission benefits estimates based on the RS data, and Section VI is a detailed analysis of station performance based on TIMS data. It covers a variety of inspection details that could indicate that fraudulent inspections are being performed, such as “clean-scanning” with the eVIN missing or not matching the VIN of record, and other anomalous test results.

II. COVERAGE

An important component of an I/M program is the level of fleet coverage, or the vehicle compliance rate. In this section, coverage is evaluated by estimating the fraction of vehicles observed on the road using RS data that also have a current and valid Texas I/M program TIMS record.

Estimates of the participation rate of vehicles subject to I/M in the DFW program area and in the HGB program area were made through a comparison of RS data and TIMS data. The RS data provide a sample of vehicles that were driven on the road, and if these vehicles were eligible for I/M, they should have an I/M test record in the TIMS database.

To perform this analysis, ERG first created a dataset of I/M-eligible vehicles captured on the road by RS at least once. To create this dataset, RS data were merged with Texas registration records by license plate. This dataset does not include vehicles from out-of-state or registered in non-I/M counties. It only consists of I/M-eligible model years. Therefore, vehicles newer than two years and older than 24 years, at the time of the RS measurement, were excluded from the analysis. Table II-1 shows the counts of unique I/M-eligible vehicles from the DFW or HGB program areas that were measured by RS between January 1, 2020, and December 31, 2021.

Table II-1. Count of Unique I/M-Eligible RS Vehicles Registered in Texas I/M Program Areas by Calendar Year

Registered at Time of RS	Unique RS-Captured Vehicles by Calendar Year		
	2020	**2021**	**Total**
DFW	112,059	107,599	219,658
HGB	102,608	87,636	190,244
Total	**214,667**	**195,235**	**409,902**

Next, the number of unique I/M-compliant vehicles (i.e., vehicles that were tested and ultimately passed or received a waiver) in each of the Texas I/M program areas during that same time frame was determined. Table II-2 shows the overall counts for the I/M tests in the DFW and HGB program areas.

Table II-2. Count of Unique I/M-Compliant Vehicles in Texas I/M Program Areas

I/M Area where Test Performed	Unique I/M-Tested Vehicles
DFW	5,761,125
HGB	4,967,331
Total	**10,728,456**

The I/M tests were then matched to the RS/registration dataset by VIN. If an I/M test occurred any time between January 1, 2020, and December 31, 2021, and was found to have a corresponding VIN with a RS measurement taken any time during the same period, this was a matched pair. Table II-3 summarizes these results for the DFW and

HGB program areas. These values were then divided by their respective values for each program area in Table II-1 to obtain an estimate for the Texas I/M program participation rate (e.g., in 2020 the DFW program area participation rate was calculated as ((102,186/112,059) x 100). Table II-3 shows that the participation rate did increase slightly overall from 2020 to 2021.

Table II-3. Count of Unique I/M Eligible RS Vehicles Paired with Unique I/M-Compliant Vehicles in Texas I/M Program Areas by Calendar Year

I/M Program Area where Test Performed	Paired RS and TIMS VIN Matches		Participation Rate	
	2020	**2021**	**2020**	**2021**
DFW	102,186	101,176	91.2%	94.0%
HGB	94,835	82,391	92.4%	94.0%
Total	**197,021**	**183,567**	**91.8%**	**94.0%**

III. INSPECTION

A. CHECK MAJOR DATA FIELDS FOR APPROPRIATENESS

The goal of this section was to analyze the ranges and values of the primary variables that make up the TIMS database. This analysis provides an indication of the ability of the Texas I/M program's analyzers and database system to accurately record the activities of the Texas I/M program. If any variables have values that are out of range or missing for unexplained reasons, it suggests that the Texas I/M program activities are not being conducted properly or monitored adequately. An iterative series of steps was used to evaluate the accuracy and completeness of the data in the database. Within the database, each record or row was a test entry that contained columns of variables or data fields. The first set of basic filters applied was to remove unusual or incomplete inspections from the dataset (e.g., aborted inspections, covert audits, etc.). Then, a frequency distribution was performed on nearly all database variables to evaluate the accuracy and completeness of data fields (excluding variables with unique information for each record, such as those for VIN, license plate, or test date, and excluding variables not relevant to this analysis such as TX96_STIK_COND, TX96_INSUR_CONFIRM, or TX96_SOFTWARE_VERSION). Additional records with obvious problems were tallied and removed from the dataset (such as invalid/undefined characters stored for a coded categorical variable, or dramatically out-of-range numerical results). Finally, combinations of variables were evaluated for consistency. These steps are described in detail below.

Initial filters and frequency distributions

The following criteria were used to delete records from the full database containing approximately 27 million inspection records to get a set of successful inspections. This deletion covered:

- Out-of-area inspections (not from HGB or DFW areas);
- Aborted inspections (TX96_ABORT = "J", "A");
- Safety-only or visual-only inspections (TX96_TEST_TYPE="H", "P");
- Inspections that were covert audits (TX96_covert_FL not "N");
- Out-of-program model years, older than 1996 or newer than 2021;
- Inspections with invalid VINs, either fewer than 17 characters, including invalid characters (such as "!", "@", etc.), or flagged (TX96_VIN_FL= "B"); and
- Any remaining inspections with TX96_TEST_SEQUENCE less than 1.

In total, these deletions removed about 7.8 million records from the dataset (mostly for safety-only inspections and out-of-area inspections), leaving about 18.9 million potentially valid emissions inspections in the dataset.

Almost every database variable that stores a categorical result was checked for completeness and appropriateness of information. As mentioned above, variables such as TX96_STIK_COND, TX96_INSUR_CONFIRM, or TX96_SOFTWARE_VERSION that have little relevance to emissions inspection impacts are examples of those that were ignored. Most of the variables in the dataset contained the expected information, but after the record deletions described above, a few variables that still contained anomalous information included:

- 6,718 records with an overall inspection cost greater than $100 (TX96_OVERALL_COST>100);
- 176 records with a repair cost greater than $2,000 (TX96_REP_OVERALL_COST>2000); and
- Various other variables that had a small number of missing value results or otherwise odd results that did not appear to be significant.

The anomalous records described in the list above were counted and listed but were not deleted from the dataset. Most of the anomalies were investigated, and the results of those investigations are discussed in further detail in other areas of the report.

B. INSPECTION STATISTICS: NUMBER OF VEHICLES INSPECTED

As a basic summary of the emissions inspections being performed under the Texas I/M program, a number of inspection statistics were calculated. The following tables have changed substantially since the prior I/M Program Evaluation was performed and reported in 2020. The first major change is that a single inspection type, the OBD inspection, is now reported, since the ASM and two-speed idle (TSI) tailpipe inspections have been phased out of the Texas I/M program. Also, new guidance from EPA's Office of Transportation and Air Quality (OTAQ) requires more detailed reporting of inspection results by model year, vehicle type, and final inspection result, so the following tables are much larger than in prior I/M evaluation reports. [2]

Table III-1 shows the inspection statistics for passenger cars in the DFW area. The table includes results for every vehicle tested, beginning with the initial inspection, and continuing through to report the breakdown in the disposition of the initial inspections, as either a passed inspection, a waiver, or a vehicle with no known final outcome. The first column on the left counts every inspection in the dataset, for the two-year period. This will include two annual inspections for most of the vehicles, as well as any retests that are needed to pass the inspection after initially failing it. The total number of initial inspections is given in the second column. A vehicle may be in this column two times (once for an initial inspection in 2020, and once for an initial inspection in 2021), but only two times – retests are not included. The first two

[2] "Guidance on Vehicle Inspection and Maintenance (I/M) Test Data Statistics as Part of Annual I/M Reporting Requirements", EPA OTAQ Transportation and Climate Division, May 2020, EPA-420-B-20-033.

columns are provided for use by TCEQ; they are not required by the OTAQ guidance. The information requested by OTAQ begins at the third column, the number of inspections of unique vehicles. This includes only one count per VIN, i.e., one count for every unique vehicle in the Texas I/M fleet. The columns to the right of that third column continue to subdivide the count of unique vehicles according to their test disposition.

Table III-2 shows the same information for light trucks in DFW. Table III-3 and Table III-4 show the same information for the HGB area.

Table III-1. Number of Inspections for DFW Passenger Cars

Model Year	Total Tests	Total Initial Tests	Total Tested Unique Veh.	Divide Total Tested Vehicles into:		Divide Initially Failing Unique Vehicles into:					
				Initial Pass	Initial Fail	Initial Fail / Ultimate Pass		Initial Fail / Waiver		Initial Fail / No Final Outcome	
						Num.	Pct.	Num.	Pct.	Num.	Pct.
1996	7,817	7,335	4,445	4,074	371	268	72.2%	1	0.3%	102	27.5%
1997	20,199	18,887	8,965	8,193	772	641	83.0%	3	0.4%	128	16.6%
1998	27,831	26,082	11,990	11,037	953	822	86.3%	1	0.1%	130	13.6%
1999	37,731	35,361	16,308	14,975	1,333	1,162	87.2%	1	0.1%	170	12.8%
2000	52,830	49,606	22,556	20,644	1,912	1,679	87.8%	2	0.1%	231	12.1%
2001	61,559	56,005	25,640	22,660	2,980	2,618	87.9%	3	0.1%	359	12.0%
2002	74,894	68,704	31,486	28,156	3,330	2,921	87.7%	3	0.1%	406	12.2%
2003	91,000	84,131	38,166	34,516	3,650	3,169	86.8%	3	0.1%	478	13.1%
2004	105,155	97,524	43,924	39,855	4,069	3,599	88.4%	1	0.0%	469	11.5%
2005	136,370	127,200	56,888	52,038	4,850	4,356	89.8%	3	0.1%	491	10.1%
2006	169,156	158,461	70,194	64,608	5,586	5,007	89.6%	6	0.1%	573	10.3%
2007	208,596	197,283	86,768	80,862	5,906	5,317	90.0%	3	0.1%	586	9.9%
2008	222,074	210,642	91,971	86,115	5,856	5,306	90.6%	1	0.0%	549	9.4%
2009	186,549	177,604	76,678	72,139	4,539	4,166	91.8%	0	0.0%	373	8.2%
2010	221,885	211,680	91,113	86,105	5,008	4,578	91.4%	5	0.1%	425	8.5%
2011	232,319	221,800	95,179	89,969	5,210	4,781	91.8%	1	0.0%	428	8.2%
2012	322,938	309,413	132,649	125,830	6,819	6,233	91.4%	0	0.0%	586	8.6%
2013	368,604	355,073	153,199	146,509	6,690	6,090	91.0%	1	0.0%	599	9.0%
2014	383,936	371,357	159,057	152,757	6,300	5,710	90.6%	0	0.0%	590	9.4%
2015	411,032	398,299	171,639	165,365	6,274	5,705	90.9%	1	0.0%	568	9.1%
2016	390,292	379,564	163,809	158,536	5,273	4,795	90.9%	0	0.0%	478	9.1%
2017	395,893	385,650	168,443	163,184	5,259	4,732	90.0%	1	0.0%	526	10.0%
2018	359,028	351,110	176,366	171,528	4,838	4,274	88.3%	0	0.0%	564	11.7%
2019	188,864	185,413	156,738	153,473	3,265	2,774	85.0%	0	0.0%	491	15.0%
2020	20,905	20,613	19,216	18,837	379	249	65.7%	0	0.0%	130	34.3%
Total	**4,697,457**	**4,504,797**	**2,073,387**	**1,971,965**	**101,422**	**90,952**	**89.7%**	**40**	**0.0%**	**10,430**	**10.3%**

Table III-2. Number of Inspections for DFW Light Trucks

Model Year	Total Tests	Total Initial Tests	Total Tested Unique Veh.	Divide Total Tested Vehicles into: Initial Pass	Initial Fail	Divide Initially Failing Unique Vehicles into: Initial Fail / Ultimate Pass Num.	Pct.	Initial Fail / Waiver Num.	Pct.	Initial Fail / No Final Outcome Num.	Pct.
1996	13,628	12,798	7,650	7,060	590	450	76.3%	1	0.2%	139	23.6%
1997	39,148	36,726	16,079	14,852	1,227	1,055	86.0%	2	0.2%	170	13.9%
1998	47,231	44,321	19,224	17,824	1,400	1,219	87.1%	2	0.1%	179	12.8%
1999	68,436	64,719	27,594	25,806	1,788	1,594	89.1%	3	0.2%	191	10.7%
2000	90,406	85,962	36,367	34,205	2,162	1,952	90.3%	0	0.0%	210	9.7%
2001	119,338	110,630	46,467	42,514	3,953	3,538	89.5%	3	0.1%	412	10.4%
2002	141,100	131,883	55,392	51,089	4,303	3,885	90.3%	0	0.0%	418	9.7%
2003	160,436	150,673	63,531	59,035	4,496	4,094	91.1%	2	0.0%	400	8.9%
2004	187,744	176,497	74,049	68,835	5,214	4,727	90.7%	2	0.0%	485	9.3%
2005	184,967	173,929	72,446	67,294	5,152	4,642	90.1%	3	0.1%	507	9.8%
2006	193,698	182,716	75,578	70,667	4,911	4,503	91.7%	2	0.0%	406	8.3%
2007	255,766	242,244	99,601	93,480	6,121	5,620	91.8%	1	0.0%	500	8.2%
2008	255,437	242,906	99,044	93,483	5,561	5,148	92.6%	0	0.0%	413	7.4%
2009	150,549	143,048	58,677	55,417	3,260	3,038	93.2%	1	0.0%	221	6.8%
2010	204,303	195,087	79,706	75,754	3,952	3,675	93.0%	2	0.1%	275	7.0%
2011	255,382	245,039	100,047	95,543	4,504	4,187	93.0%	0	0.0%	317	7.0%
2012	265,976	256,186	104,266	99,905	4,361	4,054	93.0%	1	0.0%	306	7.0%
2013	334,080	322,727	130,648	125,749	4,899	4,532	92.5%	0	0.0%	367	7.5%
2014	369,525	357,938	144,522	139,567	4,955	4,590	92.6%	0	0.0%	365	7.4%
2015	429,016	417,665	169,549	164,567	4,982	4,625	92.8%	0	0.0%	357	7.2%
2016	448,058	437,504	176,055	171,537	4,518	4,156	92.0%	1	0.0%	361	8.0%
2017	495,358	484,116	196,816	191,643	5,173	4,645	89.8%	0	0.0%	528	10.2%
2018	450,166	440,502	196,606	191,775	4,831	4,261	88.2%	0	0.0%	570	11.8%
2019	247,872	243,493	196,021	192,561	3,460	3,015	87.1%	0	0.0%	445	12.9%
2020	28,809	28,318	25,993	25,479	514	359	69.8%	0	0.0%	155	30.2%
Total	**5,436,429**	**5,227,627**	**2,271,928**	**2,175,641**	**96,287**	**87,564**	**90.9%**	**26**	**0.0%**	**8,697**	**9.0%**

Table III-3. Number of Inspections for HGB Passenger Cars

Model Year	Total Tests	Total Initial Tests	Total Tested Unique Veh.	Divide Total Tested Vehicles into: Initial Pass	Initial Fail	Divide Initially Failing Unique Vehicles into: Initial Fail / Ultimate Pass Num.	Pct.	Initial Fail / Waiver Num.	Pct.	Initial Fail / No Final Outcome Num.	Pct.
1996	5,972	5,545	3,244	2,943	301	229	76.1%	1	0.3%	71	23.6%
1997	15,205	14,128	6,617	6,024	593	482	81.3%	0	0.0%	111	18.7%
1998	21,095	19,613	8,976	8,134	842	708	84.1%	3	0.4%	131	15.6%
1999	28,246	26,288	11,987	10,871	1,116	938	84.1%	2	0.2%	176	15.8%
2000	39,734	36,902	16,715	15,173	1,542	1,321	85.7%	2	0.1%	219	14.2%
2001	46,829	42,436	19,424	17,044	2,380	2,070	87.0%	2	0.1%	308	12.9%
2002	57,721	52,597	23,799	21,104	2,695	2,348	87.1%	4	0.1%	343	12.7%
2003	69,504	63,938	28,948	25,980	2,968	2,615	88.1%	5	0.2%	348	11.7%
2004	78,726	72,543	32,722	29,401	3,321	2,899	87.3%	2	0.1%	420	12.6%
2005	105,347	97,555	43,347	39,276	4,071	3,600	88.4%	2	0.0%	469	11.5%
2006	131,495	121,955	54,387	49,364	5,023	4,450	88.6%	2	0.0%	571	11.4%
2007	163,023	153,109	67,725	62,545	5,180	4,662	90.0%	1	0.0%	517	10.0%
2008	173,505	163,423	71,777	66,535	5,242	4,688	89.4%	2	0.0%	552	10.5%

Model Year	Total Tests	Total Initial Tests	Total Tested Unique Veh.	Divide Total Tested Vehicles into: Initial Pass	Initial Fail	Divide Initially Failing Unique Vehicles into: Initial Fail / Ultimate Pass Num.	Pct.	Initial Fail / Waiver Num.	Pct.	Initial Fail / No Final Outcome Num.	Pct.
2009	150,141	141,789	61,892	57,764	4,128	3,764	91.2%	1	0.0%	363	8.8%
2010	174,264	165,078	71,612	67,038	4,574	4,201	91.8%	2	0.0%	371	8.1%
2011	183,709	174,221	75,043	70,408	4,635	4,214	90.9%	1	0.0%	420	9.1%
2012	248,262	236,350	101,465	95,648	5,817	5,336	91.7%	0	0.0%	481	8.3%
2013	291,183	278,609	119,792	113,731	6,061	5,583	92.1%	1	0.0%	477	7.9%
2014	309,627	297,943	127,098	121,483	5,615	5,182	92.3%	0	0.0%	433	7.7%
2015	335,686	323,897	138,976	133,414	5,562	5,142	92.4%	1	0.0%	419	7.5%
2016	307,932	298,281	129,075	124,592	4,483	4,124	92.0%	1	0.0%	358	8.0%
2017	317,085	308,086	135,796	131,450	4,346	4,005	92.2%	0	0.0%	341	7.8%
2018	293,230	286,607	141,570	137,874	3,696	3,361	90.9%	0	0.0%	335	9.1%
2019	159,696	156,481	125,548	122,801	2,747	2,362	86.0%	0	0.0%	385	14.0%
2020	24,609	24,132	21,705	21,160	545	386	70.8%	0	0.0%	159	29.2%
Total	**3,731,826**	**3,561,506**	**1,639,240**	**1,551,757**	**87,483**	**78,670**	**89.9%**	**35**	**0.0%**	**8,778**	**10.0%**

Table III-4. Number of Inspections for HGB Light Trucks

Model Year	Total Tests	Total Initial Tests	Total Tested Unique Veh.	Divide Total Tested Vehicles into: Initial Pass	Initial Fail	Divide Initially Failing Unique Vehicles into: Initial Fail / Ultimate Pass Num.	Pct.	Initial Fail / Waiver Num.	Pct.	Initial Fail / No Final Outcome Num.	Pct.
1996	10,612	9,862	5,704	5,190	514	393	76.5%	0	0.0%	121	23.5%
1997	31,766	29,417	12,992	11,779	1,213	1,037	85.5%	2	0.2%	174	14.3%
1998	39,657	36,888	15,856	14,505	1,351	1,191	88.2%	3	0.2%	157	11.6%
1999	56,117	52,625	22,280	20,515	1,765	1,552	87.9%	0	0.0%	213	12.1%
2000	76,893	72,214	30,354	28,180	2,174	1,959	90.1%	0	0.0%	215	9.9%
2001	102,448	94,190	39,503	35,681	3,822	3,398	88.9%	2	0.1%	422	11.0%
2002	123,138	114,144	47,716	43,470	4,246	3,777	89.0%	1	0.0%	468	11.0%
2003	137,326	127,842	53,778	49,245	4,533	4,099	90.4%	0	0.0%	434	9.6%
2004	158,071	147,463	61,895	56,848	5,047	4,549	90.1%	1	0.0%	497	9.8%
2005	162,346	151,695	63,449	58,501	4,948	4,462	90.2%	2	0.0%	484	9.8%
2006	180,841	169,671	70,088	64,955	5,133	4,669	91.0%	1	0.0%	463	9.0%
2007	229,423	215,924	89,550	83,361	6,189	5,664	91.5%	1	0.0%	524	8.5%
2008	235,979	222,598	90,750	84,802	5,948	5,491	92.3%	2	0.0%	455	7.6%
2009	140,978	133,071	54,434	50,936	3,498	3,229	92.3%	1	0.0%	268	7.7%
2010	183,428	174,060	70,805	66,717	4,088	3,820	93.4%	2	0.0%	266	6.5%
2011	234,171	223,125	90,183	85,426	4,757	4,425	93.0%	1	0.0%	331	7.0%
2012	246,516	235,880	94,548	89,972	4,576	4,234	92.5%	0	0.0%	342	7.5%
2013	311,026	298,940	119,482	114,331	5,151	4,801	93.2%	0	0.0%	350	6.8%
2014	350,607	338,083	135,045	129,849	5,196	4,849	93.3%	0	0.0%	347	6.7%
2015	413,100	400,907	161,095	155,941	5,154	4,820	93.5%	2	0.0%	332	6.4%
2016	400,819	390,346	156,445	152,081	4,364	4,098	93.9%	1	0.0%	265	6.1%
2017	454,213	443,545	181,288	176,860	4,428	4,124	93.1%	0	0.0%	304	6.9%
2018	431,433	422,104	185,714	181,599	4,115	3,823	92.9%	0	0.0%	292	7.1%
2019	240,532	235,960	182,789	179,357	3,432	3,038	88.5%	1	0.0%	393	11.5%
2020	36,556	35,741	31,712	30,912	800	594	74.3%	0	0.0%	206	25.8%
Total	**4,987,996**	**4,776,295**	**2,067,455**	**1,971,013**	**96,442**	**88,096**	**91.3%**	**23**	**0.0%**	**8,323**	**8.6%**

Inspection counts by model year are presented in the figures below. Figure III-1 shows the number of inspections by model year for the DFW and HGB program areas. The number of inspections by month of inspection is shown in Figure III-2. Finally, the failure rate by model year is shown in Figure III-3 for the DFW and HGB program areas. Only initial inspections are included, but retests are excluded. In general, the trends shown are as expected: more vehicles of newer model years are inspected than vehicles of older model years, and failure rates are considerably higher for older vehicles. The pass-fail rate jumps up for the 2020 and 2021 models; most of the failures for these models are for readiness. This happens because new vehicles usually have a readiness status of not ready for many non-continuous monitors.

Figure III-1. Number of Inspections by Model Year and I/M Program Area

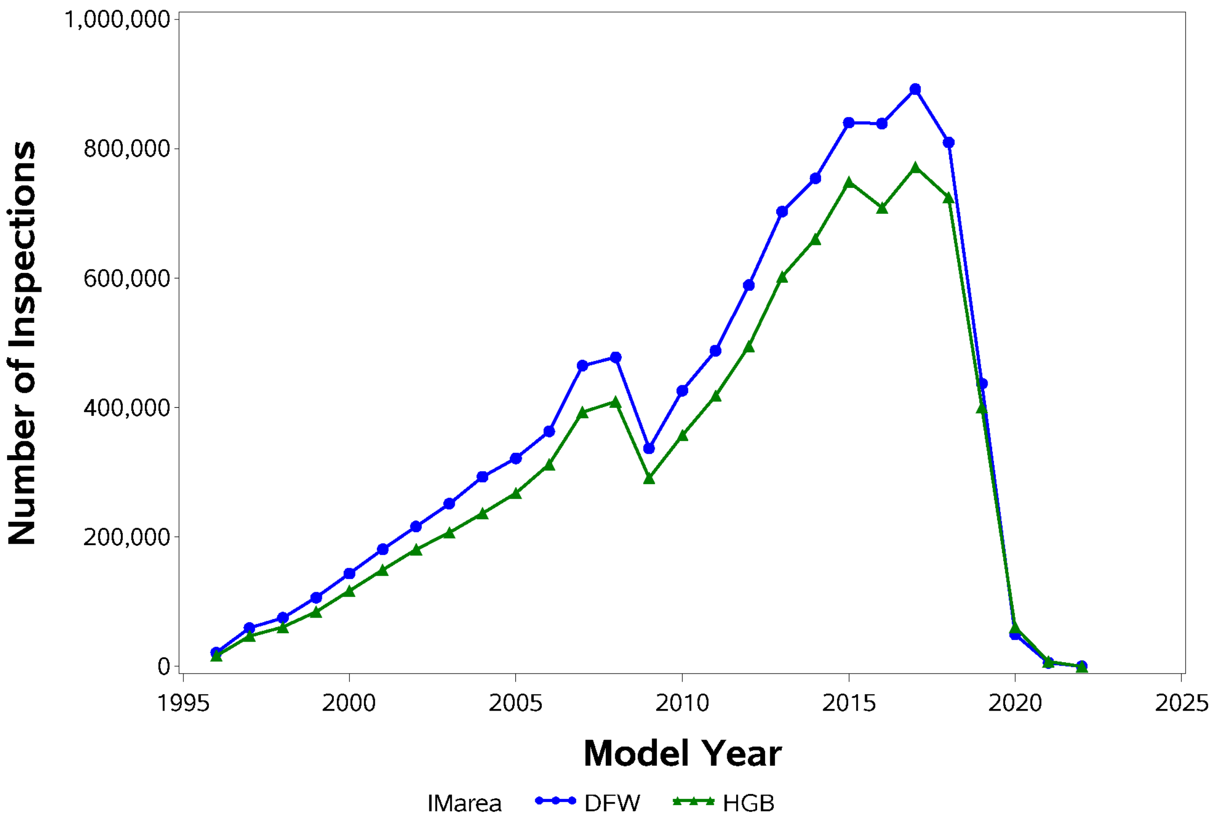


Figure III-2. Number of Inspections by Year and Month of Inspection

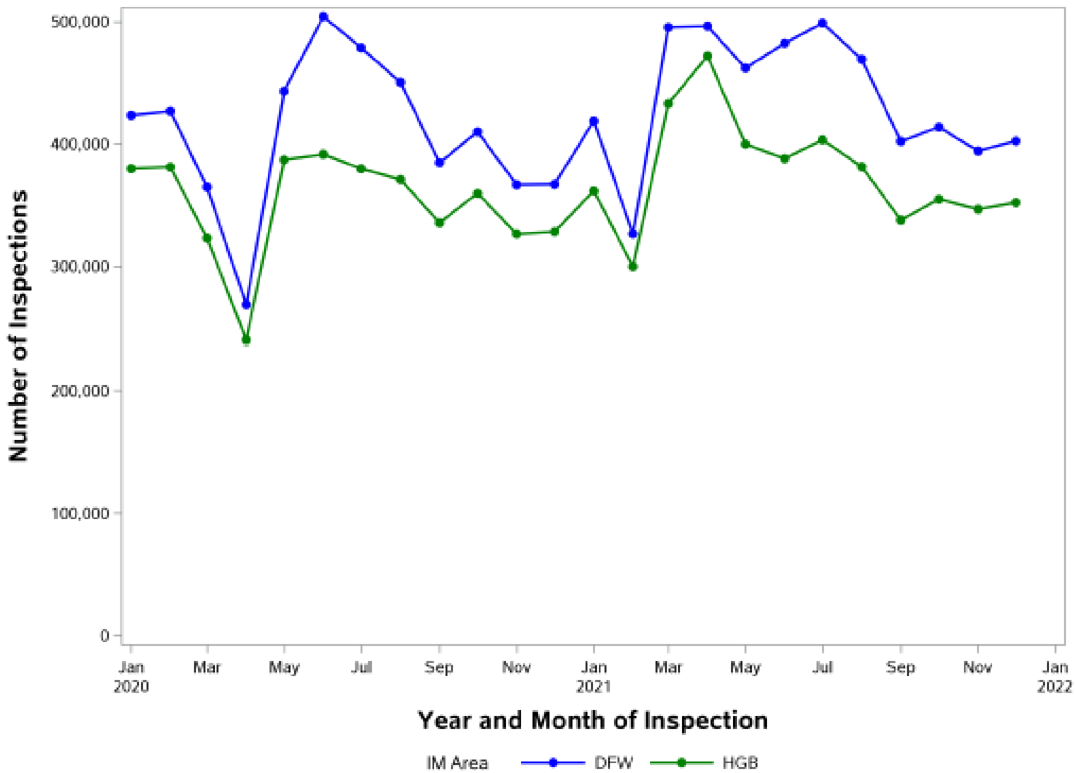
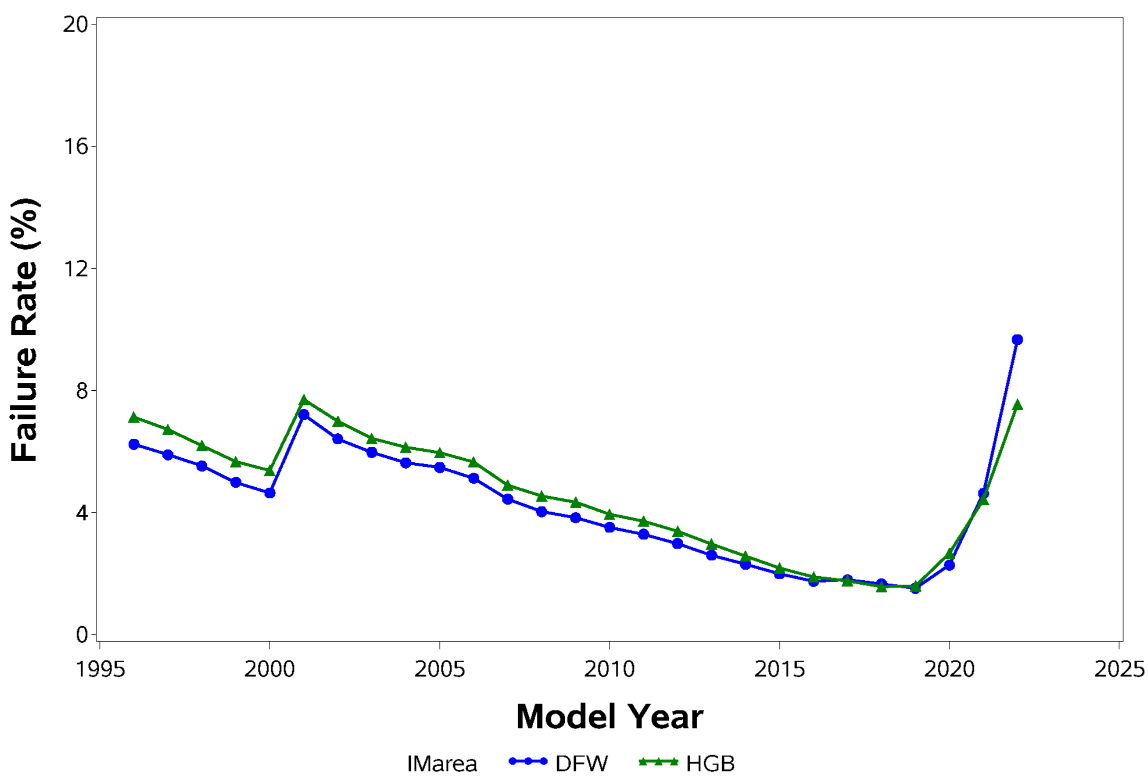


Figure III-3. Initial Inspection Failure Rate by Model Year and I/M Program Area



C. REPEAT I/M FAILURE PATTERNS

ERG examined the TIMS data to determine the patterns of repeat I/M failures. This illustrates the extent and characteristics of repairs related to the Texas I/M program. This analysis was based on the two-year evaluation period, including all of 2020 and 2021. Initial and retest inspections were not determined using the TX96_TEST_SEQUENCE or TX96_TEST_TYPE variables. These database variables are intended to store the number of inspections in an inspection sequence and indicate whether an inspection is an initial or a retest inspection. However, many factors can affect the information stored in these variables, such as the time span between an initial and a retest inspection, whether the motorist chose a different inspection station for the retest, or whether a safety-only inspection was performed at some point. For the purposes of this section and this report, ERG made new initial/retest assignments. The first inspection for a VIN was labeled an initial inspection. Additional inspections to that VIN were labeled as retests until an inspection was passed or a waiver was granted. The next inspection following a passed inspection, or a waiver was labeled an initial inspection. For identifying initial inspections, inspection cycles that appeared to begin in the first four months of 2020 were excluded from the counts as they could have been preceded by additional inspections in 2019.[3] Also, for the purpose of identifying final inspections, any inspection cycles that appeared to end in the last four months of 2021 were excluded as there could be additional inspections in early 2022.

An "inspection sequence" is the series of inspections a vehicle receives as it moves through the Texas I/M program requirements. By far, the most common sequence is a single passed inspection. The second most common sequence is a failed inspection, followed by repair and a passed retest. Additional sequences might include additional failed inspections before the ultimately passed inspection. Sequences should not be found where additional retest inspections follow a passed inspection as these indicate that the measurements and efficacy of the repairs made to the vehicles in the program are less than ideal. For example, a sequence that is fail, fail, fail, fail, pass might indicate either that the motorist is "shopping around" for a passing result, that no repairs were made to the vehicle, that the repairs done to the vehicle were inadequate, or that the test was inaccurate.

Each vehicle was tested at an I/M inspection station on one or more occasions. The dataset contains a variable that gives the type of test (Initial or Retest) and a variable that gives the result of the emissions test (Pass or Fail). Failed inspections were designated with an "F" and passes with a "P." Inspections that resulted in a waiver were designated with a "W." For each unique VIN in the dataset, the designators were concatenated in chronological order to create a sequence that describes the test

[3] In previous years, ERG used a three-month period instead of four. However, the 2020 OTAQ guidance referred to in footnote 1 suggested a change to a four-month period, and ERG has made that change for this document.

pattern that each vehicle experienced during an I/M testing cycle. For example, for a vehicle that initially failed and then passed on a retest, the test sequence would be "FP." The frequency distribution of the resulting test sequences is shown in Table III-5, with results for the DFW and HGB program areas shown separately. The infrequent waiver inspections are included in the "Other" category.

Table III-5. Frequency Distribution of Test Sequences

DFW			HGB		
Inspection Sequence	Number of Vehicles	Percent of Vehicles	Inspection Sequence	Number of Vehicles	Percent of Vehicles
P	7,981,229	95.9%	P	6,763,066	95.5%
FP	280,098	3.4%	FP	264,885	3.7%
F	28,491	0.3%	F	26,075	0.4%
FFP	21,002	0.3%	FFP	19,639	0.3%
FFFP	3,609	0.0%	FFFP	3,149	0.0%
FF	2,375	0.0%	FF	2,258	0.0%
FFFFP	840	0.0%	FFFFP	800	0.0%
FFF	524	0.0%	FFF	494	0.0%
Other	707	0.0%	Other	639	0.0%

In Table III-5, the top two rows, which represent the two "ideal" inspection sequences, comprise about 99% of the total distribution, both in the DFW and HGB program areas. However, some of the other sequences raise questions, such as, what becomes of the vehicles that fail an inspection and do not receive a passing retest? One check that was performed for this set of vehicles was to make sure that they are not being affected by sequences that start near the end of the dataset and might have later retests. It was found that the sequences that end with a failed inspection are distributed fairly uniformly over all months of 2020 and 2021, although some increase is seen in the later months of the dataset. The vehicles that did not complete their inspection sequences and ended with no final passed inspection (NFP), may have moved (or have been re-registered) out of the I/M program area, and therefore may no longer be required to participate in the I/M program. However, some of the NFP vehicles were observed in the I/M program area by RS after their incomplete inspection cycle. These non-compliant vehicles were observed at approximately half the frequency as compliant vehicles. There were 28,491 NFP vehicles in the DFW area, accounting for 8.5% of all failing vehicles, and there were 26,075 NFP vehicles in the HGB area, accounting for 8.2% of all failing vehicles.

Several hundred less common sequences accounted for the remaining 0.01-0.02% of the tested fleets. Many of these remaining sequences seem to be unlikely, involving numerous failed inspections and/or multiple passed inspections. Some of these could be the result of resale vehicles, unidentified covert audit vehicles, or possibly test classification errors instead of real situations. While it might be possible to reduce the occurrence of these unlikely test sequences, the problem is relatively uncommon.

D. OBD INSPECTION ANALYZER COMMUNICATION PERFORMANCE

ERG analyzed TIMS OBD data to look for proper analyzer communication, as it is possible that certain models of analyzers cannot communicate with certain model year, make, and model vehicles. The objective of this task was to analyze TIMS data to determine if certain manufacturers of OBD inspection analyzers appear to have communication problems with certain makes, models, or model year vehicles, which would result in elevated failure to communicate rates for those vehicle groups.

For this task, ERG reviewed OBD inspection records to identify all tests with a result other than “P” in the “OBD2_DLC_RES” field of the test record. For these records, analysis was performed to identify rates of failure to communicate by:

- vehicle model year;
- analyzer manufacturer;
- vehicle make; and
- vehicle model.

Results are presented for each of these four groups.

Three of the 18,889,565 OBD test records had no information stored in the OBD communication result field. These records all had null values for ready result, fault code result, downloaded MIL status, and OBD pass/fail result, and all three had an overall passing result (a "P" in the "OVERALL_RESULTS" field). There were also 522,305 records for vehicles of unknown gross vehicle weight rating (GVWR) or heavy-duty (HD) vehicles (i.e., >8,500 lbs. GVWR). All these records were excluded from the results, leaving 18,367,257 OBD records in the dataset.

Communication Rates by Vehicle Model Year - Table III-6 provides a summary of communication rates by model year of vehicles tested in the program.

The “MODEL_YEAR” field from the vehicle test result tables was used to determine model year. Values and percentages shown in the table are listed by model year. For example, 101,278 OBD tests were conducted on model year 1997 vehicles, and only 138 of these had an OBD fail to communicate status. Overall, very low numbers were seen for “failure to communicate” test results, and the overall “failure to communicate” rates were very low. In addition, most tests with a “failure to communicate” result were followed by a subsequent test of the same vehicle in which OBD communication was successfully established. The overall program-wide communication rate between vehicles and analyzers, excluding the inspections that were removed from the data set as described in Section III.A, is 99.9%.

Table III-6. OBD Communication Rates by Vehicle Model Year

Model Year	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Model Year
	Count	Percent	Count	Percent	Count	Percent	
1996	15	0.04%	89	0.25%	36,100	99.71%	36,204
1997	48	0.05%	190	0.19%	101,040	99.77%	101,278
1998	36	0.03%	254	0.19%	130,067	99.78%	130,357
1999	55	0.03%	338	0.19%	180,068	99.78%	180,461
2000	76	0.03%	491	0.20%	245,635	99.77%	246,202
2001	92	0.03%	593	0.19%	311,972	99.78%	312,657
2002	86	0.02%	704	0.18%	380,008	99.79%	380,798
2003	117	0.03%	789	0.18%	437,389	99.79%	438,295
2004	137	0.03%	890	0.17%	508,808	99.80%	509,835
2005	147	0.03%	953	0.17%	568,834	99.81%	569,934
2006	165	0.03%	946	0.15%	651,230	99.83%	652,341
2007	178	0.02%	946	0.11%	833,682	99.87%	834,806
2008	135	0.02%	887	0.10%	859,452	99.88%	860,474
2009	93	0.02%	589	0.10%	611,943	99.89%	612,625
2010	112	0.01%	729	0.09%	770,348	99.89%	771,189
2011	144	0.02%	844	0.10%	882,633	99.89%	883,621
2012	141	0.01%	971	0.09%	1,057,454	99.89%	1,058,566
2013	153	0.01%	979	0.08%	1,279,559	99.91%	1,280,691
2014	137	0.01%	1,010	0.07%	1,389,234	99.92%	1,390,381
2015	161	0.01%	1,170	0.08%	1,548,894	99.91%	1,550,225
2016	142	0.01%	1,197	0.08%	1,508,209	99.91%	1,509,548
2017	138	0.01%	1,252	0.08%	1,621,383	99.91%	1,622,773
2018	126	0.01%	1,169	0.08%	1,501,434	99.91%	1,502,729
2019	93	0.01%	781	0.10%	810,674	99.89%	811,548
2020	26	0.02%	251	0.23%	106,559	99.74%	106,836
2021	11	0.09%	71	0.58%	12,243	99.33%	12,325
2022	2	0.36%	2	0.36%	554	99.28%	558
Total	**2,766**	**0.02%**	**19,085**	**0.10%**	**18,345,406**	**99.88%**	**18,367,257**

Communication Rates by Equipment Manufacturer –Table III-7 provides results of communication rates among the various analyzer manufacturers. Opus Inspection makes Environmental Systems Products (ESP)-branded analyzers. Records in the TIMS data from ESP analyzers are identified by their a two-letter designation, ES. Similarly, Worldwide Environmental Products makes self-branded analyzers whose records use WW as their two-letter designation. There are very few Snap-On (SE) entries because these analyzers were phased out of the program in early 2020. Also, a small number of analyzers identified as "TX" were found to be ESP analyzers; therefore, they have been included in the ESP total.

Again, the percentages shown for the "damaged, inaccessible, or cannot be found," the "will not communicate," and the "successfully communicates" columns pertain to all tests conducted by each type of analyzer (not percentage of all tests). The two rightmost columns provide counts of tests and percentages of tests by each analyzer manufacturer relative to the total number of tests. For the most part, the rate of communication problems was consistently low for each manufacturer.

Communication Rates by Vehicle Make - To assess communication rates by vehicle make, vehicle registration records were merged with vehicle test records by VIN. Makes that were represented by 100 or fewer vehicles were removed from the table since sample sizes would be too small to provide meaningful results.

Table III-8 provides a summary of communication rates among the various vehicle makes. The incident rates for "damaged, inaccessible, or cannot be found" or "no communication" were very low.

Communication Rates by Vehicle Model - To assess communication rates by vehicle models, the model codes and model names (series) as reported in the vehicle test results tables were used. Table III-9 lists communication rates for each vehicle model code. Records for the more uncommon series, i.e., less than 100 inspection records, were excluded. Because Table III-9 is very long, in the text below, only vehicle makes through Audi are listed. The full table is provided in Appendix A.

It can be seen from the table that no model codes/vehicle series had "damaged, inaccessible, or cannot be found" or "no communication" rates that were greater than 1%, and all were below 0.8% except for Winnebago and Aston Martin. All other vehicles were below 0.5%.

Table III-7. OBD Communication Rates by Equipment Manufacturer

Equipment Manufacturer (EM)	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by EM	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
ESP	2,187	0.02%	14,743	0.11%	14,010,519	99.88%	14,027,459	76.40%
SE	19	0.08%	37	0.15%	24,315	99.77%	24,371	0.10%
WW	560	0.01%	4,305	0.10%	4,310,572	99.89%	4,315,437	23.50%
Total	**2,766**	**0.02%**	**19,085**	**0.10%**	**18,345,406**	**99.88%**	**18,367,257**	**100.0%**

Table III-8. OBD Communication Rates by Vehicle Make

Vehicle Make	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
ACURA	29	0.01%	175	0.07%	241,760	99.92%	241,964	1.37%
ASTON MARTIN	1	0.05%	6	0.33%	1,830	99.62%	1,837	0.01%
AUDI	13	0.01%	166	0.10%	158,155	99.89%	158,334	0.89%
BENTLEY	3	0.08%	2	0.05%	3,841	99.87%	3,846	0.02%
BMW	65	0.02%	511	0.15%	350,233	99.84%	350,809	1.98%
BUICK	21	0.01%	171	0.09%	184,680	99.90%	184,872	1.04%
CADILLAC	38	0.01%	337	0.12%	289,731	99.87%	290,106	1.64%
CHEVROLET	371	0.02%	2,545	0.11%	2,354,111	99.88%	2,357,027	13.31%
CHRYSLER	34	0.02%	210	0.09%	223,972	99.89%	224,216	1.27%
DODGE	142	0.02%	781	0.10%	752,678	99.88%	753,601	4.25%
FERRARI	4	0.12%	6	0.18%	3,252	99.69%	3,262	0.02%
FIAT	4	0.02%	32	0.15%	20,916	99.83%	20,952	0.12%
FORD	440	0.02%	3,247	0.13%	2,450,126	99.85%	2,453,813	13.85%
GENS	1	0.03%	1	0.03%	3,586	99.94%	3,588	0.02%
GMC	73	0.01%	592	0.10%	574,107	99.88%	574,772	3.24%
HONDA	209	0.01%	1,210	0.08%	1,554,760	99.91%	1,556,179	8.78%
HUMMER	6	0.05%	30	0.24%	12,246	99.71%	12,282	0.07%
HYUNDAI	67	0.01%	467	0.08%	559,694	99.90%	560,228	3.16%
INFINITI	22	0.01%	186	0.07%	259,600	99.92%	259,808	1.47%
ISUZU	3	0.03%	27	0.29%	9,195	99.67%	9,225	0.05%
JAGUAR	1	0.00%	58	0.15%	38,780	99.85%	38,839	0.22%
JEEP	87	0.01%	638	0.11%	586,256	99.88%	586,981	3.31%
KIA	26	0.01%	285	0.06%	454,901	99.93%	455,212	2.57%
LAND ROVER	6	0.01%	73	0.10%	72,790	99.89%	72,869	0.41%
LEXUS	66	0.01%	487	0.08%	613,206	99.91%	613,759	3.46%

Vehicle Make	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
LINCOLN	37	0.03%	260	0.18%	144,306	99.79%	144,603	0.82%
MASERATI	3	0.03%	12	0.13%	9,172	99.84%	9,187	0.05%
MAZDA	61	0.02%	683	0.23%	298,798	99.75%	299,542	1.69%
MERCEDES	15	0.03%	85	0.16%	53,509	99.81%	53,609	0.30%
MERCURY	62	0.01%	500	0.12%	423,633	99.87%	424,195	2.39%
MITSUBISHI	24	0.02%	262	0.24%	107,369	99.73%	107,655	0.61%
MINI	6	0.01%	47	0.10%	45,431	99.88%	45,484	0.26%
NISSAN	234	0.02%	1,178	0.08%	1,466,781	99.90%	1,468,193	8.29%
OLDSMOBILE	2	0.03%	16	0.27%	5,836	99.69%	5,854	0.03%
PONTIAC	14	0.02%	116	0.19%	59,939	99.78%	60,069	0.34%
PORSCHE	22	0.03%	216	0.33%	64,661	99.63%	64,899	0.37%
RAM	15	0.01%	173	0.11%	156,812	99.88%	157,000	0.89%
SAAB	2	0.04%	10	0.22%	4,444	99.73%	4,456	0.03%
SATURN	6	0.01%	77	0.19%	40,207	99.79%	40,290	0.23%
SCION	4	0.01%	56	0.09%	65,333	99.91%	65,393	0.37%
SUBARU	15	0.01%	188	0.12%	159,225	99.87%	159,428	0.90%
SUZUKI	8	0.06%	38	0.28%	13,643	99.66%	13,689	0.08%
TOYOTA	337	0.01%	2,004	0.08%	2,459,800	99.90%	2,462,141	13.90%
VOLKSWAGEN	61	0.02%	383	0.15%	260,346	99.83%	260,790	1.47%
VOLVO	9	0.01%	64	0.08%	79,793	99.91%	79,866	0.45%
OTHER	95	0.01%	449	0.07%	635,108	99.91%	635,652	3.59%
Total	**2,669**	**0.02%**	**18,611**	**0.11%**	**17,693,444**	**99.88%**	**17,714,724**	**100.00%**

Table III-9. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
ACUR								
3.2TL	1	0.03%	5	0.14%	3,673	99.84%	3,679	0.02%
ILX 20	2	0.04%	3	0.05%	5,469	99.91%	5,474	0.04%
MDX	7	0.01%	32	0.05%	64,221	99.94%	64,260	0.42%
RDX	4	0.01%	29	0.07%	43,798	99.92%	43,831	0.29%
RL	1	0.04%	3	0.12%	2,604	99.85%	2,608	0.02%
RSX	1	0.04%	6	0.23%	2,652	99.74%	2,659	0.02%

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
TL	6	0.02%	32	0.09%	36,340	99.90%	36,378	0.24%
TSX	3	0.01%	15	0.06%	24,482	99.93%	24,500	0.16%
AUDI								
A4	1	0.00%	22	0.08%	25,929	99.91%	25,952	0.17%
A5 Cabriolet	1	0.03%	2	0.05%	3,847	99.92%	3,850	0.03%
A6	4	0.02%	16	0.08%	20,472	99.90%	20,492	0.14%
Q3	1	0.01%	9	0.11%	8,002	99.88%	8,012	0.05%
Golf/GTI	3	0.02%	20	0.15%	13,022	99.82%	13,045	0.09%
Golf/GTI/Jetta/ Jetta Sportage	2	0.01%	33	0.11%	30,043	99.88%	30,078	0.20%

Again, the full table can be found in Appendix A.

E. TIMS HANDLING OF OBD CODES

ERG analyzed TIMS OBD data to evaluate the accuracy of OBD data collected in the Texas I/M program. This is a process-based measure for inspection effectiveness. The handling of OBD readiness, diagnostic trouble codes, and communication failures varies among I/M programs. The objective of this task was to analyze OBD inspection records to ensure OBD test results are appropriate for various OBD test dispositions, such as a vehicle with too many OBD monitors “not ready,” a vehicle with “pending” DTCs, or a vehicle that fails to communicate with the analyzer.

Program Description and Results of Analysis

Proper handling of various OBD test scenarios is defined in Parts 85.2207 and 85.2222 of Title 40 of the CFR and also in various OBD implementation guidance documents issued by the EPA. Appropriate responses to the various test scenarios are summarized here and serve as the basis for analysis in this task. The dataset for this analysis included records for OBD inspections between January 1, 2020, and December 31, 2021. Records for inspections that were aborted were excluded from the dataset, as were records for which either the OBD result or the overall result was not “P” (pass) or “F” (fail). Because this analysis was performed with the goal of determining whether OBD inspection guidelines are enforced, only records for light-duty vehicles were used. Downloaded OBD test pass/fail results are not enforced for HD vehicles (i.e., vehicles with a GVWR greater than 8,500 pounds); therefore, these vehicles were removed from the dataset. HD vehicles were identified as those with the tx96_type field equal to one and the tx96_gvw_actual field between zero and 8,501. Vehicles with no GVWR given were also removed since these might be HD vehicles. Following these removals, 18,366,662 records remained in the dataset.

Diagnostic Link Connector Communication Status – According to federal guidelines, a diagnostic link connector (DLC) that is missing, tampered, or otherwise inoperable is a basis for failure, but the vehicle may be "rejected" for a DLC that is inaccessible or cannot be located. Failure to communicate with an OBD analyzer is also a basis for failure. To perform this analysis, the result stored in the "OBD2_DLC_RES" field was compared with that in the "OBD2_PF_FLAG" field. No test results with a "D" (damaged), "N" (connected but will not communicate), "L" (inspector cannot find DLC), or "I" (DLC is inaccessible) in the "OBD2_DLC_RES" should have a "P" in the "OBD2_PF_FLAG". Results of this analysis are shown in Table III-10.

Table III-10. Comparison of DLC Communication Status with Overall OBD Test Results

DLC Communication Status	Overall OBD Test Results	
	Fail	Pass
"D" (damaged)	1,134	0
"I" (DLC is inaccessible)	608	1
"L" (inspector cannot find DLC)	1,002	17
"N" (connected but will not communicate)	19,082	1
Sub-Total count of "D", "I", "L", and "N" Tests	**21,826**	**19**
"P" (communication successful)	647,851	17,696,966
Total	**669,677**	**17,696,985**

As can be seen in the table, 19 test records have a DLC communication status of "D", "I", "L", or "N," yet have an OBD test result of "pass." For these records, it was noted that no result was given for monitor readiness (which should have been a "pass" in order to pass the OBD inspection). It is not clear what led to the passing result for those records. In conclusion, the DLC failure to communicate was enforced on the vast majority of OBD tests conducted on light-duty vehicles during the period of evaluation.

Because successful communication with the inspection analyzer is critical for all other OBD results, the OBD records with OBD2_DLC_RES results other than "P" were removed from the dataset for the other analyses that comprise the remainder of this section. This left 18,344,817 records in the dataset.

Agreement between OBD test result and overall test result – A vehicle that fails the OBD inspection should fail the overall inspection. To determine if OBD failures were properly recorded in the overall inspection disposition, a query was performed to quantify the number of vehicles that failed the OBD portion of the test ("F" in the "OBD2_PF_FLAG" field) but passed the overall OBD test ("P" in the "OVERALL_RESULTS" field). Table III-11 shows that no tests were recorded with a "fail" in the OBD portion of the test and a "pass" for the overall test

Table III-11. Comparison of OBD Test Result with Overall Test Result

Result of OBD Test	Overall Test Result				Total	
	Fail		Pass			
Fail	647,851	100.0%	0	0.0%	647,851	3.5%
Pass	206,124	1.2%	17,490,842	98.8%	17,696,966	96.5%
Total	**853,975**	**4.7%**	**17,490,842**	**95.3%**	**18,344,817**	**100.0%**

Inspector-Entered MIL bulb check - This is also referred to as the Key On / Engine Off (KOEO) check. The inspector is instructed to turn the vehicle's ignition key to the "on" position, but not start the vehicle, to illuminate the MIL. Results are manually entered into the analyzer (via keyboard) by the inspector. If the MIL does not illuminate, the vehicle should fail the OBD portion of the inspection.

To perform this analysis, the results for the inspector keyboard-entered MIL bulb check ("OBD2_MIL_CHECK" field of the test record) were compared with results of the overall OBD test result ("OBD2_PF_FLAG" field), to ensure that a MIL bulb check failure always results in an OBD test failure. The "OBD2_MIL_CHECK" results are "Y" or "K", which is a pass (yes, the MIL did illuminate or keyless ignition), and "N", which is a fail (no, the MIL did not illuminate). There were no records where a KOEO MIL result of "N" (fail) did not receive a failing OBD result. This is a new and positive result as prior I/M evaluation reports had observed at least a few dozen records where the "N" result did not receive a failing OBD result. The 65 inspections for which no KOEO result was available also received a failing result. The results are presented in Table III-12 below.

Table III-12. Comparison of KOEO MIL Bulb Check Result with Overall OBD Test Result

Result of KOEO MIL Bulb Check	Overall OBD Test Result		Total
	Fail	Pass	
(missing result)	65	0	65
N (fail)	13,771	0	13,771
K (pass)	49,161	2,291,954	2,341,115
Y (pass)	584,854	15,405,012	15,989,866
Total	**647,851**	**17,696,966**	**18,344,817**

Inspector-Entered Engine-Running MIL Illumination Status – The KOER result manually entered by the inspector is a basis for failure. No vehicle with an "F" in the "OBD2_MIL_ON_RUN" field should have a "P" in the "OBD2_PF_FLAG" field of the OBD test record. The "OBD2_MIL_ON_RUN" results are "Y," which is a pass (Y = MIL turned off after the vehicle was started) or "N," which is a fail (N = MIL stayed illuminated after the vehicle was started). Table III-13 shows that the MIL Illumination Status appears to be enforced as a condition for OBD failure: no inspections were recorded with a MIL Illumination status of "N" and an overall OBD result of "P." However, since the KOER MIL Illumination Status is manually entered by the inspector, accuracy of this entry is not automatically enforced by the analyzer. As shown in Table III-14, in 171,707 inspections a "pass" result was manually entered when the downloaded MIL status indicated a “fail” result, and a “fail” result was entered 7,618 times when the MIL status indicated a “pass” result. These latter cases are possible false failures; TCEQ should consider a specification change where passing MIL Status would result in a passing OBD result despite a KOER result of fail.

Table III-13. Comparison of Inspector-Entered MIL Illumination Status (Engine Running, KOER) with Overall OBD Test Result

Result of MIL Illumination Status	Overall OBD Test Result		Total
	Fail	Pass	
(missing result)	65	0	65
N (Fail)	25,872	0	25,872
Y (Pass)	621,914	17,696,966	18,318,880
Total	**647,851**	**17,696,966**	**18,344,817**

Table III-14. Comparison of Downloaded MIL Command Status with Inspector-Entered MIL Illumination Status (Engine Running, KOER)

Result of Downloaded MIL Status	Result of MIL Illumination Status			Total
	(missing result)	Fail	Pass	
(missing result)	2	0	0	2
Fail	0	18,254	171,707	189,961
Pass	63	7,618	18,147,173	18,154,854
Total	**65**	**25,872**	**18,318,880**	**18,344,817**

MIL Commanded On – A vehicle with the MIL commanded on and with stored emissions-related DTCs should fail the OBD inspection, regardless of readiness status. The TIMS software ignores manufacturer-specific (non-generic) DTCs in this pass/fail determination. To perform this analysis, all OBD test records were reviewed to determine the overall OBD pass/fail status in comparison with the downloaded MIL command status results. Specifically, any vehicle with “F” in the “OBD2_MIL_STATUS” should also have “F” in the “OBD2_PF_FLAG” field (if DTCs are present). Table III-15 provides the results of this review.

Table III-15. Comparison of Downloaded MIL Command Status with Overall OBD Test Result

Result of Downloaded MIL Status	Overall OBD Test Result				Total	
	Fail		Pass			
Fail	126,904	19.6%	63,057	0.4%	189,961	1.0%
Pass	520,945	80.4%	17,633,909	99.6%	18,154,854	99.0%
Total	**647,849**	**100.0%**	**17,696,966**	**100.0%**	**18,344,815**	**100.0%**

From Table III-15, it can be seen that 63,057 test records (0.4% of all OBD “pass” test records) have a MIL commanded on status yet receive an overall OBD pass result. However, 62,953 of the 63,057 tests had no stored DTCs, in which case it is appropriate to pass the test. The 104 remaining inspections had one or more DTCs stored, and should have resulted in a failed OBD result, since the MIL was commanded on. In conclusion, the downloaded OBD MIL command status was enforced for almost all OBD tests conducted on light-duty vehicles (≤ 8500 lbs. GVWR) with stored DTCs during the period of evaluation.

Readiness Evaluation – Federal guidelines recommend two or fewer unset non-continuous monitors be allowed for MY 1996 through 2000 vehicles and only one (or none) unset non-continuous monitors be allowed for MY 2001 and newer vehicles. Vehicles with higher counts of unset non-continuous monitors should not receive a pass result. They should be failed or rejected based on the OBD system's readiness status.

To perform this analysis, the OBD readiness status of test records was compared on a model-year basis to evaluate conformance with the readiness guidelines. Vehicles of model years 1996 through 2000 with three or more "not ready" non-continuous monitors should have an OBD readiness failure ("F" in the "OBD2_READY_RES" field of the test record) and an OBD test result of fail ("F" in the "OBD2_PF_FLAG" field of the test record). Vehicles with two or fewer "not ready" non-continuous monitors should have an OBD readiness result of pass ("P" in the "OBD2_READY_RES" of the test record). The 2001 and newer vehicles with two or more "not ready" non-continuous monitors should have an OBD readiness failure ("F" in the "OBD2_READY_RES" of the test record) and an OBD test record result of fail ("F" in the "OBD2_PF_FLAG" field of the test record), while 2001 and newer vehicles with one or fewer "not ready" non-continuous monitors should have an OBD readiness result of pass ("P" in the "OBD2_READY_RES" field of the test record).

Table III-16 compares OBD readiness status with the number of unset monitors for all OBD tests. Only non-continuous and "enabled" monitors are presented in this comparison.

Table III-16. Unset Monitors vs. Test Readiness Status for Inspections

Count of Unset Non-Continuous Monitors	Counts of Tests of Vehicles Model Year 1996 through 2000		Counts of Tests of Vehicles Model Year 2001 and newer	
	OBD "Not Ready"	OBD "Ready"	OBD "Not Ready"	OBD "Ready"
0	1	418,263	81	15,231,701
1	0	192,138	8	1,915,003
2	11	53,454	220,824	492
3	13,451	0	142,446	1
4	8,264	0	100,980	0
5	5,335	0	35,907	0
6	198	0	1,618	0
8	0	0	11	0
Total	**27,260**	**663,855**	**501,875**	**17,147,197**

Results in Table III-16 show that a small number of tests (a total of 82) appear to have received an OBD "not ready" status despite having no unset monitors and another 19 not ready despite fewer monitors below the limit. Also, 492 vehicles of model year

2001 or newer with two unset readiness monitors still received a readiness result of "pass." The majority of these were tested using the ESP equipment.

Table III-17 shows these data in greater detail, separated by model year.

Table III-17. Unset Monitors vs. Test Readiness Status for Inspections by Model Year

Model Year	Count of Unset Non-Continuous Monitors							
	0		1		2		3 or more	
	OBD Not Ready	OBD Ready	OBD Not Ready	OBD Ready	OBD Not Ready	OBD Ready	OBD Not Ready	OBD Ready
1996	0	20,689	0	10,541	0	3,001	1,633	0
1997	1	57,497	0	30,154	0	8,430	4,133	0
1998	0	77,985	0	35,809	0	10,395	5,325	0
1999	0	108,466	0	50,406	0	13,781	7,327	0
2000	0	153,626	0	65,228	11	17,847	8,830	0
2001	0	201,200	0	88,914	11,403	54	10,269	0
2002	3	256,781	0	100,404	11,168	48	11,462	0
2003	1	293,928	0	119,558	12,199	55	11,472	0
2004	1	356,824	0	125,525	13,230	82	12,923	1
2005	0	414,079	0	126,156	13,334	56	15,027	0
2006	1	483,164	0	137,445	14,096	49	16,258	0
2007	4	640,346	1	159,714	14,388	40	18,931	0
2008	2	687,588	2	139,603	14,667	31	17,294	0
2009	1	504,498	0	85,455	9,904	16	11,918	0
2010	3	653,328	0	91,531	10,722	13	14,606	0
2011	5	757,439	0	97,802	11,773	10	15,459	0
2012	10	926,453	0	101249	12,120	14	17,450	0
2013	8	1,145,642	2	102442	12,103	7	19,213	0
2014	4	1,260,024	0	99,137	11,004	8	18,915	0
2015	11	1,429,606	2	90,402	11,243	6	17,495	0
2016	7	1,409,715	0	73,903	9,724	0	14,771	0
2017	11	1,520,171	0	74,254	11,379	2	15,491	0
2018	7	1,422,325	1	55,858	9,802	0	13,373	0
2019	2	759,296	0	39,223	5,163	1	6,958	0
2020	0	98,469	0	5,561	1,152	0	1,376	0
2021	0	10,825	0	867	250	0	301	0
Total	**82**	**15,649,964**	**8**	**2,107,141**	**220,835**	**53,946**	**308,210**	**1**

Comparison of readiness result with overall pass/fail result – The pass/fail disposition of the readiness result field of the test record was compared with the overall OBD test disposition to see if any vehicles with a "not ready" status (as determined automatically by the analyzer) received an overall OBD test result of "pass." To perform this analysis, the "OBD2_READY_RES" field was compared to the "OBD2_PF_FLAG" fields in the analyzer OBD test records. These records with transitional vehicles were excluded from this analysis of readiness to prevent any confusion in the results, leaving 18,343,284 records in the dataset for this analysis. The results are shown in Table III-18.

Table III-18. Comparison of Readiness Status Field with Overall OBD Test Result

Readiness Status Check	Overall OBD Test Result					
	Fail		Pass		Total	
(Missing result)	6	0.0%	3,091	0.0%	3,097	0.0%
Fail (Not Ready)	526,906	81.3%	2,229	0.0%	529,135	2.9%
Pass (Ready)	120,864	18.7%	17,690,188	100.0%	17,811,052	97.1%
Total	**647,776**	**100.0%**	**17,695,508**	**100.0%**	**18,343,284**	**100.0%**

As can be seen in Table III-18, 2,229 of the vehicles with a "not ready" status received an overall "pass" result for the OBD portion of the test. This represents less than 0.013%; therefore, the value in Table III-18 is shown as 0.0%. This indicates that the OBD readiness status (as determined by the analyzer and stored in the OBD2_READY_RES" field of the test record) was almost always enforced for OBD tests performed during the period of evaluation. Note that the first row of the table, for 3,097 records with a missing result for the readiness status check, is a new addition for 2022. It is not clear why these records were able to receive mostly passing inspections, without having received a readiness result.

IV. REPAIR

ERG used TIMS data from January 1, 2020, through December 31, 2021, to analyze repair activities to demonstrate the extent and effectiveness of repairs directed by the Texas I/M program. This task will cover process-based measures for repair effectiveness.

There are several issues with the repair data contained in the TIMS dataset that make analysis difficult. Future changes in the way data are collected and stored may alleviate many of these issues. These issues are described below and are very similar to those listed in previous reports.

Repair data in the TIMS are entered by the inspector performing the inspection; however, the motorist often does not bring the vehicle repair form for the re-inspection, and this leads to the inspector leaving this information blank. Most repair entries in the TIMS are made by inspectors who either work in the same facility where the re-inspection takes place or make the repairs themselves.

The TIMS repair data include only five different repair types, and these types are too general to permit a detailed analysis of the data. These types include fuel system, ignition/electrical system, emissions system, engine mechanical, and miscellaneous. As listed in Table IV-1, below, "miscellaneous" repairs make up almost 40% of the reported repairs. The addition of more detailed repair types during the collection of data would allow for more specificity in analysis. Previously, the Texas I/M program did have a more detailed list of repair types. However, because the TCEQ believed that a large fraction of inspectors did not fill out the repair list correctly, the TCEQ adopted the simpler list that been used for many years. Accuracy and completeness of repair data are common issues in I/M programs that attempt to collect repair data.

It is recommended that the TCEQ consider increasing the number of repair categories in the analyzer software and eliminating the "Miscellaneous" category since that does not provide any useful information. Ideally, the repair choices that inspectors see and choose from would be only those that apply to the technology of the vehicle being inspected, although that does involve an increase in program complexity.

Another problem, described in the costs section below, exists in the reported values of repair costs. Many repairs with a cost of zero exist in the dataset, along with some extremely high (e.g., greater than $2,000) costs as well. The source of these zero cost entries is not clear, but their presence makes it difficult to comprehensively assess costs across the entire dataset because they skew the results downward.

A. NUMBER AND TYPES OF REPAIRS

ERG performed analysis on the number and types of repairs for the two years of TIMS data. The inspectors at Texas I/M stations have an opportunity to enter vehicle repair information into the inspection analyzer prior to conducting an emissions retest. A simple count of the number of repairs entered and stored in the TIMS and a distribution of the repair types suggests the Texas I/M program is resulting in vehicles being repaired.

General I/M Repairs

As noted above, the TIMS database, provided by the TCEQ for this analysis, contained many repair entries but relatively little detail on the nature of repairs performed. The five repair categories listed in the TIMS, along with the corresponding number of performed repairs, are presented in Table IV-1 by model year group.

Table IV-1. Repairs Listed in the TIMS

Repair Type	Model Year	Number of Repairs	% of Repair Type	% of Total
Fuel System	1996–1999	1,962	5.2%	2.1%
	2000–2006	13,556	36.1%	14.2%
	post-2007	22,079	58.7%	23.2%
	Total	*37,597*	*100.0%*	*39.5%*
Ignition / Electrical System	1996–1999	476	6.4%	0.5%
	2000–2006	2,768	36.9%	2.9%
	post-2007	4,252	56.7%	4.5%
	Total	*7,496*	*100.0%*	*7.9%*
Emissions System	1996–1999	966	6.4%	1.0%
	2000–2006	5,549	37.0%	5.8%
	post-2007	8,467	56.5%	8.9%
	Total	*14,982*	*100.0%*	*15.7%*
Engine Mechanical	1996–1999	80	7.6%	0.1%
	2000–2006	373	35.5%	0.4%
	post-2007	598	56.9%	0.6%
	Total	*1,051*	*100.0%*	*1.1%*
Miscellaneous	1996–1999	1,947	5.7%	2.0%
	2000–2006	12,301	36.1%	12.9%
	post-2007	19,844	58.2%	20.8%
	Total	*34,092*	*100.0%*	*35.8%*
	Grand Total	**95,218**		**100.0%**

B. SUCCESS OF REPAIRS TO VEHICLES FAILING OBD

The objective of this task was to determine whether vehicles failing the OBD inspection were being properly repaired. ERG performed an analysis of the TIMS data for OBD failures and the presence of an illuminated MIL and DTCs followed by an OBD pass (readiness criteria met, MIL commanded off and no DTCs) as an indicator that the I/M program is resulting in OBD repairs. In this analysis, it is assumed that an OBD fail result followed by an OBD pass result is due to vehicle repairs, although it is possible that some of the OBD fails followed by an OBD pass could result from intermittent problems, self-correcting problems (such as a loose gas cap that is tightened upon a vehicle refuel) or an OBD problem that is masked by unset readiness monitors (e.g., through a battery disconnect) on a subsequent passing retest. For example, after DTCs are cleared, it might be possible to pass a retest if the monitor associated with the DTC has not reset to ready. This "masking" issue is analyzed later in this section.

Since the electronic OBD information is not used to determine the pass or fail status of HD vehicles during OBD inspections, the records from their inspections were excluded from this analysis. This left a dataset of 18,345,242 OBD inspection records available for the analysis.

Overall Success of Repairs to Vehicles Failing OBD

For this task, ERG analyzed vehicle inspection records to identify tests with OBD failures and then determined how many of those failures were subsequently corrected. In addition, ERG created very specific definitions of OBD "fail" and "pass" to exclude initial test failures associated with readiness, failures due to OBD/analyzer communication problems, OBD test failures associated with inspector-entry, and bulb-illumination checks. An OBD test failure was defined to be any test record with one or more stored DTCs, coinciding with the OBD MIL command status of "on." A passing result for an OBD test was defined as a downloaded OBD MIL commanded status of "off." These definitions were needed in order to fully control the analysis of MIL status, but they did leave some inspections that did not qualify as either a full "fail" or a full "pass" (i.e., OBD test was passed but overall, I/M test was failed, etc.).

Next, all individual vehicle I/M cycles that contained at least one failed OBD test were identified. I/M cycles were defined to be a single test, or a series of tests, performed on a vehicle until the vehicle either passed the overall inspection or received a waiver. Thus, if a vehicle failed the initial OBD test, the I/M cycle for that vehicle would be the initial failure and any and all subsequent tests, until the vehicle passed its inspection or received a waiver, or the evaluation period ended. Once the vehicle passed its inspection, its next test (most likely for the following year's I/M inspection) would be a new I/M cycle. Any I/M cycles that began on or after September 1, 2021, were excluded from the analysis, since it would be possible that cycles starting so near the end of the date range of the dataset could have included additional re-inspections after December 31, 2021, and there would be no information for those inspections. Using these criteria, the dataset contained 14,823,813 OBD I/M cycles (including single-OBD-test passes) that started before September 1, 2021.

After grouping by I/M cycle for vehicles with OBD failures (as previously defined), 95,897 I/M cycles were seen to include at least one failed OBD test. Of these cycles, 77,462 (81%) had a final OBD test disposition of "pass," which for purposes of this analysis was defined as a test with a commanded MIL status of "pass" (MIL commanded off) and an OBD test disposition of "pass." Of the remaining vehicles that never passed a subsequent OBD test, 199 received waivers, but the majority simply failed to report for additional inspections to complete the program requirements, although additional re-inspections may have occurred after December 31, 2021, which would increase the overall “repaired” numbers. Note that this indicates a higher “no-final-pass” rate than that reported above in Section III. The results here are using stricter criteria for passing the test and are therefore different than the results in Section III that were simply based on the recorded pass/fail result.

It should be noted that the two allowed unset monitors could mask existing malfunctions in some of these repaired outcomes. The influence of this masking is explored later in this section.

Success of Repairs to Specific Emission Control Systems Failing OBD

For this analysis, DTCs were categorized based on the type of monitored system, and using this categorization, ERG performed an analysis of repairs based on component categories to determine if the program was resulting in effective emission control system repairs. This task was performed as a continuation of the analysis in Section C. It uses combinations of vehicles and I/M cycles defined in that section. However, for this task, failure modes were assigned based on the DTCs contained in the failed test records.

Specifically, the analysis was performed on vehicles with DTC failures associated with oxygen sensors (O_2 Sensor), exhaust gas recirculation systems (EGR System), secondary air injection systems (AI System), catalytic converter efficiency (Catalyst), and evaporative emissions control system (Evap System) components.[4] The O_2 Sensor, EGR System, AI System, and Catalyst were included with this analysis because the readiness status of these systems, as well as the evaporative system, are specifically monitored by non-continuous monitors, and therefore the extent to which malfunctions may be masked by unset readiness monitors during a retest (which could result in a false pass) can be quantified. In this analysis, the extent of this potential masking is quantified along with the overall repair rates as indicated by a “fail” test followed by a “pass” test.

For each of the failure categories, a failed inspection is defined as any inspection that contains at least one test record with stored DTCs, a downloaded OBD MIL commanded status of “on,” an OBD test disposition of “fail,” and an overall test disposition of “fail.” Passed inspections were those that had a final test in that I/M cycle with a downloaded MIL status of “pass” (not commanded on) and an OBD test disposition of “pass.”

To quantify the upper limit to which readiness may be masking unrepaired malfunctions during OBD retests, the following distinctions of “repaired” vehicles were made:

[4] A list of DTCs that were included in each of these groups is given in Appendix B.

- Total Repaired – This is the count of all vehicles that had at least one “fail” test with the final test classified as “repaired.” No regard is given to which (if any) monitors remain unset.
- Repaired with Unset Monitors – This is the count of all “repaired” vehicles that have an unset monitor that may be masking the failure mode seen in the initial “fail” test. For example, if a vehicle fails for an evaporative system malfunction, then the evaporative system monitor is unset on the final “pass” test for this vehicle, thereby possibly masking an unrepaired evaporative system malfunction. Once this monitor becomes “ready,” any unrepaired malfunction would result in a stored evaporative system DTC and MIL re-illumination.
- Confirmed Repaired – These are the vehicles whose monitors for which the initial failure occurred are “ready” in the final test, indicating that specific type of failure is not being masked by a “not-ready” monitor. Therefore, there is much higher confidence that these “confirmed repaired” vehicles are indeed properly repaired.

During this analysis of readiness status, some vehicles that failed for a certain system (e.g., EGR) were found to have a “not monitored” status for that monitored system (e.g., EGR not monitored). This might have been due to DTCs being generated by a continuous monitor; however, by definition, this should not be possible since a system with a stored code must be monitored. Therefore, this subset of results was classified as “ready.” Because this subset of inspections was failed, it seems that incorrect reporting of monitor status is truly the cause as opposed to potential inspection fraud through “clean-scanning.”

Regarding criteria used for categorizing “pass” and “fail” tests, it should also be noted that historical or permanent DTCs without MIL illumination are trouble codes for previous malfunctions that do not necessarily indicate a current malfunction. In accordance with the EPA guidance, vehicles are not failed for historical or non-MIL permanent DTCs, that is, stored DTCs but no MIL. Pending DTCs or permanent DTCs are not collected in the Texas I/M program.[5] Results from this repair analysis, therefore, only defines tests with MIL illumination and stored DTCs as “fail” tests, and only considers MIL illumination (without regard to stored DTCs) in determining whether a vehicle is successfully repaired.

Finally, it is worthwhile to note that a failed OBD test record could contain more than one DTC. In the Texas I/M program, up to 10 DTCs may be stored in the test record, and all stored DTCs were used for this analysis. Therefore, some vehicles were included in more than one set of results. For example, repair results for vehicles with both oxygen sensor DTCs and catalytic converter DTCs were included in both the oxygen sensor repair analysis and the catalytic converter repair analysis. Because of

[5] To ERG’s knowledge, no state I/M program collects pending DTC data per Mode $07 or permanent DTC data per Mode $0A of SAE J1979. States typically only use Mode $03 and DTCs read via Mode $03 are associated to MIL status, i.e., a DTC + MIL commanded on with a confirmed DTC.

the inter-dependence of the various systems (e.g., an oxygen sensor failure may lead to a future catalytic converter failure), distinctions were not made regarding the number or types of DTCs in the original OBD-fail records. Rather, vehicles were categorized as "repaired" when the MIL was extinguished and the analyzer assigned an overall OBD "pass" result, regardless of the number or type of DTCs seen in the initial test failure.

Table IV-2 provides a summary of vehicle repairs (as indicated by OBD-fails followed by OBD-passes) performed over the period of evaluation. Since this analysis was performed on I/M data collected from January 1, 2020, through December 31, 2021, it is possible that some of the unrepaired vehicles were repaired in 2022. This would increase the "repaired" counts from the numbers shown in this table.

These data show that roughly 80% of vehicles that failed an OBD test received a passing OBD test. As previously indicated, many vehicles were failed with more than one DTC. Therefore, Table IV-2 may contain vehicles included in more than one DTC category. Also, only categories directly monitored with non-continuous monitors are tabulated in Table IV-2. Other failure categories for which readiness status would be more difficult to assess are excluded from the table. Table IV-2 indicates that readiness status may be masking malfunctions of 2% to 35% of vehicles that pass OBD retests based on MIL status with these types of failures. I/M program modifications that would require confirmation of specific failure-mode monitors being set to "ready" would likely reduce the extent of potential false passes but at the expense of a potential increase in motorist inconvenience, especially for difficult to set monitors.

A comparison was also made between OBD evaporative system results and gas cap test results, on a by-test basis, for all OBD tests conducted during the period of evaluation. Table IV-3 presents a summary of these results.

Table IV-2. System Specific Repair Analysis for Vehicles

Type of Failure (DTC Category)	Total Vehicles Failed (with Indicated Failure Mode DTCs)	Total Repaired Vehicles (MIL Off)		Repaired Vehicles with Failure Mode Monitors Not Yet Set		Confirmed Repairs (Failure Mode Monitors Set)	
Evap System	26,654	21,730	81.5%	9,376	35.2%	12,354	46.3%
O_2 Sensor	13,938	10,881	78.1%	273	2.0%	10,608	76.1%
EGR System	4,257	3,266	76.7%	188	4.4%	3,078	72.3%
AI System	904	668	73.9%	62	6.9%	606	67.0%
Catalyst	19,773	15,647	79.1%	1,594	8.1%	14,053	71.1%
Totals	**65,526**	**52,192**	**79.7%**	**11,493**	**17.5%**	**40,699**	**62.1%**

Table IV-3. Comparison of OBD Evaporative Emission Control System Test Results with Gas Cap Test Results

OBD Evap System Test Results	Gas Cap Test Result				Total
	Pass		Fail		
Pass	15,148,498	98.74%	52,929	0.34%	15,201,427
Fail	139,376	0.91%	1,344	0.01%	140,720
Total	**15,287,874**	**99.65%**	**54,273**	**0.35%**	**15,342,147**

As can be seen in Table IV-3, approximately 0.91% of the tests had failed the OBD portion of the test with evaporative system DTCs, and gas cap failures were seen in 0.35% of the tests. The OBD evaporative system monitoring is designed to be a more comprehensive test since it assesses the integrity of the entire evaporative control system, but the OBD evaporative emissions control system fail rate may be lowered in part by unset evaporative system readiness monitors. Evaporative emissions control systems generally require a complex series of vehicle operating conditions before this monitor is set. Although most vehicles passed both tests, very few vehicles, less than 1%, failed both tests. Allowable pressure decay limits and enhanced OBD evaporative emissions control system test criteria may contribute to differences in fail rates of the two tests and the slight discrepancy in overlap between the two tests.

Overall OBD Repair Slates

The most common repair slates for vehicles receiving OBD inspections were also identified. The top 10 slates are listed in Table IV-4. The table also gives the total number of vehicles that received repairs, i.e., received one of the top 10 repairs or some other repair.

Table IV-4. 10 Most Common Repair Slates

Repair Description	OBD	
	Count	Percent
Fuel System	31,117	39.0%
Miscellaneous	28,079	35.2%
Emissions System	12,594	15.8%
Ignition/Electrical System	6,229	7.8%
Engine/Mechanical	847	1.1%
Fuel System & Miscellaneous	442	0.6%
Emissions & Fuel Systems	199	0.2%
Emissions System & Miscellaneous	152	0.2%
Fuel System & Ignition/Electrical	62	0.1%
Ignition/Electrical & Emissions Systems	43	0.1%
Other	112	0.1%
Total	**79,876**	**100.0%**

For OBD inspections, a failed inspection includes one or more DTCs that are set and the DTCs give information about what type of problem(s) the vehicle has that may necessitate repairs. When an OBD inspection is passed, no DTCs will be set. Therefore, the DTCs that are initially set and then finally unset (turned off) were compared to the repairs for OBD vehicles. Since there are far too many possible combinations of DTCs to create a "DTC slate" analogous to the repair slates, where all DTCs that were turned on during an inspection sequence are considered as a group, and the analysis is done on these groups, repairs were correlated with DTCs on an individual basis rather than as slates for the OBD repair analysis.

In Table IV-5, the five repair types are listed horizontally across the header row and each row of the table represents one DTC. The number of times that each DTC was "turned off" in the same inspection cycle as each repair is given in the cells of the table. For example, in row one of the table, DTC P0420 (a catalyst system DTC) was turned off most frequently by "Fuel System" repairs (1,034 times), followed by "Emissions System" repairs (875 times), and then by "Miscellaneous" repairs (689 times). Rows with DTCs that relate to similar components or problems are grouped together in the table. The DTCs listed in Table IV-5 are the most commonly recorded DTCs, representing about two-thirds of the total DTC repair counts. In some cases, the inspectors are not choosing the correct repair type. For example, most misfire DTCs should involve ignition system repairs.

Table IV-5. Most Common OBD DTCs and Associated Repairs

DTC Name	DTC Description	Repair Type										Total
		Fuel System		Ignition/ Electrical System		Emissions System		Engine Mechanical		Miscellaneous		Total
		Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count
P0420	Catalyst System Efficiency Below Threshold (Bank 1)	1,034	38%	126	5%	875	32%	31	1%	689	25%	2,755
P0430	Catalyst System Efficiency Below Threshold (Bank 2)	449	40%	51	5%	326	29%	19	2%	266	24%	1,111
P0300	Random/Multiple Cylinder Misfire Detected	451	39%	194	17%	213	18%	20	2%	289	25%	1,167
P0301	Cylinder 1 Misfire Detected	223	39%	126	22%	94	16%	11	2%	118	21%	572
P0302	Cylinder 2 Misfire Detected	229	40%	118	20%	78	14%	12	2%	139	24%	576
P0303	Cylinder 3 Misfire Detected	215	40%	101	19%	95	18%	11	2%	118	22%	540
P0304	Cylinder 4 Misfire Detected	227	37%	117	19%	90	15%	15	2%	158	26%	607
P0305	Cylinder 5 Misfire Detected	128	38%	73	22%	68	20%	1	0%	66	20%	336
P0306	Cylinder 6 Misfire Detected	127	39%	82	25%	51	16%	6	2%	58	18%	324
P0441	Evaporative Emission Control System Incorrect Purge Flow	206	34%	33	5%	190	31%	6	1%	171	28%	606
P0442	Evaporative Emission Control System Leak Detected (small leak)	358	38%	40	4%	278	29%	18	2%	255	27%	949
P0446	Evap Emiss Control Sys. Vent Control Circuit Malfunction	214	36%	33	6%	188	32%	10	2%	150	25%	595

DTC Name	DTC Description	Repair Type										Total
		Fuel System		Ignition/ Electrical System		Emissions System		Engine Mechanical		Miscellaneous		
		Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count
P0455	Evaporative Emiss Control Sys. Leak Detected (gross leak)	464	36%	62	5%	353	28%	13	1%	390	30%	1,282
P0456	Evaporative Emiss System Leak Detected (very small leak)	330	37%	46	5%	242	27%	13	1%	258	29%	889
P0457	Evaporative Emission System Leak Detected (fuel cap loose/off)	122	37%	17	5%	86	26%	6	2%	99	30%	330
P0401	Exhaust Gas Recirculation Flow Insufficient Detected	192	37%	27	5%	165	32%	8	2%	131	25%	523
P0171	Fuel System too Lean (Bank 1)	702	41%	143	8%	374	22%	27	2%	457	27%	1,703
P0172	Fuel System too Rich (Bank 1)	89	40%	18	8%	41	19%	4	2%	68	31%	220
P0174	Fuel System too Lean (Bank 2)	416	42%	90	9%	218	22%	15	1%	262	26%	1,001
P0101	Mass Air Flow (MAF) Circuit Range/Performance	136	37%	25	7%	87	24%	5	1%	116	31%	369
P0102	Mass or Volume Air Flow Circuit Low Input	81	37%	15	7%	51	24%	3	1%	67	31%	217
P0139	O_2 Sensor Circuit Slow Response Bank 1 Sensor 2	29	50%	1	2%	11	19%	1	2%	16	28%	58

DTC Name	DTC Description	Repair Type										Total
		Fuel System		Ignition/ Electrical System		Emissions System		Engine Mechanical		Miscellaneous		Total
		Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count
P0325	Knock Sensor 1 Circuit Malfunction (Bank 1 or Single Sensor2)	105	44%	26	11%	43	18%	9	4%	57	24%	240
P0011	Camshaft Position Timing Over-Advanced (Bank 1)	79	42%	12	6%	35	19%	19	10%	41	22%	186
P0014	Exhaust Camshaft Timing Over-Advanced (Bank 1)	77	43%	14	8%	33	18%	16	9%	40	22%	180
P0106	Manifold Absolute Pressure/BARO Sensor Range/Performance	50	43%	7	6%	22	19%	2	2%	34	30%	115
P0113	Intake Air Temperature Sensor 1 Circuit High Input	96	43%	19	9%	48	22%	4	2%	56	25%	223
P0121	Throttle Position Sensor/Switch A Circuit Malfunction	86	41%	14	7%	39	19%	8	4%	62	30%	209
P0128	Coolant Temperature Below Thermostat Regulating Temp.	332	35%	50	5%	169	18%	22	2%	384	40%	957
P0700	Transmission Control System Malfunction	113	43%	13	5%	38	14%	8	3%	92	35%	264

C. AVERAGE REPAIR COSTS

The TIMS dataset contains manually entered costs for I/M program repairs. This information was analyzed to provide a rough estimate of the cost of vehicle repairs because of the Texas I/M program.

To estimate repair costs based on type of repair, repair categories were developed for each vehicle for a given I/M cycle. A repair category is a concatenation of the set of repair types performed in a repair event. The five different repair types listed in Table IV-1 were combined to produce the seven most common repair categories, which account for approximately 99.5% of all vehicle and I/M cycle combinations. These categories are presented in Table IV-6.

Almost two-thirds (61.7%) of the repair costs in the TIMS were recorded as zero. There are several possible reasons for this, including repairs under warranty, inaccurate repair data entry during a vehicle re-inspection; motorists performing their own repairs; lack of repair data available during a vehicle re-inspection; or vehicles receiving a retest without receiving repairs, such as vehicles that fail due to a readiness monitor and need to simply be driven until the monitors pass their readiness tests. Because of the large number of repair records affected, no attempt was made to correct the costs as part of this analysis. Nonetheless, the existence of so many repair costs with a value of zero significantly affected the average and median repair values calculated. Table IV-6 presents the number of records with a cost of zero by repair category. It was observed that some categories listed contained about 20–40% with zero repair costs, but the most common repair types of emissions system, fuel system, and miscellaneous repairs contained a much higher percentage, at 50% or more. However, all these percentages are comparable to those in the 2014, 2016, 2018, and 2020 reports.

It was also noted than many of the repair costs seemed to be unusually large; many records were more than $2,000, with some as high as $100,000. It is suspected that these repair costs reflect invalid data entry by inspectors during vehicle re-inspections. Figure IV-1 presents a histogram of repairs that cost $2,000 or more.

Table IV-6. TIMS Records with a Repair Cost of Zero by Category

Repair Category	Cost > $0	Cost = $0	Total	% of Cost = $0
Fuel System and Emissions System	132	89	221	40.3%
Emissions System & Miscellaneous	244	268	512	52.3%
Engine Mechanical	676	301	977	30.8%
Ignition / Electrical System	4,500	2,654	7,154	37.1%
Fuel System	7,101	6,989	14,090	49.6%
Miscellaneous	9,812	22,446	32,258	69.6%
Emissions System	12,359	23,436	35,795	65.5%
Total	**34,824**	**56,183**	**91,007**	**61.7%**

Table IV-7 presents median and mean repair costs for each of the repair types specified in the TIMS. Mean and median are calculated twice – once including the zero dollar amount and >$2,000 repair costs found in the dataset (unedited), and once without (edited). According to the unedited dataset, vehicle owners performed 90,000 repairs while spending approximately $7.2 million. According to the edited dataset, which leaves out zero cost and greater than $2,000 cost observations, vehicle owners performed 35,000 repairs while spending approximately $5.6 million. These numbers are notably lower than the numbers for previous I/M evaluations, both for the numbers of repairs, and the total costs.

Figure IV-2 and Figure IV-3 present mean repair costs by inspection year and model year, for both the unedited and edited TIMS datasets. There is a significant amount of variability in the unedited data when compared to the edited data. As shown by these plots, entered repair costs have not increased from year to year. Due to the limited control in repair data entry and the large number of suspect values in the TIMS repair data, these results may be significantly different from true repair costs resulting from the Texas I/M program.

Figure IV-1. Repairs with Cost Greater than or Equal $2,000

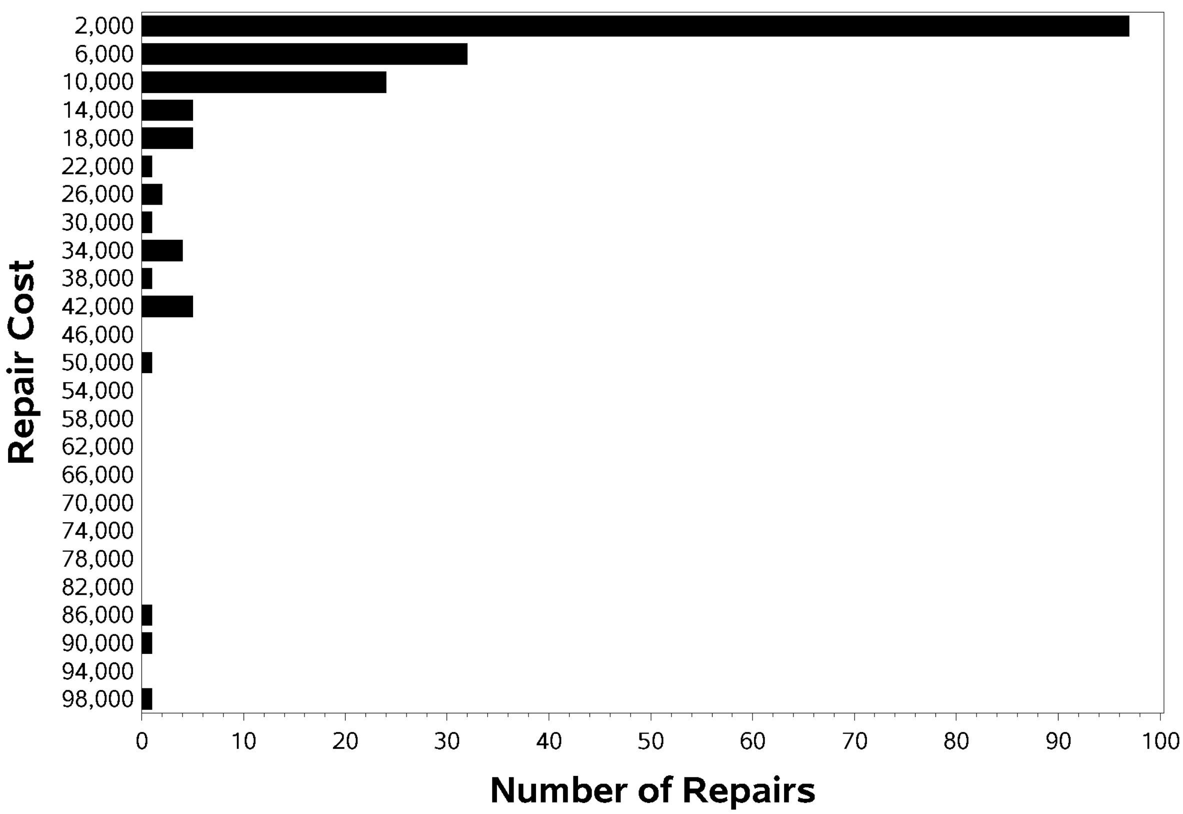


Table IV-7. Average Repair Costs

Year of Inspection	Repair Category	Original Dataset			Costs Between $0 and $2,000		
		Number of Repairs	Median Repair Cost	Mean Repair Cost	Number of Repairs	Median Repair Cost	Mean Repair Cost
2020	Fuel System and Emissions System	114	$60	$208	74	$226	$245
2020	Emissions System & Miscellaneous	94	$241	$295	81	$260	$342
2020	Engine Mechanical	569	$115	$241	366	$218	$294
2020	Ignition / Electrical System	3,923	$75	$115	2,422	$145	$183
2020	Fuel System	8,142	$0	$143	3,883	$200	$260
2020	Emissions System	17,015	$0	$76	5,568	$100	$137
2020	Miscellaneous	17,400	$0	$37	5,106	$45	$93
2021	Fuel System and Emissions System	107	$25	$252	54	$215	$302
2021	Emissions System & Miscellaneous	75	$220	$309	54	$288	$336
2021	Engine Mechanical	408	$160	$398	291	$240	$323
2021	Ignition / Electrical System	3,231	$89	$140	2,069	$149	$195
2021	Fuel System	5,948	$20	$152	3,168	$200	$266
2021	Emissions System	18,780	$0	$68	6,735	$120	$141
2021	Miscellaneous	14,858	$0	$43	4,671	$37	$93

Figure IV-2. Mean Repair Costs by Model Year and Inspection Year (Unedited Dataset)

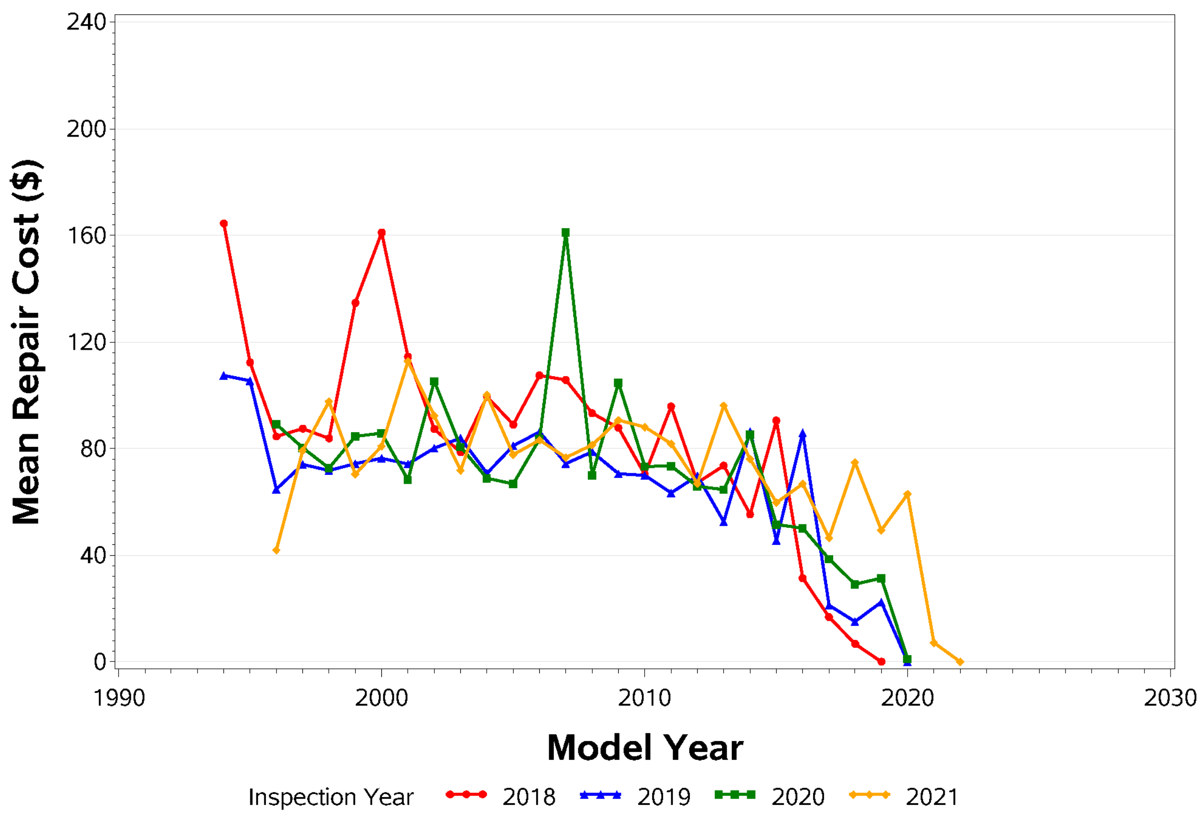


Figure IV-3. Mean Repair Costs by Model Year and Inspection Year (Edited Dataset)

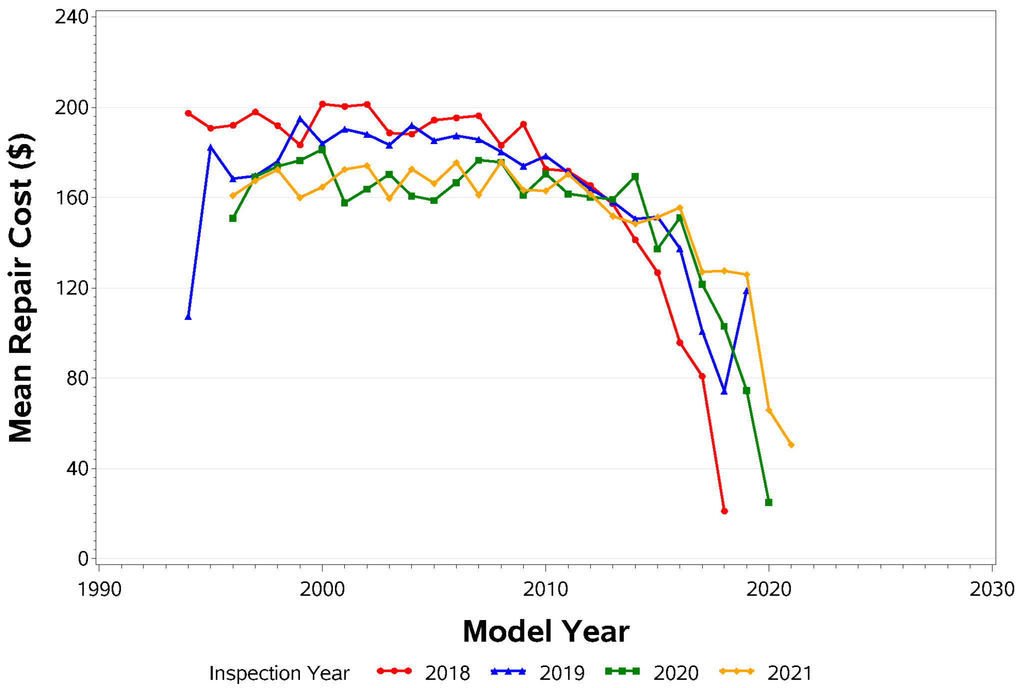


Figure IV-4 and Figure IV-5 present the percentile distribution of repair costs for the most common TIMS repair categories, for both the unedited and edited datasets. The unedited dataset contains repairs with an average cost of zero for all repair slates, but miscellaneous repairs costing zero extend close to the 70th percentile, which is considerably more than the other categories.

For both datasets, the range of average costs was most limited for miscellaneous repairs, while the greatest variation in average costs was visible in repairs performed on both the fuel and emissions systems.

Figure IV-4. Distribution of Repair Costs by Category (Unedited Dataset)

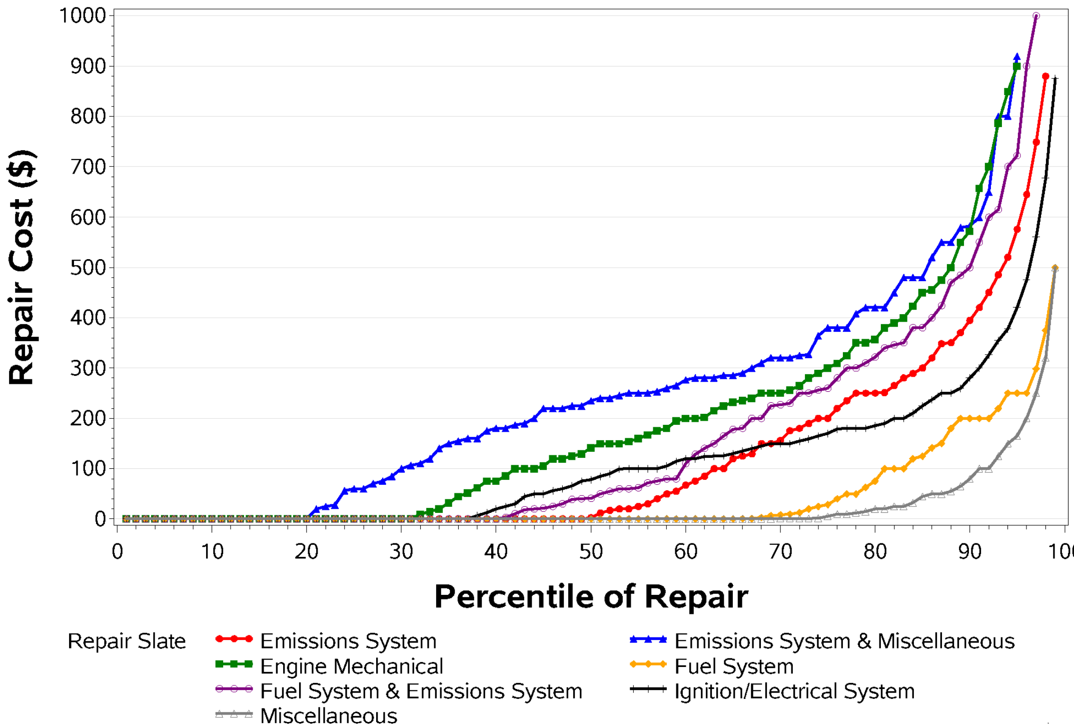
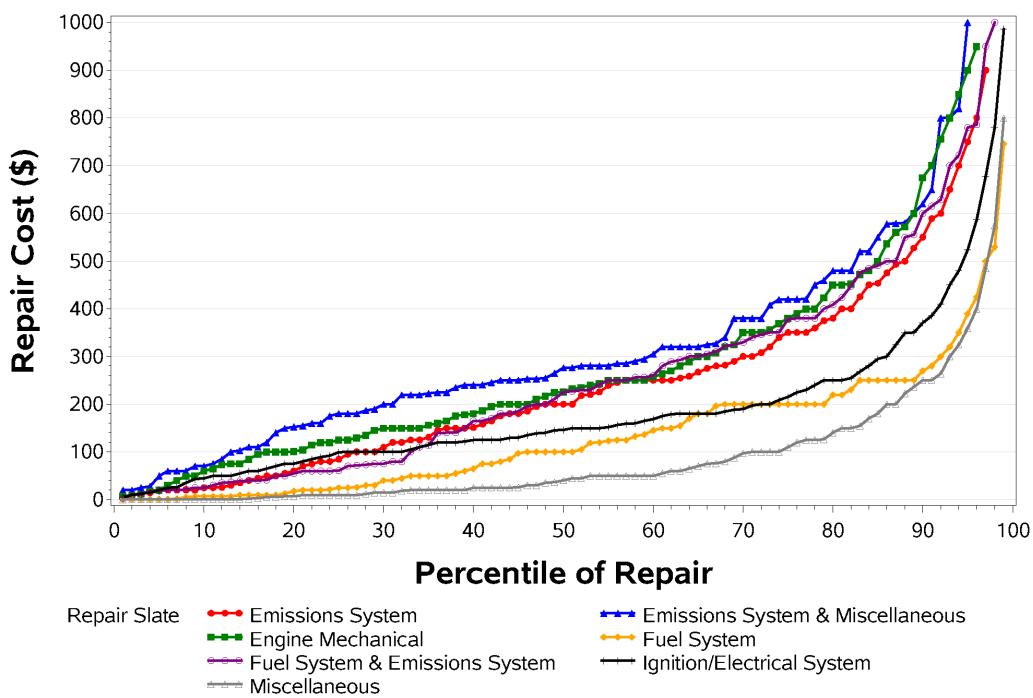


Figure IV-5. Distribution of Repair Costs by Category (Edited Dataset)



V. ESTIMATES OF I/M BENEFITS

The Annual Benefit is the size of the fleet's "saw tooth" emissions profile that occurs during each cycle as the vehicles in the fleet are repeatedly inspected and repaired. The saw tooth is produced for each vehicle by the annual change in emissions downward from I/M repair and then upward from emissions degradation before the next I/M cycle. In previous versions of this I/M Program Evaluation Report, ERG used tailpipe inspection data (ASM and TSI) to calculate emissions reductions for vehicles inspected under the program requirements. However, the tailpipe testing program ended on December 31, 2020, and all inspections are now OBD inspections. Since tailpipe emissions results are no longer available for evaluation, ERG has expanded the analysis of the paired RS/TIMS data.

Four I/M sequence categories were considered in this analysis. All the various failure patterns described in Section III.C were combined into these four categories for the purposes of calculating the annual I/M benefit. The I/M sequence categories are as follows:

- Single Pass (1P) – A vehicle completes its annual I/M requirement with a pass on the first inspection.
- Single Fail (1F) – A vehicle receives a single inspection, which it fails. The dataset does not contain any evidence that the vehicle returns or any information that it may have been waivered.
- Initial Fail, then Final Fail (FF) – A vehicle fails its first annual emissions inspection and then, perhaps after a series of repairs and re-inspections, fails its last annual inspection. Waivers are flagged separately but are not removed from these calculations.
- Initial Fail, then Final Pass (FP) – A vehicle fails its first annual emissions inspection and then ultimately passes its last annual inspection to meet the I/M requirements.

The largest numbers of sequences in the evaluation period were 1Ps since most vehicles pass their initial OBD inspection each year. The 1Ps make up about 95% of all sequences. The FP sequences are the next most common and make up about 4% of all sequences. The 1F and FF sequences are less common and make up the remaining 1% of the sequences and they do not contribute to the calculated annual I/M benefit.

A. ESTIMATE OF THE ANNUAL I/M BENEFIT FROM PAIRED I/M AND RS DATA

The Annual Benefit is the size of the fleet's "saw tooth" emissions profile that occurs during each cycle as the vehicles in the fleet are repeatedly inspected and repaired. The saw tooth is produced for each vehicle by the annual change in emissions downward from I/M-induced repair and then upward from emissions degradation during the period before the next I/M cycle. The analysis presented in this section estimates annual benefits based on pairing the TIMS data with RS data.

Although the effect of the Texas I/M program is to reduce emissions by repairing vehicles that fail an emissions test, these vehicles will then likely have increasing emissions until their next I/M test, and this is also true for passing vehicles. RS data allow this slow increase in emissions to be observed as initially passing vehicles (95% of the fleet) go through the Texas I/M program and their emissions gradually increase each year. This is often called emission creep or deterioration. Eventually, when their emissions have increased over the years to a high enough level, the vehicle fails the I/M inspection, repairs are performed, and emissions should be reduced. During those previous years, the emissions of initially-passing vehicles have gradually increased.

ERG used RS data taken in the I/M program areas to determine the annual I/M benefit produced by the Texas I/M program. This was done by pairing RS data with the TIMS inspection data by vehicle license plate and comparing the before-I/M and after-I/M RS levels.

A vehicle can be measured by RS at any time before or after its annual I/M inspection. By aligning all the RS measurements with respect to the time of I/M test with the assumption that failing vehicles receive any necessary repairs, the average of the RS measurements will reveal the change in emissions produced by the Texas I/M program and the rate of emissions degradation between I/M inspections. However, it is important to understand that the set of vehicles with RS measurements before the I/M inspection does not contain the same vehicles as those with RS measurements after the I/M inspection. Because of the large emissions variability of RS emissions measurements, the average RS emissions vs. time before and after I/M inspection will have a considerable amount of variability even when millions of RS observations are used. Nevertheless, the calculation provides an estimate of the benefits of the Texas I/M program that is independent of the program itself.

Preparation of RS Data

In this task, the RS data were collected in the DFW and HGB program areas to evaluate the annual I/M benefit. The goal was to use the RS data already being collected by the DPS as an independent means of measuring the benefit. The RS data provided by DPS started with about 2.5 million records, collected between July 1, 2019 and February 28, 2022, with about 1.3 million records coming from the HGB area and about 1.2 million records coming from the DFW area.

The RS contractor matched the RS records to registration records in the weeks after they were collected, so that matching process did not have to be performed for this analysis. This match of RS records to registration records allowed ERG to match the record to the I/M test in the TIMS dataset whenever a successful match was made. The RS records provided to ERG also contained vehicle information from the match to the registration dataset, including model year, make, and model. This information, in addition to the vehicle information in the TIMS dataset, can be used to characterize the on-road fleet for the Comprehensive Method [EPA, 2004] calculations.

The RS records provided to ERG by the DPS were already checked for validity by the RS data collection contractor. Therefore, there was no additional check made for the validity of the values within each of the RS data fields. However, a filter on the vehicle specific power (VSP) was applied to remove vehicles that happened to be observed while under very high or very low loads. Any records with a VSP outside the range of 0-35 kilowatt per ton were removed from the dataset. This left approximately 870,000 records in the dataset: 470,000 records in the DFW program area and 400,000 records in the HGB program area.

The number of RS observations collected per year has decreased dramatically over the last several years, beginning in 2014, and continuing to decrease through 2018, although record counts for 2019 saw a substantial increase. In 2020 and 2021, the counts were less than those in 2019, but greater than in 2018 and 2017. Decreases in the number of available RS observations result in much smaller groups of vehicles when the RS observations are paired with close-in-time I/M inspections.

B. CALCULATION OF THE ANNUAL I/M BENEFIT USING THE COMPREHENSIVE METHOD

The calculation of the annual I/M benefit was done using the Comprehensive Method outlined by the EPA [EPA, 2004]. In this method, RS data taken in the I/M area is paired with I/M inspections, by vehicle.

ERG calculated the time between the RS reading and the I/M test and placed each observation into a month bin. For example, one month before the initial test, two months before the initial test, three months before the initial test, one month after the final test, two months after the final test, three months after the final test, etc. Any RS readings that occurred within the I/M cycle, that is, between the initial test and the final test, were removed from the analysis, because for these mid-cycle observations it was not possible to assume the state of repair of the vehicle at the time of the RS measurement.

ERG also created a variable to describe the sequence of I/M inspection results for each vehicle inspected. There were four I/M sequence categories outlined in the EPA's description of the Comprehensive Method calculations:

1. Vehicles that passed their initial I/M tests (1P),
2. Vehicles that failed their initial I/M test and then eventually passed (FP),
3. Vehicles that failed their I/M test and did not come back for another test (1F), and

4. Vehicles that failed their I/M test and failed all other subsequent I/M tests (FF).

The average RS concentrations for HC, CO, and NO_x by month bin, by I/M sequence category, and by model year group were examined. Because the Texas I/M program is an annual program, the plots were limited to only the RS matches that happened up to six months before and six months after the I/M test. The HC, CO, and NO_x plots for the entire dataset are shown in Figure V-1 through Figure V-3 for the DFW program area and in Figure V-4 through Figure V-6 for the HGB program area. These figures show the RS averages (indicated by the dots) and the uncertainties associated with these averages at a 95% confidence level (indicated by the lines).

Figure V-1. Average RS HC vs. Month from the I/M Test RS Readings from the HGB Program Area

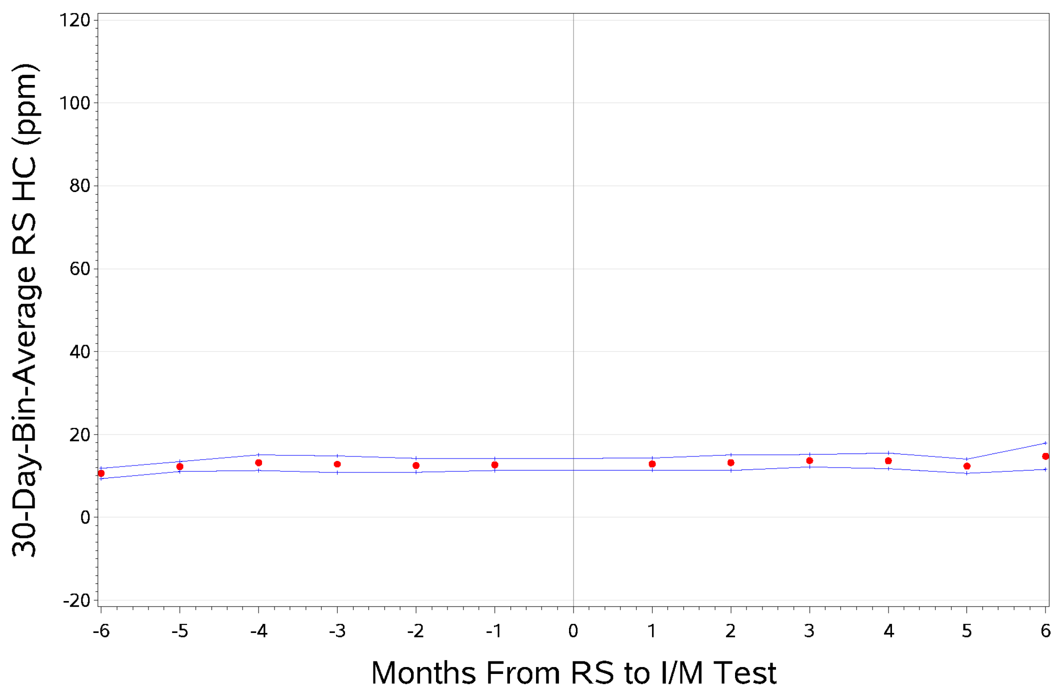


Figure V-2. Average RS CO vs. Month from the I/M Test RS Readings from the HGB Program Area

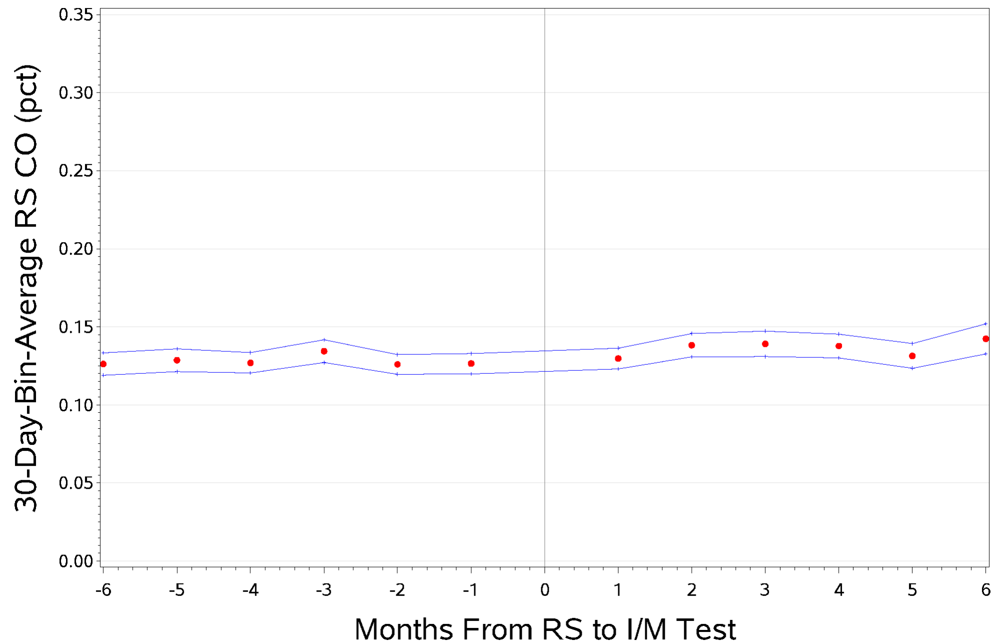


Figure V-3. Average RS NO_X vs. Month from the I/M Test RS Readings from the HGB Program Area

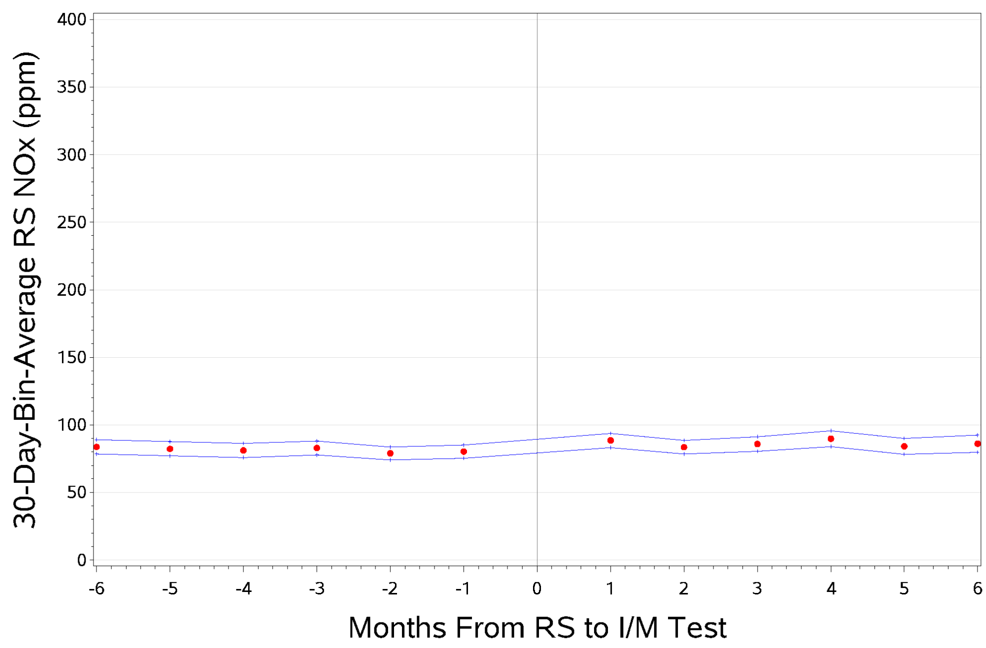


Figure V-4. Average RS HC vs. Month from the I/M Test RS Readings from the DFW Program Area

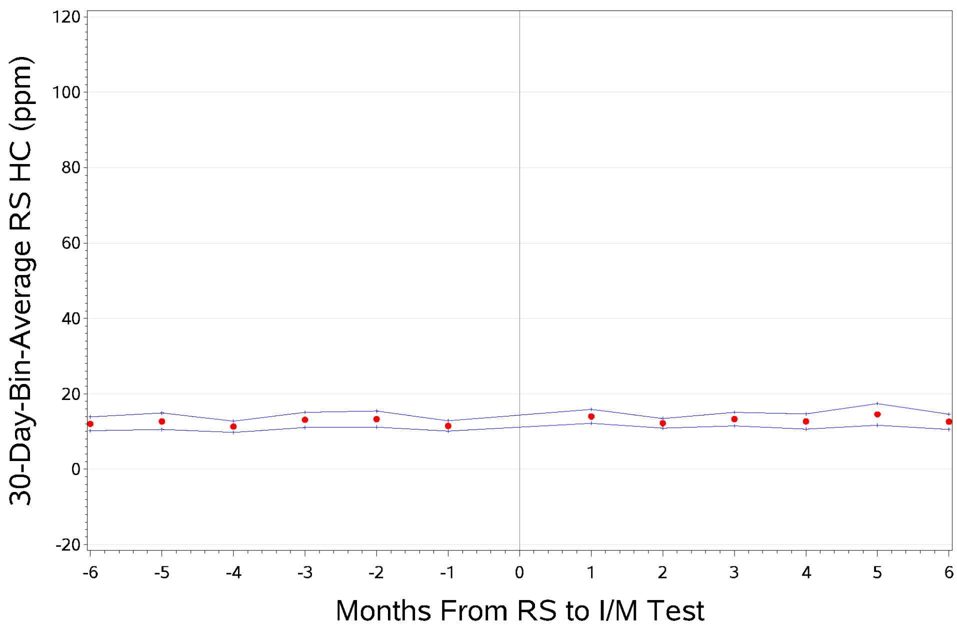


Figure V-5. Average RS CO vs. Month from the I/M Test RS Readings from the DFW Program Area

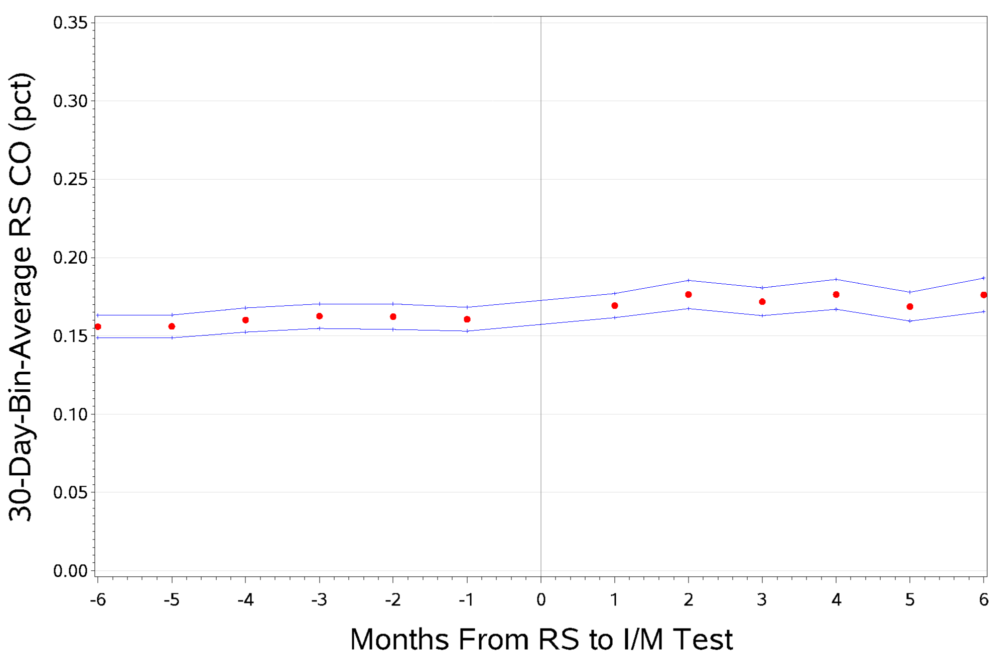
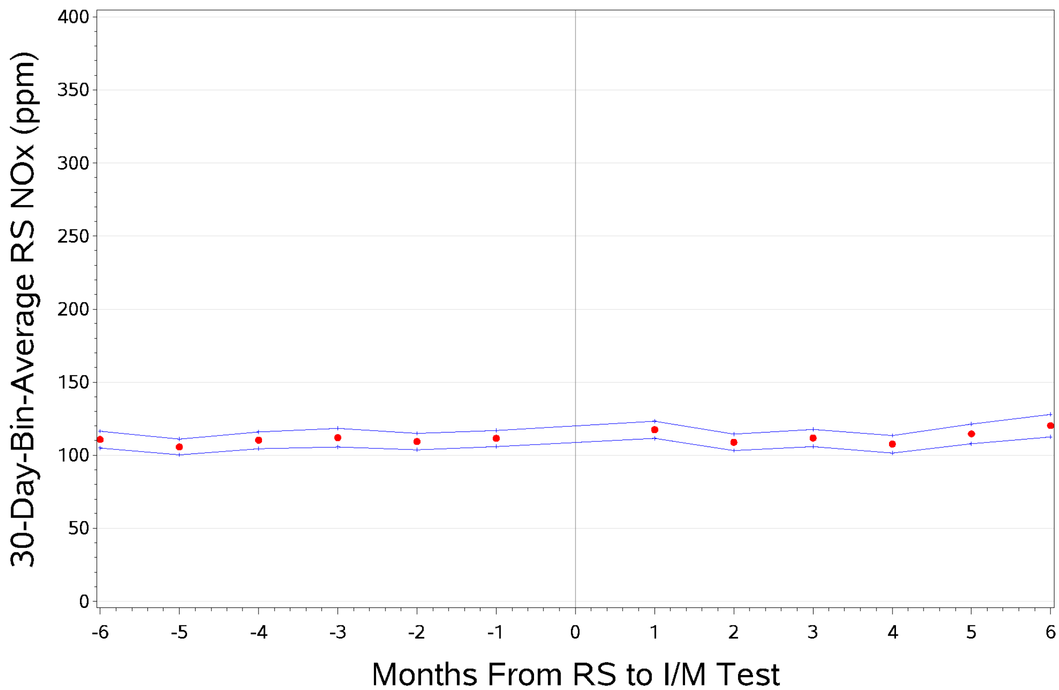


Figure V-6. Average RS NO_X vs. Month from the I/M Test RS Readings from the DFW Program Area



It is difficult to assess the impact of I/M testing from these figures as the HC readings are relatively constant around 20 parts per million (ppm) for both program areas, the CO readings are also similar in the HGB and DFW program areas near 0.15%, and the NO_x values are similar around 120 ppm. However, when the plots are done on a dataset that has been stratified by the I/M sequence category, some I/M benefits start to become evident.

Table V-1 shows the number of records in the RS-matched-with-TIMS dataset for both HGB and DFW program areas that fall into each I/M sequence category. The sample sizes are for the total number of I/M vehicles matched to RS records, but they are not necessarily the same vehicle before and after the I/M test. The table clearly demonstrates that the 1P and FP I/M sequence categories dominate the Texas I/M program vehicles that are observed on the road. Few vehicles that fail and never pass (1F and FF) are observed by remote sensing.

Table V-1. Number of Vehicles in Each I/M Sequence Category for the Dataset of RS Events Matched with I/M Tests

I/M Sequence Category	HGB		DFW	
	Number of Vehicles	Percent	Number of Vehicles	Percent
Pass Initial (1P)	157,055	96.3%	140,697	96.2%
Fail Initial (1F)	385	0.2%	392	0.3%
Fail Initial, Fail Final (FF)	38	0.0%	38	0.0%
Fail Initial, Pass Final (FP)	5,535	3.4%	5,183	3.5%
Other Misc. Sequences	4	0.0%	9	0.0%
Total	**163,017**	**100.0%**	**146,319**	**100.0%**

The plots of mean RS concentrations vs. time from I/M inspection were repeated, this time separately for the 1P and FP categories. Figure V-7, Figure V-9, and Figure V-11 show the time trend of the monthly average RS HC, CO, and NO_x for the DFW program area for vehicles that passed initially (1P). Below these figures are Figure V-8, Figure V-10, and Figure V-12 for the corresponding vehicles that failed initially and then ultimately passed (FP).

The 1P plots, which describe 96.3% of the vehicles in the DFW program area, show small emission increases from the month before to the month after the I/M test. There is no evidence of a decrease in emissions in the two months before the I/M inspection that could be attributed to pre-inspection repairs. If anything, the long-term time trend is generally upward, which may be attributed to the general long-term emissions deterioration of these vehicles.

The FP plots, which describe 3.4% of the vehicles in the DFW program area, show downward jogs in the emissions at the time of the I/M inspection, or just following the inspection. Examining the overall trend of each plot shows that downward jogs at the I/M inspection interrupts the generally upward trend of emissions creep, which is what the Texas I/M program is designed to do.

Grouping vehicles of all I/M sequence categories results in a slightly increasing trend from before to after I/M as was seen in

Figure V-2 and Figure V-3. This is because although the FP vehicles show substantial emissions decreases, they make up only 3.4% of the DFW fleet. An additional 96.3% of the fleet is made up of 1P vehicles that have slight emissions increases, as an expected result of general long-term emission creep. There was no discernible difference in the plots for the emissions in the HGB program area; therefore, they were not included here to conserve space.

Figure V-7. Average RS HC vs. Month After the I/M Test for DFW Vehicles with I/M Sequence Category = 1P

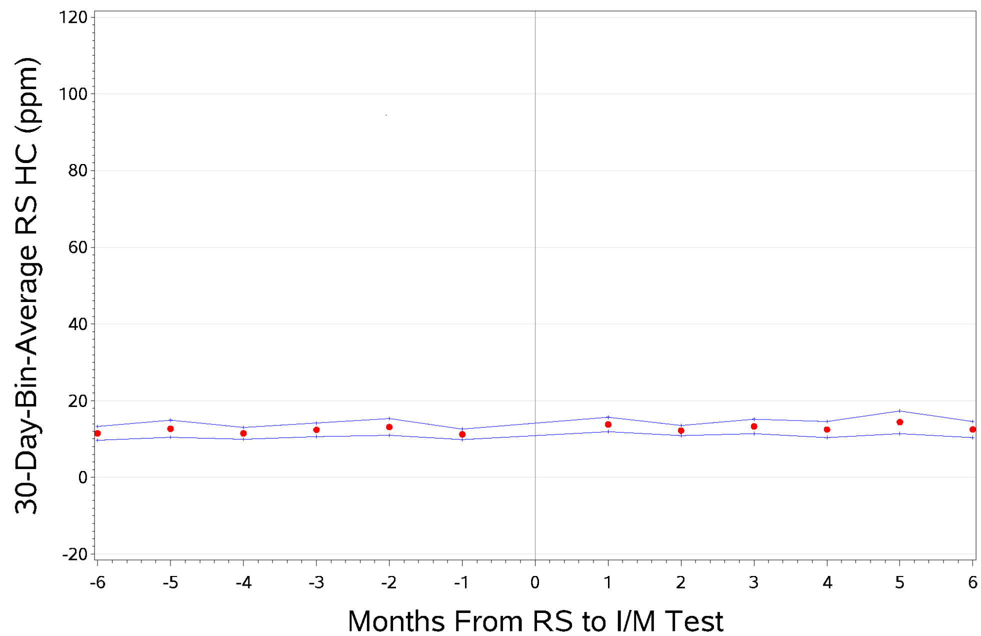


Figure V-8. Average RS HC vs. Month After the I/M Test for DFW Vehicles with I/M Sequence Category = FP

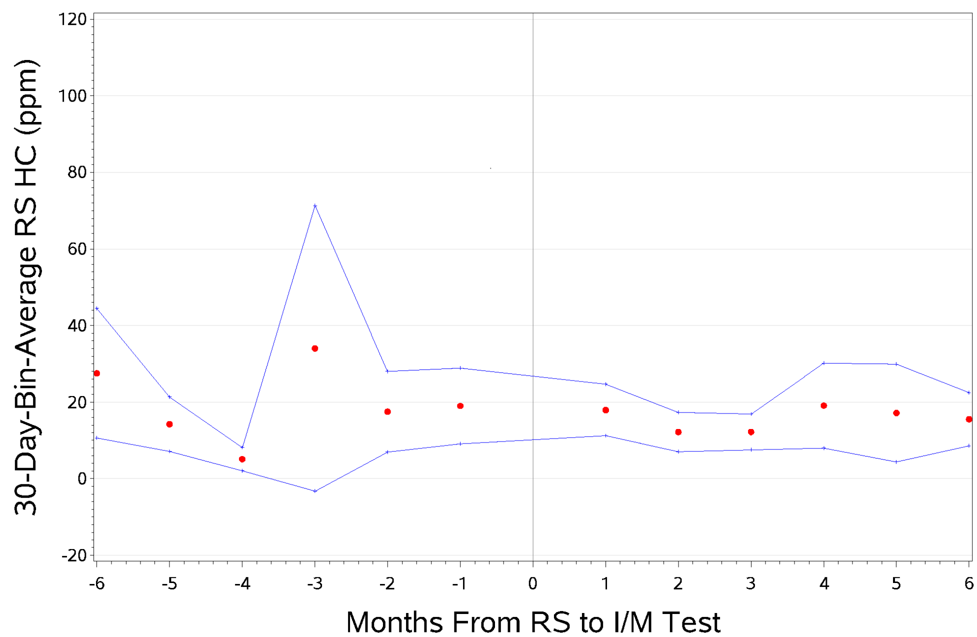


Figure V-9. Average RS CO vs. Month After the I/M Test for DFW Vehicles with I/M Sequence Category = 1P

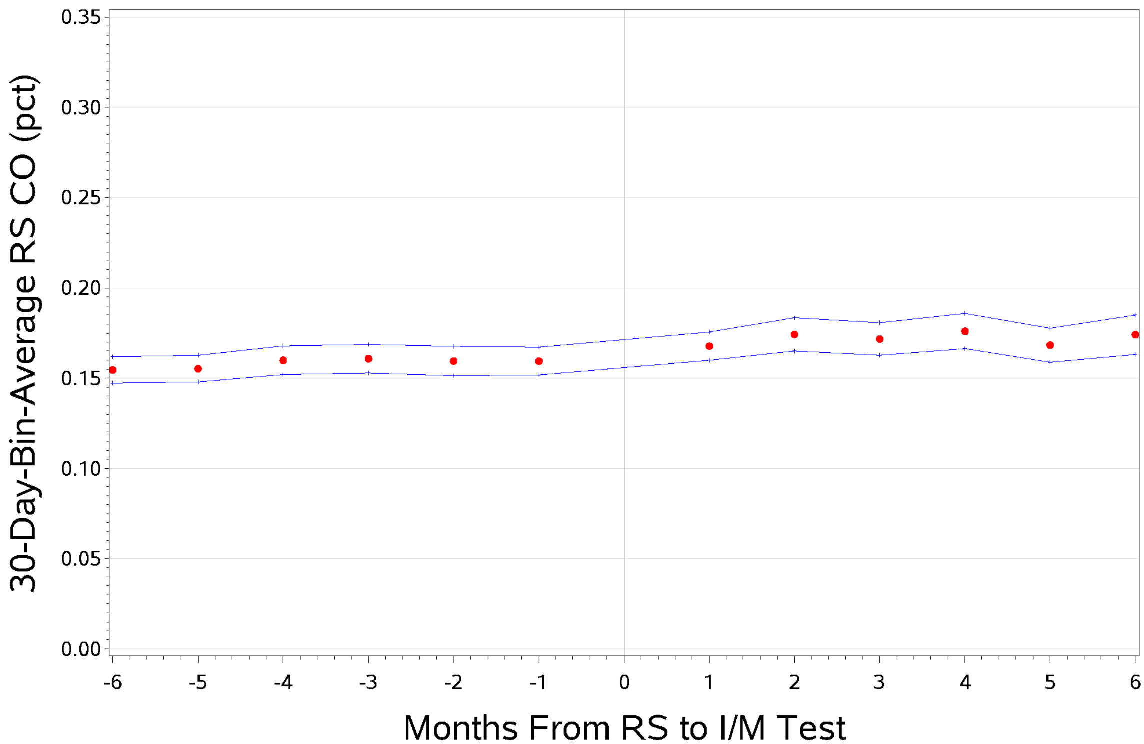


Figure V-10. Average RS CO vs. Month After the I/M Test for DFW Vehicles with I/M Sequence Category = FP

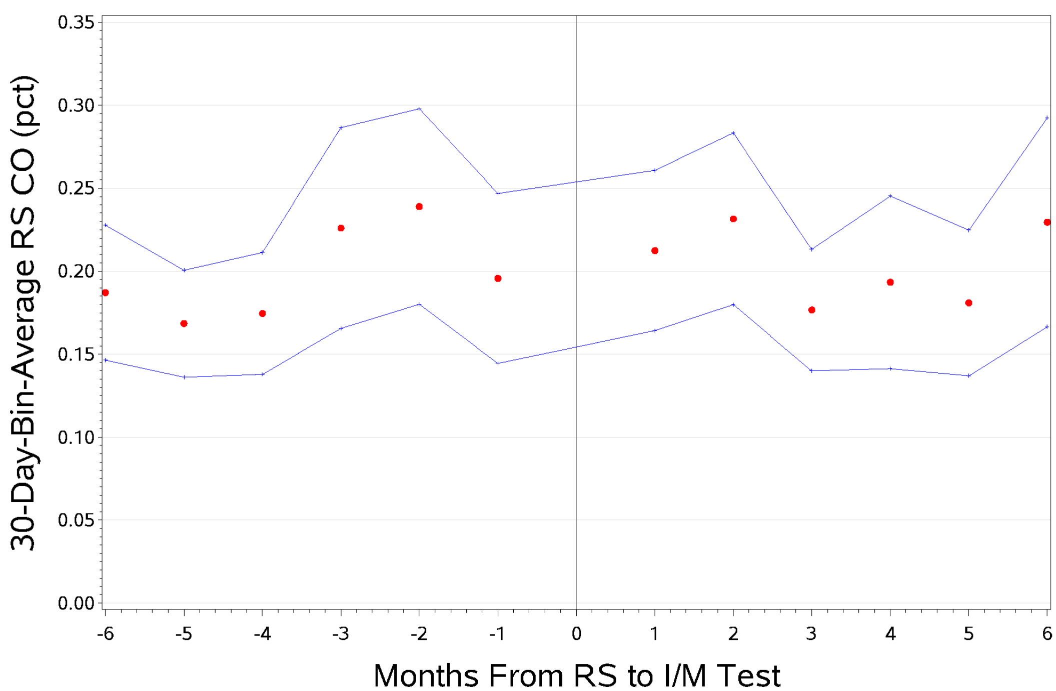


Figure V-11. Average RS NO_X vs. Month After the I/M Test for DFW Vehicles with I/M Sequence Category = 1P

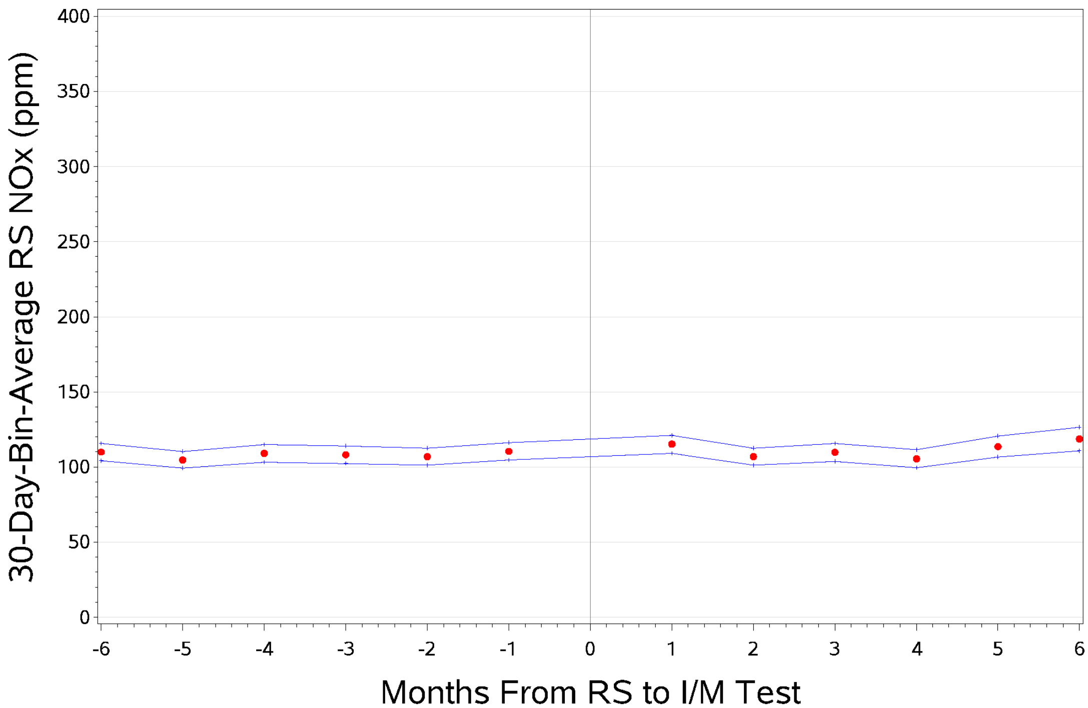
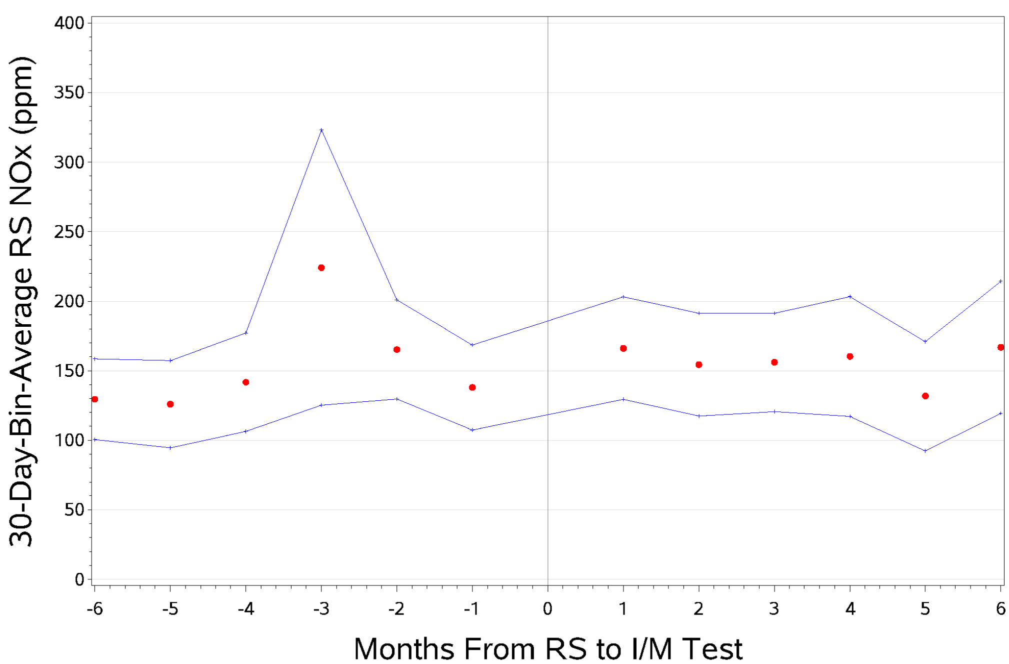


Figure V-12. Average RS NO_X vs. Month After the I/M Test for DFW Vehicles with I/M Sequence Category = FP



To quantify the annual I/M benefit, the month bins were combined to obtain a single average RS concentration before the I/M test and another average RS concentration after the I/M test. The 'before' bin consists of all RS measurements that happened between 31 and 120 days prior to the initial I/M test. The RS measurements that happened from one to 30 days prior to the I/M test were not included in the bin to minimize the effect of pre-inspection repairs on the before average. This binning methodology was suggested by the EPA in the documentation for the Comprehensive Method. The 'after' bin contains all RS tests that happened between one and 120 days following the final I/M test.

The calculations for the before and after I/M RS averages were done for the entire RS-matched TIMS dataset for each of the two major I/M sequence categories, FP and 1P, and averages were calculated separately by model year group. At the beginning of this analysis, when the fleet characteristics of the I/M fleet were compared to the fleet characteristics of the matched set of RS vehicles, the RS-matched fleet was found to contain a larger percentage of new vehicles. Therefore, each of the I/M category bins was also separated by model year group. The benefit for each model year group could be weighted by the percentage of vehicles in each model year group in the I/M fleet to translate the benefits observed in the RS-matched fleet to the I/M fleet.

These before and after I/M average RS measurements for the FP vehicles and the 1P vehicles were plotted for both the DFW and HGB program areas in Figure V-13 through Figure V-24. The graphs show the mean emissions levels, and the error bars show the 95% confidence level uncertainties for the respective averages, with the number of observations. There are two groups of vehicles shown on each plot. The first labeled "1 RSD Before I/M" is comprised of vehicles that were observed by RS prior to their I/M inspection, and the second, "2 RSD After I/M" is comprised of those vehicles that were observed by RS after their I/M inspection.

The plots for the FP vehicles show that in most cases the emissions of FP vehicles decrease, especially for the older model year groups; however, in many cases the decrease is not statistically significant – even with thousands of RS observations in the FP category. The plots for the 1P vehicles show that in some cases the emissions of 1P vehicles increase across the I/M inspections; however, in many cases the increase is not statistically significant even with tens of thousands of RS observations in the 1P category.

Figure V-13. Average 1P RS HC by Model Year Group Before and After I/M Test for DFW Vehicles

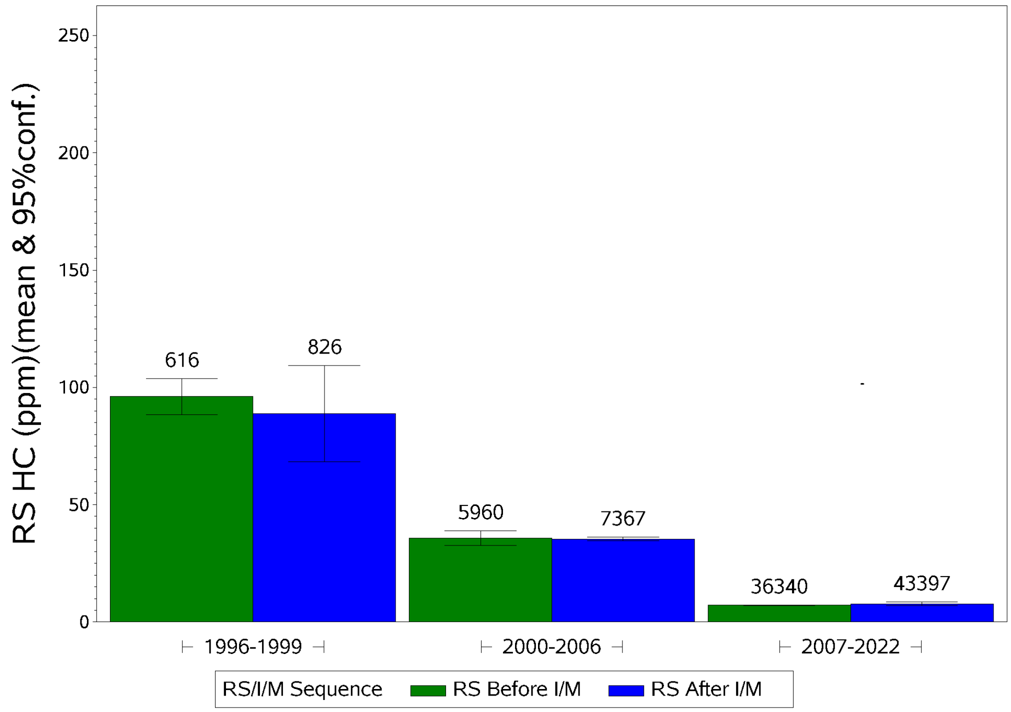


Figure V-14. Average FP RS HC by Model Year Group Before and After I/M Test for DFW Vehicles

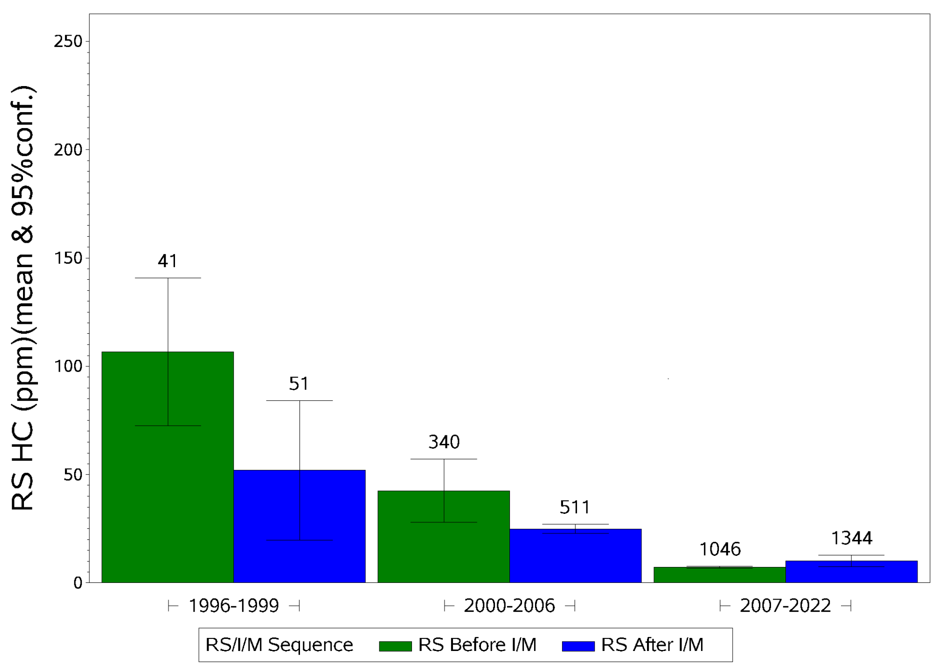


Figure V-15. Average 1P RS HC by Model Year Group Before and After I/M Test for HGB Vehicles

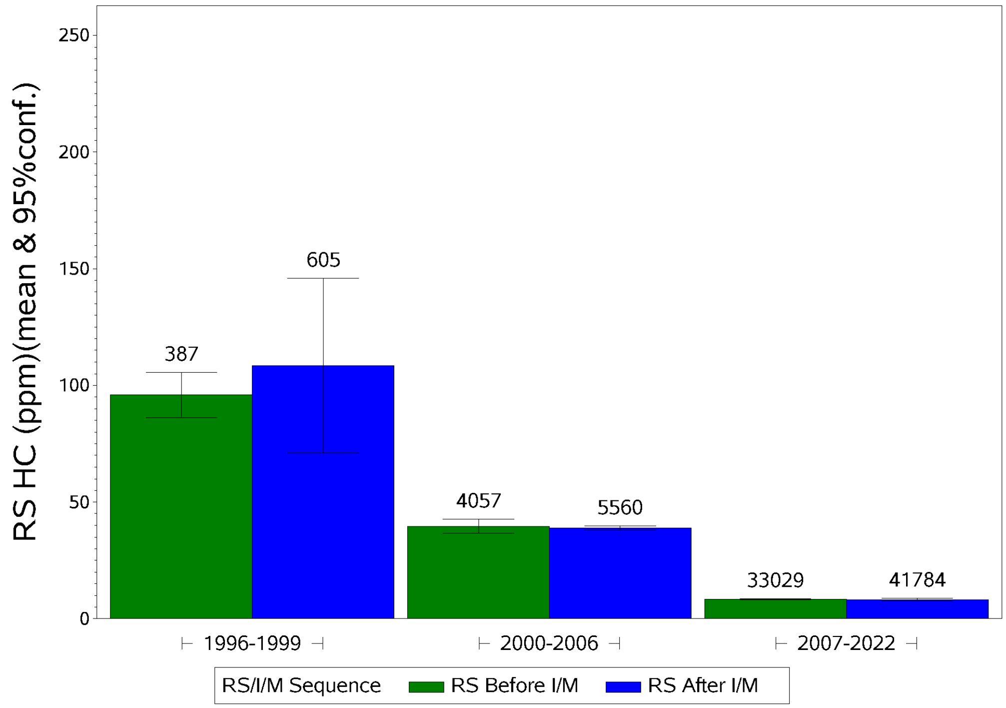


Figure V-16. Average FP RS HC by Model Year Group Before and After I/M Test for HGB Vehicles

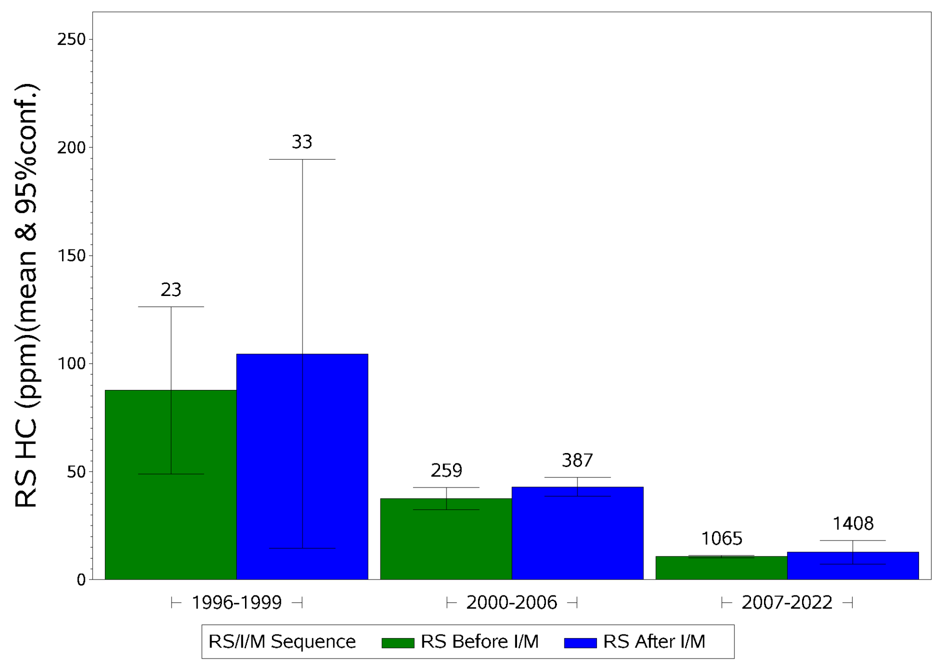


Figure V-17. Average 1P RS CO by Model Year Group Before and After I/M Test for DFW Vehicles

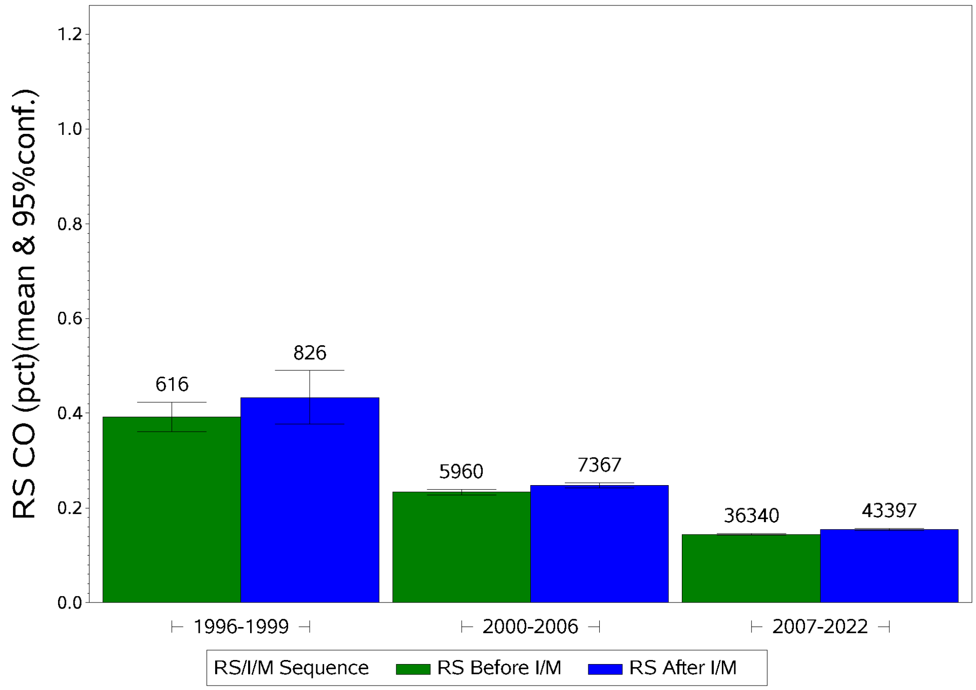


Figure V-18. Average FP RS CO by Model Year Group Before and After I/M Test for DFW Vehicles

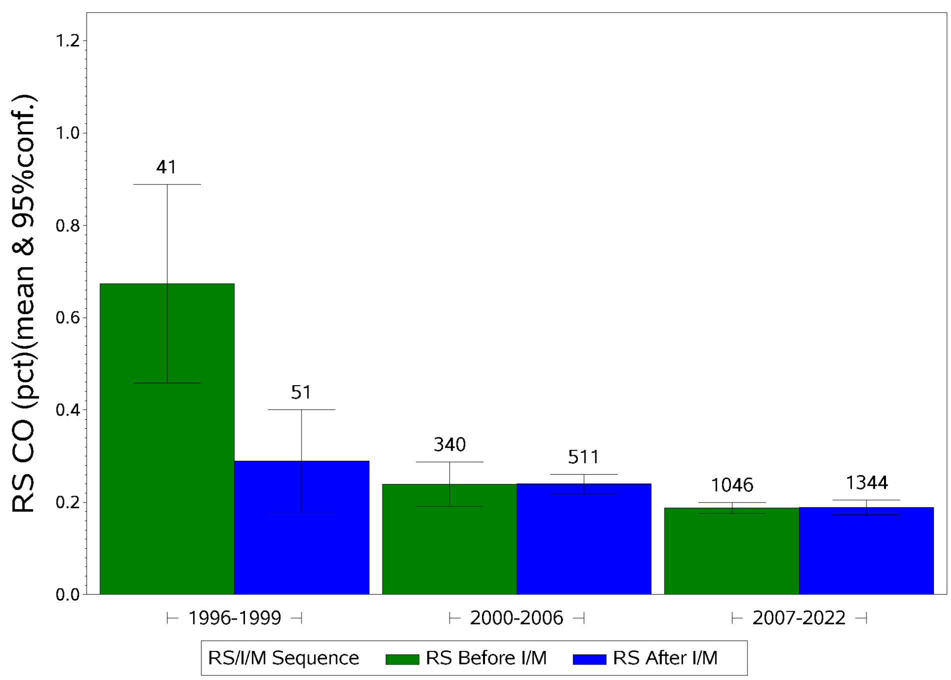


Figure V-19. Average 1P RS CO by Model Year Group Before and After I/M Test for HGB Vehicles

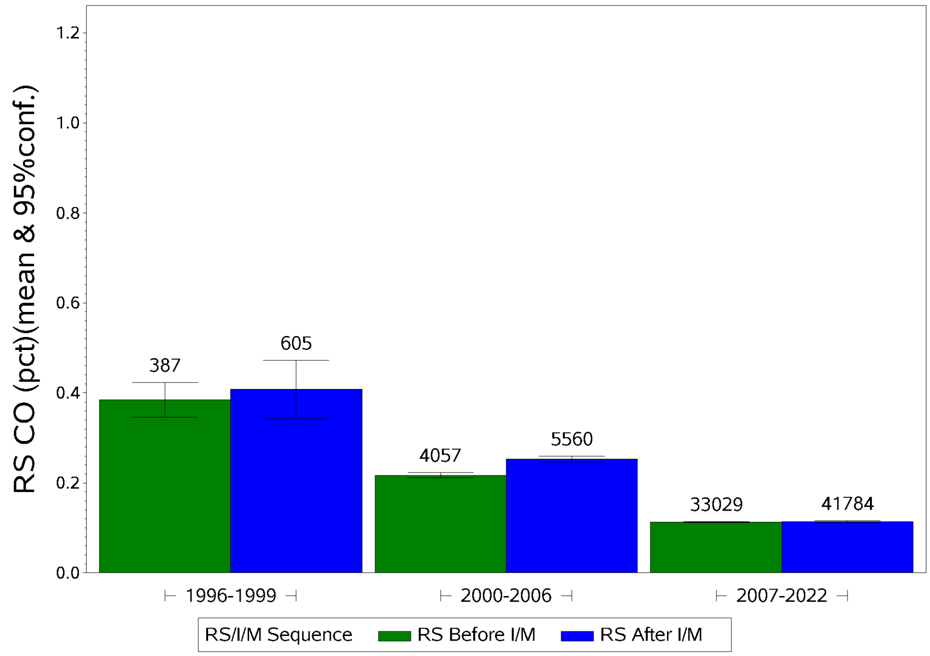


Figure V-20. Average FP RS CO by Model Year Group Before and After I/M Test for HGB Vehicles

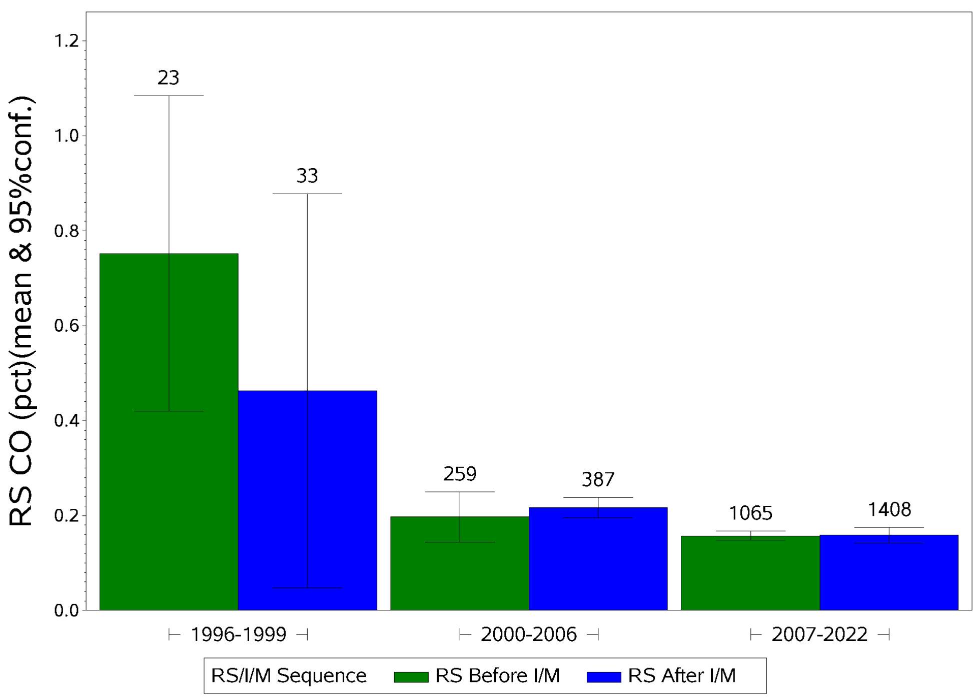


Figure V-21. Average 1P RS NO_X by Model Year Group Before and After I/M Test for DFW Vehicles

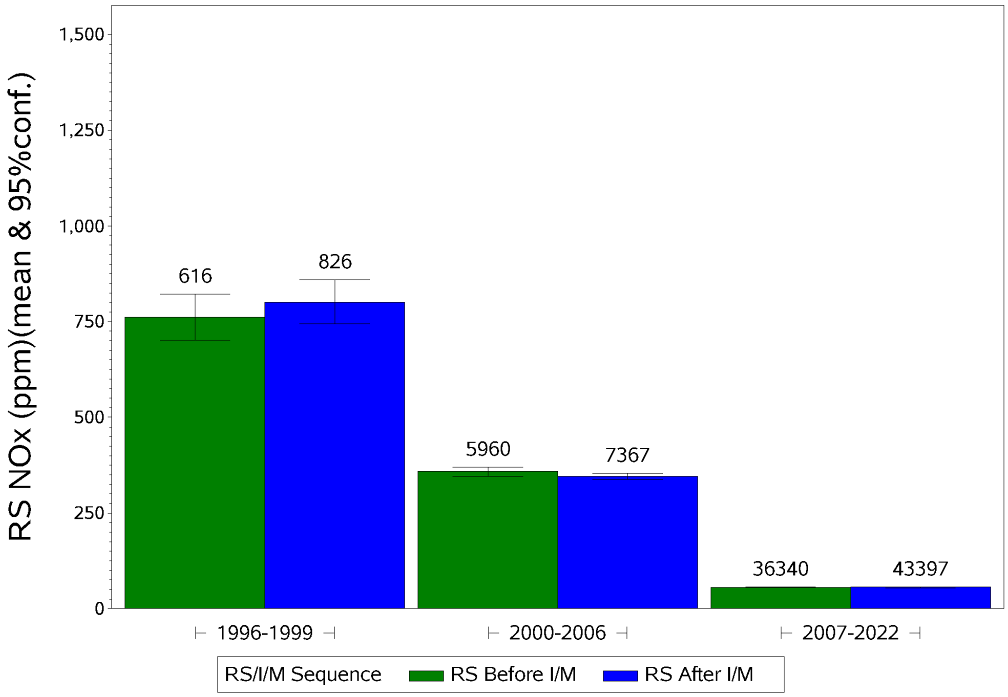


Figure V-22. Average FP RS NO_X by Model Year Group Before and After I/M Test for DFW Vehicles

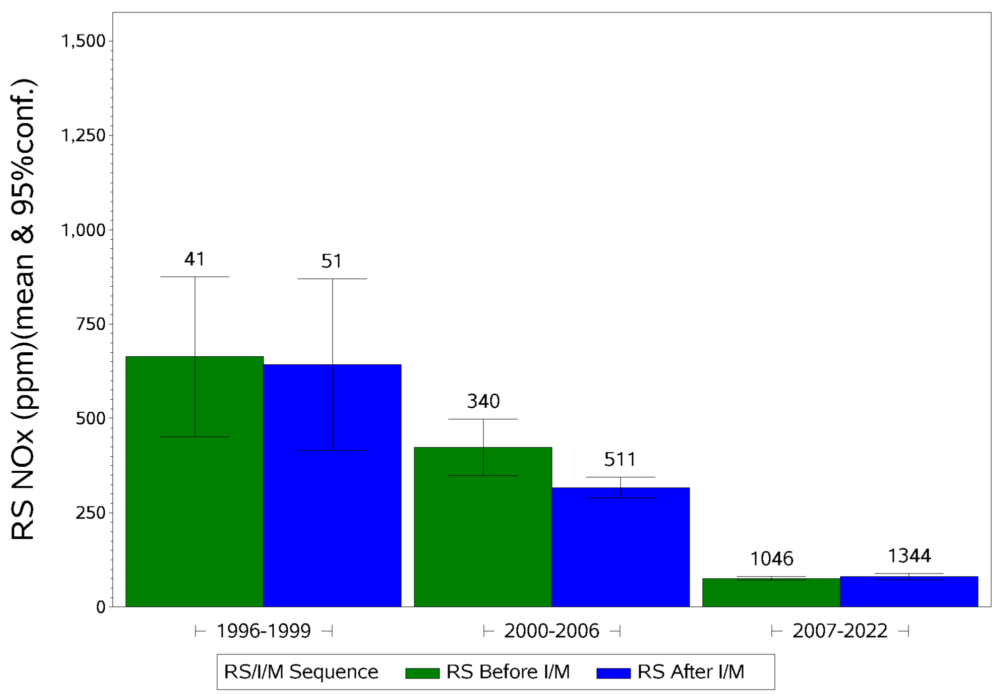


Figure V-23. Average 1P RS NO_X by Model Year Group Before and After I/M Test for HGB Vehicles

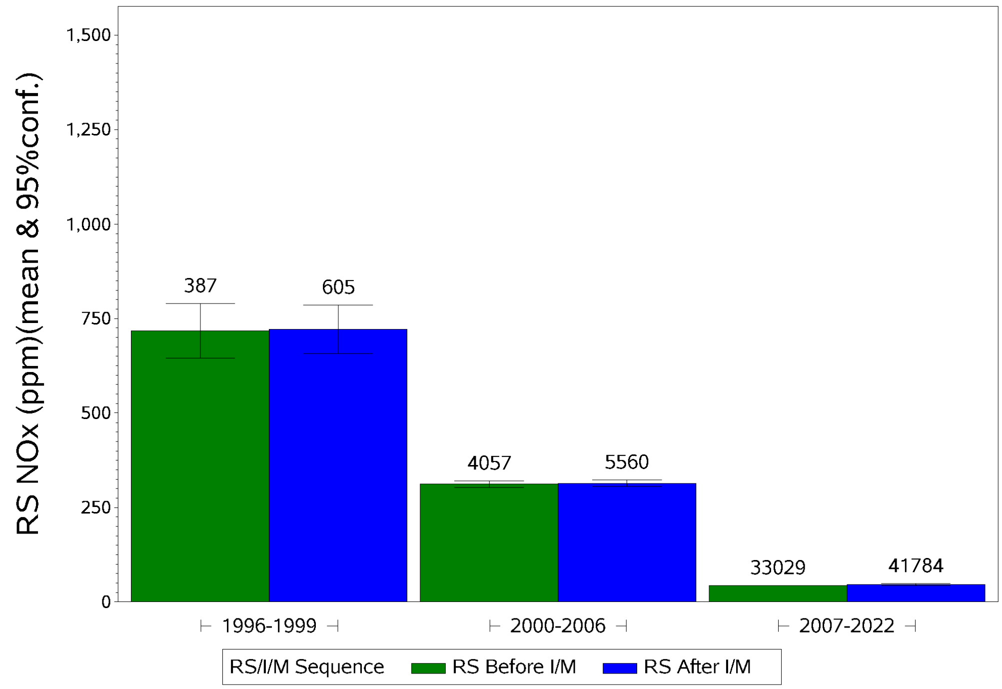
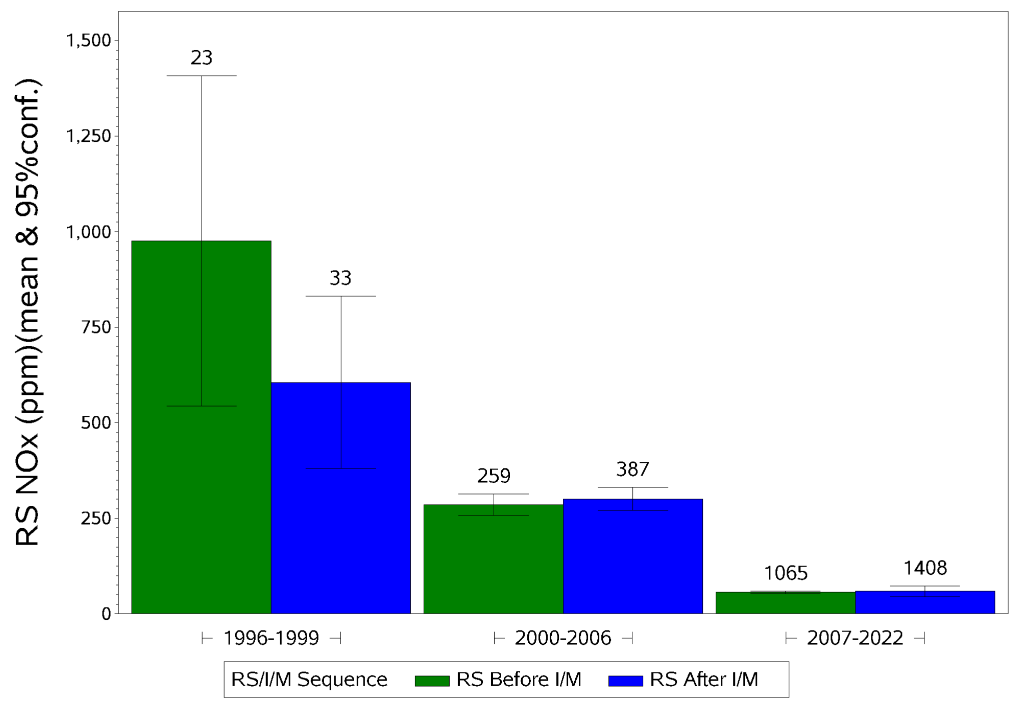


Figure V-24. Average FP RS NO_X by Model Year Group Before and After I/M Test for HGB Vehicles



The RS average concentrations shown in the figures above are summarized in Table V-2 and Table V-3. The values in Table V-2 show that for vehicles that failed and then passed, HC, CO, and NO_x emissions were substantially reduced for some model year groups, while other model year groups remained constant from before to after the I/M inspection. Table V-3 shows that for 1P vehicles, there was some variability of increases or decreases in RS average concentrations. However, looking back at Figure V-13 through Figure V-18, the changes are almost always within the error bars, and therefore, not statistically significant.

Table V-2. RS Averages Before and After an I/M Test for HGB and DFW for I/M Sequence Category = FP

MY Group	RS HC (ppm) Before I/M	RS HC (ppm) After I/M	RS CO (%) Before I/M	RS CO (%) After I/M	RS NOx (ppm) Before I/M	RS NOx (ppm) After I/M
DFW Program Area						
1996–1999	106.7	52.0	0.673	0.289	663	643
2000–2006	42.5	24.9	0.239	0.240	423	317
2007–2020	7.2	10.2	0.188	0.189	76	81
HGB Program Area						
1996–1999	87.7	104.6	0.752	0.463	976	606
2000–2006	37.6	43.0	0.197	0.217	285	301
2007–2020	10.8	12.8	0.157	0.159	56	59

Table V-3. RS Averages Before and After an I/M Test for HGB and DFW for I/M Sequence Category = 1P

MY Group	RS HC (ppm) Before I/M	RS HC (ppm) After I/M	RS CO (%) Before I/M	RS CO (%) After I/M	RS NOx (ppm) Before I/M	RS NOx (ppm) After I/M
DFW Program Area						
1996–1999	96.1	88.9	0.392	0.433	762	801
2000–2006	35.8	35.5	0.233	0.248	358	345
2007–2020	7.1	7.7	0.144	0.154	56	56
HGB Program Area						
1996–1999	95.9	108.5	0.385	0.408	718	722
2000–2006	39.6	38.9	0.217	0.253	312	315
2007–2020	8.4	8.2	0.113	0.115	43	46

The results in Table V-2 and Table V-3 show the difference in average RS concentrations between before and after I/M observations for different model year groups. These results are then combined to calculate the net overall effect on emissions of the I/M program. Because RS measurements are primarily taken on freeway on-ramps, it is generally assumed newer vehicles are driven on the highways; therefore, the average vehicle observed by RS is somewhat newer than the average vehicle in the I/M fleet. This difference is shown in Table V-4, which contains the distribution of vehicles among the model year groups for the RS measurements-matched-to-I/M fleet, and for the I/M fleet. The fact that this difference exists (i.e., that the RS measurements-matched-to-I/M fleet is somewhat newer than the I/M fleet) should be kept in mind when considering overall fleet results. The overall fleet results for the annual I/M benefit are shown in Table V-5. It should be noted that in the absence of an I/M program, fleet emissions are expected to increase as motorists are less likely to make emission repairs to pass an upcoming I/M test; therefore, the actual emission reductions are likely greater than those reported below.

Table V-4. Model Year Distributions for RS-Matched-to-I/M Fleet and I/M Tested Fleet

Model Year Group	DFW				HGB			
	RS-Matched-to-I/M Fleet		I/M Tested Fleet		RS-Matched-to-I/M Fleet		I/M Tested Fleet	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1996–1999	2,574	1.6%	213,622	2.5%	1,726	1.2%	167,017	2.3%
2000–2006	23,578	14.5%	1,472,667	17.0%	16,918	11.6%	1,206,675	16.3%
2007–2020	136,865	84.0%	6,974,331	80.5%	127,675	87.3%	6,031,232	81.4%
Total	**163,017**	**100.0%**	**8,660,620**	**100.0%**	**146,319**	**100.0%**	**7,404,924**	**100.0%**

Table V-5. RS Average Concentrations to Evaluate the Annual I/M Benefit

I/M Program Area	I/M Sequence	RS wrt* I/M	Number of Obs**	RS HC (ppm)				RS CO (%)				RS NOx (ppm)			
				Mean	UCLM***	LCLM***	Change (%)	Mean	UCLM***	LCLM***	Change (%)	Mean	UCLM***	LCLM***	Change (%)
DFW+HGB	1P+FP	Before	83,163	12.7	13.5	11.9		0.146	0.149	0.143		96	99	94	
DFW+HGB	1P+FP	After	103,273	13.2	13.8	12.6	4.1%	0.155	0.158	0.152	6.1%	100	102	97	3.2%
DFW+HGB	1P	Before	80,389	12.5	13.3	11.7		0.145	0.148	0.142		95	97	92	
DFW+HGB	1P	After	99,539	13.0	13.6	12.4	4.1%	0.154	0.157	0.151	6.4%	98	100	96	3.4%
DFW+HGB	FP	Before	2,774	17.9	24.5	11.2		0.195	0.215	0.176		147	167	126	
DFW+HGB	FP	After	3,734	18.0	21.3	14.7	0.6%	0.191	0.207	0.175	-2.1%	140	153	127	-4.5%
DFW	1P+FP	Before	44,343	12.6	13.7	11.5		0.162	0.166	0.157		110	114	107	
DFW	1P+FP	After	53,496	13.1	13.9	12.2	4.0%	0.173	0.178	0.169	7.2%	111	114	108	1.0%
HGB	1P+FP	Before	38,820	12.8	13.9	11.7		0.129	0.133	0.125		81	84	78	
HGB	1P+FP	After	49,777	13.3	14.2	12.5	4.1%	0.136	0.140	0.132	5.6%	87	89	84	7.5%
DFW	1P	Before	42,916	12.4	13.4	11.3		0.160	0.165	0.155		108	111	105	
DFW	1P	After	51,590	13.0	13.9	12.1	5.0%	0.172	0.177	0.168	7.6%	110	113	107	1.4%
DFW	FP	Before	1,427	18.5	30.6	6.4		0.214	0.245	0.183		176	211	141	
DFW	FP	After	1,906	15.2	18.7	11.8	-17.6%	0.205	0.229	0.181	-4.1%	159	178	140	-9.3%
HGB	1P	Before	37,473	12.6	13.7	11.5		0.127	0.131	0.123		79	82	77	
HGB	1P	After	47,949	13.0	13.9	12.2	3.1%	0.134	0.138	0.131	5.8%	86	88	83	7.6%
HGB	FP	Before	1,347	17.2	22.1	12.3		0.175	0.199	0.152		116	135	97	
HGB	FP	After	1,828	20.9	26.5	15.2	21.1%	0.176	0.199	0.154	0.7%	120	137	103	3.4%

* - wrt- with respect to

** - Obs- observations

*** - UCLM/LCLM- upper/lower confidence limit

C. CALCULATION OF THE ANNUAL I/M BENEFIT- REFERENCE METHOD

The remote sensing data used for this analysis were collected in the DFW and HGB areas. Most vehicles in these areas are participating in the I/M program. However, commuter vehicles that drive into the I/M area but are not registered in the I/M area may not be required to participate, as well as very new vehicles in their two-year exemption period, or vehicles that are otherwise avoiding program compliance. Unregistered vehicles cannot be included in the remote sensing dataset, because if the observed license plate is not linked to a registered vehicle, then the remote sensing record does not contain any vehicle information and isn't used for any analysis.

For this analysis, the vehicles observed by RS are divided into two groups: vehicles that have never been in the I/M program prior to the RS observation, and vehicles that have been in the I/M program prior to the RS observation. (The cutoff point for looking back in time for prior I/M inspections was January 1, 2016. This provides a four-year period before the 2020/2021 analysis years begin, and it should be sufficient to identify vehicles that are essentially in a no-I/M condition at the beginning of 2020.)

The number of vehicles available for the analysis is shown in Figure V-25, and again in Figure V-26. The first figure uses a linear scale for the vertical axis, while the second figure uses a logarithmic scale, to allow the smaller counts to be seen. The figures show that the group of no-I/M vehicles (red) is dominated by vehicles in their new-vehicle exemption period. However, for all model years 2001 and newer, there are at least 1,000 no-I/M vehicles, and that will provide a large enough sample for this analysis.

Figure V-25. Number of Remote Sensing Vehicles (linear scale) by Model Year and I/M Area

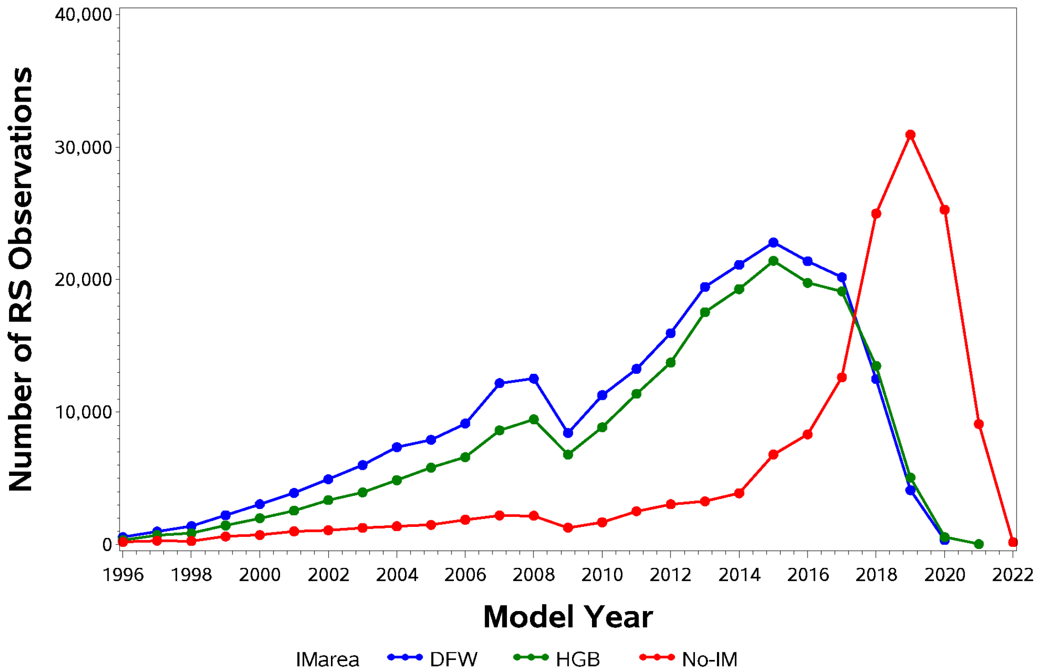


Figure V-26. Number of Remote Sensing Vehicles (log scale) by Model Year and I/M Area

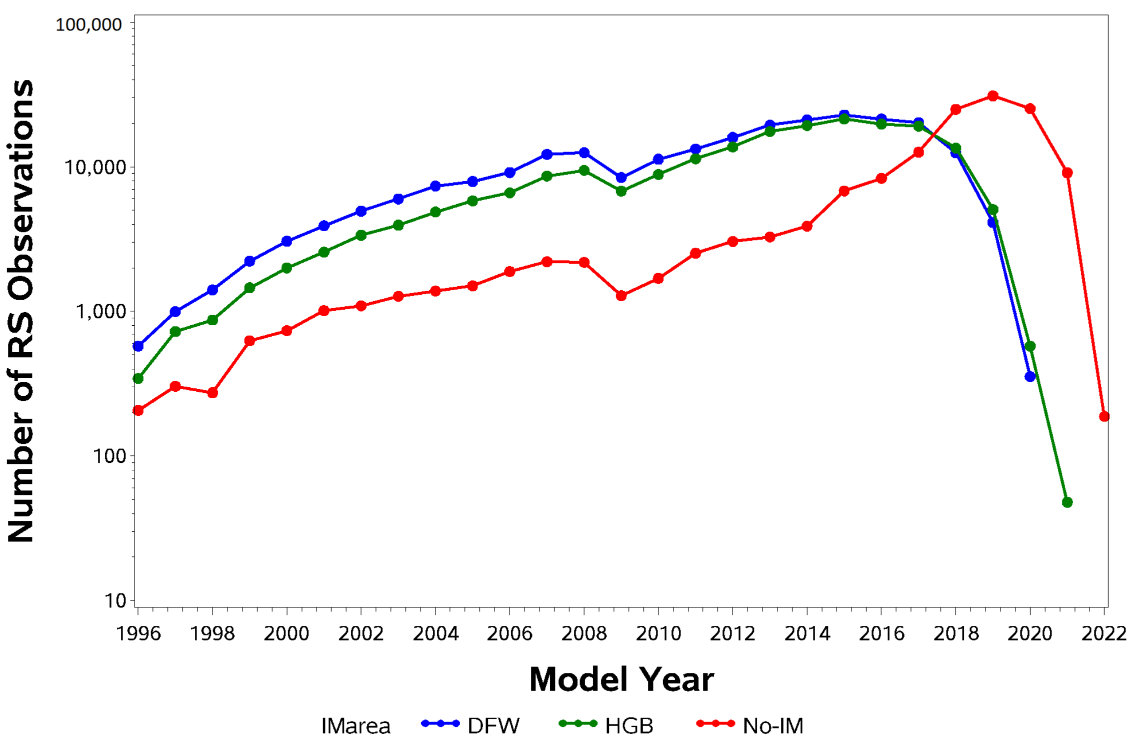
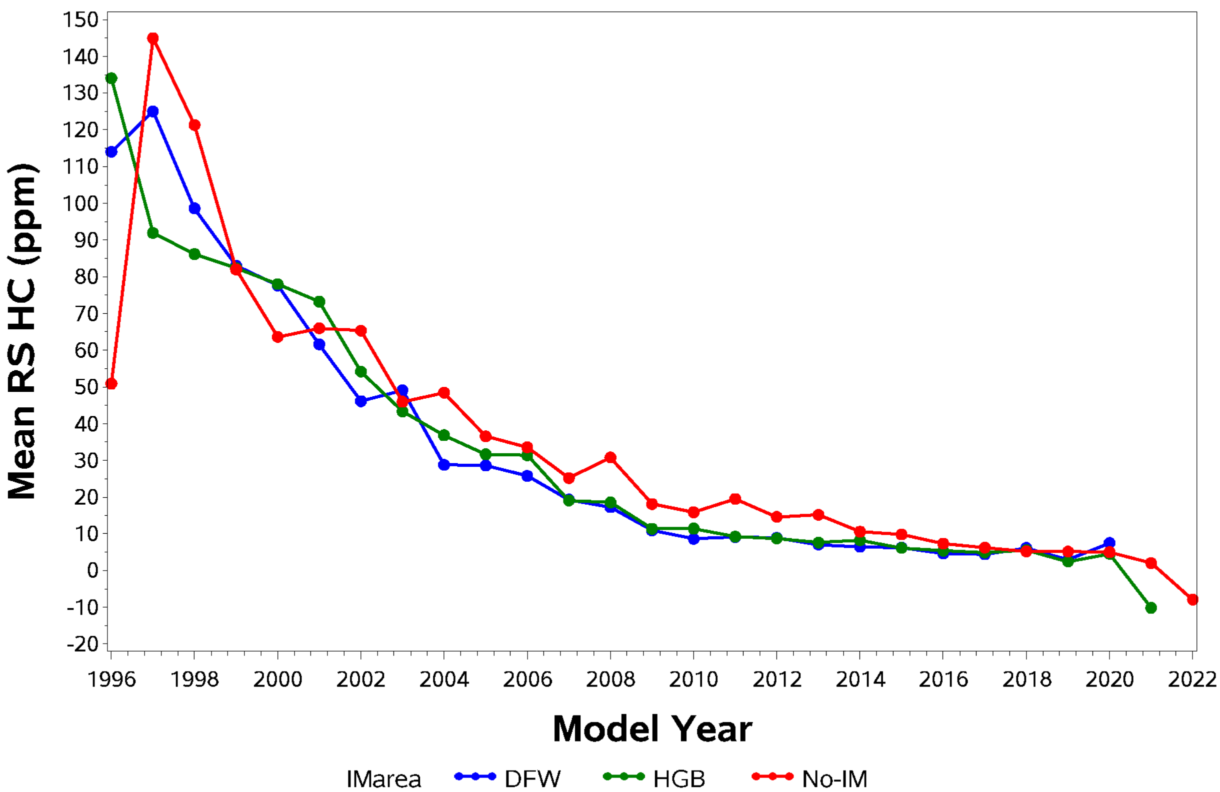


Figure V-27, Figure V-28, and Figure V-29 show the average RS HC, CO, and NO_x, for the DFW, HGB, and no-I/M areas.[6] In Figure V-27, the no-I/M HC averages are higher than the DFW or HGB HC averages for model years 2004-2017. For model years older and newer than that range, the no-I/M HC averages are very similar to the HGB and DFW averages. The no-IM CO averages shown in the Figure V-28 are lower than the HGB and DFW averages for model years 2012 and older. The no-I/M CO averages are similar to those for HGB and DFW for model years newer than 2012. Finally, Figure V-29 shows that the NO_x averages for the no-I/M fleet are substantially higher than the averages for the HGB and DFW areas. This figure indicates that the I/M program's most significant impact is on NO_x emissions. This is important since NO_x plays a major role in ozone formation.

Figure V-27. Average RS HC by Model Year and I/M Area



[6] These figures were also examined as bar charts with confidence intervals. Due to the large sample sizes in the dataset, the confidence intervals were very small. Therefore, since the overall trends are much easier to see in the line plots, the bar charts are not used here.

Figure V-28. Average RS CO by Model Year and I/M Area

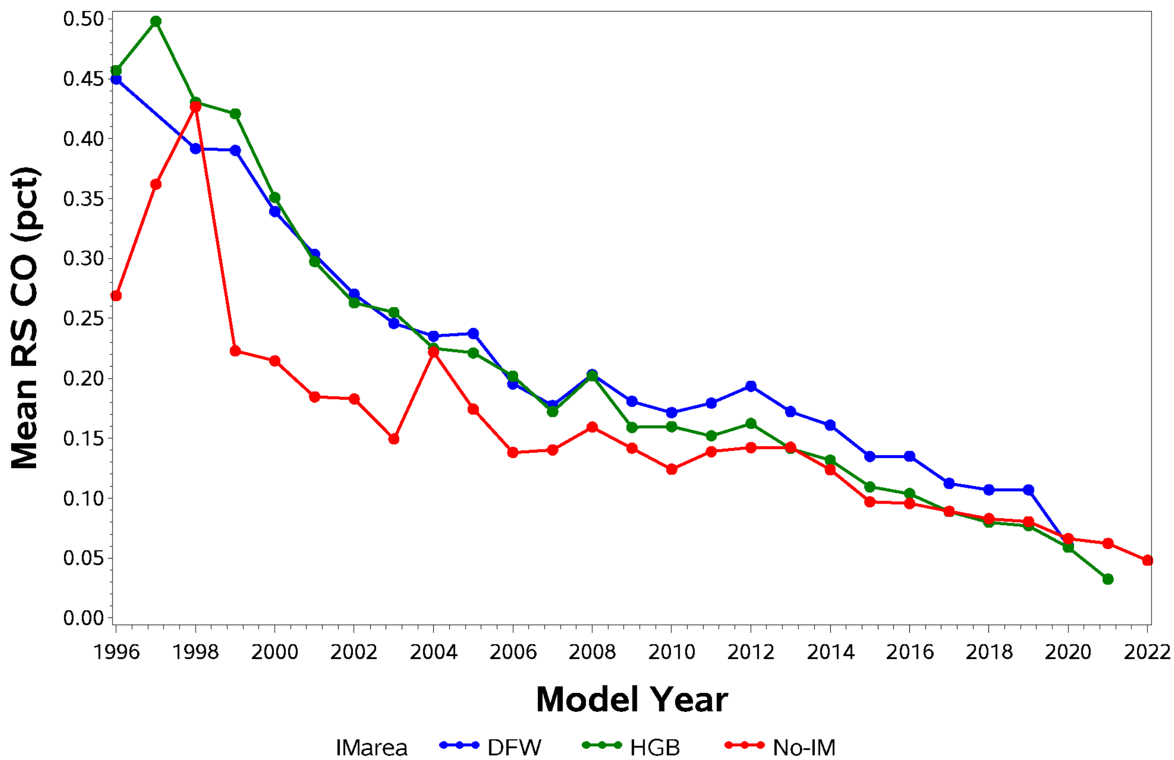
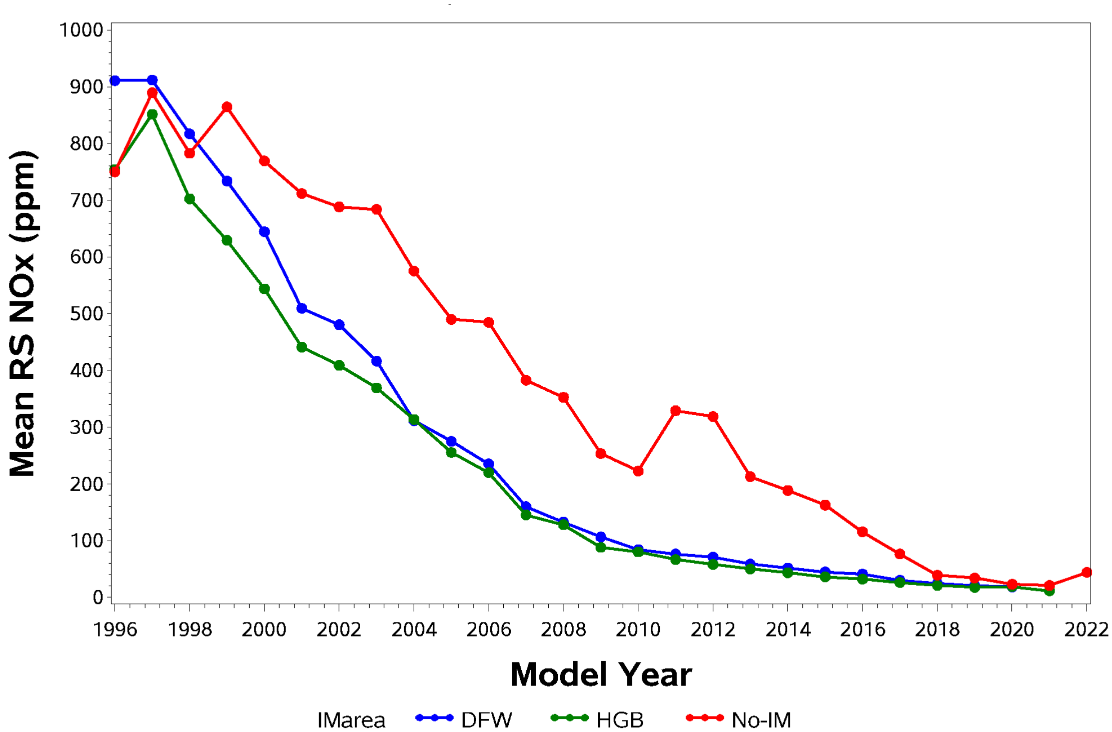


Figure V-29. Average RS NO_x by Model Year and I/M Area



VI. MEASURES FOR EVALUATING STATION PERFORMANCE

For an I/M program to function as designed, it is critical that each I/M inspection station follow the procedures and regulations that have been created to ensure that inspections are consistently performed properly. In this section, data from the TIMS database were used to explore a range of ways in which individual I/M stations and inspectors may be circumventing procedures or regulations. In past reports, these offenses were broken into two different levels: errors of commission: intentional breaking of rules to manipulate inspection results, and errors of omission: failure to routinely follow regulated procedures. However, errors of omission have become much less useful in detecting fraud now that only OBD testing is performed. Therefore, errors of omission are no longer included as a measure for evaluating station performance. The error of commission items are now broken into two different levels: a tampering with the conduct of the OBD inspection (Section VI.A), and a tampering with the overall inspection process (Section VI.B).

- OBD fraud checks for potential clean-scanning (Section VI.A)
  - VIN from vehicle does not match eVIN (VI.A.1)
  - eVIN is missing (VI.A.2)
  - Powertrain Control Module (PCM), Parameter ID (PID), VIN, and/or not ready status changes between inspections (VI.A.3)
  - Communications Protocol differs from expected (VI.A.4)
- Additional Inspection Manipulation (Section VI.B)
  - Retest too soon to have performed repairs: a passing retest follows a failed inspection within only a few minutes (VI.B.1)
  - Stations with very high safety-only inspection rates (VI.B.2)
  - Switching from light-duty (LD) (<8,500 GVWR) to HD (≥8,500 GVWR) in order to pass inspection (VI.B.3)
  - Stations with an average very high or very low fail rates relative to peers (VI.B.4)

Obviously, many stations will have the occasional inspection where the VIN was accidentally entered incorrectly and did not match the eVIN, the downloaded VIN did not match the entered VIN (which can legitimately happen for several reasons), etc. However, the goal of this section is to identify those stations where these events are frequent (search for statistical outliers), suggesting that their occurrence is not accidental, and these events are much more common than at other stations.

A percentile rank was assigned to each station for its performance on each bullet in the previous list. Using a ranking of the stations for each measure permits the comparison of one measure to another measure even if the two have different types of results. The final results were a compilation of the ranks for each station on each of the measures potential inspection fraud. These compiled ranks are discussed in Section VI.C.

Inspection stations that are operated by the state tend to exhibit a substantially different range of results than the majority of privately operated stations, skewing the distribution of the results. These stations may be identified by the “G” within the station identification number and were excluded from all of the following analysis. Fleet inspection stations may also exhibit a different range of results than public stations, but since it is possible that a fleet might have incentive to perform clean-scanned inspections, the fleet inspection stations were retained for this analysis.

A. OBD DATA CHECKS FOR EVIDENCE OF STATION FRAUD

For a vehicle receiving an OBD inspection, “clean-scanning” refers to using a vehicle with no MIL illumination in place of a vehicle with MIL illumination in an attempt to receive a passing test result. Information downloaded from the OBD system during an inspection may be used to identify possible clean-scanning activities. Parameters collected during an OBD inspection establish an electronic signature. If test parameters do not match the parameters expected for the vehicle under test, it’s possible that clean-scanning has occurred.

Mismatch Between Inspector-Entered VIN and Vehicle-Downloaded eVIN

A majority of the vehicles receiving OBD tests report the VIN electronically. These VINs downloaded with a Mode $09 request from the engine control module are referred to as eVINs. All light-duty 2005 and newer vehicles are required to report eVINs, most 2002 to 2004 vehicles also report eVINs, and some 1996 to 2001 vehicles do as well. A comparison of the inspector-entered VIN against the eVIN via the OBD connection can help verify that all OBD inspections are performed on the correct vehicle. Both the inspector-entered VIN and the eVIN are recorded in each vehicle inspection record of the TIMS.

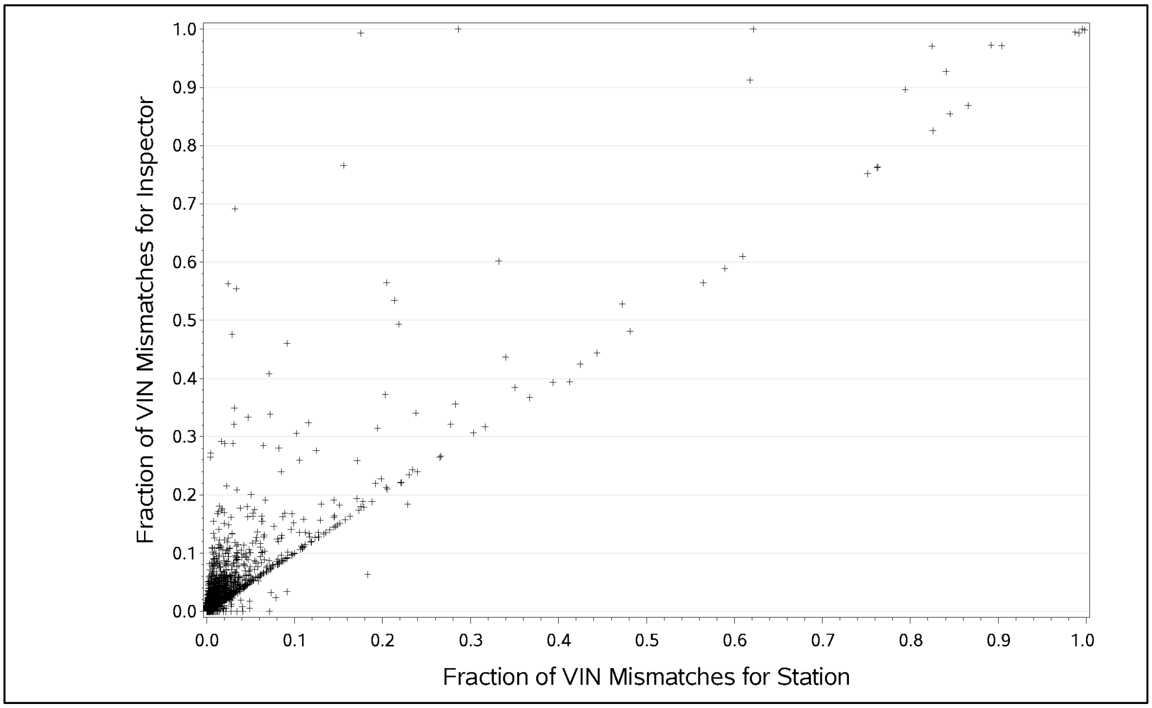
For this analysis, only those OBD inspection records that contained a valid eVIN were used (valid eVINs were confirmed using the check digit for the eVIN). This left about 14.3 million records in the dataset. For each of these records, the eVIN was compared with the VIN entered (either via keyboard or barcode scan) during the vehicle inspection. Of these, approximately 1% (136,507 records) were found to have VIN-to-eVIN discrepancies. An investigation of the VIN discrepancies, shown in Table VI-1, revealed that vehicles from the early years of OBD (1996 to 1999) had very high rates of discrepancies, with around 60% of vehicle records containing a discrepancy. Rates were very low for the later model years, largely due to federal requirements for the OBD system to provide the OBD eVIN on model year 2005 and newer vehicles. However, it should be noted that the vehicles that benefit from clean-scanning are those that fail an inspection, and that group would likely be dominated by the early model-year vehicles rather than the newer vehicles.

Table VI-1. Rates of OBD-Downloaded and Inspector-Entered VIN Discrepancies by Model Year

Model Year	Number of OBD Inspections with valid eVIN but VIN Mismatch	Percent of OBD Inspections with VIN Mismatch	Total Inspections With valid eVINs
1996	401	61.5%	652
1997	1,280	60.7%	2,108
1998	1,537	63.1%	2,434
1999	2,072	59.2%	3,501
2000	3,239	12.3%	26,229
2001	4,886	4.6%	107,378
2002	5,646	4.0%	142,266
2003	6,519	3.8%	173,668
2004	7,082	3.1%	227,864
2005	8,765	2.1%	427,103
2006	9,658	1.9%	505,531
2007	10,667	1.6%	660,216
2008	9,648	1.4%	713,939
2009	6,077	1.2%	522,790
2010	6,409	0.9%	675,491
2011	6,630	0.8%	793,380
2012	7,182	0.7%	971,807
2013	7,197	0.6%	1,195,865
2014	6,843	0.5%	1,314,016
2015	6,596	0.4%	1,499,318
2016	5,704	0.4%	1,478,341
2017	5,476	0.3%	1,607,668
2018	5,231	0.4%	1,493,802
2019	3,121	0.4%	814,447
2020	525	0.5%	107,796
2021	87	0.7%	12,707
2022	4	0.7%	589
Total	**138,482**	**0.9%**	**15,480,906**

The rate at which VIN discrepancies were recorded was calculated for each station that performed OBD inspections, and for each inspector. These are compared graphically in Figure VI-1. The horizontal axis shows the fraction of OBD inspections that contained a VIN discrepancy for each station, while the vertical axis shows the fraction of OBD inspections with a VIN discrepancy for each inspector. To reduce errors due to small sample size, stations or inspectors that performed fewer than 100 inspections were excluded from the plot. The large cluster of points at the bottom left corner of the plot includes most stations and inspections: these had a near-zero rate of VIN discrepancies. The points closer to one on the horizontal or vertical axis indicate stations or inspectors that almost always produced OBD records with a VIN discrepancy. These very-high rates could in part result from practices other than clean-scanning, such as careless data entry when the VIN is manually entered, or vehicles with an invalid eVIN (earlier model years or PCM replacements).

Figure VI-1. Rates of OBD-Downloaded and Inspector-Entered VIN Discrepancies by Station and Inspector



One additional factor that was calculated for each station was the number of times the same VIN was downloaded in different OBD inspections. If clean-scanning is taking place, there is a good chance that the "clean" vehicle would be used repeatedly, and its VIN would be downloaded numerous times, whereas VIN typos would vary with each inspection. This analysis identified that some stations were downloading the same eVIN during different OBD inspections and revealed a single station had downloaded the same eVIN in over 3,904 inspections.

These VIN mismatch findings were condensed into a rank for each station, based on the fraction of inspections that revealed a disagreement between the entered VIN and the downloaded VIN. Stations that performed fewer than 100 OBD inspections over the two-year period were again excluded from the results due to the possibility of spurious results from the small sample size. As an example of the findings, the VIN mismatch rates for the 10 worst offending stations are listed below in Figure VI-2. The table shows the rate at which there was a disagreement between the entered VIN and the eVIN, out of all inspections at that station that included a 17-digit VIN in both fields. The table also shows the maximum number of times a single VIN was tested at each station.

Table VI-2. Stations with Highest Rates of OBD and Entered VIN Mismatches

Station ID	Percent of Inspections Where VIN Did Not Match	Total Number of Inspections Performed at Station	Maximum Number of Tests on a Single VIN	Percentile Rank for Station
10 worst stations:				
1	99.8%	1,147	1,145	100.0
2	99.5%	639	575	100.0
3	99.1%	1,172	1,092	100.0
4	98.7%	394	371	99.9
5	90.4%	4,496	3,904	99.9
6	89.2%	1,571	504	99.9
7	86.5%	513	200	99.9
8	84.5%	187	99	99.9
9	84.1%	4,133	2,790	99.9
10	82.6%	172	73	99.8

eVIN is Missing

Vehicles of model years 2005 and newer are required to provide an eVIN that is downloaded during every OBD inspection. For this analysis, approximately 14.7 million inspection records for 2005 and newer vehicles that received OBD inspections during the two-year evaluation period were used. For each of these records, the eVIN was checked and the record flagged if the eVIN was missing. Of the OBD inspections for 2005 and newer vehicles, about 1.3 million inspections had a missing eVIN (entirely blank or entered as “N/A”). The counts by model year are given in Table VI-3. Rates are low for the newest model years, and much higher for the older model years, indicating that clean-scanning may be occurring.

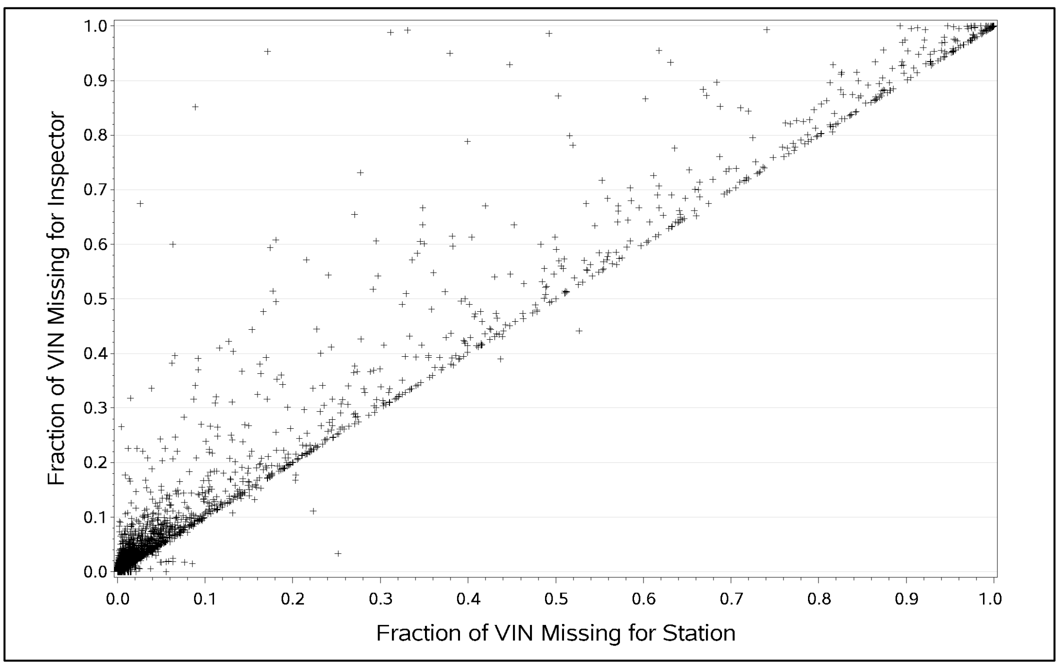
Table VI-3. Rates of OBD Inspections without eVIN by Model Year

Model Year	Number of OBD Inspections with Missing eVIN	Percent of OBD Inspections with Missing eVIN	Total OBD Inspections
2005	158,123	26.8%	589,060
2006	166,749	24.7%	675,084
2007	194,160	22.7%	856,145
2008	169,828	19.2%	885,432
2009	102,239	16.3%	625,982
2010	105,452	13.5%	781,950
2011	110,031	12.2%	904,568
2012	109,482	10.1%	1,082,340
2013	105,155	8.1%	1,302,213
2014	95,829	6.8%	1,410,858
2015	85,909	5.4%	1,586,178
2016	63,510	4.1%	1,542,373
2017	52,018	3.1%	1,660,047
2018	35,770	2.3%	1,529,767

Model Year	Number of OBD Inspections with Missing eVIN	Percent of OBD Inspections with Missing eVIN	Total OBD Inspections
2019	19,523	2.3%	834,031
2020	2,599	2.4%	110,398
2021	698	5.2%	13,405
2022	55	8.5%	644
Total	**1,577,130**	**9.6%**	**16,390,475**

The rate at which eVINs were missing was calculated for each station that performed OBD inspections, and for each inspector. These are compared graphically in Figure VI-1. The horizontal axis shows the fraction of OBD inspections that contained no eVIN for each station, while the vertical axis shows the fraction of OBD inspections that contained no eVIN for each inspector. To reduce errors due to small sample size, stations or inspectors that performed fewer than 100 inspections were excluded from the plot. The large cluster of points at the bottom left corner of the plot includes most stations and inspections: these OBD inspections almost always included an eVIN. The points closer to one on the horizontal or vertical axis indicate stations or inspectors that almost never performed OBD inspections that contained an eVIN.

Figure VI-2. Rates of OBD Inspections without eVIN by Station and Inspector



These findings of missing eVINs were condensed into a rank for each station based on the fraction of inspections that did not include an eVIN. Stations that performed fewer than 100 OBD inspections over the two-year period were again excluded from the results, due to the possibility of spurious results from the small sample size. As an example of the findings, the missing-eVIN rates for the 10 worst offending stations are listed below in Table VI-4. The table shows the rate at which the eVIN was missing from OBD inspections performed on model year 2005 and newer vehicles at the station.

Table VI-4. Stations with Highest Rates of Inspections without Downloaded eVINs

Station ID7	Percent of Inspections Without eVIN	Total Number of Inspections Performed at Station	Percentile Rank for Station
10 worst stations:			
1	100.0%	349	100.0
2	100.0%	441	100.0
3	100.0%	5,580	100.0
4	100.0%	1,852	99.9
5	100.0%	2,796	99.9
6	100.0%	3,122	99.9
7	100.0%	1,369	99.9
8	100.0%	2,217	99.9
9	100.0%	531	99.9
10	100.0%	18,128	99.8

Comparison of Vehicle-Specific Information between the First Test and Subsequent Tests

The purpose of this analysis was to compare OBD-downloaded information for a given vehicle on its first inspection, to OBD-downloaded information on retests of that same vehicle. Certain types of OBD information may be combined to create unique "electronic profiles" for each vehicle, and the electronic profile should be the same at the initial inspection and at subsequent inspections. If the electronic profile changes from one inspection to the next, inspection fraud may be suspected. For this analysis, only those vehicle inspection cycles that included an initial test and at least one retest were used, and only records where readiness monitor values were present were used, reducing the dataset from about 18 million OBD inspections to about 1.9 million inspections. This includes 688,000 initial inspections, and 760,000 retests.

In earlier years of performing this I/M Program Evaluation (2016 and earlier), three variables were used to create the first "electronic profile" for each vehicle: the eVIN, the PCM ID, and the PID Count. Beginning with the 2018 analysis, three additional variables are added: the Communications Protocol (COMM_PROT), the calibration ID (CAL_ID) and the CVN (calibration verification number). The downloaded values for these six variables from all OBD tests conducted over the two-year audit period are summarized below:

- eVIN: eVINs (valid or invalid) were only available in 81% of the test records. The eVIN or the manually entered VIN was missing in the remaining 19% of the OBD test records. The 19% that did not download correctly could be due to factors other than inspection fraud, including the vehicles age, i.e., older vehicles with nonstandard eVINs. Because of this, use of the eVIN alone would not be sufficient to positively identify clean-scanning.

- PCM ID: The PCM ID was available in all but 861 of the test records. Sixty-two unique PCM IDs were seen, but 52% of all PCM IDs had a value of "E8" and 27% had a value of "10." Two other PCM IDs each represented another 4% of records, four other PCM IDs each comprised an additional 1% of the test records, and the remaining test records were distributed among the other PCM IDs. Because of this, as with the eVIN, use of PCM ID alone would not be sufficient to positively identify clean-scanning (a substituted vehicle could easily have a value of "E8" or one of the other most common PCM IDs).
- PID Count: There were 89 unique PID Count values, and all but 2,006 OBD test records contained a value for PID Count. Eight PID Count values were seen in 57% of all OBD test records, while the remaining test records contained one of the remaining PID Count values. Therefore, the use of the PID Count alone would not be sufficient to positively identify clean-scanning.
- COMM_PROT: There were seven unique values, and all but one OBD test records contained a value for the COMM_PROT. Two COMM_PROT values were used for 76% of records, so the use of COMM_PROT along would not be sufficient to positively identify clean-scanning.
- CVN and CAL_ID each contain hundreds of unique values. These variables could be quite specific for identifying changes from one inspection to the next, except that they are only populated for about 60% of the OBD records, meaning that the other 40% of OBD records have the same values (missing) for these variables, and the CVN and CAL_ID combination alone would not be sufficient to positively identify clean-scanning.
- When the PCM ID, PID Count, COMM_PROT, CAL_ID, and CVN are looked at in combination, the five most common combinations of these variables comprise between 2.5% and 1% of inspections, with many hundreds of combinations each making up less than 1% of the remainder of inspections. Thus, the combination of these five variables is highly variable and may be a good indicator for identifying when a different vehicle is being substituted for the test.

The second electronic profile that was created was an "enabled profile." For this analysis, OBD readiness monitors were identified that are commonly found to be both "monitored" and "not monitored," depending on the make/model/model year of vehicle being inspected. For example, very few vehicles have monitored positive crankcase ventilation or air conditioning systems, so these would be poor indicators of potential clean-scanning since the monitored status is almost surely the same for two different vehicles. Similarly, catalysts and oxygen sensors are almost always monitored, so these too would be poor indicators of potential clean-scanning. Again, two different vehicles will likely both have these monitored. As shown below, EGR systems, evaporative systems, and to a lesser extent heated oxygen sensor systems and secondary air injection systems were seen to have significant percentages of vehicles with both "monitored" and "not monitored" status:

- EGR systems: There were 27% not monitored, 73% monitored;
- Evaporative systems: There were 2% not monitored, 98% monitored;
- Heated O_2 systems: There were 2% not monitored, 98% monitored; and
- Secondary air systems: There were 94% not monitored, 6% monitored.

When the status of the four monitors is looked at together, two combinations of monitor status dominated the dataset, with 69% and 22% of vehicles. Smaller numbers of vehicles comprised the remaining 14 combinations and 9% of vehicles. Since the combined monitored status of these four monitors could provide a distinguishing and characteristic profile from vehicle to vehicle, these four monitors were used for this analysis.

An electronic profile and a monitored-status profile were created for each vehicle, for its initial inspection and for any re-inspections. Any tests where either profile differed from inspection to inspection were flagged. Tests where both the electronic profile and the monitored-status profiles changed would be an indicator that a different vehicle was being substituted for the test. Note that for any individual vehicle, these downloaded values may vary among analyzer manufacturers (in particular the PID Count), so the analysis was based on vehicle/analyzer combinations. All inspections where the initial inspection took place on a different type of analyzer than that used for the retest inspection were excluded from the analysis.

Occasionally, analyzer hardware upgrades or software updates could result in OBD system PID count mismatches between multiple tests on the same vehicle, and the eVIN could be mismatched on multiple tests from the same vehicle in extremely rare instances where the PCM on the vehicle was improperly reprogrammed in an attempt to repair the vehicle. An assessment of the likelihood of fraud is provided for each of the scenarios listed below. It is also worthwhile to note that since each vehicle's OBD system "profile" was assigned based on the information collected during the vehicle's first test, this analysis would not identify any tests where a vehicle was substituted (i.e., clean-scanned) during the initial inspection.

As described above, the dataset included approximately 688,000 initial inspections and 760,000 retests. Retests that took place on an analyzer from a different manufacturer than the initial test were excluded from the results, leaving approximately 692,000 retests for analysis. The results of the analysis were:

- There were 563,612 (81.4%) retests that had matches for both the electronic profile and the readiness profile between initial test and subsequent retests on the same analyzer. These tests very likely indicate compliant testing.

- There were 33,485 (4.8%) retests that had a mismatch for both the electronic profile info and the readiness profile, between the initial test and at least one retest on the same analyzer. Test pairs where both PCM ID information and readiness profile differ are likely to be performed on two different vehicles (i.e., an indication of clean-scanning).
- There were 312 (<0.1%) retests that had a "readiness profile" mismatch between the initial test and at least one retest on the same analyzer, but the electronic profile matched between the initial test and all subsequent retests on the same analyzer. This scenario is difficult to interpret, since the readiness profile is based on "monitored versus unmonitored" status of various systems, as opposed to ready/not ready status, and therefore should never change for a vehicle despite the vehicle's state of readiness. Similarly, the computer ID information should be static for any one vehicle except for the case when PCM reprogramming is part of the repair process. Because of these difficulties in interpreting these results, the scenario of a readiness profile mismatch with a computer ID info match is not considered to be a strong indicator of non-compliant testing.
- There were 94,738 (13.7%) retests that had an electronic profile mismatch info between the initial test and at least one retest on the same analyzer, but the "readiness profile" matched between the initial test and all subsequent retests on the same analyzer. Since the computer ID serves as a unique identifier for any vehicle, this information should always match for retests on the same vehicle. A mismatch could occur only if another vehicle was substituted for a retest (clean-scanning), if an anomaly in the analyzer software interpreted the computer ID information two different ways on subsequent retests for the same vehicle, or if a vehicle repair was performed in which the vehicle's PCM was re-programmed with new ID information as a part of a repair. Although the last two scenarios are unlikely, it was not possible to quantify the likelihood of this occurring in this analysis. It is possible for two different vehicles to have common readiness profiles, so a readiness profile match does not confirm that clean-scanning did not occur. Therefore, this scenario (computer ID mismatch) is thought to be a good indicator of clean-scanning.

A summary of this information is provided in Table VI-5.

Table VI-5. Percentages of Tests with Various OBD Fraud Indicators

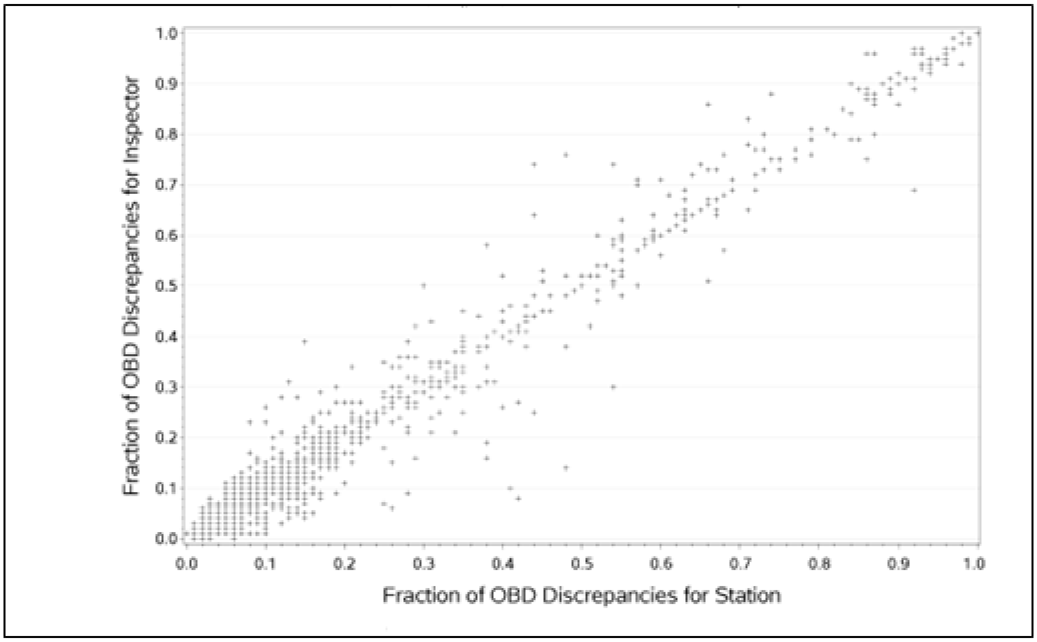
Retest Match Scenario	Retest-only Dataset
All match (compliant)	81.4%
Readiness mismatch (ambiguous)	<0.1%
PCM ID info mismatch (fraud likely)	13.7%
Both mismatch (fraud very likely)	4.8%
Estimated % of clean-scanning	5% to 19%

Next, using the complete dataset, which includes tests classified as initial tests, the following general statistics were seen for stations and inspectors with computer ID information or "readiness profile" mismatches.

- From January 1, 2020 through December 31, 2021, 91% of the 5,790 inspection stations had at least one test record with either a readiness profile or computer ID information mismatch between an initial test and a subsequent test for the same vehicle (tested using the same analyzer as the initial test). The maximum number of mismatch retest records for any one station was 4,188 records over the two-year period, and another 70 stations had more than 200 records with a mismatch. Some stations had mismatch rates as high as 94%, meaning 94% of the retest inspections performed at the station showed a mismatch in the readiness profile or computer ID information. These stations are almost certainly using clean-scanning to help failing vehicles to pass the retest.
- From January 1, 2020 through December 31, 2021, 47% of the 29,011 inspectors had at least one test record with either a readiness profile or computer ID information mismatch between an initial test and a subsequent test on the same vehicle using the same analyzer. The maximum number of mismatch retest records for any one inspector was 3,538 records over the two-year period, while an additional 31 inspectors had more than 200 mismatch retest records. Inspector mismatch rates as high as 98% were identified.

The distribution of station and inspector mismatch rates is shown in Figure VI-3. The horizontal axis shows the fraction of retest records that contained an electronic profile or readiness profile mismatch for each station. The vertical axis shows the fraction for each inspector. The large concentration of data points in the lower left corner are stations and inspectors that produced retest records that rarely had a mismatch when compared to the information from the initial inspection. In contrast, the stations/inspectors in the upper right-hand portion of the chart are those that are most likely to be clean-scanning.

Figure VI-3. Rates of Retest Discrepancies in OBD Computer and Readiness Information, by Station and Inspector



These results were condensed into a rank for each station, based on the fraction of retest inspections performed at that station that included both an electronic profile mismatch and a readiness profile mismatch. Stations with fewer than 100 OBD retest inspections over the two-year period were excluded from the results, due to the possibility of spurious results from the small sample size. The 10 stations with the highest rates of profile mismatches are listed in Table VI-6. Some electronic profile and/or readiness mismatches are to be expected, and as mentioned above, 91% of stations had at least one case of a mismatch. However, most of those stations had only one or a few mismatches. Overall, about 4.8% of retest inspections resulted in a readiness profile and electronic profile mismatch. When stations with a mismatch in more than 90% of their inspections are seen, it suggests fraudulent testing is being performed.

Table VI-6. Stations with Highest Percent of Electronic Profile and Readiness Profile Mismatches

Station ID	Percent of Re-inspections with BOTH Electronic & Readiness Mismatch	Number of Re-inspections at Station	Percentile Rank for Station
10 worst stations:			
1	94.1%	320	100.0
2	92.2%	204	100.0
3	88.2%	289	99.9
4	87.1%	278	99.9

Station ID	Percent of Re-inspections with BOTH Electronic & Readiness Mismatch	Number of Re-inspections at Station	Percentile Rank for Station
10 worst stations:			
5	84.1%	591	99.8
6	83.3%	174	99.8
7	82.8%	151	99.7
8	80.1%	256	99.7
9	79.6%	147	99.6
10	75.3%	361	99.6

Comparison of Downloaded and Expected Communication Protocol

As was done in the last program evaluation report, the OBD communications protocol indicator (TX96_COMM_PROT) was evaluated. This variable will have one of seven values, representing the six EPA approved communications protocols for vehicles sold in the U.S., or none as shown in Table VI-7.

Table VI-7. OBD Communications Protocol Codes

Code	Protocol
C	Controller Area Network (CAN)
D	CAN
P	PWM (Pulse Width Modulation)
I	ISO (International Organization for Standardization)
V	VPW (Variable Pulse Width)
K	KWP (Key Word Protocol)
N	(none found)

In theory, each type of vehicle that is manufactured uses one of the protocols, and all vehicles of the same type use the same protocol.[7]

ERG's subcontractor, de la Torre Klausmeier Consulting, Inc. (dKC) has worked extensively with comparisons of expected communication protocols with the communication protocols recorded during the OBD test, for various I/M areas. For such comparisons, dKC constructed a look-up table of communication protocols by VIN stem (comprised of VIN digits in positions 1–8, 10, and 11), using reliable data from a highly controlled, centralized I/M program.

ERG was able to match about 2/3 of the 1996 through 2009 model year vehicles in the dataset using the dKC look-up table. Because almost all vehicles after 2010 use the CAN protocol, the dKC look-up table stops with the 2009 vehicle model year. Results by model year are shown in Table VI-8. The overall mismatch rate was much higher for

[7] It is known that Chrysler vehicles from model years 1999–2005 have exhibited unreliable communications protocol values, so 1999–2005 Dodge, Jeep, and Chrysler makes were excluded from analysis in this section.

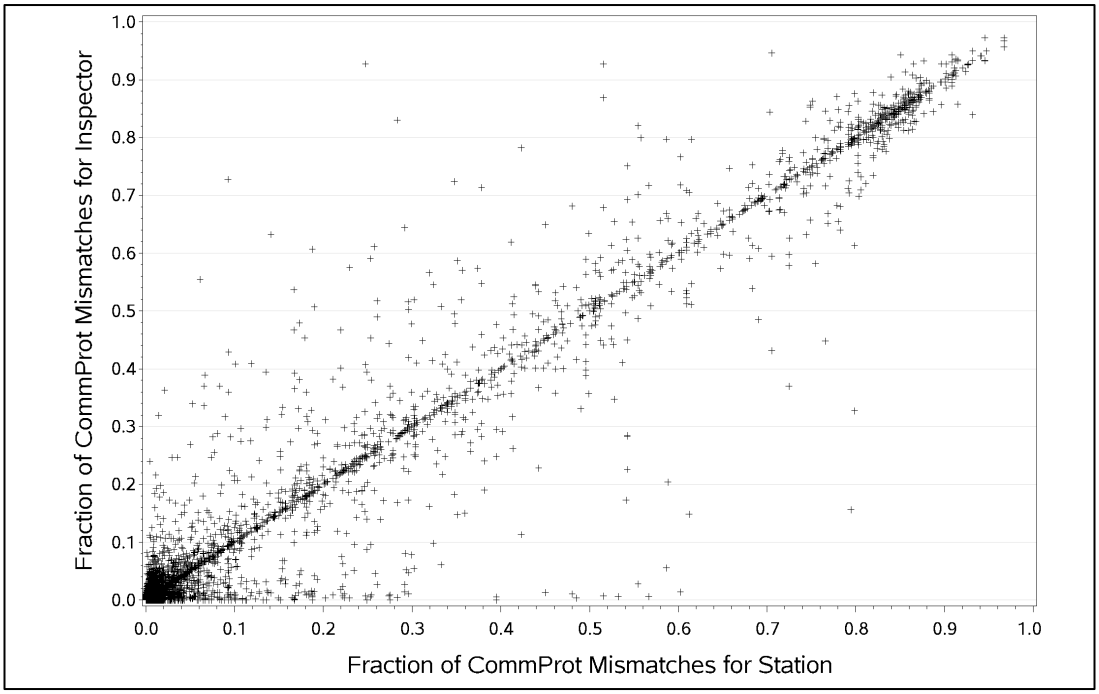
passing tests than failing tests: 19% vs. 1%. The mismatch rate is very high for vehicles of older model years where inspection fraud might be used to help the vehicle pass the inspection.

Table VI-8. Rates of Communication Protocol Mismatches by Model Year

Model Year	Mismatches: Failed Inspections		Mismatches: Passed Inspections	
	Number of Fails with Mismatch	Percent of Fails that had Mismatch	Number of Passes with Mismatch	Percent of Passes that had Mismatch
1996	27	1.5%	5,788	25.7%
1997	40	0.8%	15,128	23.4%
1998	60	1.1%	16,510	19.3%
1999	68	1.1%	18,672	19.6%
2000	91	1.0%	32,348	21.2%
2001	186	1.1%	43,586	23.5%
2002	187	1.1%	42,595	20.4%
2003	207	1.1%	49,123	18.9%
2004	244	1.2%	55,195	18.1%
2005	187	0.9%	57,752	17.5%
2006	296	1.1%	81,192	19.2%
2007	288	1.1%	92,575	18.6%
2008	258	1.0%	97,763	18.2%
2009	156	0.9%	60,379	15.4%
Total	**2,295**	**1.0%**	**668,606**	**18.8%**

The rate at which communication protocol mismatches were recorded was calculated for each station that performed OBD inspections and for each inspector. These are compared graphically in Figure VI-4. The horizontal axis shows the fraction of OBD inspections that contained a communication protocol mismatch for each station, while the vertical axis shows the fraction of OBD inspections with a mismatch for each inspector. To reduce errors due to small sample size, stations or inspectors that performed fewer than 100 inspections were excluded from the plot. The large cluster of points at the bottom left corner of the plot includes most stations and inspections: these had a very low rate of communication protocol discrepancies. The points closer to one on the horizontal or vertical axis indicate stations or inspectors that almost always produced OBD records with a communication protocol discrepancy.

Figure VI-4. Rates of Communication Protocol Mismatches by Station and Inspector



These results were condensed into a rank for each station, based on the fraction of inspections at that station that included a communication protocol mismatch. Stations with fewer than 100 OBD test inspections over the two-year period were excluded from the results, due to the possibility of spurious results from the small sample size. The 10 stations with the highest rates of mismatches are listed in Table VI-9. Some mismatches are to be expected, and most stations had at least one case of a mismatch. However, most of those stations had only one or a few mismatches. Overall, about 16% of inspections resulted in a communication protocol mismatch. As stated earlier, when stations have this high a level of mismatch it suggests fraudulent testing.

Table VI-9. Stations with Highest Percent of Communication Protocol Mismatches

Station ID	Percent of Inspections with Communication Protocol Mismatch	Number of Inspections at Station	Percentile Rank for Station
10 worst stations:			
1	96.7%	5,883	100.0
2	94.7%	1,250	100.0
3	94.6%	7,858	100.0
4	94.1%	1,367	99.9
5	94.1%	727	99.9
6	93.2%	11,482	99.9
7	92.7%	1,160	99.9
8	92.6%	593	99.9
9	92.4%	448	99.9
10	92.0%	879	99.8

B. ADDITIONAL INSPECTION MANIPULATION

Unlike OBD inspections, tailpipe emissions inspections do not include the download of vehicle-specific information that remains unchanged from an initial inspection to a re-inspection. However, several different types of inspection results have been identified that may provide good indicators that tailpipe emissions inspection fraud may be occurring at a given station. Several of these are extremely uncommon in the TIMS dataset overall but are relatively common for a handful of stations.

- Short Time Interval Between Inspections: Sometimes, a failing inspection is followed by a passing inspection only a few minutes later. This could indicate the occasional warm-up or easy repair when it happens once or twice for each station, but when it occurs many times at only a few stations, it is more likely to indicate clean-piping or clean-scanning.
- Safety-Only Inspection Rate: Vehicles that are between two and 24 years old are required to participate in the emissions inspection program by receiving OBD inspections. Vehicles older than 24 years are only required to receive a safety inspection, so it can be easier for them to pass their inspection. This can sometimes result for misclassification at the time of the inspection, but it happens more frequently at some stations than at others.
- Changing from Light-Duty to Heavy-Duty to Pass: Similarly, an initial failed inspection of a light-duty vehicle (GVWR<8,500 lbs.) is sometimes followed by a passed inspection of that vehicle as a heavy-duty vehicle. ~~Cutpoints~~ OBD pass/fail stringency is lower for HD vehicles, making the inspection easier to pass. This happens very infrequently in the dataset, but much more frequently at some stations.
- Pass/Fail Outliers: The overall failure rate at a station can be used as an indicator of whether fraud is occurring. Unusually high or unusually low failure rates may both be a cause for concern. This factor can be difficult to analyze since it is known that different areas with a different type of fleet (or a different socio-economic status) often have real differences in failure rates.

Each of these factors is discussed in more detail in the following sections, and a ranking is assigned to each station for each factor.

Short Time Interval Between Inspections

For inspection cycles that begin with a failing inspection, a retest (or retests) usually follows a day or several days after the initial failed inspection. Presumably, repairs are performed during that interval between inspections. However, some failing inspections are followed by a passing inspection within minutes, raising concern as to how the vehicle was successfully repaired so quickly, or if instead clean-scanning occurred for the passing retest. The dataset shows that many stations have one or a few cases of a passing retest following a failing initial test within a short time. These occasional cases may be the real result of a simple fix: a reconnection of a loose line or wire or other simple change. However, some stations show a much more frequent occurrence of initial inspections being quickly followed by passing inspections when compared to the majority of stations. In these cases, there may be cause for a suspicion of inspection fraud.

For this analysis, any inspections that were aborted or had dilution problems were deleted from the dataset. This left approximately 18.8 million observations in the dataset. In addition, only time differences on retest inspections that were conducted at the same inspection station as the initial inspection were used. This resulted in a dataset of about 589,000 retest observations.

The distribution of the number of times that a failed initial inspection was followed by a passing retest within 15 minutes at a given station over a two-year period is listed in Table VI-10. The table shows that this happened rarely or never for most stations. However, for 126 stations, it happened 20 or more times (up to 144 times for the highest station, not shown in the table).

Table VI-10. Number of Close-in-Time Retests per Station

Number of Close-In-Time Retests	Number of Stations	Percent of Stations
0	2,090	36.4%
1	1,118	19.5%
2	672	11.7%
3	437	7.6%
4	326	5.7%
5	231	4.0%
6	160	2.8%
7	115	2.0%
8	86	1.5%
9	84	1.5%
10	59	1.0%
11	43	0.8%
12	53	0.9%
13	33	0.6%
14	23	0.4%
15	27	0.5%
16	12	0.2%
17	13	0.2%
18	23	0.4%
19	10	0.2%
20 or more	126	2.2%
Total	5,741	**100.0%**

The 10 stations with the highest rate of close-in-time retests are listed in Table VI-11. The percentage was calculated from the number of close-in-time retests and the total number of retests at that station. Stations that performed fewer than 100 retest inspections over the two-year period are excluded from the results. From the Table VI-11, the highest ranked stations performed a third of their retest inspections within the short time period of 15 minutes or less after the initial passed inspection.

Table VI-11. Percent of Close-In-Time Retest Inspections for 10 Highest Ranking Stations

Station ID	Percent of Close-In-Time Retests	Number of Close-In-Time Retests	Total Number of Retest Inspections	Percentile Rank for Station
1	86.5%	90	104	100.0
2	41.5%	112	270	99.9
3	36.2%	144	398	99.9
4	34.7%	50	144	99.8
5	26.5%	58	219	99.8
6	25.8%	60	233	99.7
7	25.0%	25	100	99.7
8	23.5%	55	234	99.6
9	22.5%	60	267	99.5
10	21.2%	22	104	99.5

Safety-Only Inspection Rate

Another way that a station can help a vehicle to pass an inspection, even with high emissions, is to perform a safety-only inspection, instead of performing both the safety and the emissions inspection. Safety-only inspections are, in fact, found in the database, for vehicles in the age-range for emissions testing.

The performance of safety-only inspections is shown in Figure VI-5 and Figure VI-6. The figures include a green line for the number of safety-only inspections and a purple line for the number of emissions inspections, which both refer to the left vertical axis. The red line represents the percent of total inspections that were safety-only and refers to the right vertical axis. The figures focus on the older vehicle ages, 12 years and older, so that the differences can best be observed. Each figure is for one program year, either 2020 or 2021. The rate at which safety-only inspections were performed over the years is compared in Figure VI-7. This figure takes the line for the percent of total inspections that were safety-only and compares calendar years from 2016 through 2021. From Figure VI-7, it appears that the rates of safety-only inspections for the oldest model years have decreased in 2020 and 2021, compared to the prior years.

Figure VI-5. Number and Percent of Emissions and Safety-Only Inspections 2020

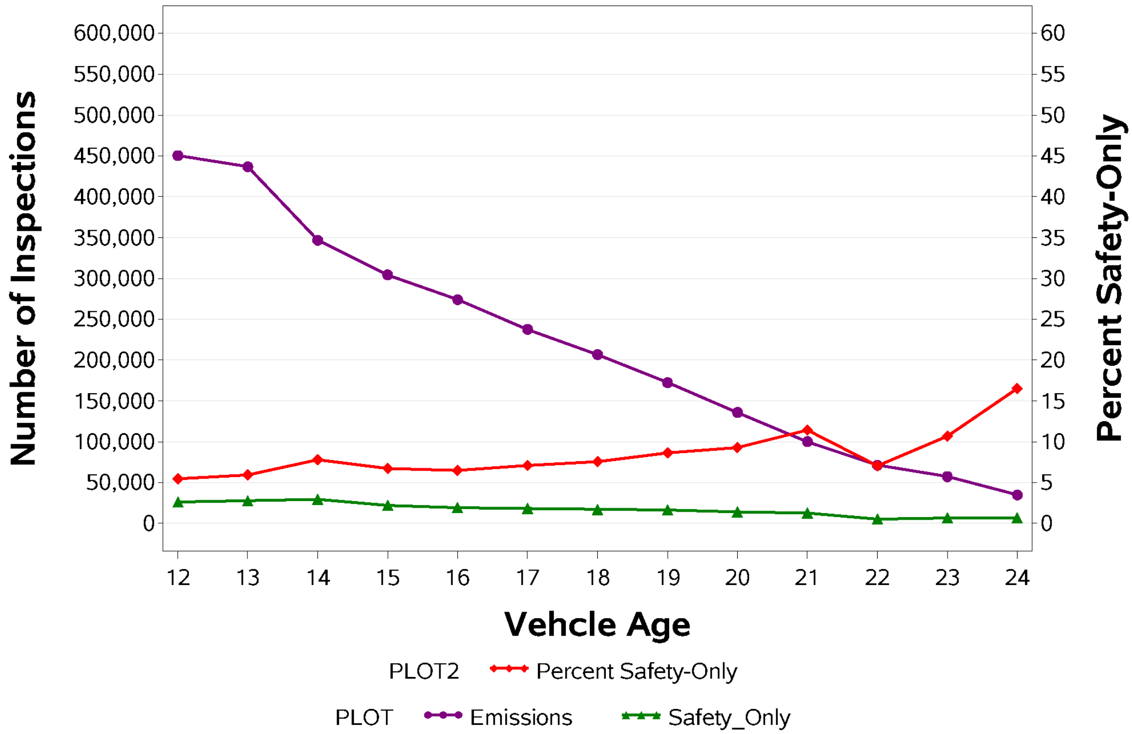


Figure VI-6. Number and Percent of Emissions and Safety-Only Inspections 2021

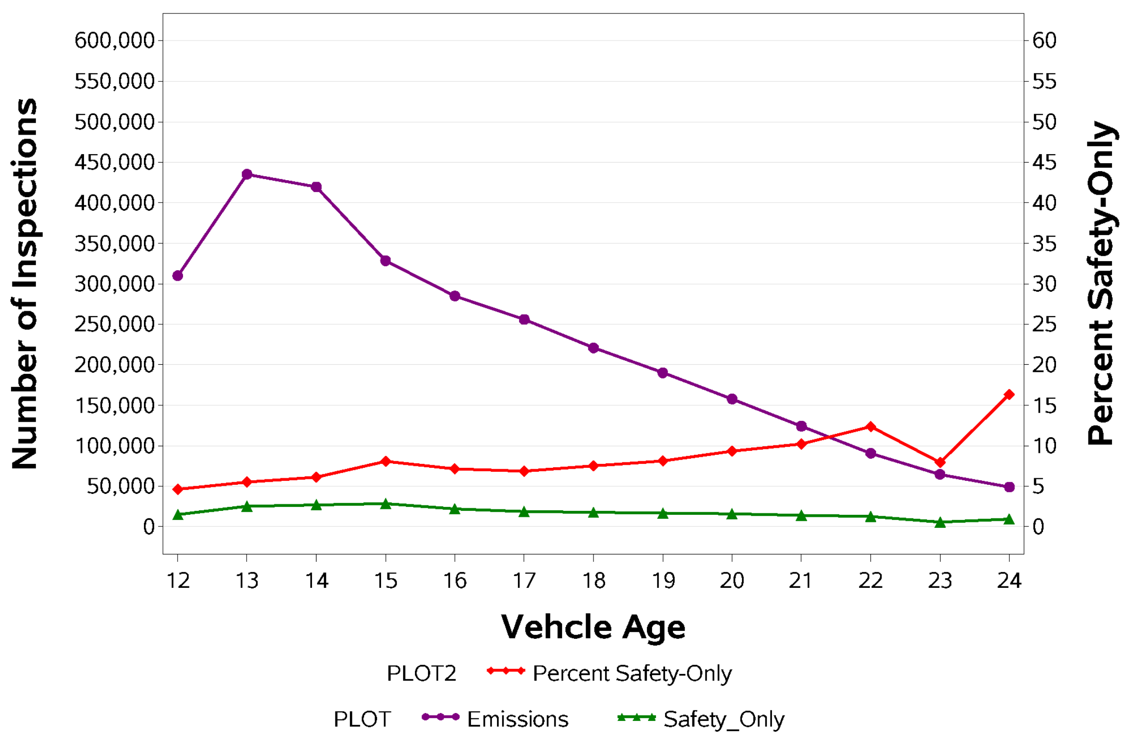
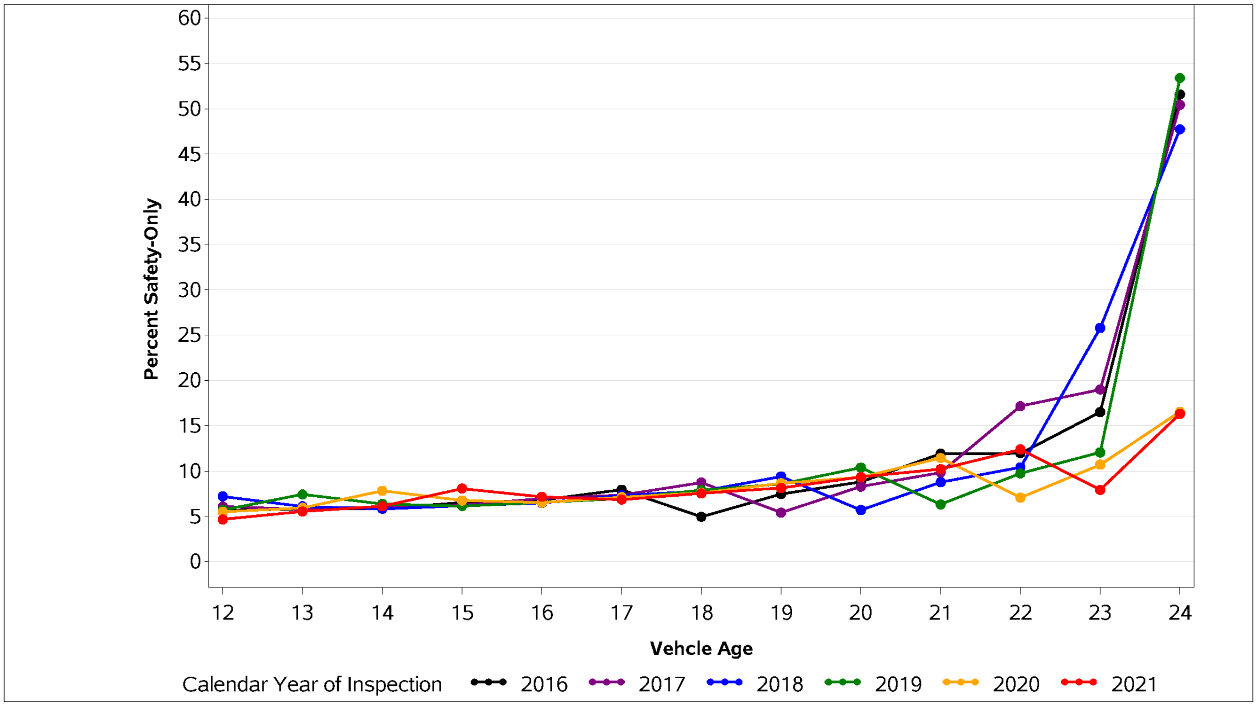


Figure VI-7. Percent of Inspections that Were Safety-Only, by Calendar Year

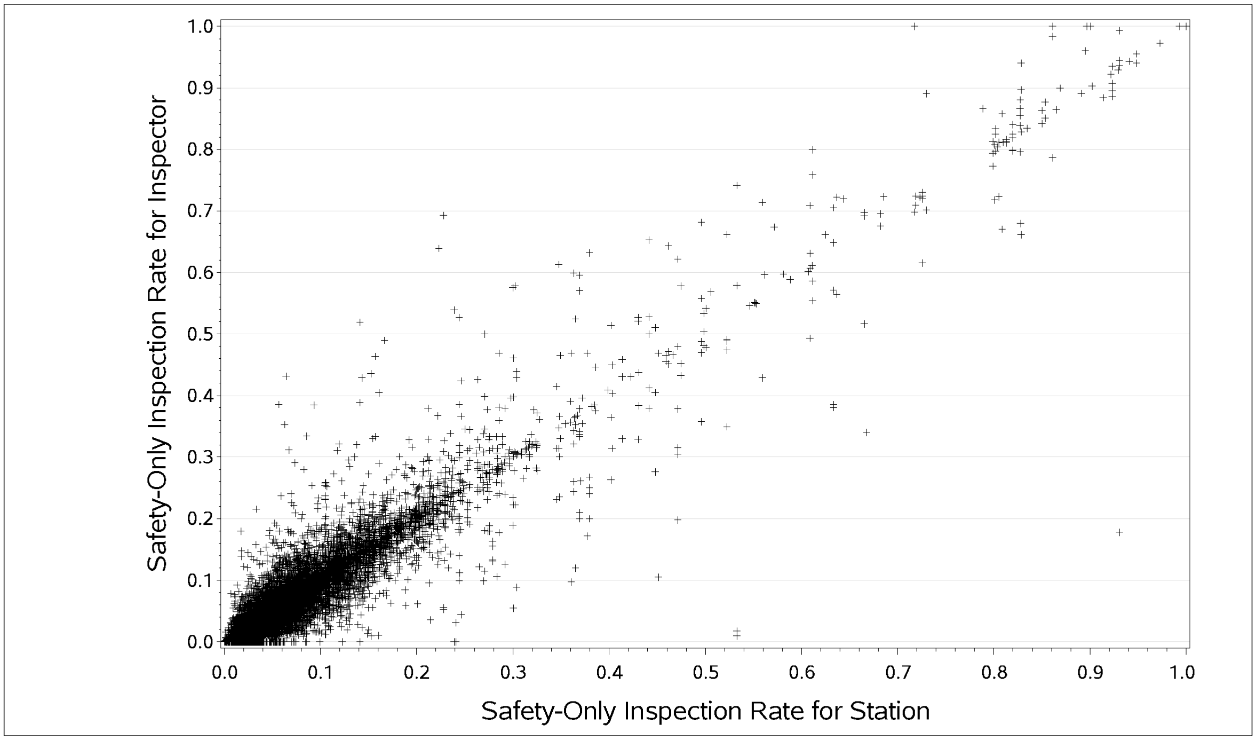


Overall, the rates of safety-only inspections are fairly low. However, they could be a possible indicator of inspection fraud if the station or inspector helped the vehicle to pass the inspection by avoiding the emissions component. If some stations show a more frequent rate of safety-only inspections than do others, then there might be cause for a suspicion of inspection fraud.

Rates of safety-only inspections were examined for all vehicles aged 12 to 24 years at the time of inspection. The data did show that some stations show a much more frequent rate of safety-only inspections than other stations: a few stations report thousands of safety-only inspections, while most stations report only one or a few. In these cases, there may be cause for a suspicion of inspection fraud.

The rate at which safety-only inspections were performed was calculated for each station that performed I/M inspections, and for each inspector. All inspections for vehicles 12 to 24 years old were used for the graph. Vehicles between two and 12 years old were omitted from the figure because the data for this cohort is essentially the same as for those vehicles between 12 and 17 years old, i.e., fairly constant around 5%. The safety-only inspection rates are compared graphically in Figure VI-8. The horizontal axis shows the fraction of inspections that were safety-only for each station, while the vertical axis shows the fraction of inspections that were safety-only for each inspector. To reduce errors due to small sample size, stations or inspectors that performed fewer than 100 inspections were excluded from the plot. The large cluster of points at the bottom left corner of the plot includes most stations and inspections: these had a very low rate of safety-only inspections. The points closer to one on the horizontal or vertical axis indicate stations or inspectors that almost always produced inspection records with a safety-only test.

Figure VI-8. Rates of Safety-Only Tests Vehicles 12-24 Years Old for Stations and Inspectors



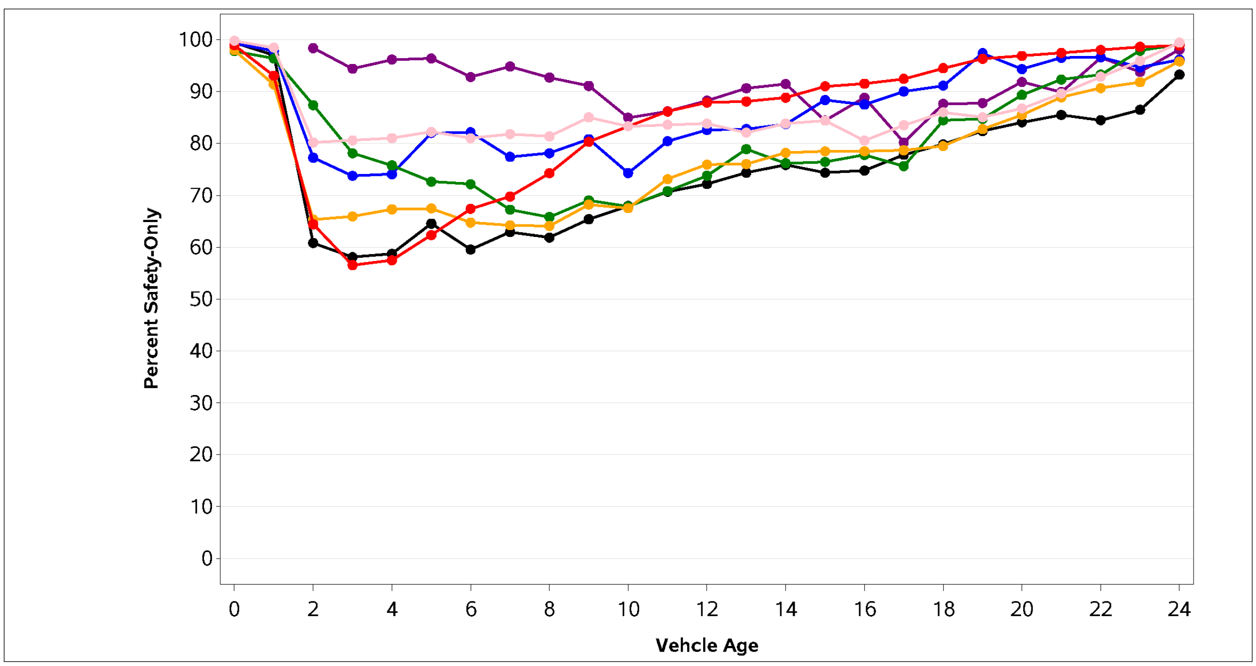
The 10 stations with the highest rate of safety-only inspections are listed in Table VI-12. Inspections for vehicles 12 years old and older, in 2020 or 2021, were used for these results: i.e., new vehicles were included, so two-year safety inspections of very new vehicles would not be included in these percentages. The percentage was calculated from the number of safety-only inspections and the total number of inspections (safety plus emissions) at that station. Stations that performed fewer than 100 inspections over the two-year period are excluded from the results. It can be seen from the table that the stations at the top of the list performed safety-only inspections on almost all of 12+ aged vehicles that they tested. It is notable that several “fleet” inspection facilities (with “F” in the second position of the station ID) made it into this top-10 list; the fleet facilities are not represented on the lists for many of the other analyses in this analysis of potentially fraudulent emissions inspections.

Table VI-12. Rate of Safety-Only Inspections for 10 Highest Ranking Stations

Station ID	Safety-Only Percent	Number of Safety-Only Inspections	Total Number of Inspections	Percentile Rank for Station
1	1.0%	105	105	100
2	1.0%	102	102	100
3	1.0%	151	150	100
4	1.0%	124	123	100
5	1.0%	1,075	1,046	100
6	0.9%	292	277	100
7	0.9%	108	102	100
8	0.9%	678	638	100
9	0.9%	7,048	6,560	100
10	0.9%	127	118	100

Because the rates of safety-only inspections are so high for some of the stations listed in Table VI-12, some of the dominant stations with the greatest numbers of safety-only inspections were investigated further. In Figure VI-9, the rate at which safety-only inspections were performed at a handful of stations are shown, each in their own color. This figure includes gasoline and non-gasoline fueled vehicles. The horizontal axis shows vehicle ages zero through 24, and it can be seen that these stations are performing safety-only inspections almost exclusively for the oldest vehicles, and a rate of 60% or more safety-only inspections for new vehicles, starting with two-year old vehicles.

Figure VI-9. Rates of Safety-Only Tests Vehicles 0-24 Years Old by Station



Changing Vehicle Type from Light-Duty to Heavy-Duty to Pass Vehicle

Given that inspection standards are less stringent for heavy-duty vehicles than for light-duty vehicles, ERG investigated whether switching a vehicle from having a light-duty GVWR (less than or equal to 8,500 lbs.) to a heavy-duty GVWR was ever used to manipulate emissions inspection results. The vehicle GVWR is an inspector-entered field in the inspection record.

For this analysis, any inspections that were aborted were deleted from the dataset. This resulted in a dataset of approximately 18.8 million inspection records. Only inspection cycles where the initial inspection and the retest inspection were conducted at the same station were used. This left about 589,000 retest inspections in the dataset.

Overall, it was found that only 0.24% of inspections (about 1,400 inspections) that were initially failed as a light-duty vehicle were followed by a passing retest as a heavy-duty vehicle. However, these inspections were clustered at a handful of stations, shown below in Table VI-13. The table shows the 10 inspection stations with the highest frequency of retests that involved a vehicle that failed as a light-duty vehicle on the initial inspection followed by a passed retest of the same vehicle as a heavy-duty vehicle. At the first station on the list, about 21% of vehicles that failed as a light-duty vehicle passed the retest when the inspector entered it as a heavy-duty vehicle.

Table VI-13. Percent of Retest Inspections Switched from Light-Duty to Heavy-Duty for 10 Highest Ranking Stations

Station ID	Percent of Retests Switched from LD to HD	Number of Switched Retests	Total Number of Retest Inspections	Percentile Rank for Station
1	21.2%	32	151	100.0
2	11.0%	13	118	99.9
3	9.3%	10	107	99.9
4	9.0%	24	266	99.8
5	8.7%	12	138	99.8
6	7.7%	18	233	99.7
7	6.8%	18	264	99.7
8	6.5%	9	139	99.6
9	5.8%	6	104	99.5
10	5.7%	12	209	99.5

Pass/Fail Outliers

Stations can also be evaluated based upon the percentage of vehicles that they pass or fail. Extremely high rates of either passing or failing vehicles may warrant further scrutiny by the DPS.

It is recognized that differences in inspection failure rates among stations are often due to factors other than fraud. For instance, the age and maintenance level of the fleet tested at each station may vary widely. However, evaluation of the fleet quality and/or socio-economic status of the area for each station is beyond the scope of this evaluation, and only overall pass/fail rates for each station are considered here.

Since it was necessary to identify both very low and very high failure rates, the stations were divided into two groups: stations with a failure rate that was above the mean failure rate over all stations and stations with a failure rate that was below the mean failure rate over all stations. The stations with a failure rate that was above the mean were ranked with the 0% rank for the station at the mean and the 100% rank for the station with the highest failure rate. The stations with a failure rate that was below the mean were ranked with the 0% rank for the station at the mean, and the 100% rank for the station with the lowest failure rate. Thus, each station gets one rank, either for being high or being low. The highest OBD failure rate stations are listed in Table VI-14, and the lowest failure rate stations are listed in Table VI-15. Stations with fewer than 100 inspections are excluded from the results.

Table VI-14. Stations with Highest OBD Failure Rates

Station ID	Failure Rate (%)	Number of Failed Inspections	Total Number of Inspections	Percentile Rank for Station
1	26.3%	74	281	100.0
2	25.6%	1,005	3,927	100.0
3	25.2%	31	123	99.9
4	24.8%	27	109	99.9
5	23.5%	31	132	99.8
6	22.1%	25	113	99.8
7	21.5%	108	503	99.7
8	21.2%	28	132	99.7
9	20.6%	52	253	99.7
10	20.4%	22	108	99.6

Table VI-15. Stations with Lowest OBD Failure Rates

Station ID	Failure Rate (%)	Number of Failed Inspections	Total Number of Inspections	Percentile Rank for Station
1	0.0%	0	121	100.0
2	0.0%	0	932	100.0
3	0.0%	0	839	99.9
4	0.0%	0	2,406	99.9
5	0.0%	0	189	99.9
6	0.0%	0	107	99.8
7	0.0%	0	478	99.8
8	0.0%	0	104	99.8
9	0.0%	0	699	99.8
10	0.0%	0	137	99.7

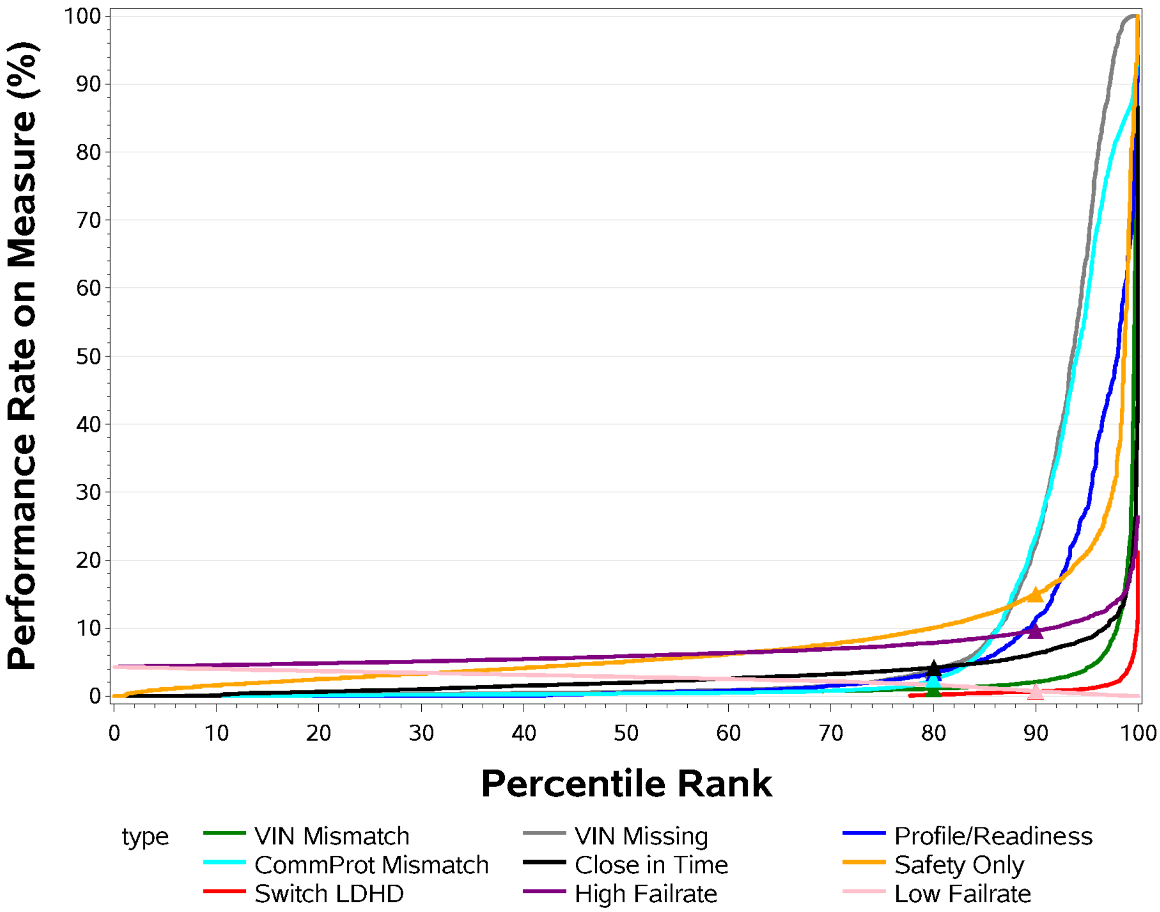
C. COMPILATION OF PERCENTILE RANKINGS

After a separate ranking was assigned for each of the measures of potential inspection fraud, the ranks were used to score the stations and identify the stations with the highest likelihood of inspection fraud.

Some of the details of the ranking procedure and the resulting ranks make it challenging to combine the ranks for an overall score. First, many stations did not perform enough inspections to receive a rank for all measures. Secondly, it is known from the measures listed in the previous sections that the range of results was not the same for each measure. For example, for the eVIN mismatch section, about 80% of stations had very low VIN mismatch rates. The remaining 20% had VIN mismatch rates that might be cause for concern, or about the top 20 percentiles in the ranking. In contrast, for the high OBD inspection failure rates, at least 90% of stations had reasonably low rates, and only the top 10% of stations would lead one to suspect possible fraud. Figure VI-10 shows the distribution of the results and the rankings that were created from those results for each of the measures of errors of commission (from sub-sections VI.A and VI.B).

The green line for the eVIN mismatch shows that the stations from zero to the 80th percentile had a very low percentage of mismatches. Above the 80th percentile, the mismatch rate quickly increases. Similarly, the blue line for the OBD electronic readiness profile shows that stations up to the 80th percentile had a low rate of mismatches. For the other measures, missing eVIN, rate of OBD communication protocol mismatch, the rate of overly close in time inspections, and retests switched from light-duty to heavy-duty, the stations below about the 80th percentile also had very low results. Above the 80th percentile, the rate of potentially fraudulent results rapidly increases. The red and purple lines show the rankings for OBD inspection failure rates. For both of those lines, the 0th percentile is the mean failure rate over all stations. The percentiles for the red line increase as the failure rate increases further above the mean, while the percentiles for the purple line increase as the failure rate decreases further below the mean. For both of these, one sees a "break" at about the 90th percentile, where the OBD fail rate starts to change rapidly as the percentile continues to increase.

Figure VI-10. Distribution of Results and Percentiles for Errors of Commission



At percentiles below the "break" (the percentile above which the results rapidly worsen) in each line on Figure VI-10, it is probably not likely that the station is performing the type of fraudulent activity that can be detected through this analysis. At percentiles above the break, there is evidence for suspicion of fraud. Thus, the visual results of the location of the break were used to create an indicator flag for each of the measures. Stations above the break for the given measure were flagged. Then, the total number of flags that each station received was determined. The stations were then sorted in descending order according to the number of flags received to create a final list ordered from most suspicious to least suspicious. The results for the top 50 most suspicious stations are given in Table VI-16. Table VI-17 gives the results for an additional 50 stations from near the middle of the range of results for comparison purposes.

Some of the first lines in the table show stations that should be investigated (if they have not already been, as a result of other analysis tools or audits). For example, the first station in the first row of the table had a very high rate of eVIN mismatches, high rates of OBD readiness and electronic profile mismatches, and a high rate of OBD communication protocol mismatches. This indicates a high possibility of OBD inspection fraud. This station also had a high rate of close-in-time retests, as well as a very low OBD inspection failure rate. This station is likely clean-scanning, and would be a good candidate for an investigation.

If this table were to be used for identifying stations for investigations, audits, etc., the user would have to review the tables to identify the stations with the clearest combination of factors for the type of fraud being considered. The entire table with all stations is available in electronic format.

Table VI-16. Top 50 Most Suspicious Stations for Potentially Fraudulent Inspections

Station ID	Sum of Rank Flags	Max Rank for Station	Individual Ranks								
			eVIN Mismatch	OBD eVIN Missing	OBD Profile/ Readiness	OBD Communication Protocol Mismatch	Close-In-Time	Safety-Only Test	Switch LD to HD	OBD High Fail Rate	OBD Low Fail Rate
1	6	100.0	100.0	98.6	98.1	98.7	99.5	11.2	31.9		98.0
2	6	99.9	99.9	97.4	97.7	97.6	99.9	6.1	32.4		94.7
3	6	98.8	96.9	87.9	95.0	88.5	98.8	85.7	97.4	62.5	
4	6	97.6	97.6	81.2	92.7	84.9	96.8	62.4	93.5	2.0	
5	6	96.2	96.2	81.3	87.9	84.8	92.3	68.9	90.5	66.6	
6	6	96.2	92.7	85.4	90.2	85.9	96.2	13.2	95.8	70.8	
7	6	95.5	91.4	89.3	95.5	89.2	95.1	55.5	90.7	52.1	
8	5	100.0	100.0	98.3	98.9	99.0		12.0			97.3
9	5	100.0	100.0	97.3	98.4	99.1		69.8			93.9
10	5	100.0	98.8	98.3	96.8	100.0		49.9			93.7
11	5	99.9	99.9	98.2	97.7	99.0		52.3			93.8
12	5	99.9	99.8	97.9	95.9	99.9		37.5			95.7
13	5	99.9	94.6	93.2	93.7	93.0	99.9	9.8	52.9	56.4	
14	5	99.9	80.1	97.7	99.9	99.1		14.0			91.7
15	5	99.8	86.3	98.0	82.5	99.8	25.0	44.0	73.0		96.6
16	5	99.8	99.8	97.4	96.6	99.7		9.6			95.6
17	5	99.8	95.9	98.0	99.8	98.6		18.9			91.7
18	5	99.6	96.5	98.2	95.5	99.6		20.8			97.0
19	5	99.6	91.0	98.8	99.6	99.2		11.5			97.9
20	5	99.5	92.7	96.7	96.2	96.4	99.5	4.8	23.8		81.6
21	5	99.2	73.4	93.0	98.3	92.8	99.2	91.1	51.0	83.3	
22	5	99.2	99.2	98.3	99.0	97.3		9.3			94.8
23	5	99.1	88.0	87.4	94.0	87.3	99.1	47.3	35.9	61.1	
24	5	99.1	99.1	95.4	95.4	96.1	98.6	21.9	60.3		78.9
25	5	99.0	91.3	98.2	90.0	99.0		10.6			95.6
26	5	99.0	97.1	98.1	99.0	97.4		18.7			94.2
27	5	98.9	93.8	81.0	67.7	76.9	87.2	90.7	98.9	83.6	
28	5	98.7	93.7	89.9	88.7	93.2		36.1			98.7
29	5	98.7	85.2	97.7	98.7	96.9		4.1			94.0
30	5	98.7	98.7	97.6		97.7		96.5			91.2

Station ID	Sum of Rank Flags	Max Rank for Station	Individual Ranks								
			eVIN Mismatch	OBD eVIN Missing	OBD Profile/ Readiness	OBD Communication Protocol Mismatch	Close-In-Time	Safety-Only Test	Switch LD to HD	OBD High Fail Rate	OBD Low Fail Rate
31	5	98.6	98.6	96.3	96.5	96.6	94.8	8.9	72.6	77.4	
32	5	98.6	90.1	95.5	93.1	95.3	98.6	28.4	57.4		61.3
33	5	98.5	78.8	94.7	88.7	94.9	98.5	15.1	84.9		92.1
34	5	98.4	93.3	98.2	97.0	98.4		7.0			90.4
35	5	98.3	86.8	97.9	98.3	97.2		11.3			90.7
36	5	98.0	81.8	93.8	92.9	93.7	98.0	18.7	61.6		0.2
37	5	97.8	91.2	81.1	83.7	77.8	95.2	35.0	97.8	13.4	
38	5	97.8	97.8	84.1	97.3	90.5		19.2			90.8
39	5	97.7	96.2	81.8		83.3		97.7		97.4	
40	5	97.5	96.8	91.0	97.5	91.5	77.1	26.6	95.1	20.0	
41	5	97.4	77.6	83.0	81.5	82.5	97.4	85.4	51.0		93.1
42	5	97.3	97.3	71.4	88.3	82.8	28.2	95.8	29.7	97.1	
43	5	97.2	97.2	87.4	92.5	88.2	91.4	29.6	75.7		8.1
44	5	96.9	90.8	96.4	96.9	96.4	.	12.0			94.6
45	5	96.6	96.6	89.1	92.2	85.7	84.5	79.3	45.4	71.8	
46	5	96.5	80.6	96.5	85.8	95.9	0.0	26.1	71.8	93.9	
47	5	96.3	83.6	86.2	90.5	86.5	62.0	96.3	89.6	11.6	
48	5	95.9	65.1	90.8	88.1	91.1	85.0	62.3	62.8	95.9	
49	5	95.7	80.6	92.7	95.7	93.2		93.7			45.9
50	5	95.0	88.2	80.6	81.0	80.5	56.8	52.8	95.0		20.0

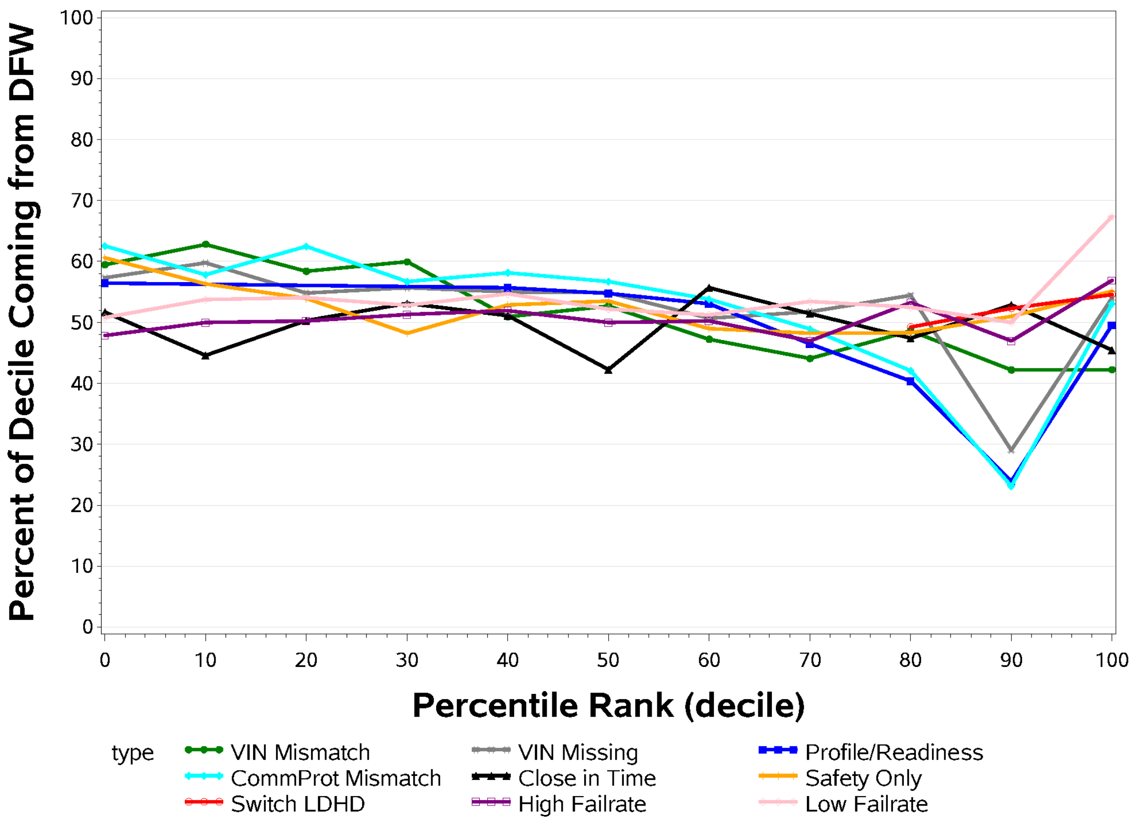
Table VI-17. 50 Mid-Range Stations for Potentially Fraudulent Inspections

Station ID	Sum of Rank Flags	Max Rank for Station	Individual Ranks								
			eVIN Mismatch	OBD eVIN Missing	OBD Profile/ Readiness	OBD Communication Protocol Mismatch	Close-In-Time	Safety-Only Test	Switch LD to HD	OBD High Fail Rate	OBD Low Fail Rate
3285	0	80.8	29.6	43.6		46.4		80.8		45.4	.
3286	0	80.8	41.9	7.0		28.3		80.8			69.9
3287	0	80.8	48.5	58.3		33.9		80.8			68.2
3288	0	80.8	21.5	35.7	11.2	22.7	10.7	74.2	80.8		1.4
3289	0	80.8	40.3	29.9		0.3					80.8
3290	0	80.7	29.5	21.4		69.9		7.2			80.7
3291	0	80.7	3.8			71.0				80.7	
3292	0	80.7	16.8	37.8		40.6		80.7			41.7
3293	0	80.7	53.7	65.9	70.8	65.3	34.4	80.7	10.5	60.0	
3294	0	80.7	18.3	32.4	11.7	22.6	10.7	80.7	17.2	40.7	
3295	0	80.7	52.8	43.0		36.3		38.9	.	.	80.7
3296	0	80.7	39.6	64.8	43.0	51.3	32.5	78.1	80.7	33.3	.
3297	0	80.6	12.1	14.7		12.4					80.6
3298	0	80.6	44.1	59.0	49.7	62.1	62.9	37.9	80.6	61.8	
3299	0	80.6	3.7	51.9		64.8		18.8		80.6	
3300	0	80.6	68.7	36.6		74.0		80.6			1.7
3301	0	80.6	63.7	15.6	66.9	42.2	51.2	80.6	77.1		18.1
3302	0	80.6	48.1	53.6	43.1	42.9	62.5	70.9	80.6		52.9
3303	0	80.5	27.9	65.1		9.6					80.5
3304	0	80.5	65.2	52.0	38.7	57.5	60.9	64.0	80.5	78.4	.
3305	0	80.5	35.1	17.2	48.5	41.1	68.7	80.5	52.1		17.8
3306	0	80.5	18.2	76.5		15.3					80.5
3307	0	80.5	42.8	14.2	22.0	18.5		69.4		80.5	
3308	0	80.4	51.6	70.0	58.3	47.4	67.8	41.0	80.4		36.8
3309	0	80.4	5.5	49.1		8.5				80.4	
3310	0	80.4	21.9	23.5		16.7		12.1		.	80.4
3311	0	80.4	46.8	14.2	68.1	17.6	61.7	80.4	5.6	54.1	
3312	0	80.4	37.3	20.8		35.0		80.4			7.8
3313	0	80.3	35.5	58.6	68.5	47.3	39.6	8.8	80.3	48.8	
3314	0	80.3	21.0	68.6	.	43.3		51.2			80.3

Station ID	Sum of Rank Flags	Max Rank for Station	Individual Ranks								
			eVIN Mismatch	OBD eVIN Missing	OBD Profile/ Readiness	OBD Communication Protocol Mismatch	Close-In-Time	Safety-Only Test	Switch LD to HD	OBD High Fail Rate	OBD Low Fail Rate
3315	0	80.3	62.2	19.6		28.5		5.7		80.3	
3316	0	80.3	46.3	51.2	68.7	40.4	53.8	80.3	67.3	42.3	
3317	0	80.3	22.0	67.2	20.2	40.4	67.7	53.9	31.9		80.3
3318	0	80.2	1.9	58.7		57.9		56.8		80.2	
3319	0	80.2	36.9	33.1	6.0	23.4	55.8	72.8	80.2		46.3
3320	0	80.2	20.9	62.8		16.4					80.2
3321	0	80.2	79.9	3.1		6.6		80.2			51.5
3322	0	80.2	25.6	59.0		50.1		80.2			80.1
3323	0	80.2	17.3	73.3		20.3		80.2			40.5
3324	0	80.2	34.1	73.2	31.4	45.9	0.0	80.2	55.9	68.9	
3325	0	80.2	9.1	43.2	24.9	16.7	0.0	57.8	41.2		80.2
3326	0	80.2	7.1	5.4		51.5				80.2	
3327	0	80.2	51.2	68.8	27.7	25.3	34.3	29.8	80.2	64.2	
3328	0	80.1	42.1	7.8		56.2		6.1			80.1
3329	0	80.1	18.9	42.2		59.0		9.0			80.1
3330	0	80.1	18.3	12.9		21.5		80.1			69.2
3331	0	80.1	79.3	58.5		4.0		80.1		40.3	
3332	0	80.1	24.9	12.0		5.3		80.1			50.9
3333	0	80.1	58.9	71.6		38.5		80.1		14.4	
3334	0	80.1	38.0	28.5		29.7		80.1			61.2

Finally, one additional investigation for this section is a comparison of the potential-fraud rates by I/M program area. If fraud rates were higher in one area than the other, it might be possible that this would result in the Texas I/M program having a different degree of impact in the two program areas. The result of the investigation is shown below in Figure VI-11. Each of the eight different types of errors of commission is shown on the plot (this is the same group of categories as was shown in Figure VI-10). However, the plot now shows the fraction of stations that are from the DFW program area, for each decile of the ranks. For example, looking at the green dots on the green line (VIN/eVIN mismatch), we can see that at the zero-percentile group, the fraction of stations in that group is 60% DFW (and by inference, 40% HGB). At the 10th decile group, we see about 64% of stations are from the DFW program area (and so 36% from the HGB program area). By contrast, at the 90th decile groups, the percentage of stations from the DFW program area is about 42% (so the HGB program area would be 68%). This indicates that at the low end of the ranks (where fraud of this type is unlikely), there are more DFW stations, and at the high end of the ranks (where fraud of this type is much more likely) there are more HGB stations. A similar, and even more significant, trend can be seen for the squares on the dark blue line, for the OBD electronic profile comparisons, and on the light blue line, for the OBD communication protocol mismatches. For the other measures, it is much more difficult to see any sort of meaningful trend. However, it does appear that for the three major OBD fraud checks, the VIN/eVIN, the electronic profile, and the communication protocol, more stations are potentially committing fraudulent inspections in the HGB program area than in the DFW program area. Since OBD vehicles now dominate the fleet, fraudulent OBD inspections could significantly undermine the Texas I/M program’s effectiveness.

Figure VI-11. Fraction of Stations from the DFW Program Area by Rank Decile for Potential Inspection Fraud Indicators



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Appendix A-
DTC Groups

Table A-1. Evap DTCs

DTC	DTC Description	DTC	DTC Description
P0093	Fuel System Leak Detected - Large Leak	P0496	Evap High Purge Flow
P0094	Fuel System Leak Detected - Small Leak	P0497	Evap Low Purge Flow
P0440	Evap Malfunction	P0498	Evap Vent Valve Control Circuit Low
P0441	Evap Incorrect Purge Flow	P0499	Evap Vent Valve Control Circuit High
P0442	Evap Leak Detected (small leak)	P2024	Evap Fuel Vapor Temperature Sensor Circuit
P0443	Evap Purge Control Valve Circuit	P2025	Evap Fuel Vapor Temperature Sensor Performance
P0444	Evap Purge Control Valve Circuit Open	P2026	Evap Fuel Vapor Temperature Sensor Circuit Low Voltage
P0445	Evap Purge Control Valve Circuit Shorted	P2027	Evap Fuel Vapor Temperature Sensor Circuit High Voltage
P0446	Evap Vent Control Circuit Malfunction	P2028	Evap Fuel Vapor Temperature Sensor Circuit Intermittent
P0447	Evap Vent Control Circuit Open	P2400	Evap Leak Detection Pump Control Circuit/Open
P0448	Evap Vent Control Circuit Shorted	P2401	Evap Leak Detection Pump Control Circuit Low
P0449	Evap Vent Valve/Solenoid Circuit Malfunction	P2402	Evap Leak Detection Pump Control Circuit High
P0450	Evap Pressure Sensor Malfunction	P2403	Evap Leak Detection Pump Sense Circuit/Open
P0451	Evap Pressure Sensor Range/Performance	P2404	Evap Leak Detection Pump Sense Circuit Range/Performance
P0452	Evap Pressure Sensor Low Input	P2405	Evap Leak Detection Pump Sense Circuit Low
P0453	Evap Pressure Sensor High Input	P2406	Evap Leak Detection Pump Sense Circuit High
P0454	Evap Pressure Sensor Intermittent	P2407	Evap Leak Detection Pump Sense Circuit Intermittent/Erratic
P0455	Evap Leak Detected (gross leak)	P2408	Fuel Cap Sensor/Switch Circuit
P0456	Evap Leak Detected (very small leak)	P2409	Fuel Cap Sensor/Switch Circuit Range/Performance
P0457	Evap Leak Detected (fuel cap loose/off)	P2410	Fuel Cap Sensor/Switch Circuit Low
P0458	Evap Purge Control Valve Circuit Low	P2411	Fuel Cap Sensor/Switch Circuit High
P0459	Evap Purge Control Valve Circuit High	P2412	Fuel Cap Sensor/Switch Circuit Intermittent/Erratic
P0465	Purge Flow Sensor Circuit Malfunction	P2418	Evap Switching Valve Control Circuit / Open
P0466	Purge Flow Sensor Circuit Range/Performance	P2419	Evap Switching Valve Control Circuit Low
P0467	Purge Flow Sensor Circuit Low Input	P2420	Evap Switching Valve Control Circuit High
P0468	Purge Flow Sensor Circuit High Input	P2421	Evap Vent Valve Stuck Open
P0469	Purge Flow Sensor Circuit Intermittent	P2422	Evap Vent Valve Stuck Closed

Table A-2. Catalyst DTCs[8]

DTC	DTC Description	DTC	DTC Description
P0420	Catalyst System Efficiency Below Threshold	P0431	Warm Up Catalyst Efficiency Below Threshold
P0421	Warm Up Catalyst Efficiency Below Threshold	P0432	Main Catalyst Efficiency Below Threshold
P0422	Main Catalyst Efficiency Below Threshold	P0433	Heated Catalyst Efficiency Below Threshold
P0423	Heated Catalyst Efficiency Below Threshold	P0434	Heated Catalyst Temperature Below Threshold
P0424	Heated Catalyst Temperature Below Threshold	P0435	Catalyst Temperature Sensor
P0425	Catalyst Temperature Sensor	P0436	Catalyst Temperature Sensor Range/Performance
P0426	Catalyst Temperature Sensor Range/Performance	P0437	Catalyst Temperature Sensor Low
P0427	Catalyst Temperature Sensor Low	P0438	Catalyst Temperature Sensor High
P0428	Catalyst Temperature Sensor High	P0439	Catalyst Heater Control Circuit
P0429	Catalyst Heater Control Circuit	P2423	HC Adsorption Catalyst Efficiency Below Threshold
P0430	Catalyst System Efficiency Below Threshold	P2424	HC Adsorption Catalyst Efficiency Below Threshold

Table A-3. EGR DTCs

DTC	DTC Description	DTC	DTC Description
P0400	EGR Flow	P0489	EGR Control Circuit Low
P0401	EGR Flow Insufficient Detected	P0490	EGR Control Circuit High
P0402	EGR Flow Excessive Detected	P2141	EGR Throttle Control Circuit Low
P0403	EGR Control Circuit	P2142	EGR Throttle Control Circuit High
P0404	EGR Control Circuit Range/Performance	P2143	EGR Vent Control Circuit/Open
P0405	EGR Sensor "A" Circuit Low	P2144	EGR Vent Control Circuit Low
P0406	EGR Sensor "A" Circuit High	P2145	EGR Vent Control Circuit High
P0407	EGR Sensor "B" Circuit Low	P2413	EGR System Performance
P0408	EGR Sensor "B" Circuit High	P2425	EGR Cooling Valve Control Circuit/Open
P0409	EGR Sensor "A" Circuit	P2426	EGR Cooling Valve Control Circuit Low
P0486	EGR Sensor "B" Circuit	P2427	EGR Cooling Valve Control Circuit High
P0487	EGR Throttle Position Control Circuit	P2428	Exhaust Gas Temperature Too High
P0488	EGR Throttle Position Control Range/Perf	P2429	Exhaust Gas Temperature Too High

[8] Includes heated catalyst DTCs, although none were present in the data analyzed for this study.

Table A-4. O_2 System DTCs[9]

DTC	DTC Description	DTC	DTC Description
P0030	HO2S Heater Control Circuit	P0166	O2 Sensor Circuit No Activity Detected
P0031	HO2S Heater Control Circuit Low	P0167	O2 Sensor Heater Circuit
P0032	HO2S Heater Control Circuit High	P2195	O2 Sensor Signal Stuck Lean
P0036	HO2S Heater Control Circuit	P2196	O2 Sensor Signal Stuck Rich
P0037	HO2S Heater Control Circuit Low	P2197	O2 Sensor Signal Stuck Lean
P0038	HO2S Heater Control Circuit High	P2198	O2 Sensor Signal Stuck Rich
P0040	O2 Sensor Signals Swapped B1 S1/ B2 S1	P2231	O2 Sensor Signal Circuit Shorted to Heater Circuit
P0041	O2 Sensor Signals Swapped B1 S2/ B2 S2	P2232	O2 Sensor Signal Circuit Shorted to Heater Circuit
P0042	HO2S Heater Control Circuit	P2233	O2 Sensor Signal Circuit Shorted to Heater Circuit
P0043	HO2S Heater Control Circuit Low	P2234	O2 Sensor Signal Circuit Shorted to Heater Circuit
P0044	HO2S Heater Control Circuit High	P2235	O2 Sensor Signal Circuit Shorted to Heater Circuit
P0050	HO2S Heater Control Circuit	P2236	O2 Sensor Signal Circuit Shorted to Heater Circuit
P0051	HO2S Heater Control Circuit Low	P2237	O2 Sensor Positive Current Control Circuit/Open
P0052	HO2S Heater Control Circuit High	P2238	O2 Sensor Positive Current Control Circuit Low
P0053	HO2S Heater Resistance	P2239	O2 Sensor Positive Current Control Circuit High
P0054	HO2S Heater Resistance	P2240	O2 Sensor Positive Current Control Circuit/Open
P0055	HO2S Heater Resistance	P2241	O2 Sensor Positive Current Control Circuit Low
P0056	HO2S Heater Control Circuit	P2242	O2 Sensor Positive Current Control Circuit High
P0057	HO2S Heater Control Circuit Low	P2243	O2 Sensor Reference Voltage Circuit/Open
P0058	HO2S Heater Control Circuit High	P2244	O2 Sensor Reference Voltage Performance
P0059	HO2S Heater Resistance	P2245	O2 Sensor Reference Voltage Circuit Low
P0060	HO2S Heater Resistance	P2246	O2 Sensor Reference Voltage Circuit High
P0061	HO2S Heater Resistance	P2247	O2 Sensor Reference Voltage Circuit/Open
P0062	HO2S Heater Control Circuit	P2248	O2 Sensor Reference Voltage Performance
P0063	HO2S Heater Control Circuit Low	P2249	O2 Sensor Reference Voltage Circuit Low
P0064	HO2S Heater Control Circuit High	P2250	O2 Sensor Reference Voltage Circuit High
P0130	O2 Sensor Circuit	P2251	O2 Sensor Negative Current Control Circuit/Open
P0131	O2 Sensor Circuit Low Voltage	P2252	O2 Sensor Negative Current Control Circuit Low`
P0132	O2 Sensor Circuit High Voltage	P2253	O2 Sensor Negative Current Control Circuit High
P0133	O2 Sensor Circuit Slow Response	P2254	O2 Sensor Negative Current Control Circuit/Open
P0134	O2 Sensor Circuit No Activity Detected	P2255	O2 Sensor Negative Current Control Circuit Low
P0135	O2 Sensor Heater Circuit	P2256	O2 Sensor Negative Current Control Circuit High
P0136	O2 Sensor Circuit	P2270	O2 Sensor Signal Stuck Lean
P0137	O2 Sensor Circuit Low Voltage	P2271	O2 Sensor Signal Stuck Rich
P0138	O2 Sensor Circuit High Voltage	P2272	O2 Sensor Signal Stuck Lean
P0139	O2 Sensor Circuit Slow Response	P2273	O2 Sensor Signal Stuck Rich
P0140	O2 Sensor Circuit No Activity Detected	P2274	O2 Sensor Signal Stuck Lean
P0141	O2 Sensor Heater Circuit	P2275	O2 Sensor Signal Stuck Rich
P0142	O2 Sensor Circuit	P2276	O2 Sensor Signal Stuck Lean
P0143	O2 Sensor Circuit Low Voltage	P2277	O2 Sensor Signal Stuck Rich
P0144	O2 Sensor Circuit High Voltage	P2278	O2 Sensor Signals Swapped B1 S3 / B2 S3
P0145	O2 Sensor Circuit Slow Response	P2297	O2 Sensor Out of Range During Deceleration
P0146	O2 Sensor Circuit No Activity Detected	P2298	O2 Sensor Out of Range During Deceleration
P0147	O2 Sensor Heater Circuit	P2414	O2 Sensor Exhaust Sample Error
P0150	O2 Sensor Circuit	P2415	O2 Sensor Exhaust Sample Error
P0151	O2 Sensor Circuit Low Voltage	P2416	O2 Sensor Signals Swapped B1 S2 / B1 S3

[9] Includes oxygen sensor and oxygen sensor heater.

DTC	DTC Description	DTC	DTC Description
P0152	O2 Sensor Circuit High Voltage	P2417	O2 Sensor Signals Swapped B2 S2 / B2 S3
P0153	O2 Sensor Circuit Slow Response	P2626	O2 Sensor Pumping Current Trim Circuit/Open
P0154	O2 Sensor Circuit No Activity Detected	P2627	O2 Sensor Pumping Current Trim Circuit Low
P0155	O2 Sensor Heater Circuit	P2628	O2 Sensor Pumping Current Trim Circuit High
P0156	O2 Sensor Circuit	P2629	O2 Sensor Pumping Current Trim Circuit/Open
P0157	O2 Sensor Circuit Low Voltage	P2630	O2 Sensor Pumping Current Trim Circuit Low
P0158	O2 Sensor Circuit High Voltage	P2631	O2 Sensor Pumping Current Trim Circuit High
P0159	O2 Sensor Circuit Slow Response	P2A00	O2 Sensor Circuit Range/Performance
P0160	O2 Sensor Circuit No Activity Detected	P2A01	O2 Sensor Circuit Range/Performance
P0161	O2 Sensor Heater Circuit	P2A02	O2 Sensor Circuit Range/Performance
P0162	O2 Sensor Circuit	P2A03	O2 Sensor Circuit Range/Performance
P0163	O2 Sensor Circuit Low Voltage	P2A04	O2 Sensor Circuit Range/Performance
P0164	O2 Sensor Circuit High Voltage	P2A05	O2 Sensor Circuit Range/Performance
P0165	O2 Sensor Circuit Slow Response		

Table A-5. Secondary Air Intake System DTCs

DTC	**DTC Description**	**DTC**	**DTC Description**
P0410	Secondary Air Injection System	P2431	Secondary Air Injection System Air Flow/Pressure Sensor Circuit Range/Performance
P0411	Secondary Air Injection System Incorrect Flow Detected	P2432	Secondary Air Injection System Air Flow/Pressure Sensor Circuit Low
P0412	Secondary Air Injection System Switching Valve "A" Circuit	P2433	Secondary Air Injection System Air Flow/Pressure Sensor Circuit High
P0413	Secondary Air Injection System Switching Valve "A" Circuit Open	P2434	Secondary Air Injection System Air Flow/Pressure Sensor Circuit Intermittent/Erratic
P0414	Secondary Air Injection System Switching Valve "A" Circuit Shorted	P2435	Secondary Air Injection System Air Flow/Pressure Sensor Circuit
P0415	Secondary Air Injection System Switching Valve "B" Circuit	P2436	Secondary Air Injection System Air Flow/Pressure Sensor Circuit Range/Performance
P0416	Secondary Air Injection System Switching Valve "B" Circuit Open	P2437	Secondary Air Injection System Air Flow/Pressure Sensor Circuit Low
P0417	Secondary Air Injection System Switching Valve "B" Circuit Shorted	P2438	Secondary Air Injection System Air Flow/Pressure Sensor Circuit High
P0418	Secondary Air Injection System Control "A" Circuit	P2439	Secondary Air Injection System Air Flow/Pressure Sensor Circuit Intermittent/Erratic
P0419	Secondary Air Injection System Control "B" Circuit	P2440	Secondary Air Injection System Switching Valve Stuck Open
P0491	Secondary Air Injection System Insufficient Flow	P2441	Secondary Air Injection System Switching Valve Stuck Closed
P0492	Secondary Air Injection System Insufficient Flow	P2442	Secondary Air Injection System Switching Valve Stuck Open
P2257	Secondary Air Injection System Control "A" Circuit Low	P2443	Secondary Air Injection System Switching Valve Stuck Closed
P2258	Secondary Air Injection System Control "A" Circuit High	P2444	Secondary Air Injection System Pump Stuck On
P2259	Secondary Air Injection System Control "B" Circuit Low	P2445	Secondary Air Injection System Pump Stuck Off
P2260	Secondary Air Injection System Control "B" Circuit High	P2446	Secondary Air Injection System Pump Stuck On
P2430	Secondary Air Injection System Air Flow/Pressure Sensor Circuit	P2447	Secondary Air Injection System Pump Stuck Off

Appendix B-
OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

Table B-1. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
ACUR								
3.2TL	1	0.03%	5	0.14%	3,673	99.84%	3,679	0.02%
ILX 20	2	0.04%	3	0.05%	5,469	99.91%	5,474	0.04%
MDX	7	0.01%	32	0.05%	64,221	99.94%	64,260	0.42%
RDX	4	0.01%	29	0.07%	43,798	99.92%	43,831	0.29%
RL	1	0.04%	3	0.12%	2,604	99.85%	2,608	0.02%
RSX	1	0.04%	6	0.23%	2,652	99.74%	2,659	0.02%
TL	6	0.02%	32	0.09%	36,340	99.90%	36,378	0.24%
TSX	3	0.01%	15	0.06%	24,482	99.93%	24,500	0.16%
AUDI								
A4	1	0.00%	22	0.08%	25,929	99.91%	25,952	0.17%
A5 Cabriolet								
A6	4	0.02%	16	0.08%	20,472	99.90%	20,492	0.14%
Q3	1	0.01%	9	0.11%	8,002	99.88%	8,012	0.05%
Q5	1	0.01%	16	0.08%	19,679	99.91%	19,696	0.13%
Q5/SQ5	3	0.02%	17	0.11%	16,051	99.88%	16,071	0.11%
Q7	1	0.01%	20	0.10%	19,841	99.89%	19,862	0.13%
TT	1	0.03%	10	0.34%	2,974	99.63%	2,985	0.02%
BMW								
228i	1	0.08%	2	0.15%	1,294	99.77%	1,297	0.01%
320i	1	0.01%	7	0.09%	7,826	99.90%	7,834	0.05%
320i xDrive	1	0.10%	4	0.40%	1,005	99.50%	1,010	0.01%
325i	1	0.02%	12	0.19%	6,145	99.79%	6,158	0.04%
328i	11	0.03%	43	0.12%	36,247	99.85%	36,301	0.24%

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
328i SA	2	0.02%	12	0.14%	8,538	99.84%	8,552	0.06%
328i xDrive	1	0.02%	4	0.10%	4,160	99.88%	4,165	0.03%
330Ci	3	0.11%	6	0.22%	2,739	99.67%	2,748	0.02%
330i	1	0.01%	6	0.08%	7,076	99.90%	7,083	0.05%
335i	7	0.07%	31	0.31%	9,935	99.62%	9,973	0.07%
428i	1	0.02%	11	0.17%	6,441	99.81%	6,453	0.04%
528i	6	0.03%	32	0.17%	18,381	99.79%	18,419	0.12%
528i xDrive	2	0.16%	4	0.33%	1,217	99.51%	1,223	0.01%
530i	1	0.01%	1	0.01%	6,713	99.97%	6,715	0.04%
535i xDrive	1	0.06%	2	0.12%	1,629	99.82%	1,632	0.01%
550i	1	0.03%	8	0.22%	3,553	99.75%	3,562	0.02%
740iL (Auto)	2	0.34%	2	0.34%	578	99.31%	582	0.00%
i3	1	0.22%	5	1.12%	439	98.65%	445	0.00%
X3	2	0.01%	36	0.13%	28,744	99.87%	28,782	0.19%
X3 3.0i	2	0.11%	5	0.27%	1,847	99.62%	1,854	0.01%
X5	2	0.01%	43	0.11%	37,695	99.88%	37,740	0.25%
X5 3.0i	1	0.03%	8	0.25%	3,189	99.72%	3,198	0.02%
X6	1	0.02%	7	0.12%	5,600	99.86%	5,608	0.04%
Z4	2	0.10%	13	0.64%	2,011	99.26%	2,026	0.01%
BUIC								
Enclave	4	0.01%	14	0.03%	40,564	99.96%	40,582	0.27%
Encore	2	0.01%	17	0.06%	29,195	99.93%	29,214	0.19%
LaCrosse CX	1	0.02%	10	0.17%	5,909	99.81%	5,920	0.04%
LaCrosse CXL	2	0.06%	4	0.11%	3,508	99.83%	3,514	0.02%
LaCrosse CXS	1	0.03%	1	0.03%	3,222	99.94%	3,224	0.02%

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
LeSabre Custom	4	0.04%	21	0.22%	9,579	99.74%	9,604	0.06%
Lucerne CXL	1	0.02%	2	0.03%	6,102	99.95%	6,105	0.04%
Regal Gran Sport	1	0.24%	1	0.24%	417	99.52%	419	0.00%
Regal LS	1	0.06%	1	0.06%	1,801	99.89%	1,803	0.01%
Regal Premium I	1	0.05%	4	0.18%	2,171	99.77%	2,176	0.01%
Rendezvous 2WD	1	0.02%	18	0.42%	4,218	99.55%	4,237	0.03%
Verano	1	0.01%	7	0.07%	10,121	99.92%	10,129	0.07%
CADI								
1500 Suburban 4WD Luxury	1	0.06%	8	0.46%	1,742	99.49%	1,751	0.01%
ATS Luxury	1	0.01%	5	0.05%	9,677	99.94%	9,683	0.06%
CTS	3	0.03%	3	0.03%	9,492	99.94%	9,498	0.06%
CTS Auto RWD	1	0.02%	3	0.07%	4,156	99.90%	4,160	0.03%
CTS Luxury	2	0.02%	8	0.06%	13,240	99.92%	13,250	0.09%
CTS Standard	1	0.05%	5	0.24%	2,064	99.71%	2,070	0.01%
CTS V6	1	0.02%	3	0.06%	5,397	99.93%	5,401	0.04%
DeVille	1	0.01%	18	0.24%	7,625	99.75%	7,644	0.05%
Escalade	2	0.01%	37	0.14%	26,404	99.85%	26,443	0.17%
Escalade 1500 2WD	3	0.05%	24	0.42%	5,628	99.52%	5,655	0.04%
Escalade 1500 2WD Luxury	3	0.07%	15	0.33%	4,543	99.61%	4,561	0.03%
Escalade 1500 4WD	5	0.05%	36	0.37%	9,593	99.57%	9,634	0.06%
Escalade 1500 4WD Luxury	1	0.01%	25	0.36%	6,831	99.62%	6,857	0.05%
Escalade ESV	1	0.01%	15	0.09%	16,847	99.91%	16,863	0.11%
Escalade EXT	1	0.04%	1	0.04%	2,328	99.91%	2,330	0.02%
SRX	5	0.01%	36	0.07%	52,815	99.92%	52,856	0.35%
SRX RWD	1	0.06%	1	0.06%	1,626	99.88%	1,628	0.01%

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
XLR	1	0.14%	3	0.43%	686	99.42%	690	0.00%
CHEV								
1500 2WD	30	0.02%	214	0.12%	183,024	99.87%	183,268	1.21%
1500 4WD	5	0.02%	33	0.11%	30,248	99.87%	30,286	0.20%
2500 2WD	3	0.01%	25	0.11%	23,185	99.88%	23,213	0.15%
2500 4WD	1	0.02%	4	0.08%	4,787	99.90%	4,792	0.03%
3500 2WD	2	0.04%	6	0.13%	4,745	99.83%	4,753	0.03%
Astro 2WD	2	0.03%	27	0.37%	7,218	99.60%	7,247	0.05%
Avalanche LT	1	0.03%	2	0.06%	3,584	99.92%	3,587	0.02%
Aveo LS	1	0.45%	1	0.45%	222	99.11%	224	0.00%
Blazer / Trailblazer 2WD	7	0.04%	41	0.21%	19,339	99.75%	19,387	0.13%
Blazer / Trailblazer 4WD	4	0.09%	11	0.26%	4,250	99.65%	4,265	0.03%
C1500 Pickup 2WD	21	0.02%	179	0.19%	95,898	99.79%	96,098	0.63%
C1500 Silverado 2WD	25	0.04%	141	0.25%	56,453	99.71%	56,619	0.37%
C1500 Suburban 2WD	16	0.03%	110	0.24%	46,119	99.73%	46,245	0.31%
C2500 Pickup 2WD	5	0.10%	7	0.14%	4,995	99.76%	5,007	0.03%
C3500 Pickup 2WD	2	0.22%	1	0.11%	906	99.67%	909	0.01%
Camaro 1LT	5	0.03%	8	0.05%	17,136	99.92%	17,149	0.11%
Camaro LT	2	0.02%	5	0.04%	12,836	99.95%	12,843	0.08%
Camaro Sport	2	0.04%	10	0.20%	5,102	99.77%	5,114	0.03%
Cavalier	5	0.06%	10	0.12%	8,381	99.82%	8,396	0.06%
Cobalt	4	0.02%	33	0.17%	19,514	99.81%	19,551	0.13%
Colorado / Trailblazer 2WD	3	0.03%	7	0.08%	9,075	99.89%	9,085	0.06%
Colorado Work Truck	2	0.02%	19	0.15%	12,818	99.84%	12,839	0.08%
Corvette	6	0.02%	48	0.19%	24,790	99.78%	24,844	0.16%

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Equinox	2	0.01%	19	0.06%	32,573	99.94%	32,594	0.22%
Equinox / Captiva FWD	1	0.03%	3	0.10%	3,058	99.87%	3,062	0.02%
Equinox 1LT	3	0.01%	26	0.06%	42,248	99.93%	42,277	0.28%
Equinox 2LT	1	0.00%	14	0.05%	26,999	99.94%	27,014	0.18%
Equinox 2WD	1	0.01%	1	0.01%	7,424	99.97%	7,426	0.05%
Equinox LS	2	0.01%	12	0.05%	22,128	99.94%	22,142	0.15%
Express 1500	1	0.02%	5	0.08%	5,893	99.90%	5,899	0.04%
Express 1500 2WD	3	0.03%	18	0.15%	11,755	99.82%	11,776	0.08%
Express 2500	1	0.04%	12	0.46%	2,571	99.50%	2,584	0.02%
Express 2500 2WD	3	0.09%	13	0.37%	3,508	99.55%	3,524	0.02%
Express 3500	2	0.14%	3	0.21%	1,452	99.66%	1,457	0.01%
Express 3500 2WD	2	0.10%	2	0.10%	2,029	99.80%	2,033	0.01%
G1500 Van 2WD	1	0.06%	3	0.17%	1,780	99.78%	1,784	0.01%
HHR	3	0.02%	26	0.17%	14,967	99.81%	14,996	0.10%
Impala	5	0.05%	14	0.13%	10,401	99.82%	10,420	0.07%
Impala LS	1	0.01%	3	0.02%	12,260	99.97%	12,264	0.08%
Impala LS Sedan	3	0.02%	11	0.09%	12,655	99.89%	12,669	0.08%
Impala LT	1	0.00%	11	0.05%	22,066	99.95%	22,078	0.15%
Impala LT Sedan	2	0.01%	9	0.06%	14,233	99.92%	14,244	0.09%
Impala Police Sedan	1	0.10%	2	0.19%	1,046	99.71%	1,049	0.01%
Impala SS Sedan	2	0.06%	1	0.03%	3,133	99.90%	3,136	0.02%
K1500 Pickup 4WD	6	0.03%	32	0.17%	18,638	99.80%	18,676	0.12%
K1500 Silverado 4WD	3	0.04%	8	0.11%	7,048	99.84%	7,059	0.05%
K1500 Suburban 4WD	2	0.02%	23	0.21%	11,034	99.77%	11,059	0.07%
Malibu 1LS	2	0.04%	11	0.25%	4,471	99.71%	4,484	0.03%

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Malibu 1LT	3	0.08%	6	0.15%	3,944	99.77%	3,953	0.03%
Malibu 2LT	2	0.01%	20	0.12%	16,246	99.86%	16,268	0.11%
Malibu LS	3	0.01%	55	0.16%	34,330	99.83%	34,388	0.23%
Malibu LT	7	0.02%	33	0.10%	34,171	99.88%	34,211	0.23%
Malibu LTZ	2	0.02%	4	0.05%	8,145	99.93%	8,151	0.05%
NV200	2	0.10%	5	0.25%	1,992	99.65%	1,999	0.01%
S Series Pickup 2WD	1	0.01%	28	0.27%	10,247	99.72%	10,276	0.07%
S Series Pickup 4WD	1	0.23%	1	0.23%	436	99.54%	438	0.00%
S10 Pickup 2WD	2	0.03%	12	0.18%	6,655	99.79%	6,669	0.04%
Sierra 1500	1	0.03%	4	0.10%	3,992	99.87%	3,997	0.03%
Silverado	4	0.02%	17	0.08%	21,772	99.90%	21,793	0.14%
Silverado 1500	28	0.01%	201	0.06%	339,026	99.93%	339,255	2.24%
Silverado 3500	2	0.35%	1	0.18%	568	99.47%	571	0.00%
Silverado LS	2	0.01%	18	0.13%	13,880	99.86%	13,900	0.09%
Spark 1LT	1	0.02%	4	0.07%	5,769	99.91%	5,774	0.04%
SSR / Colorado / Trailblazer	6	0.03%	38	0.19%	19,575	99.78%	19,619	0.13%
Suburban LT	1	0.00%	18	0.07%	25,007	99.92%	25,026	0.17%
Suburban LTZ	1	0.01%	11	0.09%	11,589	99.90%	11,601	0.08%
Tahoe 2WD	16	0.02%	173	0.19%	90,197	99.79%	90,386	0.60%
Tahoe 4WD	7	0.03%	58	0.23%	25,163	99.74%	25,228	0.17%
Tahoe LS	3	0.01%	16	0.07%	23,448	99.92%	23,467	0.16%
Tahoe LT	3	0.01%	33	0.06%	59,727	99.94%	59,763	0.39%
Tahoe LTX	3	0.04%	7	0.09%	7,387	99.86%	7,397	0.05%
Tahoe LTZ	3	0.01%	9	0.04%	22,784	99.95%	22,796	0.15%
Tracker ZR2 Sport	1	0.76%	1	0.76%	129	98.47%	131	0.00%

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Trailblazer 2WD	1	0.02%	12	0.21%	5,730	99.77%	5,743	0.04%
Traverse 2LT	2	0.01%	2	0.01%	16,474	99.98%	16,478	0.11%
Traverse LT/Traverse 1LT	2	0.01%	23	0.08%	30,532	99.92%	30,557	0.20%
Venture 2WD	1	0.04%	7	0.29%	2,427	99.67%	2,435	0.02%
Venture 2WD Extended Van	1	0.32%	2	0.64%	309	99.04%	312	0.00%
Venture/Uplander EXT LS	1	0.15%	1	0.15%	661	99.70%	663	0.00%
CHRY								
300	1	0.02%	3	0.06%	5,443	99.93%	5,447	0.04%
200 Limited	3	0.01%	21	0.10%	20,287	99.88%	20,311	0.13%
200 Touring	1	0.01%	5	0.06%	8,332	99.93%	8,338	0.06%
200S	2	0.05%	5	0.12%	4,298	99.84%	4,305	0.03%
300 Touring	3	0.02%	9	0.05%	16,739	99.93%	16,751	0.11%
300C	4	0.03%	11	0.08%	13,975	99.89%	13,990	0.09%
300S	1	0.01%	4	0.04%	10,423	99.95%	10,428	0.07%
PT Cruiser Classic LHD	1	0.02%	10	0.15%	6,588	99.83%	6,599	0.04%
PT Cruiser GT LHD	2	0.45%	4	0.89%	442	98.66%	448	0.00%
Sebring Limited	1	0.08%	1	0.08%	1,330	99.85%	1,332	0.01%
Sebring LX	2	0.07%	6	0.21%	2,911	99.73%	2,919	0.02%
Sebring Touring	1	0.02%	10	0.18%	5,703	99.81%	5,714	0.04%
Town & Country	1	0.00%	17	0.08%	20,429	99.91%	20,447	0.14%
Town & Country FWD LHD	1	0.02%	6	0.12%	4,981	99.86%	4,988	0.03%
Town & Country FWD LWB & SWB	2	0.04%	6	0.13%	4,567	99.83%	4,575	0.03%
Town & Country LX FWD	1	0.08%	4	0.30%	1,308	99.62%	1,313	0.01%
DODG								
1500	1	0.01%	19	0.10%	19,252	99.90%	19,272	0.13%

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Avenger R/T	1	0.03%	4	0.10%	3,925	99.87%	3,930	0.03%
Avenger SE	8	0.03%	14	0.06%	24,434	99.91%	24,456	0.16%
Caliber Mainstreet	1	0.06%	2	0.11%	1,792	99.83%	1,795	0.01%
Caliber SXT	1	0.01%	5	0.07%	6,917	99.91%	6,923	0.05%
Caravan / Grand Caravan SE	2	0.05%	8	0.21%	3,762	99.73%	3,772	0.02%
Caravan / Grand Caravan SXT FW	4	0.05%	10	0.13%	7,661	99.82%	7,675	0.05%
Caravan C/V FWD	1	0.01%	6	0.08%	7,657	99.91%	7,664	0.05%
Caravan SE / Grand Caravan SE	1	0.07%	8	0.54%	1,473	99.39%	1,482	0.01%
Caravan Sport FWD	1	0.07%	1	0.07%	1,504	99.87%	1,506	0.01%
Challenger	1	0.01%	11	0.07%	16,630	99.93%	16,642	0.11%
Challenger R/T	1	0.01%	19	0.14%	13,564	99.85%	13,584	0.09%
Challenger SCAT Pack	2	0.05%	4	0.09%	4,209	99.86%	4,215	0.03%
Challenger SRT Hellcat	1	0.06%	1	0.06%	1,639	99.88%	1,641	0.01%
Challenger SXT	5	0.04%	8	0.06%	14,182	99.91%	14,195	0.09%
Charger	4	0.02%	13	0.06%	22,608	99.92%	22,625	0.15%
Charger (RWD)	4	0.03%	15	0.11%	14,153	99.87%	14,172	0.09%
Charger R/T	2	0.01%	28	0.14%	19,955	99.85%	19,985	0.13%
Charger SE	1	0.01%	8	0.10%	7,812	99.88%	7,821	0.05%
Charger SXT	6	0.02%	32	0.11%	29,203	99.87%	29,241	0.19%
Dakota 2WD	5	0.06%	17	0.22%	7,851	99.72%	7,873	0.05%
Dakota 4WD	1	0.09%	1	0.09%	1,090	99.82%	1,092	0.01%
Dakota SLT 2WD	2	0.03%	14	0.20%	7,068	99.77%	7,084	0.05%
Dart SXT	1	0.01%	7	0.06%	11,735	99.93%	11,743	0.08%
Durango 2WD	1	0.03%	3	0.10%	3,011	99.87%	3,015	0.02%
Durango 4WD	2	0.10%	9	0.47%	1,906	99.43%	1,917	0.01%

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Durango SLT 2WD	2	0.03%	3	0.04%	7,415	99.93%	7,420	0.05%
Durango Sport 2WD	1	0.16%	1	0.16%	634	99.69%	636	0.00%
Durango SXT	3	0.02%	11	0.07%	15,404	99.91%	15,418	0.10%
Grand Caravan GT	2	0.03%	6	0.09%	6,942	99.88%	6,950	0.05%
Grand Caravan SE	3	0.02%	15	0.11%	14,057	99.87%	14,075	0.09%
Grand Caravan SXT	1	0.01%	14	0.08%	17,328	99.91%	17,343	0.11%
Journey Crossroad	2	0.02%	3	0.03%	8,792	99.94%	8,797	0.06%
Journey SE	4	0.02%	20	0.10%	20,920	99.89%	20,944	0.14%
Journey SXT	1	0.01%	20	0.10%	19,685	99.89%	19,706	0.13%
Magnum / Magnum SXT	3	0.10%	1	0.03%	2,940	99.86%	2,944	0.02%
Neon	1	0.16%	1	0.16%	625	99.68%	627	0.00%
Neon SXT	2	0.10%	2	0.10%	1,957	99.80%	1,961	0.01%
ProMaster City	1	0.07%	7	0.48%	1,455	99.45%	1,463	0.01%
RAM 1500	1	0.01%	3	0.03%	8,594	99.95%	8,598	0.06%
Ram Pickup	1	0.06%	2	0.12%	1,641	99.82%	1,644	0.01%
Ram Pickup 1500 2WD	15	0.01%	96	0.08%	117,737	99.91%	117,848	0.78%
Ram Pickup 1500 4WD	1	0.01%	15	0.11%	14,226	99.89%	14,242	0.09%
Ram Pickup 2500 2WD	2	0.32%	1	0.16%	624	99.52%	627	0.00%
Ram Pickup 2WD	15	0.06%	114	0.43%	26,132	99.51%	26,261	0.17%
Ram Pickup 4WD	1	0.03%	17	0.45%	3,760	99.52%	3,778	0.02%
RAM PK Light Duty 1500	2	0.01%	14	0.08%	17,711	99.91%	17,727	0.12%
Stratus SE	1	0.14%	1	0.14%	730	99.73%	732	0.00%
FERR								
360 Spider	1	0.74%	2	1.47%	133	97.79%	136	0.00%
FIAT								

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500 Pop	1	0.02%	5	0.08%	6,382	99.91%	6,388	0.04%
FORD								
500 SE FWD	1	0.11%	1	0.11%	947	99.79%	949	0.01%
Bronco 4WD	2	0.63%	2	0.63%	315	98.75%	319	0.00%
C-Max SE FHEV	1	0.08%	1	0.08%	1,187	99.83%	1,189	0.01%
Crown Victoria	1	0.08%	2	0.16%	1,251	99.76%	1,254	0.01%
Crown Victoria Police Intercep	1	0.04%	3	0.12%	2,600	99.85%	2,604	0.02%
E150 2WD	6	0.07%	22	0.26%	8,321	99.66%	8,349	0.06%
E250 2WD	1	0.04%	3	0.11%	2,738	99.85%	2,742	0.02%
E250 Cargo Van	1	0.31%	1	0.31%	322	99.38%	324	0.00%
E350 2WD	2	0.12%	4	0.25%	1,596	99.63%	1,602	0.01%
Econoline E350	1	0.08%	3	0.25%	1,203	99.67%	1,207	0.01%
Ecosport SE	1	0.06%	1	0.06%	1,604	99.88%	1,606	0.01%
Edge SE FWD	2	0.06%	1	0.03%	3,330	99.91%	3,333	0.02%
Edge SEL	1	0.01%	16	0.09%	17,577	99.90%	17,594	0.12%
Edge Sport	1	0.04%	2	0.07%	2,760	99.89%	2,763	0.02%
Edge Titanium	1	0.01%	26	0.16%	15,795	99.83%	15,822	0.10%
Escape	12	0.02%	48	0.07%	72,405	99.92%	72,465	0.48%
Escape S	3	0.02%	33	0.20%	16,245	99.78%	16,281	0.11%
Escape SE	8	0.02%	86	0.21%	41,675	99.77%	41,769	0.28%
Escape SEL	3	0.06%	43	0.90%	4,750	99.04%	4,796	0.03%
Escape Titanium	4	0.02%	31	0.16%	19,229	99.82%	19,264	0.13%
Escape XLS 2WD	2	0.02%	1	0.01%	10,779	99.97%	10,782	0.07%
Escape XLT 2WD	2	0.01%	21	0.10%	21,134	99.89%	21,157	0.14%
Excursion XLT 2WD	2	0.79%	1	0.40%	249	98.81%	252	0.00%

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Expedition	3	0.01%	24	0.06%	40,598	99.93%	40,625	0.27%
Expedition Eddie Bauer 2WD	9	0.03%	44	0.12%	35,782	99.85%	35,835	0.24%
Expedition XLT 2WD	6	0.02%	30	0.11%	28,103	99.87%	28,139	0.19%
Expedition XLT 4WD	1	0.03%	6	0.18%	3,400	99.79%	3,407	0.02%
Explorer	15	0.02%	60	0.08%	73,758	99.90%	73,833	0.49%
Explorer Limited	4	0.02%	34	0.13%	26,031	99.85%	26,069	0.17%
Explorer LTD 2WD	1	0.04%	12	0.43%	2,785	99.54%	2,798	0.02%
Explorer Platinum	1	0.02%	5	0.11%	4,701	99.87%	4,707	0.03%
Explorer Sport	1	0.01%	15	0.13%	11,226	99.86%	11,242	0.07%
Explorer Sport 2WD	2	0.05%	6	0.16%	3,854	99.79%	3,862	0.03%
Explorer Sport Trac 2WD	2	0.01%	29	0.21%	14,112	99.78%	14,143	0.09%
Explorer XL	1	0.01%	11	0.15%	7,506	99.84%	7,518	0.05%
Explorer XLS 2WD	2	0.02%	13	0.13%	9,847	99.85%	9,862	0.07%
Explorer XLT	4	0.01%	42	0.09%	45,483	99.90%	45,529	0.30%
Explorer XLT 2WD	1	0.00%	36	0.17%	20,854	99.82%	20,891	0.14%
F150	69	0.01%	646	0.11%	601,882	99.88%	602,597	3.98%
F150 2WD	30	0.03%	200	0.18%	108,459	99.79%	108,689	0.72%
F150 2WD Super Crew	22	0.02%	144	0.14%	103,438	99.84%	103,604	0.68%
F150 4WD	8	0.06%	21	0.15%	14,122	99.80%	14,151	0.09%
F150 4WD Super Crew	8	0.02%	38	0.12%	32,570	99.86%	32,616	0.22%
F150 Heritage 2WD	2	0.08%	6	0.23%	2,605	99.69%	2,613	0.02%
F150 Regular Cab	2	0.15%	6	0.46%	1,297	99.39%	1,305	0.01%
F150 Regular Cab Styleside	1	0.01%	7	0.09%	7,986	99.90%	7,994	0.05%
F150 Super Cab	1	0.20%	3	0.59%	502	99.21%	506	0.00%
F150 Super Cab Flareside	4	0.06%	3	0.04%	6,903	99.90%	6,910	0.05%

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F150 Super Cab Styleside	1	0.00%	18	0.08%	21,794	99.91%	21,813	0.14%
F150 Super Cab Styleside 4WD	1	0.04%	2	0.08%	2,602	99.88%	2,605	0.02%
F150 Super Crew 2WD	9	0.02%	92	0.22%	42,018	99.76%	42,119	0.28%
F150 Super Crew 4WD	1	0.01%	32	0.33%	9,700	99.66%	9,733	0.06%
F250	2	0.05%	6	0.15%	3,876	99.79%	3,884	0.03%
F250 SRW	1	0.26%	2	0.53%	376	99.21%	379	0.00%
F250 Super Cab	7	0.78%	5	0.55%	890	98.67%	902	0.01%
F350	2	0.29%	2	0.29%	674	99.41%	678	0.00%
Fiesta S	2	0.04%	8	0.15%	5,164	99.81%	5,174	0.03%
Fiesta SE	5	0.02%	25	0.10%	23,954	99.87%	23,984	0.16%
Focus LX	1	0.08%	1	0.08%	1,314	99.85%	1,316	0.01%
Focus S	3	0.03%	13	0.12%	10,752	99.85%	10,768	0.07%
Focus SE	3	0.00%	62	0.08%	76,310	99.91%	76,375	0.50%
Focus SEL	2	0.02%	7	0.08%	8,823	99.90%	8,832	0.06%
Focus SES	1	0.01%	9	0.10%	8,698	99.89%	8,708	0.06%
Focus ST	1	0.02%	5	0.11%	4,555	99.87%	4,561	0.03%
Freestar Sport	2	0.48%	2	0.48%	416	99.05%	420	0.00%
Fusion Hybrid	2	0.07%	8	0.29%	2,714	99.63%	2,724	0.02%
Fusion S	7	0.03%	27	0.13%	20,706	99.84%	20,740	0.14%
Fusion SE	30	0.03%	216	0.21%	101,680	99.76%	101,926	0.67%
Fusion SE Hybrid	1	0.01%	24	0.21%	11,477	99.78%	11,502	0.08%
Fusion SEL	6	0.03%	80	0.45%	17,569	99.51%	17,655	0.12%
Fusion Titanium PHEV	2	0.14%	2	0.14%	1,424	99.72%	1,428	0.01%
GT	5	2.49%	12	5.97%	184	91.54%	201	0.00%
Mustang	12	0.03%	67	0.17%	38,760	99.80%	38,839	0.26%

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Mustang Cobra GT	2	0.26%	1	0.13%	753	99.60%	756	0.00%
Mustang GT	6	0.01%	78	0.14%	55,476	99.85%	55,560	0.37%
Mustang I4	3	0.01%	24	0.11%	21,858	99.88%	21,885	0.14%
Mustang Shelby	1	0.03%	2	0.07%	2,881	99.90%	2,884	0.02%
Mustang Shelby GT500	2	0.12%	3	0.18%	1,681	99.70%	1,686	0.01%
Mustang V6	5	0.02%	15	0.05%	29,962	99.93%	29,982	0.20%
Ranger	5	0.04%	23	0.20%	11,706	99.76%	11,734	0.08%
Ranger 2WD	15	0.03%	86	0.18%	47,902	99.79%	48,003	0.32%
Ranger Regular Cab 2WD	1	0.01%	13	0.19%	6,746	99.79%	6,760	0.04%
Ranger Super Cab 2WD	1	0.01%	20	0.26%	7,623	99.73%	7,644	0.05%
Sport Trac	1	0.09%	1	0.09%	1,115	99.82%	1,117	0.01%
Taurus SE	1	0.01%	12	0.07%	16,064	99.92%	16,077	0.11%
Taurus SE Comfort	2	0.04%	9	0.17%	5,194	99.79%	5,205	0.03%
Taurus SE SVG	1	0.15%	1	0.15%	647	99.69%	649	0.00%
Taurus SEL	3	0.02%	13	0.08%	15,422	99.90%	15,438	0.10%
Taurus SES	1	0.02%	3	0.06%	4,795	99.92%	4,799	0.03%
Taurus SHO	1	0.05%	2	0.11%	1,839	99.84%	1,842	0.01%
Transit Connect	6	0.03%	42	0.20%	20,443	99.77%	20,491	0.14%
Transit T150	1	0.11%	6	0.67%	894	99.22%	901	0.01%
Windstar SEL	1	0.21%	2	0.43%	466	99.36%	469	0.00%
GMC								
1500 2WD	9	0.02%	38	0.08%	45,359	99.90%	45,406	0.30%
1500 Suburban 2WD	1	0.01%	24	0.21%	11,493	99.78%	11,518	0.08%
1500 Suburban 4WD	1	0.04%	3	0.13%	2,317	99.83%	2,321	0.02%
2500 2WD	1	0.02%	3	0.05%	5,777	99.93%	5,781	0.04%

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Acadia SLE2	1	0.01%	5	0.05%	9,668	99.94%	9,674	0.06%
Acadia SLT(1) FWD	1	0.03%	1	0.03%	3,052	99.93%	3,054	0.02%
Canyon / Envoy 2WD	1	0.02%	14	0.21%	6,563	99.77%	6,578	0.04%
Envoy/Envoy XL SLE 2WD	1	0.01%	16	0.17%	9,671	99.82%	9,688	0.06%
Full Size Truck 1500 4WD	1	0.07%	3	0.21%	1,410	99.72%	1,414	0.01%
Full Size Truck 4WD 1500	1	0.12%	5	0.62%	802	99.26%	808	0.01%
Safari 2WD	2	0.14%	4	0.28%	1,431	99.58%	1,437	0.01%
Savanna 1500 2WD	1	0.06%	2	0.11%	1,798	99.83%	1,801	0.01%
Savanna 3500 2WD	1	0.64%	1	0.64%	154	98.72%	156	0.00%
Sierra 1500	10	0.01%	104	0.07%	138,837	99.92%	138,951	0.92%
Sierra 1500 2WD	7	0.03%	53	0.19%	27,679	99.78%	27,739	0.18%
Sierra 1500 Pickup 2WD	4	0.04%	21	0.21%	9,931	99.75%	9,956	0.07%
Sierra 1500 Pickup 4WD	1	0.02%	12	0.20%	5,947	99.78%	5,960	0.04%
Sierra 2500 Pickup 2WD	2	0.22%	1	0.11%	920	99.67%	923	0.01%
Sierra Denali / Yukon 1500 4WD	1	0.02%	5	0.08%	6,055	99.90%	6,061	0.04%
Sierra SL	1	0.03%	3	0.09%	3,292	99.88%	3,296	0.02%
Sierra SLE	1	0.02%	2	0.04%	4,581	99.93%	4,584	0.03%
Terrain SLE1	1	0.01%	12	0.07%	16,379	99.92%	16,392	0.11%
Terrain SLE2	2	0.02%	2	0.02%	9,249	99.96%	9,253	0.06%
Terrain SLT	1	0.01%	6	0.08%	7,397	99.91%	7,404	0.05%
Terrain SLT1	1	0.01%	2	0.03%	7,650	99.96%	7,653	0.05%
Yukon 2WD	6	0.03%	52	0.23%	22,169	99.74%	22,227	0.15%
Yukon 4WD Luxury	6	0.18%	12	0.36%	3,270	99.45%	3,288	0.02%
Yukon Denali	1	0.00%	18	0.07%	25,279	99.92%	25,298	0.17%
Yukon SLT	2	0.01%	14	0.07%	19,352	99.92%	19,368	0.13%

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Yukon XL Denali	2	0.01%	7	0.04%	15,883	99.94%	15,892	0.10%
HOND								
Accord	10	0.04%	22	0.09%	23,556	99.86%	23,588	0.16%
Accord DX Value Pkg	1	0.06%	1	0.06%	1,594	99.87%	1,596	0.01%
Accord EX	24	0.02%	83	0.08%	102,002	99.90%	102,109	0.67%
Accord EX L	1	0.01%	18	0.12%	15,364	99.88%	15,383	0.10%
Accord EX L V6	1	0.01%	13	0.11%	11,733	99.88%	11,747	0.08%
Accord EX-L	1	0.00%	23	0.06%	40,656	99.94%	40,680	0.27%
Accord EX-L Sensing	1	0.03%	4	0.13%	3,167	99.84%	3,172	0.02%
Accord EX-L V6	7	0.02%	14	0.04%	33,641	99.94%	33,662	0.22%
Accord EX-ULEV	1	0.11%	1	0.11%	875	99.77%	877	0.01%
Accord LX	17	0.01%	116	0.10%	121,657	99.89%	121,790	0.80%
Accord LX Premium	2	0.02%	3	0.03%	8,713	99.94%	8,718	0.06%
Accord SE	5	0.02%	15	0.07%	22,108	99.91%	22,128	0.15%
Accord Sport	8	0.02%	24	0.05%	51,494	99.94%	51,526	0.34%
Accord Sport SE	2	0.04%	1	0.02%	4,470	99.93%	4,473	0.03%
Accord Touring	2	0.02%	7	0.06%	11,368	99.92%	11,377	0.08%
Accrod EX-L	4	0.03%	8	0.05%	14,915	99.92%	14,927	0.10%
Civic	4	0.03%	19	0.13%	14,054	99.84%	14,077	0.09%
Civic EX	8	0.01%	65	0.07%	90,675	99.92%	90,748	0.60%
Civic EX HS	1	0.05%	3	0.16%	1,875	99.79%	1,879	0.01%
Civic EX L	1	0.03%	1	0.03%	3,726	99.95%	3,728	0.02%
Civic EX-L	1	0.01%	8	0.06%	12,729	99.93%	12,738	0.08%
Civic EX-TL	1	0.02%	3	0.05%	5,552	99.93%	5,556	0.04%
Civic Hybrid	1	0.01%	5	0.07%	7,599	99.92%	7,605	0.05%

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Civic LX	26	0.01%	125	0.07%	173,292	99.91%	173,443	1.15%
Civic LX-S	1	0.04%	1	0.04%	2,406	99.92%	2,408	0.02%
Civic Si	1	0.01%	6	0.05%	11,793	99.94%	11,800	0.08%
Civic Sport	1	0.01%	1	0.01%	6,730	99.97%	6,732	0.04%
Civic Touring	1	0.02%	7	0.13%	5,241	99.85%	5,249	0.03%
CR-V	17	0.01%	147	0.07%	214,539	99.92%	214,703	1.42%
CR-V EX	3	0.05%	9	0.15%	6,140	99.80%	6,152	0.04%
CR-V EX 2WD	1	0.02%	6	0.12%	5,099	99.86%	5,106	0.03%
CR-V EX 4WD	1	0.03%	3	0.08%	3,578	99.89%	3,582	0.02%
CR-V EX-L 2WD	1	0.01%	4	0.05%	8,442	99.94%	8,447	0.06%
CR-V LX	4	0.04%	6	0.06%	10,390	99.90%	10,400	0.07%
CR-V LX 2WD	1	0.01%	7	0.07%	10,690	99.93%	10,698	0.07%
CR-V LX 4WD	1	0.07%	1	0.07%	1,388	99.86%	1,390	0.01%
Element	3	0.02%	22	0.16%	13,794	99.82%	13,819	0.09%
Fit DX-A (Canada)	1	0.16%	1	0.16%	613	99.67%	615	0.00%
FIT HB Sport	1	0.01%	11	0.14%	7,824	99.85%	7,836	0.05%
Fit Sport	2	0.02%	5	0.06%	8,532	99.92%	8,539	0.06%
Odyssey	12	0.01%	117	0.08%	144,955	99.91%	145,084	0.96%
Passport 2WD	2	0.21%	3	0.31%	959	99.48%	964	0.01%
Pilot	18	0.01%	112	0.07%	150,780	99.91%	150,910	1.00%
Ridgeline	3	0.02%	19	0.10%	19,395	99.89%	19,417	0.13%
S2000	2	0.06%	10	0.30%	3,291	99.64%	3,303	0.02%
HUMM								
H3 - SUV 4WD	3	0.08%	13	0.37%	3,525	99.55%	3,541	0.02%
HYUN								

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Accent	3	0.01%	27	0.08%	33,020	99.91%	33,050	0.22%
Elantra	11	0.01%	74	0.06%	120,236	99.93%	120,321	0.79%
Genesis / Equus	1	0.01%	8	0.04%	18,584	99.95%	18,593	0.12%
Genesis Coupe	1	0.01%	1	0.01%	8,857	99.98%	8,859	0.06%
Santa Fe	12	0.01%	76	0.08%	96,839	99.91%	96,927	0.64%
Sonata	25	0.02%	141	0.10%	140,289	99.88%	140,455	0.93%
Tucson	3	0.01%	30	0.07%	44,496	99.93%	44,529	0.29%
Veloster	2	0.01%	6	0.04%	15,111	99.95%	15,119	0.10%
Veracruz	1	0.02%	6	0.14%	4,377	99.84%	4,384	0.03%
INFI								
Cube	1	0.01%	8	0.06%	13,063	99.93%	13,072	0.09%
EX35	1	0.02%	2	0.05%	4,047	99.93%	4,050	0.03%
FX35/FX50	1	0.02%	3	0.06%	4,781	99.92%	4,785	0.03%
G25/G37 Coupe	3	0.02%	13	0.08%	15,653	99.90%	15,669	0.10%
G35	1	0.01%	22	0.13%	16,718	99.86%	16,741	0.11%
G35 Coupe	1	0.01%	9	0.06%	14,904	99.93%	14,914	0.10%
G37	1	0.01%	12	0.09%	13,458	99.90%	13,471	0.09%
I30	1	0.04%	1	0.04%	2,256	99.91%	2,258	0.01%
Murano	2	0.01%	7	0.04%	19,864	99.95%	19,873	0.13%
Q40 / Q60	1	0.04%	3	0.12%	2,400	99.83%	2,404	0.02%
Q50	2	0.01%	14	0.07%	19,966	99.92%	19,982	0.13%
QX50	2	0.02%	14	0.12%	11,742	99.86%	11,758	0.08%
QX56	1	0.01%	2	0.03%	7,680	99.96%	7,683	0.05%
QX60	3	0.01%	20	0.05%	40,976	99.94%	40,999	0.27%
ISU								

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Axiom 2WD	1	0.28%	1	0.28%	361	99.45%	363	0.00%
Rodeo 2WD	2	0.06%	9	0.29%	3,081	99.64%	3,092	0.02%
JEEP								
Cherokee	12	0.02%	59	0.10%	57,872	99.88%	57,943	0.38%
Cherokee 2WD	4	0.09%	23	0.54%	4,240	99.37%	4,267	0.03%
Cherokee 4WD	1	0.03%	6	0.18%	3,249	99.79%	3,256	0.02%
Compass	2	0.02%	17	0.19%	9,090	99.79%	9,109	0.06%
Compass Rallye LHD FWD	1	0.04%	2	0.09%	2,246	99.87%	2,249	0.01%
Compass Sport	1	0.03%	2	0.05%	3,760	99.92%	3,763	0.02%
Compass/Reneade	3	0.01%	43	0.16%	26,814	99.83%	26,860	0.18%
Grand Cherokee	8	0.01%	80	0.07%	111,767	99.92%	111,855	0.74%
Grand Cherokee 2WD	2	0.04%	14	0.26%	5,448	99.71%	5,464	0.04%
Grand Cherokee Laredo 2WD	1	0.01%	9	0.07%	12,943	99.92%	12,953	0.09%
Grand Cherokee Laredo 4WD	1	0.02%	8	0.13%	5,950	99.85%	5,959	0.04%
Grand Cherokee Limited 2WD	1	0.03%	4	0.13%	3,055	99.84%	3,060	0.02%
Grand Cherokee Limited 4WD	1	0.03%	2	0.06%	3,548	99.92%	3,551	0.02%
Liberty Limited 2WD	2	0.04%	9	0.18%	4,922	99.78%	4,933	0.03%
Liberty Limited 4WD	1	0.04%	7	0.29%	2,434	99.67%	2,442	0.02%
Liberty Sport 2WD	2	0.02%	8	0.09%	9,100	99.89%	9,110	0.06%
Patriot	7	0.02%	36	0.11%	33,318	99.87%	33,361	0.22%
Patriot LHD FWD	1	0.03%	2	0.05%	3,846	99.92%	3,849	0.03%
Renegade	4	0.02%	25	0.10%	23,819	99.88%	23,848	0.16%
Wrangler	13	0.01%	124	0.10%	130,169	99.89%	130,306	0.86%
Wrangler 4WD	2	0.01%	34	0.25%	13,390	99.73%	13,426	0.09%
Wrangler Rubicon 4WD	1	0.04%	3	0.12%	2,430	99.84%	2,434	0.02%

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Wrangler Rubicon/Unlimited Rub	1	0.05%	3	0.14%	2,098	99.81%	2,102	0.01%
Wrangler Sahara / Unlimited Sa	1	0.02%	4	0.08%	5,326	99.91%	5,331	0.04%
Wrangler SE 4WD	1	0.10%	3	0.30%	1,005	99.60%	1,009	0.01%
Wrangler Sport	2	0.05%	6	0.15%	3,909	99.80%	3,917	0.03%
Wrangler Sport 4WD	4	0.08%	10	0.21%	4,802	99.71%	4,816	0.03%
Wrangler Unlimited XS / Sport	1	0.03%	3	0.09%	3,231	99.88%	3,235	0.02%
Wrangler X / Wrangler Willys	1	0.03%	10	0.27%	3,694	99.70%	3,705	0.02%
KIA								
Amanti	2	0.14%	3	0.21%	1,427	99.65%	1,432	0.01%
Borrego 2WD	1	0.07%	1	0.07%	1,504	99.87%	1,506	0.01%
Borrego/Sorento	1	0.01%	7	0.07%	10,693	99.93%	10,701	0.07%
Cadenza	1	0.05%	1	0.05%	1,855	99.89%	1,857	0.01%
Optima	1	0.01%	4	0.05%	8,435	99.94%	8,440	0.06%
Optima / Optima Hybrid	6	0.01%	38	0.05%	76,970	99.94%	77,014	0.51%
Rio	2	0.01%	19	0.08%	23,904	99.91%	23,925	0.16%
Sedona VQ	2	0.04%	4	0.09%	4,517	99.87%	4,523	0.03%
Sorento	2	0.01%	15	0.05%	29,684	99.94%	29,701	0.20%
Sorento 2WD	1	0.01%	12	0.10%	11,936	99.89%	11,949	0.08%
Sorento/Sportage	1	0.00%	29	0.06%	49,719	99.94%	49,749	0.33%
Soul/Tucson	2	0.00%	41	0.05%	87,210	99.95%	87,253	0.58%
Spectra	3	0.02%	14	0.08%	17,733	99.90%	17,750	0.12%
LEXS								
CT 200h	3	0.04%	8	0.11%	7,082	99.84%	7,093	0.05%
ES 350	3	0.00%	40	0.06%	70,524	99.94%	70,567	0.47%
ES300	4	0.03%	28	0.18%	15,455	99.79%	15,487	0.10%

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ES330	5	0.04%	12	0.09%	13,519	99.87%	13,536	0.09%
ES350	3	0.01%	22	0.09%	24,715	99.90%	24,740	0.16%
GS 350	7	0.03%	20	0.09%	21,476	99.87%	21,503	0.14%
GS300	1	0.02%	2	0.04%	5,172	99.94%	5,175	0.03%
GS300/GS450	1	0.02%	5	0.12%	4,312	99.86%	4,318	0.03%
GX470	4	0.03%	8	0.07%	11,765	99.90%	11,777	0.08%
IS 250	3	0.01%	26	0.10%	25,387	99.89%	25,416	0.17%
IS250	4	0.03%	13	0.08%	15,511	99.89%	15,528	0.10%
LS 460	1	0.01%	13	0.10%	12,578	99.89%	12,592	0.08%
LS430	1	0.02%	7	0.11%	6,596	99.88%	6,604	0.04%
LX 570	1	0.01%	3	0.04%	7,178	99.94%	7,182	0.05%
LX450	1	0.34%	1	0.34%	295	99.33%	297	0.00%
LX470	2	0.05%	4	0.10%	3,966	99.85%	3,972	0.03%
NX 200t	1	0.00%	20	0.09%	23,193	99.91%	23,214	0.15%
RX 350	5	0.00%	72	0.05%	138,699	99.94%	138,776	0.92%
RX300	1	0.01%	10	0.09%	11,472	99.90%	11,483	0.08%
RX330	2	0.01%	29	0.18%	16,405	99.81%	16,436	0.11%
RX350	10	0.04%	33	0.14%	22,860	99.81%	22,903	0.15%
RX400h	1	0.02%	7	0.17%	4,091	99.80%	4,099	0.03%
SC300	1	0.25%	3	0.74%	404	99.02%	408	0.00%
LINC								
Aviator	1	0.03%	13	0.43%	3,030	99.54%	3,044	0.02%
Continental Reserve	1	0.10%	1	0.10%	985	99.80%	987	0.01%
LS	2	0.07%	8	0.28%	2,893	99.66%	2,903	0.02%
Mark LT 2WD SpuerCrew	1	0.04%	5	0.18%	2,705	99.78%	2,711	0.02%

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Mark LT 4WD SuperCrew	1	0.10%	1	0.10%	979	99.80%	981	0.01%
MKS	1	0.01%	6	0.08%	7,145	99.90%	7,152	0.05%
MKX FWD	1	0.02%	4	0.09%	4,388	99.89%	4,393	0.03%
MKZ	2	0.01%	26	0.15%	16,858	99.83%	16,886	0.11%
Navigator 2WD	4	0.03%	37	0.27%	13,921	99.71%	13,962	0.09%
Navigator 4WD	1	0.03%	5	0.17%	2,890	99.79%	2,896	0.02%
Town Car Executive	4	0.08%	18	0.38%	4,685	99.53%	4,707	0.03%
Town Car Signature	5	0.06%	31	0.37%	8,269	99.57%	8,305	0.05%
Town Car Signature Limited	5	0.09%	11	0.19%	5,772	99.72%	5,788	0.04%
Town Car Ultimate	1	0.11%	1	0.11%	930	99.79%	932	0.01%
LNDR								
Range Rover	6	0.01%	73	0.10%	72,731	99.89%	72,810	0.48%
MASE								
Ghibli	1	0.02%	5	0.12%	4,279	99.86%	4,285	0.03%
MAZD								
3	3	0.01%	44	0.22%	20,214	99.77%	20,261	0.13%
5	1	0.03%	11	0.36%	3,036	99.61%	3,048	0.02%
6	6	0.06%	78	0.72%	10,711	99.22%	10,795	0.07%
626	2	0.13%	14	0.94%	1,473	98.93%	1,489	0.01%
CX-5	1	0.00%	28	0.05%	51,287	99.94%	51,316	0.34%
CX-7	5	0.04%	80	0.69%	11,529	99.27%	11,614	0.08%
CX-9	2	0.01%	7	0.04%	17,652	99.95%	17,661	0.12%
CX-9 GS	1	0.02%	2	0.04%	4,497	99.93%	4,500	0.03%
Mazda 2	1	0.03%	16	0.43%	3,734	99.55%	3,751	0.02%
Mazda 3	10	0.03%	129	0.39%	32,722	99.58%	32,861	0.22%

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Mazda 5	1	0.12%	2	0.25%	807	99.63%	810	0.01%
Mazda 5 Sport	1	0.04%	10	0.36%	2,766	99.60%	2,777	0.02%
Mazda 6	8	0.09%	62	0.72%	8,512	99.18%	8,582	0.06%
Mazda 6 Touring	1	0.01%	2	0.02%	8,398	99.96%	8,401	0.06%
Mazda3	3	0.02%	8	0.06%	13,978	99.92%	13,989	0.09%
MazdaSpeed 3	1	0.09%	4	0.37%	1,070	99.53%	1,075	0.01%
MPV	1	0.03%	27	0.91%	2,931	99.05%	2,959	0.02%
MX5 Miata	6	0.26%	14	0.60%	2,304	99.14%	2,324	0.02%
MX-5 Miata	1	0.01%	22	0.32%	6,857	99.67%	6,880	0.05%
Protege	2	0.05%	23	0.52%	4,400	99.44%	4,425	0.03%
RX-8	1	0.06%	11	0.63%	1,734	99.31%	1,746	0.01%
Tribute I / Low 2WD	1	0.06%	1	0.06%	1,644	99.88%	1,646	0.01%
MERC								
Grand Marquis GS	6	0.06%	21	0.22%	9,593	99.72%	9,620	0.06%
Grand Marquis LS	4	0.03%	27	0.17%	15,560	99.80%	15,591	0.10%
Mountaineer	1	0.13%	1	0.13%	768	99.74%	770	0.01%
Mountaineer 2WD	1	0.03%	3	0.10%	3,047	99.87%	3,051	0.02%
Sable LS	1	0.15%	3	0.45%	667	99.40%	671	0.00%
MERZ								
C240	2	0.08%	9	0.34%	2,602	99.58%	2,613	0.02%
C250	2	0.01%	28	0.14%	20,197	99.85%	20,227	0.13%
C300	5	0.02%	34	0.13%	26,513	99.85%	26,552	0.18%
CLA250	3	0.02%	7	0.04%	16,325	99.94%	16,335	0.11%
CLK350	3	0.09%	6	0.19%	3,189	99.72%	3,198	0.02%
CLK430	1	0.11%	1	0.11%	879	99.77%	881	0.01%

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CLS 500	1	0.09%	3	0.28%	1,060	99.62%	1,064	0.01%
CLS550	1	0.02%	2	0.04%	4,657	99.94%	4,660	0.03%
E300	1	0.01%	16	0.14%	11,233	99.85%	11,250	0.07%
E320	2	0.11%	1	0.06%	1,815	99.83%	1,818	0.01%
E350	6	0.01%	45	0.10%	44,824	99.89%	44,875	0.30%
E63 AMG	1	0.29%	2	0.58%	343	99.13%	346	0.00%
GL450	1	0.01%	16	0.12%	12,947	99.87%	12,964	0.09%
GL550	1	0.03%	4	0.12%	3,429	99.85%	3,434	0.02%
GLA250	2	0.02%	22	0.17%	13,024	99.82%	13,048	0.09%
GLB250	1	0.35%	1	0.35%	281	99.29%	283	0.00%
GLC300	2	0.01%	29	0.12%	23,950	99.87%	23,981	0.16%
GLE350	2	0.01%	19	0.09%	20,414	99.90%	20,435	0.14%
GLE43 AMG	1	0.04%	2	0.08%	2,457	99.88%	2,460	0.02%
GLK350	4	0.02%	9	0.05%	16,682	99.92%	16,695	0.11%
ML320	1	0.04%	4	0.16%	2,467	99.80%	2,472	0.02%
ML350	3	0.01%	26	0.09%	28,818	99.90%	28,847	0.19%
S500V	1	0.06%	4	0.24%	1,649	99.70%	1,654	0.01%
S550	3	0.02%	8	0.04%	18,872	99.94%	18,883	0.12%
SLK230	2	0.14%	3	0.21%	1,430	99.65%	1,435	0.01%
MITS								
Eclipse GS	2	0.07%	16	0.56%	2,836	99.37%	2,854	0.02%
Eclipse GS Special	1	0.30%	2	0.60%	328	99.09%	331	0.00%
Endeavor LS FWD	1	0.04%	5	0.22%	2,229	99.73%	2,235	0.01%
Galant ES / GTZ / LS	1	0.05%	5	0.24%	2,080	99.71%	2,086	0.01%
Galant FE	8	0.34%	16	0.69%	2,296	98.97%	2,320	0.02%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Lancer GTS	1	0.06%	1	0.06%	1,751	99.89%	1,753	0.01%
Mirage DE	1	0.04%	7	0.25%	2,808	99.72%	2,816	0.02%
Montero Limited	1	0.09%	7	0.63%	1,099	99.28%	1,107	0.01%
Montero Sport 2WD	2	0.07%	5	0.17%	2,942	99.76%	2,949	0.02%
Outlander GT AWC	1	0.14%	3	0.42%	717	99.45%	721	0.00%
Outlander SE FWD	2	0.02%	15	0.17%	8,661	99.80%	8,678	0.06%
MNNI								
Cooper	2	0.04%	7	0.12%	5,681	99.84%	5,690	0.04%
Cooper S	1	0.02%	10	0.23%	4,296	99.74%	4,307	0.03%
Mini Cooper S Countryman	2	0.03%	3	0.05%	5,769	99.91%	5,774	0.04%
NISS								
Altima	61	0.02%	322	0.09%	365,599	99.90%	365,982	2.42%
Armada/Titan	1	0.01%	11	0.06%	17,982	99.93%	17,994	0.12%
Cube	1	0.03%	6	0.16%	3,698	99.81%	3,705	0.02%
Frontier	7	0.01%	63	0.08%	83,531	99.92%	83,601	0.55%
GT-R	1	0.10%	1	0.10%	1,017	99.80%	1,019	0.01%
I30	1	0.02%	9	0.14%	6,358	99.84%	6,368	0.04%
Juke	1	0.00%	19	0.08%	23,017	99.91%	23,037	0.15%
Kicks	1	0.02%	7	0.12%	5,611	99.86%	5,619	0.04%
Maxima	10	0.01%	51	0.07%	72,188	99.92%	72,249	0.48%
Murano	12	0.01%	65	0.07%	95,850	99.92%	95,927	0.63%
NV200	2	0.03%	11	0.16%	7,040	99.82%	7,053	0.05%
Pathfinder	16	0.02%	57	0.06%	91,961	99.92%	92,034	0.61%
Pathfinder Armada	5	0.03%	18	0.11%	15,846	99.86%	15,869	0.10%
Pickup Crew Cab	1	0.01%	5	0.06%	7,823	99.92%	7,829	0.05%

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Pickup King Cab	4	0.04%	13	0.12%	10,897	99.84%	10,914	0.07%
Quest	3	0.02%	8	0.06%	12,364	99.91%	12,375	0.08%
Rogue	21	0.01%	120	0.06%	198,495	99.93%	198,636	1.31%
Rogue Select	2	0.01%	10	0.07%	13,698	99.91%	13,710	0.09%
Rogue Sport	1	0.01%	8	0.05%	15,507	99.94%	15,516	0.10%
Sentra	35	0.02%	153	0.09%	179,716	99.90%	179,904	1.19%
Titan	11	0.03%	36	0.08%	43,741	99.89%	43,788	0.29%
Truck Regular Bed	2	0.05%	5	0.12%	4,107	99.83%	4,114	0.03%
Versa	20	0.02%	67	0.08%	80,714	99.89%	80,801	0.53%
Versa Note	1	0.01%	13	0.07%	19,178	99.93%	19,192	0.13%
Xterra	4	0.01%	38	0.13%	29,427	99.86%	29,469	0.19%
OLDS								
Aurora	1	0.23%	2	0.46%	432	99.31%	435	0.00%
OTHR								
1500	3	0.05%	4	0.07%	5,667	99.88%	5,674	0.04%
Accord LX	1	0.04%	1	0.04%	2,803	99.93%	2,805	0.02%
Altima	2	0.02%	5	0.05%	9,508	99.93%	9,515	0.06%
BRZ	1	0.45%	1	0.45%	218	99.09%	220	0.00%
Challenger R/T	1	0.22%	1	0.22%	444	99.55%	446	0.00%
Civic EX	1	0.04%	1	0.04%	2,789	99.93%	2,791	0.02%
Civic LX	1	0.03%	1	0.03%	3,069	99.93%	3,071	0.02%
Corolla	2	0.02%	7	0.07%	9,423	99.90%	9,432	0.06%
E300	1	0.07%	1	0.07%	1,456	99.86%	1,458	0.01%
Elantra	1	0.02%	2	0.03%	5,878	99.95%	5,881	0.04%
Explorer	1	0.07%	1	0.07%	1,382	99.86%	1,384	0.01%

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Explorer Limited	2	0.10%	4	0.20%	1,957	99.69%	1,963	0.01%
F150	2	0.01%	10	0.04%	23,111	99.95%	23,123	0.15%
Forester	1	0.02%	2	0.04%	4,481	99.93%	4,484	0.03%
Fusion SE	1	0.03%	2	0.06%	3,181	99.91%	3,184	0.02%
Grand Caravan SE	1	0.04%	1	0.04%	2,291	99.91%	2,293	0.02%
Mustang GT	1	0.06%	3	0.17%	1,717	99.77%	1,721	0.01%
Odyssey	3	0.02%	16	0.08%	19,359	99.90%	19,378	0.13%
Passat	1	0.06%	2	0.12%	1,603	99.81%	1,606	0.01%
Pathfinder	1	0.03%	1	0.03%	3,302	99.94%	3,304	0.02%
Patriot	1	0.17%	3	0.50%	598	99.34%	602	0.00%
RAV4 XLE	1	0.02%	3	0.07%	4,256	99.91%	4,260	0.03%
Rogue	2	0.02%	7	0.06%	11,513	99.92%	11,522	0.08%
Rogue Sport	2	0.09%	3	0.13%	2,239	99.78%	2,244	0.01%
Santa Fe	1	0.02%	4	0.08%	5,035	99.90%	5,040	0.03%
Sentra	2	0.03%	5	0.07%	6,965	99.90%	6,972	0.05%
Sienna XLE	1	0.02%	2	0.05%	4,030	99.93%	4,033	0.03%
Silverado 1500	1	0.01%	6	0.04%	15,630	99.96%	15,637	0.10%
Town & Country	1	0.04%	3	0.13%	2,265	99.82%	2,269	0.01%
Town & Country Touring FWD	1	0.22%	2	0.43%	459	99.35%	462	0.00%
Tundra Ltd	1	0.16%	2	0.31%	641	99.53%	644	0.00%
Wrangler	2	0.03%	6	0.09%	6,976	99.89%	6,984	0.05%
XTS	1	0.02%	1	0.02%	4,005	99.95%	4,007	0.03%
PONT								
Firebird	1	0.08%	7	0.55%	1,276	99.38%	1,284	0.01%
Formula / Trans Am	1	0.03%	5	0.15%	3,227	99.81%	3,233	0.02%

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G6 SE1	4	0.05%	14	0.19%	7,479	99.76%	7,497	0.05%
Grand Am SE1	1	0.05%	10	0.54%	1,842	99.41%	1,853	0.01%
Sunfire	1	0.05%	5	0.27%	1,820	99.67%	1,826	0.01%
Vibe	3	0.05%	10	0.15%	6,628	99.80%	6,641	0.04%
PORS								
911	5	0.03%	72	0.44%	16,402	99.53%	16,479	0.11%
986 Boxster	1	0.03%	20	0.67%	2,950	99.29%	2,971	0.02%
Boxster / Cayman	2	0.03%	19	0.32%	5,850	99.64%	5,871	0.04%
Cayenne	3	0.02%	26	0.16%	16,498	99.82%	16,527	0.11%
Cayman / Boxster	1	0.04%	16	0.63%	2,531	99.33%	2,548	0.02%
Macan	5	0.05%	10	0.09%	10,789	99.86%	10,804	0.07%
Panamera	5	0.06%	41	0.48%	8,537	99.46%	8,583	0.06%
RAM								
1500	3	0.01%	56	0.10%	53,834	99.89%	53,893	0.36%
ProMaster City	1	0.04%	18	0.81%	2,215	99.15%	2,234	0.01%
RAM 1500	2	0.01%	10	0.07%	14,136	99.92%	14,148	0.09%
SAA								
9/3/2022	1	0.04%	7	0.25%	2,847	99.72%	2,855	0.02%
SCIO								
Scion tC	2	0.01%	10	0.06%	16,795	99.93%	16,807	0.11%
Scion xA	1	0.03%	5	0.14%	3,518	99.83%	3,524	0.02%
STRN								

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Aura XE	1	0.03%	6	0.19%	3,138	99.78%	3,145	0.02%
ION Level 3	2	0.13%	2	0.13%	1,540	99.74%	1,544	0.01%
SC1 / SL	1	0.49%	1	0.49%	204	99.03%	206	0.00%
SL2 Auto	1	0.17%	1	0.17%	600	99.67%	602	0.00%
SUBA								
BRZ	3	0.08%	11	0.30%	3,636	99.62%	3,650	0.02%
Crosstrek	1	0.01%	7	0.04%	19,582	99.96%	19,590	0.13%
Forester	4	0.01%	72	0.15%	46,999	99.84%	47,075	0.31%
Impreza	1	0.01%	37	0.21%	17,282	99.78%	17,320	0.11%
Legacy	1	0.01%	4	0.05%	7,816	99.94%	7,821	0.05%
Legacy / Outback	2	0.09%	1	0.05%	2,185	99.86%	2,188	0.01%
Outback	3	0.01%	26	0.06%	42,269	99.93%	42,298	0.28%
SUZI								
Grand Vitara	1	0.18%	10	1.77%	553	98.05%	564	0.00%
Grand Vitara 2WD	5	0.27%	13	0.69%	1,862	99.04%	1,880	0.01%
TOYT								
4dr Wagon 2WD	1	0.02%	6	0.14%	4,220	99.83%	4,227	0.03%
4Runner	2	0.00%	59	0.07%	80,669	99.92%	80,730	0.53%
4Runner Limited	1	0.01%	10	0.08%	11,789	99.91%	11,800	0.08%
4Runner SR5	7	0.01%	42	0.08%	50,055	99.90%	50,104	0.33%
Avalon	15	0.02%	77	0.10%	74,692	99.88%	74,784	0.49%
Camry	99	0.02%	434	0.08%	545,292	99.90%	545,825	3.61%
Camry Hybrid	2	0.01%	25	0.13%	18,703	99.86%	18,730	0.12%
Celica	2	0.05%	9	0.21%	4,199	99.74%	4,210	0.03%
Corolla	48	0.01%	249	0.07%	348,197	99.91%	348,494	2.30%

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Corolla/Matrix	13	0.02%	68	0.12%	55,334	99.85%	55,415	0.37%
FJ Cruiser	3	0.02%	15	0.08%	18,015	99.90%	18,033	0.12%
Highlander	8	0.01%	60	0.08%	71,869	99.91%	71,937	0.48%
Highlander LE	4	0.02%	15	0.08%	18,065	99.89%	18,084	0.12%
Highlander Ltd	2	0.01%	8	0.04%	18,652	99.95%	18,662	0.12%
Highlander SE/XLE	4	0.02%	21	0.10%	21,455	99.88%	21,480	0.14%
Highlander XLE	2	0.01%	6	0.03%	17,653	99.95%	17,661	0.12%
Land Cruiser	1	0.02%	6	0.10%	6,012	99.88%	6,019	0.04%
Land Cruiser VX-R	1	0.06%	4	0.23%	1,699	99.71%	1,704	0.01%
Matrix	4	0.04%	12	0.12%	10,093	99.84%	10,109	0.07%
Prius	3	0.02%	25	0.15%	16,638	99.83%	16,666	0.11%
Prius C Hybrid	1	0.01%	6	0.08%	7,833	99.91%	7,840	0.05%
Prius Hybrid	3	0.01%	37	0.08%	45,863	99.91%	45,903	0.30%
Prius V Hybrid	2	0.03%	4	0.06%	7,026	99.91%	7,032	0.05%
RAV4	4	0.01%	41	0.07%	54,899	99.92%	54,944	0.36%
RAV4 4dr 4WD	1	0.24%	1	0.24%	414	99.52%	416	0.00%
RAV4 LE	9	0.01%	36	0.06%	61,389	99.93%	61,434	0.41%
RAV4 XLE	3	0.00%	55	0.09%	64,443	99.91%	64,501	0.43%
Sequoia / Highlander	2	0.02%	14	0.16%	8,564	99.81%	8,580	0.06%
Sequoia Limited	2	0.02%	10	0.08%	11,790	99.90%	11,802	0.08%
Sequoia SR5	1	0.01%	12	0.08%	15,754	99.92%	15,767	0.10%
Sienna	2	0.02%	4	0.04%	9,679	99.94%	9,685	0.06%
Sienna 5dr	1	0.04%	1	0.04%	2,365	99.92%	2,367	0.02%
Sienna LE	14	0.02%	41	0.07%	56,627	99.90%	56,682	0.37%
Sienna Ltd	2	0.01%	19	0.08%	24,382	99.91%	24,403	0.16%

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Sienna XLE	4	0.02%	21	0.10%	20,734	99.88%	20,759	0.14%
Solara	3	0.02%	20	0.13%	15,742	99.85%	15,765	0.10%
Tacoma	8	0.01%	42	0.08%	55,098	99.91%	55,148	0.36%
Tacoma Deluxe	5	0.02%	37	0.14%	26,938	99.84%	26,980	0.18%
Tacoma DLX	5	0.01%	34	0.08%	45,042	99.91%	45,081	0.30%
Tacoma Ltd	2	0.05%	6	0.15%	3,931	99.80%	3,939	0.03%
Tacoma PreRunner XTRACAB	1	0.03%	2	0.07%	3,015	99.90%	3,018	0.02%
Tacoma Regular Cab 2WD	2	0.08%	1	0.04%	2,432	99.88%	2,435	0.02%
Tacoma SR/SR5/TRD	2	0.01%	12	0.07%	16,363	99.91%	16,377	0.11%
Tacoma SR5	1	0.02%	10	0.18%	5,609	99.80%	5,620	0.04%
Tacoma SR5/TRD	2	0.02%	8	0.06%	13,149	99.92%	13,159	0.09%
Tacoma XTRACAB 2WD	2	0.05%	10	0.27%	3,748	99.68%	3,760	0.02%
Tundra	2	0.01%	8	0.04%	18,407	99.95%	18,417	0.12%
Tundra SR/SR5	4	0.01%	24	0.05%	45,137	99.94%	45,165	0.30%
Tundra Platinum	1	0.01%	10	0.06%	16,242	99.93%	16,253	0.11%
Tundra SR5	8	0.01%	104	0.10%	108,927	99.90%	109,039	0.72%
Tundra SR5/TRD	7	0.03%	11	0.04%	24,900	99.93%	24,918	0.16%
Yaris	2	0.01%	16	0.06%	24,656	99.93%	24,674	0.16%
VOLK								
Beetle	1	0.01%	15	0.10%	15,108	99.89%	15,124	0.10%
Eos	4	0.12%	5	0.14%	3,468	99.74%	3,477	0.02%
Golf / GTI / Jetta Wagon	2	0.10%	4	0.20%	2,040	99.71%	2,046	0.01%
Golf/Golf R/GTI/Jetta/Jetta Sp	2	0.02%	4	0.04%	10,876	99.94%	10,882	0.07%
Golf/GTI	3	0.02%	20	0.15%	13,022	99.82%	13,045	0.09%
Golf/GTI/Jetta/Jetta Sportwage	2	0.01%	33	0.11%	30,043	99.88%	30,078	0.20%

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Jetta	11	0.03%	64	0.15%	43,059	99.83%	43,134	0.28%
Jetta/Golf/GTI	1	0.10%	10	1.01%	979	98.89%	990	0.01%
Jetta/Rabbit/GTI	5	0.03%	37	0.21%	17,505	99.76%	17,547	0.12%
New Beetle	7	0.11%	22	0.34%	6,359	99.55%	6,388	0.04%
New Beetle Convertible	1	0.03%	12	0.38%	3,163	99.59%	3,176	0.02%
Passat	13	0.03%	81	0.17%	47,750	99.80%	47,844	0.32%
Tiguan	3	0.01%	41	0.13%	32,264	99.86%	32,308	0.21%
Touareg	4	0.10%	1	0.02%	4,049	99.88%	4,054	0.03%
VOLV								
S40 / V40	1	0.25%	1	0.25%	395	99.50%	397	0.00%
S40 / V50	1	0.02%	4	0.09%	4,256	99.88%	4,261	0.03%
S70 / V70	2	0.21%	2	0.21%	957	99.58%	961	0.01%
V70 / XC70 AWD	1	0.05%	2	0.10%	1,946	99.85%	1,949	0.01%
XC60	1	0.01%	9	0.05%	17,308	99.94%	17,318	0.11%
XC90	1	0.00%	21	0.10%	21,891	99.90%	21,913	0.14%
Grand Total	**2,639**	**0.02%**	**15,813**	**0.10%**	**15,117,440**	**99.88%**	**15,135,892**	**100.00%**