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NHTSA Tire-Related Surveys: Results and Implications

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16. Abstract

Low tire pressure has been shown to be an issue of safety and of fuel economy. Federal Motor Vehicle Safety Standard No. 138 required a tire pressure monitoring system (TPMS) in most passenger vehicles with a gross vehicle weight rating under 10,000 lb as of September 2008 with a phase-in starting in September 2006. NHTSA conducted an evaluation survey in 2010 and 2011 that found direct TPMS to be 55.6 percent effective at reducing severe underinflation (more than 25% under the vehicle's recommended tire pressure). In the evaluation, questions arose about TPMS malfunction in older vehicles possibly reducing TPMS effectiveness. The Fixing America's Surface Transportation (FAST) Act in 2015 mandated the Secretary of Transportation to update FMVSS No. 138 to ensure that TPMS cannot be overridden, reset, or recalibrated in a way that will prevent the system from identifying a tire that is significantly underinflated, and that the revised requirements shall not contain any provision that has the effect of prohibiting the availability of direct or indirect tire pressure monitoring systems that meet the requirement. To help inform these topics, NHTSA conducted the Tire Pressure Monitoring Systems Outage Rates and Repair Costs (TPMS-ORRC) study, including a vehicle and driver survey, to learn more about TPMS operational status and driver facts, and a repair facilities survey to learn more about malfunction incidences and repair costs. This report compiles the TPMS-ORRC operations and results and looks at earlier survey results for historical perspective. Topics examined include TPMS operational status and related factors; driver knowledge about TPMS and tire pressure; driver engagement with tire pressure; TPMS malfunction reasons, repairs, and repair costs; driver acceptance of TPMS and reaction to malfunction; indirect TPMS; and State requirements.

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Table of Contents

List of Figures

List of Tables

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Executive Summary

Federal Motor Vehicle Safety Standard (FMVSS) No. 138 requires that drivers of most passenger vehicles of gross vehicle weight ratings (GVWR) of 10,000 lb or less are warned when the air pressure in one or more vehicle tires have fallen to 25 percent or more below the recommended pressure ("severe underinflation"). The system also must notify the driver if the system is in malfunction status. The rule, mandated in the Transportation Recall Enhancement, Accountability, and Documentation (TREAD) Act of 2000, had a phase-in period in model years (MY) 2006 and 2007 and was required in MY 2008 and beyond.

The vehicle technology that monitors tire pressure is referred to as a tire pressure monitoring system, TPMS. Two different technologies have been developed: Direct TPMS uses sensors mounted directly in each wheel to detect tire pressure, while indirect TPMS uses wheel speed sensors in the vehicle's antilock brake system, or other inputs, to detect small changes in wheel speed that occur when a tire loses pressure, comparing the relative speed of the four tires.

A 2012 evaluation of TPMS effectiveness in passenger vehicles based on survey data from 2010 and 2011 estimated that direct TPMS reduced the likelihood of severe underinflation as defined in FMVSS No. 138 by 55.6 percent (indirect TPMS did not have enough sample for estimation). Effectiveness appeared to be lower in older vehicles than in newer ones; the report proposed that TPMS maintenance and malfunction could be involved in the differences and suggested that a follow-up survey of TPMS malfunction and associated circumstances would be useful to fully understand the results of the evaluation.

The Fixing America's Surface Transportation (FAST) Act was signed into law in 2015. Section 24115 directed the Secretary of Transportation to update FMVSS No. 138 to ensures that TPMS cannot be overridden, reset, or recalibrated to prevent the system from identifying a significantly underinflated tire, and that the revised requirements shall not contain any provision that has the effect of prohibiting the availability of direct or indirect TPMS. The Infrastructure Investment and Jobs Act of 2021, also known as the Bipartisan Infrastructure Law, requires NHTSA to provide a rulemaking report including the tire pressure monitoring standards in the FAST Act.

In response to the earlier evaluation and to help inform the rulemaking required in the FAST Act, NHTSA conducted a new study, the TPMS Outage Rates and Repair Costs (TPMS-ORRC) study, with nationally representative survey components conducted in 2016 to 2018. Results were made available internally at NHTSA. This report examines the results for details and implications and examines previous NHTSA tire pressure surveys for historical perspective.

Some key findings and implications were:

TPMS Effectiveness and Functionality

- **TPMS operational status.** In driven passenger vehicles up to 13 years old at the time of the survey with a TPMS compliant to FMVSS No. 138, prevalence of a TPMS malfunction warning was about 4 percent and for a low-pressure warning, 8 percent - giving a combined TPMS warning prevalence of 12 percent in vehicles on the road. A vehicle with TPMS malfunction may or may not be experiencing low pressure, but data from earlier surveys suggested that a substantial proportion of vehicles may be. Both kinds of TPMS warnings tended to increase in prevalence with vehicle age; TPMS malfunction ranged from 1.5 percent in vehicles up to 4 years old to 13.9 percent in vehicles 11 to 13 years old, and prevalence of a pressure warning ranged from 5.8 percent in vehicles up to 4 years old to 14.8 percent in vehicles 11 to 13 years old.

- **TPMS effectiveness.** Low pressure in 8 to 12 percent of passenger vehicles with TPMS (above) is an improvement over the 20 to 25 percent of passenger vehicles without TPMS found to have low pressure in earlier surveys. Similar findings in 2010/2011 generated an estimate that TPMS reduced the likelihood of severe underinflation by about 56 percent. A related earlier finding that TPMS effectiveness may be lower in older vehicles appears related to unresolved TPMS malfunction as vehicles age, but also to a general tendency for tire pressure to be low more frequently in older vehicles.
- **TPMS malfunctions and repair costs.** Tire pressure sensor failure including battery failure appears to be the most common contributor to direct TPMS malfunctions. Wheel-mounted sensors may be a contributor in indirect TPMS. Malfunctions in indirect TPMS appear to be rarer than in direct TPMS, but the fleet is also newer. The most common repair for direct TPMS was for new tire pressure sensors, estimated to cost around $400 for four sensors (2016 dollars).
- **Indirect TPMS.** Vehicles with indirect TPMS are a smaller but growing share of the U.S. passenger vehicle fleet. Drivers with indirect TPMS were found to have low knowledge and experience in recalibrating the TPMS after adjusting pressure or other tire events, a requirement for indirect TPMS. Tire checks found about 9 percent of vehicles with indirect TPMS showing a warning or lack of warning inconsistent with the measured pressure; this result could be related to calibration, but this cannot be definitively known from the available data.

Driver Factors

- **Driver acceptance and willingness to pay.** Most drivers said they prefer to have TPMS, but many have concerns about the cost of TPMS repair. Many drivers with TPMS malfunction said they do not plan to repair it or were not sure, noting that TPMS is not needed to operate the vehicle. Although the most common repair for direct TPMS was new tire pressure sensors at about $400 for four, under two percent of drivers said they'd be willing to spend more than $300 on a hypothetical TPMS repair.
- **Driver knowledge.** Drivers have high levels of general knowledge about having TPMS, knowing the warning light is related to tire pressure, and how to add air, but a smaller portion of drivers with current malfunction lights knew what the lights mean. To find a vehicle's recommended air pressure, about a third of drivers incorrectly look at the tire sidewall rather than the vehicle placard typically on the driver door jamb or driver door - a concern because the sidewall gives the tire's maximum pressure, not the recommended pressure. Driver awareness about the vehicle placard has improved since the placard became required but is still under 40 percent. For either direct or indirect TPMS, driver knowledge about TPMS reset and recalibration appears to be low. Reset terminologies, displays, and procedures vary across vehicle makes, and many drivers are not sure who can do a reset and when it needs to be done.
- **Drivers following recommendations.** NHTSA recommends that drivers with TPMS still check their tire pressure once a month and not rely on the TPMS warning light to replace the pressure check, but less than half of drivers with TPMS reported that they checked

their tire pressure in the last month. A possible result may be driving with tires that are underinflated but not low enough to trigger a TPMS warning. NHTSA also recommends that TPMS warning lights be given attention as soon as possible, but half of drivers with a pressure warning and 96 percent of drivers with a malfunction warning said the warning had been on over a week.

- **More likely to be driving with a warning light.** Driving with a TPMS warning (low-pressure or malfunction) was comparatively more prevalent in younger drivers, drivers of lower income and education, drivers whose first language is not English, and drivers of older vehicles or vehicles with higher mileage. Vehicles being driven with higher occurrences of TPMS malfunction were older vehicles, vehicles with spare or non-matching tires, and vehicles with irregular tire valve stems or caps. Having a vehicle warranty or believing there is a legal requirement for TPMS to be working was associated with lower prevalence of driving with a TPMS malfunction light.

Some possible further activities suggested by the findings were:

- **Driver education and outreach** could focus on what a TPMS light means, finding recommended pressure, recalibrating the TPMS, and following NHTSA recommendations about tire pressure and TPMS warnings. A public campaign about driving with underinflated tires could be targeted to younger drivers, drivers whose first language is not English, drivers of older vehicles, and drivers in lower-income areas or who have lower education levels.
- **Further TPMS detection research** could expand TPMS vehicle tire pressure checks to assess the accuracy of TPMS warnings compared to measured tire pressure and the effect of TPMS malfunction on tire pressure status.
- **Behavioral research** could examine how drivers react to TPMS warnings and tire pressure in general and as vehicles age, possibly proposing countermeasures to reduce driving with underinflated tires.
- **Tracking surveys** such as a vehicle and driver survey every 10 years or so could incorporate the added checks and topics mentioned above, allowing checks on progress in the population.
- **State regulations** could be compared in a special study of low-pressure prevalence in different States with varying practices, including a California regulation requiring air service at all service visits, or other State policies such as advising drivers about their tire pressure during a safety inspection.

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1. Introduction

1.1 Motivation for a Comprehensive Review of Tire Survey Data

According to NHTSA, poor tire maintenance, including not having enough air in tires, can lead to a flat tire, blowout, or the tread coming off a tire (NHTSA, n.d.-a). An analysis from a NHTSA crash causation study found that a vehicle is more likely to experience tire problems when one or more tires are underinflated (Choi, 2012). NHTSA also states that properly inflated tires can save drivers as much as 11 cents per gallon on fuel compared to underinflated tires, can extend the average life of tires by 4,700 miles, and that 562 people died on the road in tire-related crashes in 2022 (NHTSA, n.d.-a).

NHTSA has had extensive involvement with tire pressure safety issues and rulemaking. FMVSS No. 138 requires most passenger vehicles that have a GVWR of 10,000 lb or less to have a TPMS (See Section 2. for details). Since 2001 NHTSA has conducted data collection on tire pressure issues. Results were documented in publications to varying degrees, but more data elements and analyses exist than what has been previously published.

The most recent data collection is the TPMS-ORRC study, a set of surveys with focus on TPMS operational status and related issues. This report documents the new study and reviews two previous tire pressure surveys for context and comparisons over time. This report's goal is to explain the TPMS-ORRC study, review the key findings and context with previous data collections, extract topic results, synthesize conclusions, and propose implications of the findings as they relate to the effectiveness of TPMS as mandated by FMVSS No. 138.

In support of those goals, documenting these results is intended to

- provide follow-up to questions raised by NHTSA's 2012 evaluation of TPMS;
- inform future NHTSA rulemaking related to FMVSS No. 138;
- show comparisons of tire pressure and TPMS results over time;
- inform the public and decision makers on what NHTSA has done in tire pressure data;
- make NHTSA results available to tire industry stakeholders and the public;
- help validate surveys when results are consistent;
- assist development of future surveys by identifying successes and areas for improvement;
- stimulate ideas for behavioral safety research and public messaging on tire pressure; and.
- encourage other researchers to access NHTSA data for analysis.

This report also gathers tire pressure and interview data from various NHTSA tire surveys for historical perspective. Surveys from 2001 and 2010/2011 are summarized, and previously unpublished response tables are provided in appendices. Previously published reports on the earlier surveys, cited in sections in this report, have details on the earlier surveys' designs and protocols and are recommended for full coverage of their topics.

1.2 Report Topics and Preparation

Sections 1 to 4 of the report describe the topic background, data sources, and result highlights. Sections 5 to 13 address some research topics and questions that were proposed by NHTSA offices. The proposed topics and questions were:

- Follow-up from NHTSA's 2012 TPMS evaluation (Section 5): Is a 2012 finding that TPMS was less effective in older vehicles related to TPMS maintenance?
- Driver knowledge about TPMS and tire pressure (Section 6): Do drivers of vehicles with TPMS have knowledge about their TPMS and the dash lights, putting air in tires, where to find information about recommended tire pressure, and resetting TPMS?
- Driver engagement with tire pressure (Section 7): Do drivers of vehicles with TPMS have experience and follow recommendations about checking and maintaining their tire pressure?
- TPMS malfunction and repairs (Section 8): What are reasons for TPMS to not be functioning? What are the main reasons that TPMS need repairs and component parts that are commonly replaced?
- TPMS repair costs (Section 9): What are maintenance and repair costs of TPMS, as related to diagnosed problems?
- Driver acceptance of TPMS (Section 10): What is drivers' acceptance of the TPMS? Do owners repair TPMS, and if not, why not? How often and for what reasons are TPMS lights disabled?
- Indirect TPMS (Section 11): Do drivers of vehicles with indirect TPMS know about and have experience recalibrating the system?
- Related factors (Section 12): Does tendency to have an unresolved TPMS malfunction or low-pressure warning differ by vehicle age, type, or mileage, or by driver demographics?
- State requirements (Section 13) were not planned survey topics, but interest arose when examining State regulations for potential influence on survey results.

This report informally uses a process of data analysis, data synthesis, and data interpretation based on guidelines published by the Centers for Disease Control and Prevention (CDC, n.d.) in which "data analysis" is the process of organizing and classifying the information collected, tabulating it, summarizing it, and presenting the results in an easily understandable manner; "data synthesis" brings together results and examines the findings together for patterns; and "data interpretation,," called "Implications" for this report, is making sense of the findings, including any key takeaways for stakeholders, and how these findings address the topic questions. A NHTSA behavioral research psychologist contributed consultation to the report including the implications. The presented implications are proposals to encourage discussion and could be subject to different interpretations.

1.3 Report Scope

This report focuses on survey results about tire pressure and TPMS. Topics on TPMS technology and rulemaking are summarized for background but are not intended to be comprehensive. Responses about TPMS component costs and lifespans are the respondents' best estimates, not analysis of cost or repair data from other sources. The surveys did not cover topics specific to after-market TPMS.

1.4 Terminology Used in the Report

The following terminology conventions are used in the report.

Passenger vehicles, in relation to TPMS-equipped vehicles or their peers, in this report means vehicles covered by FMVSS No. 138. NHTSA's National Center for Statistics and Analysis defines passenger vehicles as motor vehicles weighing 10,000 pounds or less including passenger cars and light trucks (SUVs, pickup trucks, vans, and other light trucks) (NHTSA, 2023). The specific coverage of FMVSS No. 138 is for all new passenger cars, trucks, multipurpose passenger vehicles, and buses with a GVWR of 10,000 lb or less, except those vehicles with dual wheels on an axle.

Tire pressure means tire air inflation pressure, typically pounds per square inch (psi).

Warning light in this report is interchangeable with **warning telltale** or sometimes **telltale** as used in FMVSS No. 138 for an illuminated dashboard alert. Since the surveys used "warning light" in questions to drivers, the response analyses often use that term. The synonymous "telltale" is often used in NHTSA and industry writing but may be less familiar to drivers. (A warning "lamp," on the other hand, may refer to the equipment, illuminated or not.)

TPMS-equipped or **vehicle with TPMS** in this report generally means TPMS that was original equipment on the vehicle. In the 2018 Field Survey, only vehicles that were known to have been equipped with TPMS compliant to FMVSS No. 138 were admitted into the survey. Thus, it is unlikely that any of the admitted vehicles had an after-market TPMS. In the 2010/2011 TPMS Special Study, vehicles were admitted regardless of TPMS status, so it could be possible that some vehicles had after-market TPMS, but there is no data field to identify them.

Severe underinflation in this report means tire air inflation more than 25 percent under the recommended pressure, the definition used in FMVSS No.138. In this report, the term **low pressure** refers to severe underinflation.

Disabled TPMS in this report means a TPMS that has been made inoperative. In industry writing or other articles, disabled TPMS may also be referred to by other terms such as "disengaged," "deactivated," "disconnected," or "defeated."

Dollars in this report are given as they were reported at the time of the survey. For example, the Repair Facilities Survey was conducted in 2016, so estimates for costs of replacing parts are in 2016 dollars. According to the Bureau of Labor Statistics, a 2016 dollar's purchasing power is equivalent to $1.28 in 2024 (BLS, n.d.).

Vehicle age in this report is approximated by subtracting the model year of the vehicle from the "model year" (September-August) in which the survey took place. Since the Field Survey went through November 2018, it is considered as occurring in MY 2019 for this purpose. (A negative result would be set to 0, but this did not happen in the surveys covered in this report.)

1.5 Statistical Conventions Used in the Report

The following conventions were used in the analyses and presentations in this report. SAS techniques described are documented in SAS user manuals for the referenced procedures.

Outcomes. Most outcomes in this report are categorical variable percentages. When cited as "rates" they are per 100. "Prevalence" is also used as the percentage of a group with a condition.

SAS procedures. SAS PROC SURVEYFREQ and SURVEYMEANS were used with CLUSTER, STRATA, and WEIGHT statements to incorporate the sample design when calculating point estimates, confidence intervals, or statistical significance. The significance level used was alpha=0.05. Confidence intervals (CI) for percentages are Wilson intervals using PROC SURVEYFREQ option CL(TYPE=WILSON) where CL denotes confidence limits, or the lower and upper bounds of the confidence intervals. Unlike the often seen Wald confidence interval, Wilson intervals are not necessarily symmetric about the point estimate. An advantage is that the Wilson interval bounds for a percentage will not unrealistically go below zero or above 100 percent (Newcombe, 1998). Since significance level is .05, confidence intervals are at the 95 percent level. Confidence intervals are presented as (lower limit, upper limit).

Domain analysis. SAS techniques for domain (population subset) analysis were used when using SURVEY procedures on a sample subset (instead of a WHERE or BY statement). Domain techniques incorporate the full sample size for variance estimation. In PROC SURVEYFREQ, the domain variables are the first specified in a cross-tabulation. In PROC SURVEYMEANS, domains are specified in a DOMAIN statement. Domains often occur because some questions are only applicable to a certain subgroup. Domains and domain sample sizes are reported with response tables.

Missing data. Item response data may be missing when the respondent was not in the domain for the question, when an in-domain respondent did not have a response for some reason, or when a respondent was not selected in a subsample. PROC SURVEYFREQ's option NOMCAR was not used because it would treat missing data as a domain rather than as missing at random. Item data that is missing because the respondent was not in the question's domain is not an issue because domain analysis was used. Responses of "Don't Know" were retained when assessing respondent knowledge about a topic. Responses of "Refused" were treated as missing.

Tests for association. The *F*-test statistic in SAS PROC SURVEYFREQ (CHISQ option) is an available ratio test for association. For *F*-tests cited in this report, the *F* value, numerator and denominator degrees of freedom (*df*), and *p*-value are shown. The numerator *df* is (r-1)(c-1) where r is the number of rows and c is the number of columns. The denominator *df* is the numerator *df* times the variance *df*, where the variance *df* is the number of clusters (PSUs) minus the number of strata (PSU strata). If the *p*-value is less than the designated significance level of .05, the null hypothesis of independence is considered rejected and the association between them is considered statistically significant at the .05 level. In other words, if the *p*-value is under .05, the data suggest association between the factors being tested. Statistically significant results are generally shown in **bold type** when reported in tables in this report.

Sample sizes. Following practices in NHTSA reports, sample sizes were considered too small for statistical inference if the denominator was under 30 or the numerator was under 5 (for example, Enriquez, 2021). An exception to the numerator would be if a reasonable sample size had a very small incidence of a characteristic and this was considered informative about the population. Cases have sometimes been grouped to avoid sample size problems (for example, vehicle age groups are used instead of individual ages).

Variable names and codes. SAS variable names are shown in upper case inside brackets for reference. For example: [TPMSMALF]. The names may help SAS file users or readers connecting narratives to variables. SAS code translations are used in tables. For data users, the SAS files are formatted with translations, and the survey instruments show the codes.

2. NHTSA's Role in Tire Pressure and Data Collection

A safety concern and a law. In the 1990s highly publicized incidents took place involving tire failures (NHTSA, n.d.-b). In response, in 2000 the Congress passed the TREAD Act. Section 13 directed the Secretary of Transportation to revise and update the FMVSS for tires to improve labeling on tires and require a system in new motor vehicles that warns the operator when a tire is significantly underinflated.

Studies on the topic. NHTSA conducted the TPSS in 2001 to help inform NHTSA's rulemaking process for the TREAD Act requirement. The TPSS collected tire pressure measurements and driver interview responses from over 10,000 passenger vehicles and drivers in a nationally representative sample. NHTSA's National Center for Statistics and Analysis (NCSA) produced research notes on the TPSS methodology and results (NCSA, 2001a, 2001b, 2001c). The research notes reported that about 25 percent of passenger vehicles were being driven with low pressure and about 34 percent of passenger vehicle drivers stated that they check their tires for air pressure at least monthly.

Another survey supported the TPSS finding about the frequency with which drivers check tire pressure when in a September 2000 Omnibus Household Survey, the Bureau of Transportation Statistics (BTS, n.d.-a) asked a telephone sample: How often do you, or the person who checks your tires, check the air pressure in your tires? About 29 percent stated that they check the air pressure in their tires monthly; another 29 percent said only when one or more of their vehicle's tires appears underinflated; 19 percent said only when the vehicle is serviced; 5 percent said only before taking their vehicle on a long trip; and 17 percent said on some other occasion. Thus, 71 percent of the respondents stated that they check the air pressure in the vehicles tires less than once a month.

NHTSA noted that it seemed likely that the respondents in both cited surveys may have overstated the frequency with which they check tire pressure, particularly given the fact that these surveys were conducted during the height of publicity about tire failures on SUVs in late 2000 and early 2001 (FMVSS No. 138, 2005).

The rule. With the TPSS data as a resource, NHTSA initiated a rulemaking process in response to the requirement in the TREAD Act. The eventual final rule, FMVSS No. 138, requires that drivers of all new passenger cars, trucks, multipurpose passenger vehicles, and buses with GVWRs of 10,000 lb or less, except those vehicles with dual wheels on an axle, be warned when the pressure in one or more of the vehicle's tires has fallen to 25 percent or more below the placard pressure, or a minimum level of pressure specified in the standard, whichever pressure is higher. The standard specified a phase-in period that required 20 percent fleet compliance per manufacturer for MY 2006 (considered as starting September 1, 2005); 70 percent compliance for MY 2007 (considered as starting September 1, 2006); and 100 percent compliance for MY 2008 (considered as starting (September 1, 2007) and later. Starting in MY 2008, TPMS is also required to warn the driver if the system is in malfunction status. A malfunction indicator lamp relays the warning; it is allowed to be combined with the pressure warning indicator lamp. In the rule, the term "telltale" refers to a TPMS warning light (FMVSS No. 138, 2005).

Technologies. Vehicle technology for monitoring tire pressure is typically referred to as a tire pressure monitoring system. Manufacturers may implement technologies known as direct TPMS or indirect TPMS to comply with FMVSS No. 138. Direct TPMS (often denoted in industry writing as dTPMS) uses sensors mounted directly in each wheel to detect tire pressure. The sensors send a signal to the vehicle dashboard. Indirect TPMS (often denoted in industry writing as iTPMS) uses wheel speed sensors in the vehicle's antilock brake system or (in later years) other inputs to detect small changes in wheel speed that occur when a tire loses pressure. When a tire loses air, its diameter decreases and its rotational speed increases. The system compares the relative speed of one tire to the other tires on the vehicle. An indirect TPMS does not "know" the tire pressures, and thus does not sense when they have changed, so requires an action to recalibrate the baseline stored values after any tire event including adjusting air pressure or rotating tires (FMVSS No. 138, 2005).

TPMS effect in proper tire pressure maintenance. Federal agencies are required to evaluate their existing regulations and programs and measure their effectiveness in achieving objectives. To collect data toward fulfilling this requirement for FMVSS No. 138, NHTSA in 2010 conducted the TPMS-SS, a vehicle and driver survey that collected nationally representative data to estimate the effectiveness of TPMS in promoting proper tire inflation in passenger vehicles. Indirect TPMS did not have enough cases for analysis, but direct TPMS was estimated to reduce the likelihood of severe underinflation as defined in FMVSS No. 138 by 56 percent (Sivinsky, 2012). The estimate was calculated over vehicles that were 4 to 7 years old at the time of the survey, and it was noted that effectiveness was lower in vehicles that were in the oldest part of the group. The TPMS-SS did not collect data on TPMS malfunctions, so no analysis was possible in that topic; but a possible reason conjectured for the lower effectiveness in older vehicles was that TPMS maintenance and malfunction could be involved. Sivinsky's 2012 report suggested that a follow-up survey of TPMS malfunction and associated circumstances could be useful to fully understand the results.

A new law. The FAST Act's Section 24115 directed the Secretary of Transportation to "publish a proposed rule that (1) updates the standards pertaining to TPMS to ensure that a TPMS that is installed in a new motor vehicle cannot be overridden, reset, or recalibrated in such a way that the system will no longer detect when the inflation pressure in one or more of the vehicle's tires has fallen to or below a significantly underinflated pressure level; and (2) does not contain any provision that has the effect of prohibiting the availability of direct or indirect tire pressure monitoring systems that meet the requirements of the standards updated pursuant to paragraph (1)."

A new survey. Questions raised by the TPMS evaluation and the FAST Act language motivated NHTSA to design a new study, the TPMS-ORRC study, with components conducted in 2016 and 2018. Its components were a vehicle survey of TPMS operational status and driver interviews, a telephone or mail survey of businesses that service tires and TPMS, and a written survey of TPMS suppliers. Topic areas of interest for the study included TPMS operational status, driver knowledge and acceptance of TPMS, TPMS malfunction causes and repair costs, and issues of TPMS reset or recalibration.

Bipartisan Infrastructure Law. The Infrastructure Investment and Jobs Act of 2021, also known as the Bipartisan Infrastructure Law, requires NHTSA to provide a rulemaking report including the tire pressure monitoring standards required in the FAST Act.

Timeline. Figure 2-1 shows a timeline of legal milestones (above timeline) and data collection (below timeline) involving NHTSA and tire pressure.[1]

[1] Chart by Kathryn Wochinger, NHTSA's Office of Behavioral Safety Research.

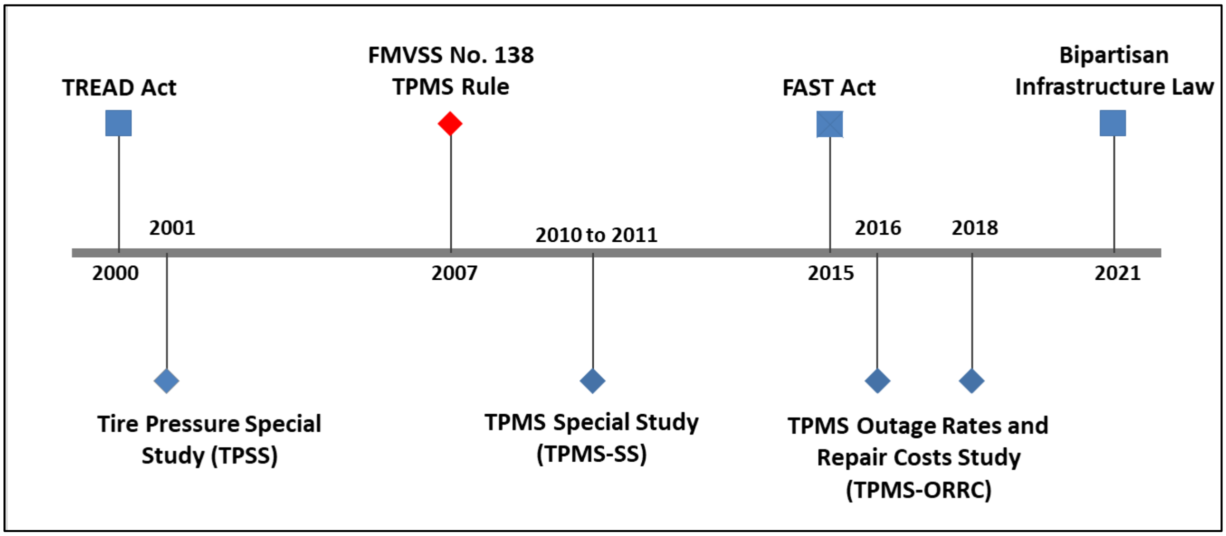

Figure 2-1. Timeline of NHTSA Tire Pressure Legal Milestones and Data Collection Studies

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3. TPMS Outage Rates and Repair Costs Study

The TPMS-ORRC study is the most recent NHTSA tire data collection and a key focus of this report. In 2016 and 2018, the study was conducted in three components focusing on three different segments:

1. The Field Survey, a nationally representative survey of passenger vehicles with TPMS and their drivers, conducted at fuel stations (2018).
2. The Repair Facilities Survey (RFS), a nationally representative survey of businesses that provide tire service for passenger vehicles (2016).
3. The Supplier Survey, a survey of major suppliers in the TPMS market regarding their role in the market and knowledge about TPMS malfunction for their products (2016).

The surveys were authorized under O.M.B. No. 2127-0626. ICF[2] and KLD Associates[3] were the contractor and subcontractor that conducted the TPMS-ORRC surveys.

3.1 Field Survey

The Field Survey, conducted from June 21 to November 10, 2018, was a nationally representative survey of TPMS-equipped passenger vehicles and their drivers conducted at fueling stations in the United States. Data collection included an observational inspection of the vehicle and an interview with the driver[4] about TPMS subject matter.

3.1.1 Sample Design

A probability sample was used to allow nationally representative estimates in the Field Survey. Data collectors approached vehicles and their drivers at selected fuel stations located in selected ZIP Codes of selected primary sampling units (PSUs). The sample design is briefly summarized below and explained in more detail in Appendix A.

Survey universe. The survey universe of interest was U.S. registered passenger vehicles (cars, SUVs, light trucks, and vans) under 10,000 lb GVWR that have TPMS compliant to FMVSS No. 138 and a malfunction telltale.[5] This universe starts to exist in MY 2006, when the TPMS rule phase-in starts, so the universe is partial fleet in MY 2006-2007 and full fleet in 2008 and later.[6] NHTSA's Office of Vehicle Safety Compliance provided internal spreadsheets with data on which models had which TPMS technology in MY 2006 and later.

24 primary sampling units. The survey used a 24-PSU design of NHTSA's Crash Investigation Sampling System (CISS). Each PSU is a geographical area n one of eight strata: urban or rural per OMB definition of metropolitan statistical area, and in one of four Census Bureau regions.

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[2] ICF International, Inc., Reston, VA.
[3] KLD Associates, Inc., Smithtown, NY.
[4] Driver definition is operationalized as primary driver of vehicle or individual responsible for maintenance/upkeep of vehicle. This may or may not be the vehicle owner.
[5] Although the malfunction indicator lamp was required as of the full mandate year, it wasn't always on the phase-in models. Vehicles without it were not useful to the survey so were omitted from the survey universe and sample. This is only a small number in MY 2006-07. Information about which models had the malfunction warning was provided by NHTSA's Office of Vehicle Safety Compliance.
[6] Unlike the 2010/2011 study, vehicles without TPMS were not available as a comparison group in the model years admitted into the 2018 survey because the TPMS mandate was in full effect by MY 2008.

NHTSA provided the weights for the 24-PSU design. Appendix A has more information on CISS and a map and list of the 24-PSU CISS sample.

Two ZIP Codes in each PSU. One ZIP[7] was chosen out of all PSU ZIPs with probability proportional to size (ZIP population). The median income of that ZIP was compared to the median of all ZIP median incomes in the PSU. The second ZIP was chosen at random from ZIPs that were no more than 20 miles away from the first ZIP (for operational needs) and were on the other side of the PSU ZIP median income (for better coverage in representation).[8] The ZIPs or income groups were not treated as strata or analytical domains.

Two service stations in each selected ZIP. The data collection subcontractor listed the stations in selected ZIPs from online maps and a commercial database. The list was randomly sorted, and the contractor went down the list from the top to find the first viable station, where viable includes: physically feasible, safe, and accessible; steady customers, multiple islands; manager or chain willing to cooperate, allow survey; more local traffic than highway traffic. Two stations per ZIP were selected this way.[9]

Vehicles at the station. At the station, a focal island was purposefully selected based on criteria such as safety, accessibility, traffic, and station manager input. The team approached all passenger vehicles that pulled up to the focal island and appeared to be eligible and presented information to the driver for possible participation. If the driver consented to participate, a data collection team member scanned the VIN from the doorjamb placard to confirm eligibility. Some vehicles or drivers were screened out as ineligible per the following criteria.

- Out-of-State plate (data collector observation)
- Vehicle obviously too old for the survey (data collector observation)
- Vehicle is a short-term rental or Zipcar (ask driver)
- Driver is not the primary driver or main upkeep person for the vehicle and the main upkeep person is not present to respond (ask driver)
- The vehicle is earlier than MY 2006 (VIN scan)
- MY 2006-07 but doesn't have FMVSS-compliant TPMS with a malfunction indicator (VIN scan)

The point of the focal island was to avert potential selection bias. Exceptions were in the following situations: team should approach any indirect TPMS vehicles at any time at any spot; team should approach any vehicles at a diesel pump; if focal island empty, team should approach other islands in a pre-determined order; if no one at islands, team should approach parked vehicles or vehicles in inspection line. (Indirect TPMS vehicles and diesel vehicles were to be sampled as highly as possible due to their low proportions of the vehicle population.)

VIN scan for eligibility. With owner consent, the team used a barcode scanner to scan the vehicle's VIN from the doorjamb or could manually enter it if necessary.[10] A data collection tablet computer being used by the data collection team submitted the VIN to NHTSA's online VIN translator, which identified MY, make, and model. From those, the tablet determined eligibility per lookup tables in the tablet, where vehicles in MY 2008 and later, and TPMS phase-

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[7] 'ZIP' here means U.S. Census Bureau ZIP Code Tabulation Areas.
[8] If ZIPs proved infeasible or unproductive, some were replaced.
[9] If stations lost cooperation or were not productive, some were replaced.
[10] In the final data, all VINs had been read by scanning.

in vehicles in MY 2006-07 with a malfunction indicator, were eligible. Lookup tables programmed in the tablet identified the eligible vehicle's TPMS as direct or indirect. NHTSA's Office of Vehicle Safety Compliance provided the data for the tablet lookup tables.

Subsample for extended interviews. The survey inspection and brief "basic" interview were administered for all participating vehicles and drivers. All cases where the vehicle had TPMS malfunction or indirect TPMS also went to an extended interview with topic-specific modules and an added general module. Cases where the vehicle had working direct TPMS, expected to be the largest group by far, were subsampled by the data collection tablet for an extended interview at a goal of about 360 cases over all PSUs. The extended interview for the subsampled drivers had the same added general module as the other extended interviews. If a subsampled vehicle had a low-pressure warning, the driver got an added interview module about that situation.

Traffic counts. At short periods assigned by the tablet to be evenly divided during the workday, teams recorded traffic counts of vehicles arriving at the station. These counts were collected for later extrapolation to sampling denominators.

Case weighting. Case weights were developed using selection probabilities and known information of ZIP Code populations, PSU populations, PSU vehicle registrations, and national vehicle registrations. For extended interviews, it proved necessary to have separate weights, since not all extended interviews were selected at random (vehicles with TPMS malfunction or indirect TPMS were selected with certainty).

Appendix A gives a more detailed description of the sample design and case weighting.

3.1.2 Operations and Protocol

Operations. A trained supervisor and four trained data collectors traveled to the PSUs for data collection per a schedule developed by the survey contractor. The schedule allowed for a week in each PSU. Teams of two data collectors worked 8-hour days with a lunch break at a station. Two stations in a PSU were surveyed at the same time. The supervisor would be available to be at either station. Teams stayed in a station for three days unless circumstances required an earlier change. Days off and travel days were worked into the schedule between PSUs. Saturdays and Sundays were worked into the schedule as much as possible to get more variety of drivers.

A productive station could produce several cases per hour. The average number of cases per day per station over the whole survey was 15.7 cases per day per station.

Team protocol. In approaching drivers, the data collection teams followed a pre-determined protocol for vehicle sampling as detailed in Appendix A. When a driver consented to the survey and the vehicle was found eligible, one data collection team member (denoted the inspector) conducted the vehicle inspection and entered the findings in a tablet computer. Concurrently, the other team member (denoted the interviewer), using a separate tablet, asked some questions of the driver per the tablet's prompts and recorded the responses into the tablet. The interview tablet was programmed to route the interview per subject matter modules and skip patterns.

Drivers were approached before refueling had started and could refuel during the interview.

The teams wore safety vests and identification and presented a letter from NHTSA that explained the survey. As a thank you and motivation to participate, the teams offered participating drivers a vehicle recall check using NHTSA's recall website.

Team training. Data collectors had thorough training and practice in the above-mentioned protocols at the subcontractor's office in San Antonio, Texas. A behavioral research psychologist from NHTSA's Office of Behavioral Safety Research helped prepare the training and attended the training sessions. Training covered approaching drivers, following the sample hierarchy, the different TPMS display types and telltale icons, and using the tablet computers and barcode scanners. Practices were conducted at a large auto dealership using different models/makes and at local gas stations in the San Antonio area.

Non-response data collection. For all vehicles approached, while the interviewer made introductions to the driver, the inspector recorded a set of data elements by observation. The data were saved for refusing drivers as well as for completed cases, to enable "non-response" comparisons that may assess any response bias that might occur if drivers who participated (or their vehicles) were different from those who refused. The fields collected for this purpose were vehicle body type, vehicle make, surmised driver sex, surmised driver age group, driver language, number of adult/child occupants, degree of any damage to vehicle, presence of rear hitch on vehicle, and whether the vehicle was a hybrid vehicle.

3.1.3 Questionnaire Design

Basic observation and interview topics. Table 3-1 shows the information in the basic interview/inspection and how it was collected. Note that the ON ignition position refers to the second stage of vehicle ignition, where diagnostic lights appear before the ignition moves to the START position.

Table 3-1. Field Survey Basic Topic Data and How Collected

Basic Interview/Inspection Data		**How Collected**
Non-response data		Inspection
Make/model/MY/TPMS indirect or direct		From VIN scan
Dashboard check: TPMS indicator status at ON and START ignition position Other warning lights		Interviewer and inspector with driver participation
Odometer, spare tire in use, electromagnetic equipment in evidence		Inspection
Direct TPMS: Inspect tire valve stems and caps Indirect TPMS: Take tire pressure		Inspection
A few questions about driver's TPMS knowledge and preference		Interview
Respondent age, education, home ZIP		Interview
Recall check at option of driver (not part of analytical data)		Submit VIN to NHTSA recall site

Extended interview topics. Extended interview survey modules, their subject matter, and the criteria to enter them are summarized in Table 3-2.

Table 3-2. Field Survey Extended Interview Modules Topics and Routing

Module	**Content**	**Cases Entering**
MALFUNCTION #1	TPMS malfunction	Malfunction light is on
MALFUNCTION #2	low pressure	Working direct TPMS subsample and low-pressure warning is on
MALFUNCTION #3	disabling TPMS	No TPMS light shows in the ON position and the driver says TPMS hasn't been disabled
DISABLED	disabling TPMS	No TPMS light shows in the ON position and the driver says TPMS has been disabled
INDIRECT	indirect TPMS (inspection routed to tire pressure)	Working indirect TPMS
PAST MALFUNCTION#1	any past TPMS malfunctions	All extended interviews except current TPMS malfunction
CLOSE	general TPMS and air	All extended interviews

A flow chart for the survey path is shown in Appendix E. The survey instrument specification is provided in Appendix P.

3.1.4 Achieved Sample

The survey completed 4,480 cases. The non-response file of observational data for approached drivers who refused participation (refused at introduction, refused at VIN scan, etc.) had 2,719 cases. Screen-outs were not included. Per the file case counts, the response rate was 4,480/(2,719+4,480) = 62 percent.

Data checks on the completed cases file found three trucks over 10,000 lb GVWR. They are not in the survey universe, so they were dropped from weighted analysis, leaving 4,477 cases.

Table 3-3 shows the sample distribution of vehicle type by MY group.

Table 3-3. Field Survey Sample Counts, Vehicle Type by Model Year Group

Vehicle Type/Model Year	2006-08	2009-11	2012-14	2015-19	Total
Passenger Car	240	421	678	644	1,983
Light Truck/SUV/Van	277	496	752	969	2,494
Total	517	917	1,430	1,613	4,477

The sample had 4,185 vehicles with direct TPMS and 292 with indirect TPMS. Charts showing other distributions of population characteristics in the sample are shown in Appendix D.

3.1.5 Data Checks and Sample Validation

The data were checked for topics such as ineligible vehicles, ZIP Code anomalies, misclassified TPMS type, and others. Results of these checks are detailed in Appendix B.

Non-response analysis comparing distributions of the observational variables in responding cases and refused cases did not find evidence of non-response bias. Weighted sample distributions of vehicle make compared to known national registered vehicles helped validate survey representation. Details of the non-response and vehicle make analyses are shown in Appendix C.

3.1.6 Result Highlights

This section covers key research area results of the Field Survey. Later sections will go into detail on specific topic areas.

Percentages are rounded to the nearest whole percent unless otherwise shown. All estimates are weighted. In this survey, "drivers" are always drivers of TPMS-equipped vehicles.

TPMS operational status, dashboard check. TPMS operational status refers to the TPMS indicator light situation at the time of data collection. It was collected as part of the vehicle inspection for every surveyed vehicle. The driver was invited to work with the inspector to achieve it. The inspector or driver turned the ignition key or operated the ignition button to the ignition ON and START positions. The data collection team recorded the TPMS light status at each position.

In the ON position, a TPMS icon should briefly illuminate; if it does not, TPMS may be in a disabled situation. In the START position, if no TPMS icon appears, the TPMS is not detecting a problem with either pressure or malfunction. If there is a problem, t, low pressure typically triggers a solid icon and malfunction triggers a temporarily flashing, then solid, icon. There are two different low tire pressure warning indicators allowed by the Federal standard: a cross-section of a tire with an exclamation mark inside and a top view of a car with all four tires exposed (FMVSS 138). Some indicators may have added text such as "Check Tire Pressure," "Tire Pressure Too Low," "TPMS System Malfunction," or variants of those. The data collectors had practiced at a dealership with many models and had a menu of icon options to choose from (Appendix E).

The data collection tablet mapped the check results at ignition positions ON and START into the TPMS operational status variable [TPMSMALF]. The variable mapping logic can be seen in Appendix E, and is summarized in Table 3-4.

Table 3-4 shows the nationally weighted results of TPMS operational status by the percentage of vehicles with the status and 95 percent confidence intervals for the percentages. Variable codes (1-5) are included as they may be referred to in other sections.

Table 3-4. TPMS Operational Status Results, TPMS-ORRC Field Survey

TPMS Operational Status [TPMSMALF], *n*=4,477 ON=ignition ON position START=ignition START position (Variable Code) and Description of Status		Population Percentage Estimate (95% Confidence Interval)
(1)	TPMS icon appears at ON, and TPMS malfunction warning appears at START.	3.8 (2.9, 5.0)
(2)	TPMS icon appears at ON, and TPMS underinflation warning appears at START.	8.3 (5.8, 11.7)
(3)	TPMS icon does not appear at ON, and no warning appears at START.	0.3 (0.1, 0.8)
(4)	TPMS icon appears at ON, and no TPMS warning appears at START.	87.3 (83.4, 90.4)
(5)	Status is unclear.	0.2 (0.1, 0.8)

Source: NHTSA, TPMS-ORRC Field Survey, 2018

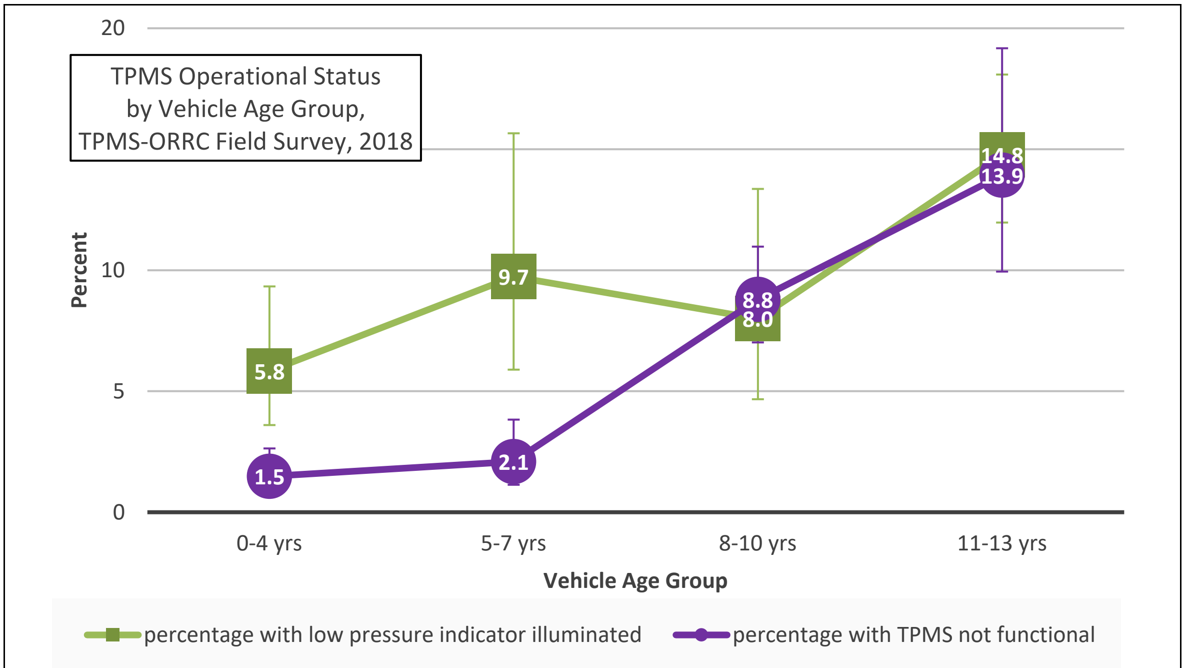
As seen in Table 3-4, about 87 percent of vehicles with FMVSS-compliant TPMS (direct or indirect) had functioning TPMS with no telltale illuminated, about 4 percent were experiencing a malfunction warning, and about 8 percent were experiencing a low-pressure warning. No indicator in the ON position or an unclear status, either of which could indicate disabled TPMS or some other non-functional situation, were very rare even when combined (0.5%).

Percentage of vehicles being driven with a TPMS issue. From Table 3-4, the percentage of vehicles being driven with either a TPMS low-pressure telltale or TPMS not functioning properly was 100-87.3 percent or almost 13 percent.

TPMS not functioning. In the results of this report starting with the following highlights, operational status codes 1,3 and 5 are usually combined to be considered “TPMS not functioning.” Codes 3 and 5 are grouped into this category because they are not showing evidence of TPMS in a vehicle known to be equipped with a TPMS. As seen in Table 3-4, codes 3 and 5 are very rare, so the combination of status codes 1,3 and 5 is almost completely made up of status code 1, in which a TPMS malfunction indicator light appears at START.

Operational status by vehicle age group and TPMS type. Earlier surveys noted issues with tire pressure as vehicles aged. Figure 3-3 plots the operational status percentages by vehicle age group (combining direct and indirect TPMS). Vertical error bars mark 95 percent confidence intervals for the estimates. The generating data is shown beneath the chart for reference.

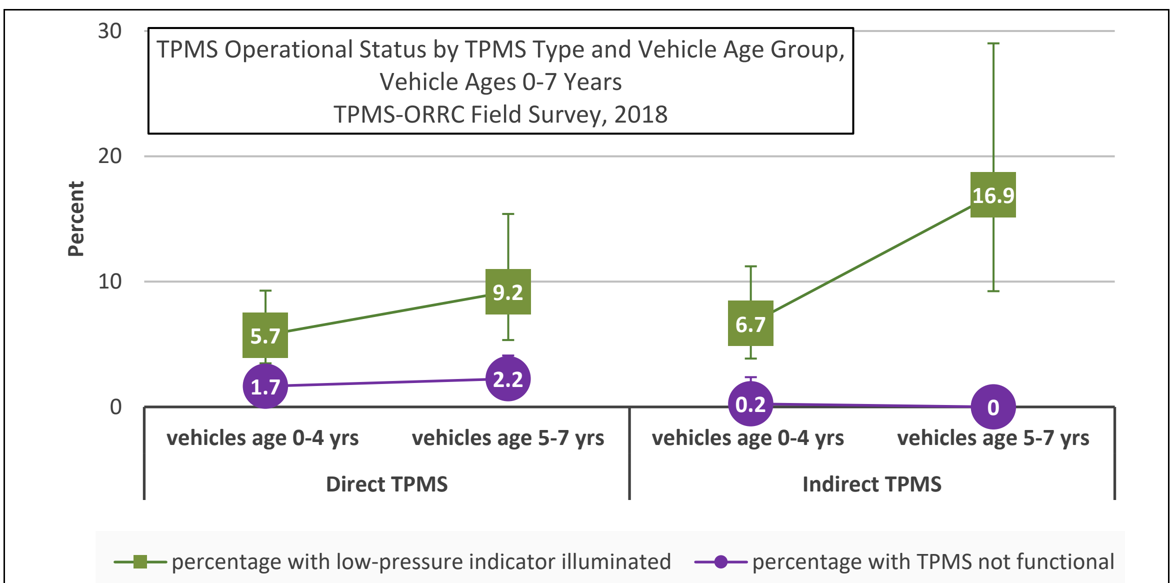
The results in Figure 3-1 combine direct and indirect TPMS but are largely dominated by direct TPMS, because indirect TPMS was relatively rare in the population and sample (see details in Table 11-1). To compare operational status by TPMS type (direct or indirect), vehicles up to 7 years old made a better comparison since vehicles age 8 and older in 2018 had very few indirect TPMS in the sample (*n*=5, Table 11-1). Figure 3-2 charts the status percentages and their confidence intervals by TPMS type over vehicles in age groups 0-4 and 5-7 years. The generating data is shown beneath the chart. (Note that since tires may be replaced, vehicle age and tire age may differ. Tire age is not available in the surveys covered in this report.)



Vehicle Age Group	0-4 years	5-7 years	8-10 years	11-13 years
% w/ low-pressure ind. (95% CI)	5.8 (3.6, 9.3)	9.7 (5.9, 15.7)	8.0 (4.7, 13.4)	14.8 (12.0, 18.1)
% w/ TPMS not functioning (95% CI)	1.5 (0.8, 2.6)	2.1 (1.1, 3.8)	8.8 (7.0, 11.0)	13.9 (9.9, 19.2)

Source: NHTSA, TPMS-ORRC Field Survey, 2018

Figure 3-1. TPMS Operational Status by Vehicle Age Group



TPMS Type	Direct TPMS		Indirect TPMS	
Vehicle Age Group	0-4 years	5-7 years	0-4 years	5-7 years
% w/ low-pressure ind. (95% CI)	5.7 (3.5, 9.3)	9.2 (5.3, 15.4)	6.7 (3.9, 11.2)	16.9 (9.2, 29.0)
% w/ TPMS not functioning (95% CI)	1.7 (0.9, 2.9)	2.2 (1.2, 4.1)	0.2 (0.0, 2.4)	0

Source: NHTSA, TPMS-ORRC Field Survey, 2018

Figure 3-2. TPMS Operational Status by TPMS Type, Vehicle Age 0-7 Years

As seen in Figure 3-1, about 1.5 percent of vehicles that were up to 4 years old at the time of the survey had a non-functioning TPMS compared to about 2 percent of vehicles 5-to 7 years old, 9 percent of vehicles 8 to 10 years old, and 14 percent of vehicles 11 to 13 years old. For low pressure, about 6 percent of vehicles that were up to 4 years old had a low-pressure telltale illuminated, compared to about 10 percent of vehicles 5 to 7 years old, 8 percent of vehicles 8 to 10 years old, and 15 percent of vehicles 11 to 13 years old. Comparing by TPMS type in Figure 3-2, for vehicles up to 7 years old, TPMS malfunction was rare in either direct or indirect TPMS but appeared to be rarer in indirect.

The data of Figure 3-1 and Figure 3-2 are further covered in Section 12.2.1 with statistical comparisons.

Key interview results. Some Field Survey key driver interview response results were:

- About 95 percent of drivers with TPMS knew they had TPMS.
- About 15 percent of drivers correctly identified their TPMS as direct or indirect.
- About 96 percent of drivers with a TPMS malfunction warning illuminated at the time of the survey said the light had been on at least a week, and 24 percent said at least a year.
- About 37 percent of drivers with a malfunction warning did not plan to get it fixed, and 42 percent of those drivers said the primary reason was cost.
- About 47 percent of drivers with a malfunction warning thought it meant low pressure.
- About 46 percent of drivers with a low-pressure warning said it had been on more than a week.
- About 51 percent of drivers with a low-pressure warning had not checked the pressure since the light came on.
- About 83 percent of all drivers said they knew how to inflate their tires to the proper pressure and 37 percent would look for the recommended pressure on the vehicle placard.
- About 88 percent of drivers said they would prefer to have a TPMS on their next vehicle.

Additional results. These results and others are discussed in Sections 5-12 addressing specific topic areas. Complete response tables are shown in Appendix E.

3.2 Repair Facilities Survey

The RFS was a national survey of commercial facilities that provide tire and TPMS service and repair to passenger vehicles. The survey sampled 100 qualifying facilities from a nationwide sample in telephone or mail-in surveys. Results were delivered to NHTSA in 2017 and have been internally available but have not previously been published.

In keeping with the TPMS-ORRC overall project objectives about TPMS malfunction, the RFS concentrated on questions about TPMS component functionality, lifespan, and repair costs.

3.2.1 Sample Design

The universe for the RFS included maintenance and repair facilities of three types: automobile dealerships or automobile dealership-connected facilities; chain/franchised brick-and-mortar tire stores; and independently owned tire repair facilities.

The RFS sampling plan was designed as a national probability sample of at least 500 facilities from a purchased frame to collect at least 100 interviews (anticipating a completion rate of 20% due to known issues with telephone survey response). The North American Industry Classification System (NAICS) was used to identify, target, and purchase a sample from a commercial vendor. Table 3-5 shows specifics of the NCAIS codes, strata, and frame and sample counts.

Table 3-5. Repair Facilities Survey Drawn Sample

NAICS Code	Description	Type	Sample Frame Counts	Sample Drawn From Frame Initially	Additional Sample	Completed Interviews
441110	New car dealers	1	48,369	400	375	30
441320	Tire dealers	2	26,161	400		55
447110	Gasoline stations with convenience stores	3	209,660	800		15
447190	Other gasoline stations					
811111	General automotive repair					
811198	Other automotive repair & maintenance					

The first drawn sample was more than 500 to account for uncertainty over whether the establishments serviced passenger vehicles and if so, TPMS systems; introductory survey questions screened out establishments that did not service those categories. As shown in the table, a supplementary sample was drawn as completion rates were difficult to achieve (due to refusals, non-working numbers, not answering, not a business or TPMS repair facility, not answering messages left, and so on). Ultimately, it took 876 sample attempts to get 100 competed interviews, and the data collection stopped when the 100 was achieved. The response rate was 100/876=11 percent.

There is no sample frame information that divides the NAICS categories into establishments that do and do not service TPMS, so post-stratification was not possible. For analyses in this report, the final sample of 100 is treated as a simple random sample.

3.2.2 Operations and Protocol

Introductory letter. A NHTSA letter explaining the survey and requesting participation was sent to sampled facilities about a week before the first telephone contact. The letter was signed by the director of NHTSA's Office of Regulatory Analysis and Evaluation (ORAE). It included a toll-free telephone contact number for the survey contractor or NHTSA for questions.

Introduction and screener. The telephone survey initial contact asked for the service manager or equivalent staff member at the facility. It gave information about the study's sponsor, the purpose of the telephone call, what the study was about, how long the survey would take, that the survey was voluntary and collected basic information to establish the facility's survey eligibility. Only facilities that serviced TPMS in passenger vehicles were screened into the survey.

Respondent. If the service manager was not available, the interviewer was asked to identify a proxy— a person knowledgeable about TPMS repair at the facility—to complete the survey.

Mail option. A mail survey was offered as an alternative to telephone interview.

3.2.3 Questionnaire Design

The RFS questionnaire subject matter sections were:

- **Facility information:** time the facility had been in business; makes/models serviced; number of vehicles serviced in the previous 90 days; relative volume of TPMS-related service; whether TPMS is routinely checked as part of any service work.
- **Component lifespan:** best estimates of TPMS lifespan (direct, indirect) at the system and individual sensor levels.
- **TPMS malfunction:** TPMS (direct, indirect) malfunctions serviced by the facility in the previous 90 days; whether customers identified the malfunction; malfunction source, cause, and service needed; and customer requests and reasons to disable TPMS.
- **Repair costs:** for a roster of TPMS components and services, best estimate for the average total price the facility charges to customers, including both parts and labor, independent of tire replacement.

The full RFS instrument specification is shown in Appendix Q.

3.2.4 Achieved Sample

In the final RFS sample of 100 facilities, 30 were new car dealerships, 55 were tire dealers, 13 were general auto repair shops, and 2 were other repair or gas station; 5 were franchises, 22 were connected to dealerships, 64 were independently owned, 8 were corporate- or company-owned; 89 served general makes and 11 serviced only specific makes; 88 serviced both indirect and direct TPMS, 11 serviced only direct TPMS, and 1 serviced only indirect TPMS; 98 cases were interviewed by telephone and 2 were mail-in.

Appendix F shows pie charts of the sample for the characteristics detailed above and others such as number of employees, years open, and customer volume.

3.2.5 Result Highlights

Some key results from the RFS are shown below. Questions about past service specified the reference period as the last 90 days. Survey percentage estimates are rounded to the nearest whole percent unless otherwise specified.

TPMS inspections. Facilities were asked when they inspect TPMS:

- About 53 percent perform TPMS system inspections on all TPMS-equipped vehicles that come in.
- Of facilities that do not check TPMS for all vehicles, about 85 percent check it for vehicles that come in to get wheel or tire service, and 50 percent check it when the vehicle has been involved in an accident or is in for scheduled maintenance.

TPMS malfunctions. A TPMS malfunction was defined to respondents as any time a TPMS system was not working correctly including problems with sensors or on-board components:

- The source of direct TPMS malfunction most cited was tire pressure sensors at over 80 percent. The most common service to fix these malfunctions was installing new sensors at 60 percent (20% rim-mounted sensors, 40% stem-mounted sensors). The next most common service was recalibration, cited by 27 percent.

- The most common cause cited in the top three causes of direct TPMS malfunctions was worn-out batteries (over 50%). Others were tire replacement (almost 30%) and weather including flood or snow at just over 20 percent. Vehicle age was cited as a cause by 19 percent. Sensors were frequently mentioned in "other, specify" responses.
- About 58 percent said that vehicles with direct TPMS rarely or never came in with TPMS malfunction. For vehicles that came in with TPMS malfunction, 37 percent said the owners had almost always identified the malfunction.
- The most cited source of indirect TPMS malfunction was chassis-mounted sensors (such as wheel speed sensors) at 70 percent. The most common service to fix these malfunctions was installing new chassis-mounted sensors at 58 percent. The next most common service was recalibration, cited by 27 percent.
- About 73 percent said that vehicles with indirect TPMS rarely or never came in with TPMS malfunction. For vehicles that did, 32 percent said the owner had almost always identified the malfunction.

Already disabled TPMS. About 65 percent of facilities said they rarely or never have seen vehicles with direct TPMS already disabled when the vehicles were brought in, while 30 percent said they've seen this sometimes or frequently. For indirect TPMS, 78 percent said they rarely or never have seen this, while 18 percent said they've seen this sometimes or frequently.

Requests to disable TPMS or not repair it. When asked how often drivers asked for their TPMS to be disabled or left unrepaired, for direct TPMS, 40 percent said sometimes or frequently, and for indirect TPMS, 35 percent said sometimes or frequently.

Facilities cited the reason most often given by owners for the request was that the TPMS repair costs too much (73% for direct TPMS, 67% for indirect TPMS). Other reasons were that TPMS is not necessary for the operation of the vehicles (15% for direct TPMS, 17% for indirect) and that they felt the TPMS was not accurate or reliable (10% for direct TPMS, 8% for indirect).

Component life spans. Facility respondents were asked to give their best estimate for the average functional life spans of a TPMS and some components, basing answers on knowledge about servicing TPMS systems, not on any marketing or other information provided by the suppliers of these products:

- For direct systems, the median estimate for overall system lifespan before they require service was 4 years.
- Within direct TPMS, the average functional lifespan estimated for a rim-mounted sensor had a median estimate of 5 years, and for a stem-mounted sensor, also 5 years.
- For indirect systems, the average lifespan before repair is required for a system had a median estimate of 5 years, and the life span of a chassis-mounted sensor such as a wheel speed sensor had a median estimate of 6 years.

Repair costs. Respondents were asked to provide their best estimate for the average total price they charge to customers to repair components in TPMS systems, including both parts and labor, independent of tire replacement, for direct and indirect TPMS. The most common repair, a direct TPMS tire pressure sensor replacement, was about $99 for one sensor. A table of results for all the cost responses is shown in Section 9.

Other results. More results are discussed in Sections 6 to 10 addressing specific topic areas. Complete response tables are provided in Appendix G.

3.3 Supplier Survey

The Suppliers Survey component of the TPMS-ORRC study was a survey of major suppliers in the TPMS market regarding their role in the market and sources of TPMS malfunction for their products. The survey contractor and NHTSA designed the Supplier Survey questionnaire based on NHTSA's TPMS-ORRC research topics as relevant to suppliers: TPMS malfunction sources and causes, TPMS design, and TPMS pricing.

The Supplier Survey universe was major passenger vehicle TPMS sensor and systems equipment suppliers. There was no sampling plan as the intent was to interview as many companies as would participate. The survey frame was developed by the survey contractor by means of industry publications, industry organizations, advocacy groups, and boards including Auto Alliance, Global Automakers, Tire Industry Association, and Equipment and Tool Institute.

A frame of eligible respondents was developed with 36 companies. The survey contractor carried out extensive outreach and follow-up, but securing participation was difficult due to business concerns, time elements, available personnel, company legal advice, etc. By the final deadline, 9 eligible respondents returned the survey.

The Supplier Survey's front page stated that survey results will be reported only in aggregate and published results will not include any information that specifically identifies a respondent. It also informed respondents of a multi-step process to request confidentiality of business information. No company used the process, but most companies omitted pricing information presumably or explicitly out of business concerns. With a small set of respondents, some item non-response, and the reporting restrictions, it is only possible to report some general results. More information on the survey and the available results are presented in Appendix H. The survey form is shown in Appendix R.

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4. Historical Surveys and Data

The two previous NHTSA tire-related vehicle surveys mentioned in Section 2 were available to give historical perspective to the findings of the TPMS-ORRC surveys.[11] Additionally, two monthly Omnibus Household Surveys conducted by the Bureau of Transportation Statistics featured a few questions about tire pressure. This section gives information and highlights of these data sources.

4.1 TPMS Special Study (2010/2011)

Certain Executive Orders and Federal legislation require Federal agencies to evaluate their existing regulations and programs and measure their effectiveness in achieving objectives. To support such requirements for FMVSS No. 138, NHTSA designed and conducted the TPMS-SS (OMB #2127-0626) in 2010 and 2011. The TPMS-SS was a vehicle and driver survey that collected nationally representative data to estimate effectiveness of TPMS in promoting proper tire inflation in passenger vehicles.

The key analytical goal of the data collection was to compare severe underinflation in vehicles with TPMS and their peers without TPMS. The survey also interviewed drivers about their interactions and knowledge about tire pressure and TPMS.

Survey design and operations. The TPMS-SS evaluation report (Sivinsky, 2012) describes the survey sample design and operations in detail. In brief, the survey was conducted as a special study in NHTSA's National Automotive Sampling System (NASS) (predecessor to the Crash Investigation Sampling System). Like the TPMS-ORRC Field Survey, it was conducted in fuel stations in 24 PSUs, although the later survey was in different PSUs. The data were recorded on paper forms that can be seen in the evaluation report. The survey was conducted between August 2010 and April 2011.

The universe of interest and the data collected differed in some ways from the 2018 Field Survey. In the TPMS-SS, the universe was passenger vehicles with GVWR under 10,000 lb that were 7 years old or newer at the time of the survey (MYs 2004-11), with or without TPMS. An attempt was made to physically take tire pressures for every surveyed vehicle. TPMS light warning status was not recorded.

Severe underinflation was defined and calculated the same as in the Field Survey: temperature-adjusted underinflation greater than 25 percent, the threshold required for warning the driver in FMVSS No. 138.

The achieved sample size for the TPMS-SS was 6,503, of which 6,103 achieved complete tire pressure measurements. For reference, previously unpublished sample makeup charts for the survey are shown in Appendix I.

Result highlights. Passenger vehicles up to 3 years of age at the time of the TPMS-SS were from MYs 2008-11, which had the TPMS mandate in full force. Since there was no comparison group without TPMS in those MYs, the evaluation was restricted to vehicles of MYs 2004-07, which were 4 to 7 years old at the time of the survey. The overall evaluation was limited to direct TPMS because indirect was rare at the time and technology effectiveness could differ. From

[11] A 2009 NHTSA report titled "Tire Pressure Maintenance – A Statistical Investigation" covers a data collection effort that was terminated early, but the data used in that report was not available for analysis.

comparing low pressure rates in direct TPMS vehicles and their peers without TPMS, direct TPMS was estimated to be 55.6 percent effective at averting severe underinflation.

When analyzed by MY, this effectiveness appeared to be lower in vehicles from MY 2004, the oldest vehicle age group in the evaluation data. The final report proposed various ideas as reasons that may contribute to lower effectiveness with age, including TPMS attrition if systems age into malfunction and remain unrepaired. The 2018 TPMS-ORRC study had strong focus on TPMS malfunction because of this proposed issue. Section 5 of this report covers this topic in detail.

Driver interview data from the TPMS-SS had not been previously reported. According to the report, [t]he "TPMS-SS survey also included driver interview items to measure driver knowledge about the importance of proper tire inflation and to identify the methods by which drivers are informed about issues pertaining to tire pressure maintenance. Subsequent analyses may be conducted to explore this interview data. This information could then inform data-driven and targeted behavioral programs that aim to promote proper tire inflation" (Sivinsky, 2012, p. 5). Thus, for the current report, the interview data from the TPMS-SS has been examined. For reference, complete driver interview response tables are shown in Appendix J. The survey forms can be seen in the evaluation report (Sivinski, 2012, pp. A4-A11).

4.2 Tire Pressure Special Study (2001)

Section 13 of the TREAD Act directed the Secretary of Transportation to conduct rulemaking actions to require a system in new motor vehicles that warns the operator when a tire is significantly underinflated. To help inform the rulemaking process, NHTSA conducted the TPSS over 2 weeks in February 2001. The survey recorded tire pressures from a nationwide sample of passenger vehicles and conducted short driver interviews. TPSS results were cited during the FMVSS No. 138 rulemaking process.

Survey design and operations. The TPSS methodology is detailed in a NHTSA research note (NCSA, 2001a). Like the TPMS-SS, the TPSS was conducted as a special study of the NASS program in 24 PSUs, and like the two later surveys it was conducted at fueling stations. The PSUs were the same ones used in the TPMS-SS but not in the TPMS-ORRC. During the two-week period of the TPSS, all NASS crash researchers were diverted to collecting only TPSS data, which allowed for the surveying of all PSUs in one short time span.

The universe for the TPSS was passenger vehicles and their drivers using fuel stations from 8 a.m. and 5 p.m. There was no restriction on vehicle model year. No distinction was made about TPMS because at that time TPMS was a rare option.

The achieved sample size was 11,530, of which 10,881 had complete tire pressure readings. Previously unpublished sample makeup charts for the TPSS are shown in Appendix K.

Underinflation calculation. In previously published analyses of the TPSS, severe underinflation was calculated as pressure more than 8 psi under the recommended pressure on at least one tire. This is different from the criterion used in the later survey analyses, which used the FMVSS No. 138 definition of at least 25 percent under the recommended pressure in at least one tire. For this report, TPSS data were recalculated to match the FMVSS No. 138 criterion. (The criteria match when the recommended pressure is 32 psi, the most common recommended pressure.)

Result highlights. Some key published TPSS results (NCSA, 2001b, 2001c) were:

- In 2001, 27 percent of passenger cars with regular passenger car tires had at least one tire underinflated by 8 psi or more.
- A correlation was found between vehicle age and magnitude of deviation in pressure from the recommended pressure, with older vehicles deviating more than newer vehicles.
- The proportion of pickup trucks, SUVs, and vans with all four tires underinflated by 8 psi or more was twice that of passenger cars.
- About 85 percent of drivers said maintaining proper tire inflation was a concern for them.
- The most frequent driver response for how often they check tire pressure was "when serviced."
- About 48 percent of drivers checked their tire pressures by using a tire pressure gauge. Fifteen percent checked their tire pressure visually.

Previously unpublished complete response tables and flow chart for the TPSS interview are shown in Appendix L. The TPSS survey forms can be seen in the methodology research note (NCSA, 2001a).

4.3 Questions in Omnibus Household Surveys

The Omnibus Household Survey was a monthly Bureau of Transportation Statistics (BTS) random-digit-dialing phone survey targeting 1,000 household respondents with varying questions about transportation issues. In coordination with NHTSA, BTS included four questions about tire pressure in the September 2000 survey. Results reported by BTS were:

1. Almost half of all the survey respondents checked the air pressure in their tires themselves. Men, however, were almost three times as likely to check the air pressure in their tires themselves than were women.
2. About 29 percent of respondents said they checked the air pressure in their tires monthly and another 29 percent checked when they seemed low. Approximately five percent of the respondents reported that they checked their tires weekly.
3. Respondents who checked the air pressure in their own tires were asked what methods they used to determine the proper air pressure for their tires. About 45 percent of the respondents cited relying on the information printed on the side of their tires. More than one in four, however, used their vehicle's owner's manual to determine the proper air pressure. Other methods reported included using air pressure or tire gauges or relying on others such as a relative, friend or mechanic.
4. Respondents who checked the air pressure in their own tires were also asked what methods they used to determine when the desired air pressure had been reached. Sixty-eight percent reported that they used a hand-held tire gauge. Another 27 percent relied on the tire pump gauge or bell. Other methods mentioned were based on the vehicle's performance and the response of the tire after being pushed. (BTS, 2000)

In the July 2001 Omnibus Household Survey, respondents were asked: To what extent do you agree that an indicator light in your vehicle that warns the driver about under-inflation in any of the vehicles' tires would allow you to be less concerned with routinely maintaining the recommended tire pressure? About 40 percent responded they agreed to a very great extent, 25 percent responded they agreed to a great extent, 25 percent to some or a little extent, and 10 percent to no extent (BTS, 2001).

The Omnibus Survey results were cited during the FMVSS No. 138 rulemaking process (2005, p. 37). Caution may be warranted in comparing Omnibus Survey results with NHTSA tire pressure surveys as the Omnibus Survey was a household telephone survey while the NHTSA surveys were administered to passenger vehicle drivers at fuel stations.

Searches did not find any other Omnibus Household Surveys with questions about tire pressure. The Omnibus Household Survey program was suspended in 2009 (BTS, n.d.).

4.4 Survey Design Comparison

Noting differences in survey design and protocols may help in understanding the results of the surveys and in designing future surveys. Appendix M gives a comparison of the design and protocol for the three NHTSA vehicle tire-related surveys covered in this report. (The Omnibus Household Surveys are not included in the comparison because they were not specific to tire issues.)

If countermeasures are developed to help increase proper tire pressure practices, future surveys could help study their effects. Based on the comparisons of past surveys, some steps that could help future similar surveys might be standardizing in areas of sample design, questions, variables, weighting, and analysis to make surveys compatible and results comparable over time.

5. Question From NHTSA 2012 TPMS Evaluation

5.1 Topic Background

Previous report. The 2012 evaluation report based on the 2010/2011 TPMS-SS survey found that direct TPMS reduced the likelihood of underinflation as defined in FMVSS No. 138 by 56 percent in passenger vehicles, but that effectiveness appeared to be lower for vehicles from older model years. One proposed explanation was that TPMS may suffer from attrition if aging systems go into malfunction and are not repaired. The 2010/2011 survey did not record the TPMS warning light status in the surveyed vehicles, so the idea about TPMS malfunction could not be checked with that survey's data. The question was a motivator for the TPMS-ORRC study. Some other possible explanations proposed in the 2012 report were that TPMS technology may have improved from 2004 to 2010, that TPMS may suffer if the systems are not reset after sensors are replaced, and that drivers may pay less attention to messages from TPMS as the vehicles age (Sivinsky, 2012).

The key research question proposed for this topic was: Is a 2012 finding that TPMS was less effective at reducing severe underinflation in older vehicles related to TPMS maintenance?

5.1.1 Review of the 2010/2011 Data

The 2010/2011 data included passenger vehicles with direct TPMS and their comparison peer vehicles without TPMS from MYs 2004-07 that had achieved tire pressure measurements for all four tires – criteria that qualified 3,050 vehicles out of 6,503 in the full data. The vehicles in this subset were 4 to seven years old at the time of the survey. TPMS presence and display type were determined for this group during the survey, but TPMS operational status was not recorded.[12] (Passenger vehicles from MY 2008 to 2011, which were zero to three years old at the time of the survey, all had TPMS under the FMVSS No. 138 mandate, so no comparison group was available in those model years. They were surveyed, but not included in the evaluation computation.)

Calculating effectiveness. Vehicle TPMS type was assigned during data follow-up based on NHTSA make and model information. Indirect TPMS vehicles and their model peers without TPMS were not included in the overall evaluation analysis because they were few and the technology effectiveness might be different. The report defined effectiveness (of reducing severe underinflation) as 1 – (risk ratio)*100% where the risk ratio is the ratio of the observed odds of severe underinflation in vehicles with TPMS to the same odds in peer vehicles without TPMS. The odds for a proportion can be found as the proportion divided by 1 – the proportion. The risk ratio can be found in SAS as the odds ratio for a 2 by 2 table in PROC SURVEYFREQ. The confidence bounds for effectiveness are derived from those reported by SAS for the odds ratios. The evaluation reported that the comparative prevalence was about 23 percent without TPMS and 12 percent with direct TPMS for an overall effectiveness at 56 percent with confidence interval (36%, 69%). The effectiveness was noted in the report as applying to direct TPMS only.

[12] Per instructions obtained internally from the TPMS-SS survey procedures manual, data collectors were to use a list of equipped vehicles and manuals provided as references by the survey contractor; if this is not successful, ask the owner to see the owner's manual; if needed, turn the vehicle ignition to the ON position.
The TPMS display variable was further broken into display only, display with each tire, or display with psi for each tire. This distinction was used in some supplemental analyses, but not in the main evaluation.

5.1.2 Model Year Question

The 2012 report had a plot of the evaluation subset's low-pressure rates by model year and TPMS presence. It is reproduced in Figure 5-1. It showed that the severe underinflation rates for vehicles with direct TPMS and their peers without TPMS were much closer in MY 2004 than in MY 2005-07. Per the effectiveness computation and the vehicle age at the time of the survey, this translates to lower effectiveness for older vehicles. The added trend lines can be seen as pulled by MY 2004, where the second panel shows that without MY 2004, the lines are close to parallel.

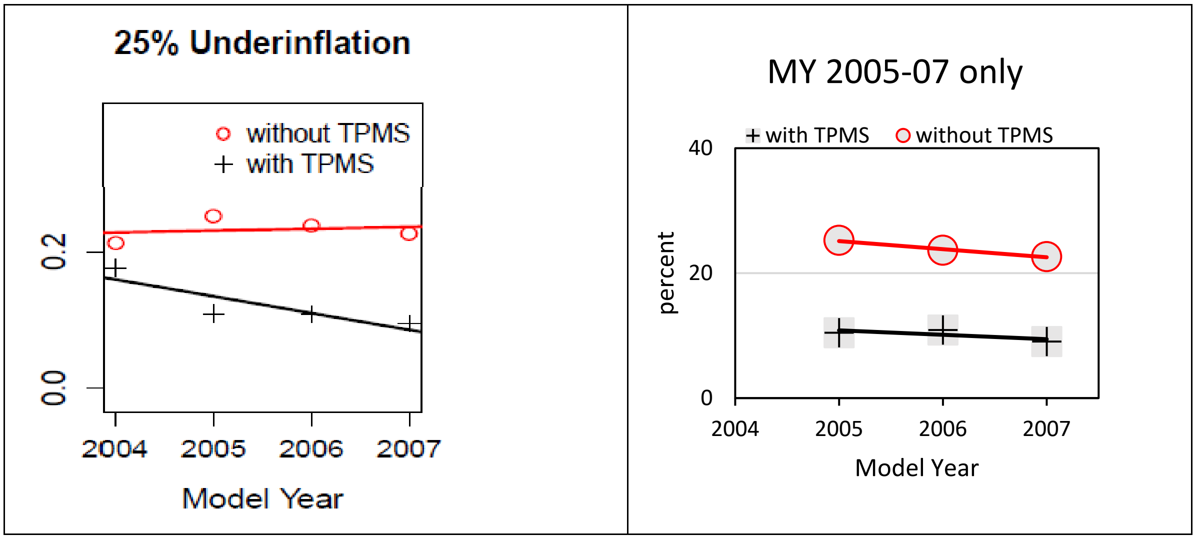

Figure 5-1. Severe Underinflation, Model Year 2004-07 in the TPMS-SS, 2010/2011

Effectiveness computations by model year, not shown in the 2012 report but conducted from the underlying data for this review, were found to be 20 percent for MY 2004 and 60 to 66 percent for MY 05-07, yet with large confidence intervals. Table 5-1 shows the results and a visual representation is shown in Figure 5-2.[13]

Table 5-1. Low Pressure by TPMS Presence, MY 2004-07, Direct TPMS, 2010/2011 (95% CI)

Model Year	Vehicle Age at Survey	Percent with Low Pressure no TPMS*	Percent with Low Pressure TPMS*	Risk Ratio (Odds Ratio)	Effectiveness (%)	Sample Size
2004	7 yrs	21.2 (14.9,29.4)	17.8 (10.1,29.4)	0.801 (0.409,1.571)	19.9 (-57.1,59.1)	455 no TPMS 162 w/ TPMS
2005	6 yrs	25.2 (19.9,31.5)	10.5 (5.1,20.1)	0.346 (0.202,.593)	65.4 (40.7,79.8)	475 no TPMS 233 w/ TPMS
2006	5 yrs	23.6 (16.9,32.1)	10.9 (6.2,18.3)	0.395 (0.167,.932)	60.5 (6.8,83.3)	432 no TPMS 377 w/ TPMS
2007	4 yrs	22.6 (14.5, 33.6)	9.0 (4.6,16.9)	0.340 (0.129,.895)	66.0 (10.5,87.1)	250 no TPMS 666 w/ TPMS

*Wilson confidence intervals are used. Total 3050

Source: NHTSA TPMS Special Study, 2010/2011

[13] Confidence intervals for the odds ratios as reported by SAS are not symmetric about the point estimate because a log transform is involved.

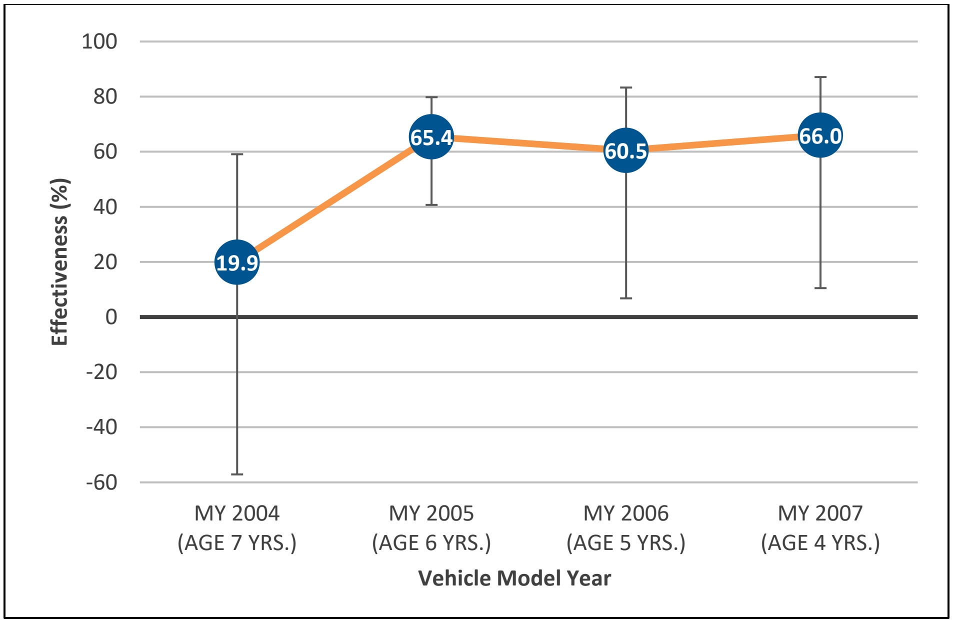

Figure 5-2. Effectiveness by Model Year, Direct TPMS, MY 2004-2007, TPMS-SS 2010/2011

An effectiveness of zero would mean no effect. By including zero in its confidence interval, the estimate for MY 2004 lacks evidence of being statistically significant. Smaller sample sizes (as from splitting the data into individual model years) will make the confidence intervals wider, and an effect that is not statistically significant in a certain sample can still be real but lacking sample size to show it.

The Sivinsky report (2012) also noted that the percentage of vehicles with TPMS that were driving with severe underinflation decreased as model years got newer as shown in Figure 5-3, which is directly reproduced from that report (note the vertical axis is compressed).

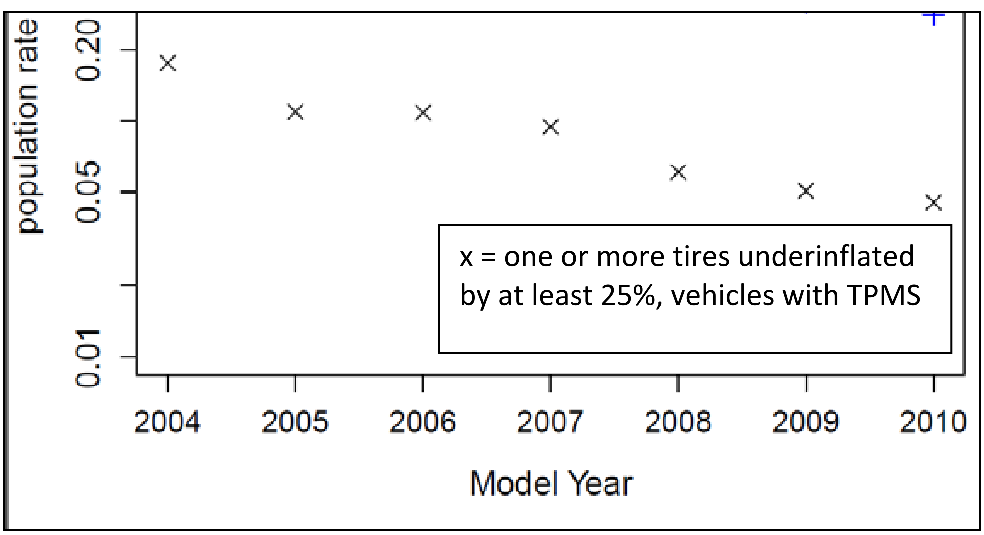

Figure 5-3. Severe Underinflation, MY 2004 to 2010, TPMS-SS, 2010/2011

5.2 Data Analysis

The results in Section 5.1.2 raised questions about whether the data of MY 2004 were an anomaly, and if not, whether TPMS malfunction was a factor in the different effectiveness by vehicle age. Some ideas to explore these questions are to conduct statistical association tests on the evaluation data and to compare the 2010/2011 survey data to other survey results.

Statistical association. A logistic regression[14] on the evaluation data, modeling severe underinflation by main effects of TPMS (vehicle equipped or not) and vehicle age (treated as numeric 4,5,6,7), reported that presence of TPMS was a significant factor (F=31.33,1,12, p=.0001) and vehicle age was not (F=0.76,1,12, p=.4002). Since small sample sizes can mask a real effect, a model was run combining years 2004-05 and 2006-07, for which TPMS was significant (F=31.10,1,12, p=.0001) and model year group as a class was not (F=0.49,1,12, p=0.4989).

However, if limiting to vehicles with direct TPMS of vehicle ages 0-7, an F-test showed evidence of association between vehicle age and severe underinflation (F=3.4,7,84, p=.0027).

In general, the statistical results did not offer persuasive evidence of whether the data at MY 2004 were to be expected or were an anomaly.

Data comparisons across surveys. As discussed in Section 3. , the TPMS-ORRC Field Survey looked at TPMS operational status in 4,477 passenger vehicles in 2018, some 7 years after the TPMS-SS. Also, 10 years before the TPMS-SS, the TPSS of 2001 recorded tire pressure for a sample of about 10,000 vehicles as discussed in Section 4.2. There are differences among the surveys: the 2001 and 2010/2011 surveys measured tire pressure, while the 2018 survey looked at TPMS warnings. Also, these three surveys are from different time periods and had different survey protocols. However, comparing their results may be useful for understanding them.

Each survey has its own population and weighting, so they are not amenable to combining the data into one dataset (pooling). Thus, each survey is analyzed individually for these comparisons.

The different survey data do not line up nicely by model year, being from different calendar years, but model years can be converted to vehicle age at the time of the survey, which then is in common across all three surveys. However, the 2001 survey allowed vehicles of all ages, the 2010/2011 survey had vehicles up to 7 years old, and the 2018 survey had vehicles up to 13 years old, so not all comparisons are possible in all vehicle age groups.

In these comparisons, differences in other vehicle safety equipment of the type that would affect crash occurrences or injuries are not controlled for, with the assumption that such differences should not tend to affect tire pressure.

Only direct TPMS is included in the comparison, since the 2012 evaluation, the topic of this section, was based on direct TPMS. (Indirect TPMS is a small percentage of vehicles in data from 2010/2011 and 2018.) Table 5-2 shows percentages of vehicles being driven with low pressure (either measured or inferred by presence of telltale) by survey year and vehicle age group at the time of the survey, and by (direct) TPMS presence when applicable. In 2001 TPMS presence is not a variable and is presumed to be negligible. In 2010/2011 vehicles with direct TPMS and their peers without TPMS are in the data. In 2018 only vehicles with TPMS are in the data. TPMS malfunction percentages from 2018 are also included. The last column sums the low

[14] The analysis used SAS PROC SURVEYLOGISTIC with parameters for the sample design and alpha=.05.

pressure and malfunction percentages from 2018. *F* statistics shown are for tests of association between vehicle age group and the column category (see Section 1.5). *F*-tests for associations are conducted within surveys, not across surveys.

Table 5-2. Percentages of Vehicles With Severe Underinflation in Vehicles With Direct TPMS or Their Peers Without TPMS by Survey Year and Vehicle Age Group at Time of Survey

Direct TPMS		**Percentage vehicles with situation (95% CI)**					
	Survey Year	2001	2010/2011	2010/2011	2018	2018	2018
	TPMS Equip	No TPMS	No TPMS	TPMS	TPMS	TPMS	TPMS
	Situation	Low Pressure	Low Pressure	Low Pressure	Low Pressure	Malfunction	Sum Low,Malf.
Vehicle age in years at time of survey	0-3	15.3 (13.7,17)	Not applicable*	5.5 (3.9,7.7)	5.7 (3.0,10.4)	1.2 (0.6,2.4)	6.9 (4.0, 11.4)
	4-5	20.5 (17.6,23.7)	23.3 (18.9,28.3)	10.0 (7.3,13.7)	6.7 (4.6,9.7)	2.2 (1.0,4.4)	8.9 (6.1, 12.8)
	6-7	26.4 (21.1,32.4)	23.3 (17.2,30.8)	16.3 (8.7,28.3)	9.8 (5.4,16.9)	2.6 (1.4,4.6)	12.3 (7.5, 19.5)
	8-10	24.6 (21.2,28.5)	Not surveyed	Not surveyed	8.1 (4.7,13.6)	8.9 (7.1,11.1)	17.0 (12.2, 23.0)
	11-13	33.5 (29.0,38.4)	Not surveyed	Not surveyed	14.8 (12.0,18.1)	13.9 (9.9,19.2)	28.7(24.6, 33.2)
	14-24	32.9 (29.9,36.1)	Not surveyed	Not surveyed	Not surveyed	Not surveyed	Not surveyed
	Sample size	*n*=10,875	*n*=1,712	*n*=4,390	*n*=4,297	*n*=4,477	*n*=4,477
	F statistic *p*-value	***F*=21.3,5,60, *p*=<.0001**	*F*=.0062,1,12 *p*=.9385	***F*=19.3,2,24 *p*=<.0001**	***F*=7.0,4,64 *p*=.0001**	***F*=29.1,4,64 *p*=<.0001**	***F*=21.2,4,64 *p*=<.0001**
*Age 0-3 not applicable for 2010/2011 No TPMS because TPMS mandate was in effect for all vehicles up to 3 by then.							
Source: NHTSA, National Center for Statistics and Analysis							

Model Year Key			
Vehicle Age Group	Model Year		
	TPSS (2001)	TPMS-SS (2010-11)	TPMS-ORRC (2018)
0-3	1998-2001	2008-11	2016-19
4-5	1996-1997	2006-07	2014-15
6-7	1994-1995	2004-05	2012-13
8-10	1991-1993	Not surveyed	2009-11
11-13	1988-1990	Not surveyed	2006-08
14-34	1967-1987	Not surveyed	Not surveyed

In Figure 5-4, the percentages of the various outcomes seen above are graphed by vehicle age group at the time of the survey.

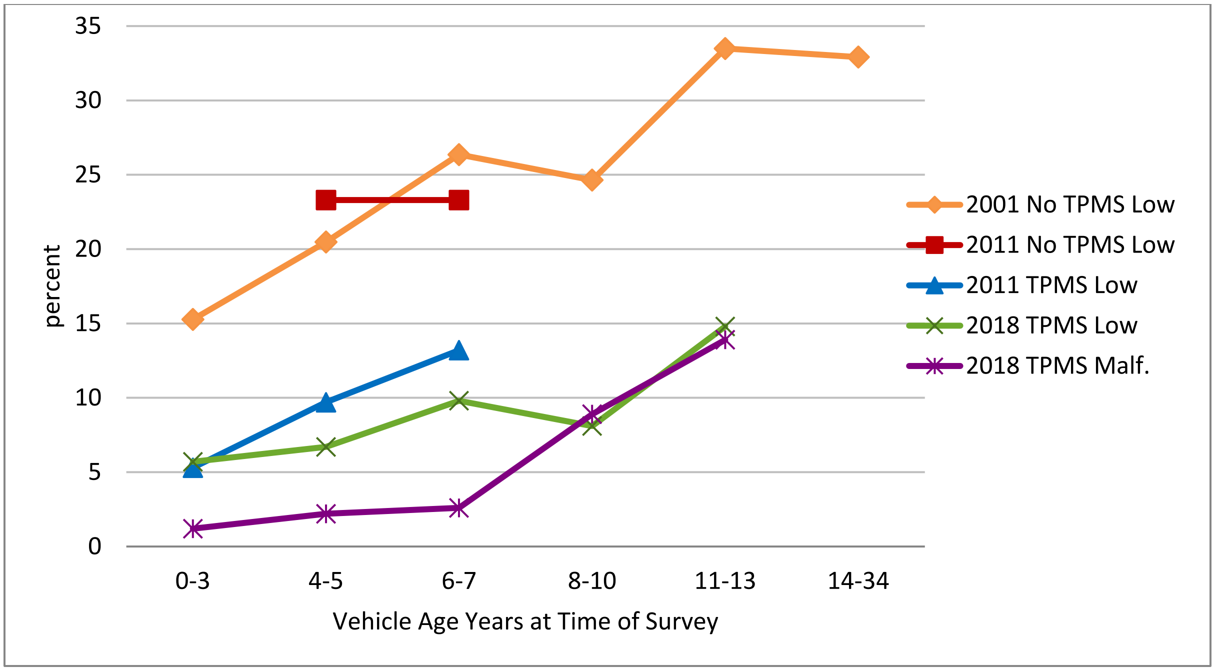

Figure 5-4. Tire Pressure/TPMS Situations by Vehicle Age in Three Surveys

Figure 5-5 replicates Figure 5-4 but also shows the sum of 2018 low-pressure warning and TPMS malfunction percentages (the last column of Table 5-2). For reference, the components of each sum are plotted as symbols without connecting lines.

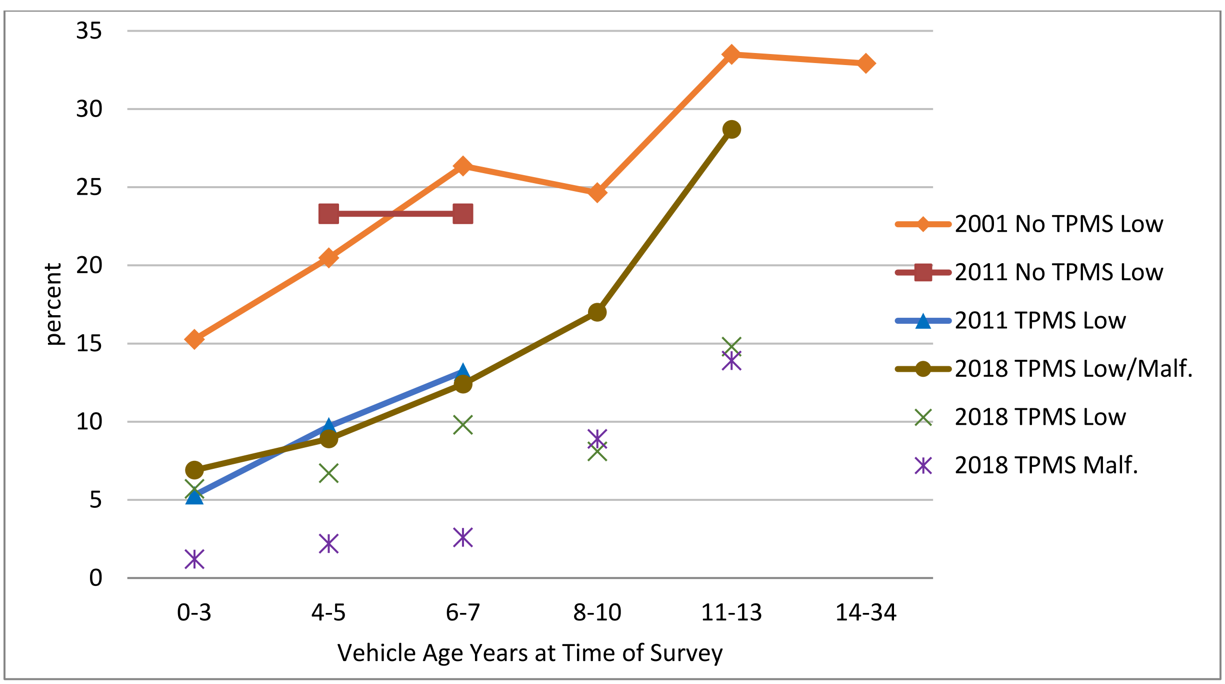

Figure 5-5. Tire Pressure/TPMS Situations Summing 2018 Pressure and Malfunction Warnings

5.3 Data Synthesis

Key points noted from Table 5-2, Figure 5-4, and Figure 5-5 were:

- TPMS and non-TPMS vehicle clusters are distinctly seen in the figures, with TPMS vehicles lower on the graph, signifying lower percentages. This result is consistent with the 2011 evaluation finding that TPMS reduces underinflation. The figures also show the rates of both low pressure and malfunction rising with vehicle age in all three surveys.
- The exception to rising rates was 2010/2011 data, where low pressure rates for non-TPMS vehicles were flat for vehicles 4 to 7 years old. However, the flatness falls at about the mean low-pressure rate found in 2001 for those age groups. The flatness may be an anomaly that partially contributed to the apparent lower effectiveness of TPMS found in vehicles 7 years old in the 2010/2011 data, since the comparison vehicles with TPMS did show somewhat different rates for vehicles 4 to 7 years old.
- The combined percentage of vehicles with TPMS with low-pressure warning or TPMS malfunction in 2018 closely tracked the percentages of vehicles with TPMS that had low pressure per gauge measurement in 2010/2011 in the vehicle ages available for analysis. This could be a circumstantial indication that vehicles with TPMS malfunction may also often be in a low-pressure status.
- The percentage of TPMS vehicles that had either kind of telltale in 2018 gets relatively high after about vehicle age 8 and is seen approaching non-TPMS low-pressure rates seen in 2001. This may be a concern for the effectiveness of TPMS as vehicles age beyond 8 years if drivers do not respond to TPMS warnings.
- It should also be noted that even when differences between proportions are similar, the percent reduction is smaller if the start value is higher. For instance, a reduction from 20 to 10 is a (20-10)/20 = 50 percent reduction, while a reduction from 50 to 40 is a (50-40)/50 = 20 percent reduction. This could come into play for TPMS effectiveness risk ratios when compared by vehicle ages.

5.4 Implications

TPMS (direct) was previously found to be about 56 percent effective for averting low pressure in vehicles 4-7 years old. The 2018 data did not have non-TPMS vehicles, so the comparison cannot be redone, but the 2018 findings from TPMS vehicles tended to be consistent with 2010/2011 findings. In the 2012 report, reductions in underinflation appearing to be lower in vehicles 6-7 years old compared to 4-5 years could be due in part to a data anomaly but also to older vehicles having more TPMS malfunctions and incidents of low pressure. TPMS warning lights were more prevalent as vehicles aged beyond 8 years, reaching almost 30 percent in vehicles 11 to 13 years old. Vehicles with TPMS malfunction may also have low pressure.

5.5 Other Areas

The 2012 report also conjectured that TPMS reset or driver responses to aging vehicles could be issues with TPMS. Reset topics are examined in Sections 6 and 11 of this report. Driver responses to TPMS warnings are covered in Sections 7 and 10. Factors associated with TPMS operational status are examined in Section 12. Sample sizes for domains were not always large enough to test by vehicle age. Some of these areas could be topics for future research.

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6. Driver Knowledge About TPMS and Tire Pressure

In Sections 6 through 11, survey variables that contributed to data bullets are shown in footnotes for reference to the question involved. Variable response tables may be seen in the appendices.

6.1 Topic Background

A driver needs some knowledge of the TPMS and tire pressure to properly interact with the systems. Research questions proposed for this topic included: Do drivers of vehicles with TPMS have knowledge of their TPMS and dashboard lights, putting air in tires, where to find recommended air pressure, and resetting their TPMS?

6.2 Data Analysis

General knowledge. Some results about driver basic knowledge of TPMS and pressure were:

6a. In 2018, about 95 percent of drivers with a TPMS-equipped vehicle knew the vehicle had a TPMS, 98 percent could pick out a TPMS light they had seen on the dashboard either when starting or when the engine was running, and 93 percent identified the light as related to tire pressure.[15]

6b. About 71 percent of drivers with TPMS said they did not know whether their system used direct or indirect technology when given the terms and a description of what they mean. About 15 percent of drivers identified their correct TPMS type, 13 percent had indirect TPMS but misidentified it as direct, and 1 percent had direct TPMS but misidentified it as indirect. [16]

6c. About 83 percent of drivers with TPMS reported that they knew how to inflate their tires to the proper pressure.[17]

6d. About 93 percent of drivers with TPMS malfunction warnings were aware that a TPMS dashboard light was on; 47 percent of them thought it meant low pressure, 37 percent thought it meant TPMS malfunction, and 16 percent something else or did not know.[18]

6e. About 88 percent of drivers with a low-pressure warning were aware that a TPMS light was on; 73 percent of them thought it meant the pressure was low, 9 percent thought it meant TPMS malfunction, and 18 percent thought something else or did not know.[19]

6f. About 37 percent of repair facility representatives said that owners with direct TPMS malfunction almost always identified the malfunctions when bringing in the vehicles for service, and 32 percent said the same for indirect TPMS.[20]

6g. In 2010/2011, about 96 percent of drivers who said they had TPMS knew their vehicle had a pressure warning light or a combined warning/malfunction light of some kind, and 98 percent of that group could say where it was located.[21]

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[15] Field Survey, Module INTRO [TPMSEQ], [TPMSDASH], [TPMSDASHA]
[16] Field Survey, Module INTRO [TPMSTYPE], [IND_TPMS]
[17] Field Survey, Module CLOSE [AIR2]
[18] Field Survey, Module MALFUNCTION#1 [MALF1AW1], [MALF1AW1A]
[19] Field Survey, Module MALFUNCTION#2 [MALF2AW1], [MALF2AW1A]
[20] Repair Facilities Survey [MALIDENTD], [MALIDENTI]
[21] TPMS-SS [TPMSWARNID], [TPMSLAMPLOCID]

Recommended pressure and vehicle placard. As of September 2003, FMVSS No. 110 requires automobile manufacturers to place tire information placards in a standardized location and follow a common format. The placards identify the original equipment tire sizes and inflation pressures (including the spare), along with the vehicles' weight capacity. A vehicle must have a placard located on the driver's side doorjamb (the B-pillar), but if a vehicle does not have a B-pillar, then the placard is to be placed on the rear edge of the driver's door. If the vehicle does not have a B-pillar and the driver's door edge is too narrow, the placard is to be affixed on an inward facing surface next to the driver's seating position.

The 2000 Omnibus Survey and the 2001, 2010/2011, and 2018 NHTSA surveys had interview questions asking where or how drivers would find the required pressure for their vehicles (with variations in wording). Increasing knowledge about the placard can be seen in the percentage citing the placard in 2001 (8%), 2010/2011 (19%) and 2018 (37%) as compiled in Table 6-1.

Table 6-1. Where Drivers Would Look for Recommended Pressure by Survey Year

Response	**Percentage giving response by survey year**			
	2000	2001	2010/2011	2018
Vehicle placard		8	19	37
Owner's manual	27	17	20	13
Tire wall	45	28	13	32
Service tech/other person		21	35	4
Other		10	18	6
Don't know		7	3	10

Sources: Bureau of Transportation Statistics Household Survey (2000) and NHTSA Surveys (2001-18)

The owner's manual may give the recommended tire pressure, but it sometimes simply refers the owner to the placard (for example: Volvo, p. 515). The tire sidewall is not a correct place to look for the recommended pressure (NHTSA, n.d.-a). It gives the maximum pressure for the tire, not the recommended pressure (Ashley, 2015).

Reset/recalibration. TPMS systems have various needs for resetting or recalibrating system values after tire or TPMS events. Terminology may vary; online searches found use of terms such as "reset," "calibrate," "recalibrate," "relearn," "store tire pressure," "store values," etc., sometimes with overlapping meanings. A direct TPMS "reset" or "relearn" is usually required after rotating or installing tires or replacing sensors, where the system must relearn which wheels the sensors are broadcasting from. The relearn may require a special tool used by a service technician. Recalibrating after adjusting pressure is not typically required by direct TPMS but is required for indirect TPMS (see Section 11. for more information on indirect TPMS).

Extended interviews in 2018 asked drivers with either type of TPMS two questions about resetting TPMS. Relevant results were:

6k. Drivers were asked: Who would be able to reset the TPMS system in your vehicle when needed, such as after adding air to the tires or doing work on the tires or wheels? Select all that apply.[22] Table 6-2 shows results by TPMS type.

[22] Field Survey, Module CLOSE [RESET1], [IND_TPMS]

Table 6-2. Percentages Driver Response, Who Can Reset the TPMS, by TPMS Type

Who would be able to reset the TPMS?		**Response Percentages* (95% CI)**			
		Driver	Dealer/Repair	Other	Don't Know**
TPMS Type	Direct	20% (13, 29)	67% (59, 74)	2% (1,3)	15% (9, 23)
	Indirect	29% (22, 37)	63% (53, 72)	0	11% (5, 21)

Source: NHTSA TPMS-ORRC, 2018

6l. Drivers were next asked: What action is required to reset the TPMS system? [23] Table 6-3 shows results by TPMS type.

Table 6-3. Percentages Driver Response, How to Reset the TPMS, by TPMS Type

What action is required to reset the TPMS?		**Row Percent Response (95% CI)**				
		Press Button	Electronic Menu Option	Special Tool Used by Repair Shop/ Dealer	Other	Don't Know
TPMS Type	Direct	14% (7, 27)	7% (4,12)	6% (4,8)	5% (3, 8)	67% (59, 75)
	Indirect	24% (18,32)	13% (9,18)	3% (2,7)	1% (0.3,4)	58% (52, 64)

Source: NHTSA TPMS-ORRC, 2018

6m. Among drivers who said the driver could reset the system, about 35 percent of drivers with direct TPMS and 15 percent with indirect also said they didn't know how to do it.

6n. For comparison, in 2010/2011, 61 percent of drivers with TPMS (mostly direct) said they did not know how to reset their TPMS, 21 percent said it could be reset it using a button in the vehicle or the menu, 35 percent said it is somewhat or very easy to reset the TPMS, 2 percent said it was somewhat or very difficult, and 63 percent didn't know.[24]

Additional recalibration topics specific to indirect TPMS are covered in Section 11.

Knowledge index. For an assessment tool of overall driver knowledge in the 2018 data, a "knowledge index" derived from knowledge-related survey questions may be useful. The proposed index is the number of questions (out of eight) where the respondent indicated positive knowledge, with an extra point for the vehicle placard. Four questions were from extended interviews only, so the index is drawn from extended interviews using extended interview weights for proper representation. The index specification is detailed in Appendix N. In brief, the index gives a point for each positive knowledge response to the following questions:

1. To your knowledge, is this vehicle equipped with a tire pressure monitoring system, known as TPMS,—whether or not it is currently working?
2. To your knowledge, is the TPMS system in this vehicle "direct," using sensors in the wheels, or "indirect," using sensors in the antilock braking system?
3. Looking at these pictures – and allowing for minor variations in style – please point to those items that you have seen on your vehicle's dash at any time in the past, either when starting the engine or later when the vehicle was running.
4. What does this light/these lights mean to you?

[23] Field Survey, Module CLOSE [RESET1_01], [RESET2]
[24] TPMS-SS [RESETUSEID], [RESETCONVENIENTID]

5. Where would you look to find the pressure required for correct inflation of the tires on this vehicle? (tire wall not correct, owner's manual OK, vehicle placard adds extra point)
6. Do you know how to inflate your tires to the correct pressure?
7. Who would be able to reset the TPMS system in your vehicle when needed, such as after work has been done to the tires or wheels?
8. What action is required to reset the TPMS system?

Questions specific to drivers with current malfunction or indirect TPMS were not included because their sample sizes were too small. If any component response was missing, the index was not calculated. The resulting sample is based on national representation of 862 drivers in extended interviews. The possible range of the index was 0 to 9. The percentages of drivers scoring each index are shown in Figure 6-1. If scores are grouped as 1 to 4 (lower), 5 to 7 (moderate), and 8 or 9 (highest), 17 percent of drivers had lower scores, 69 percent had moderate scores, and 14 percent had highest scores.

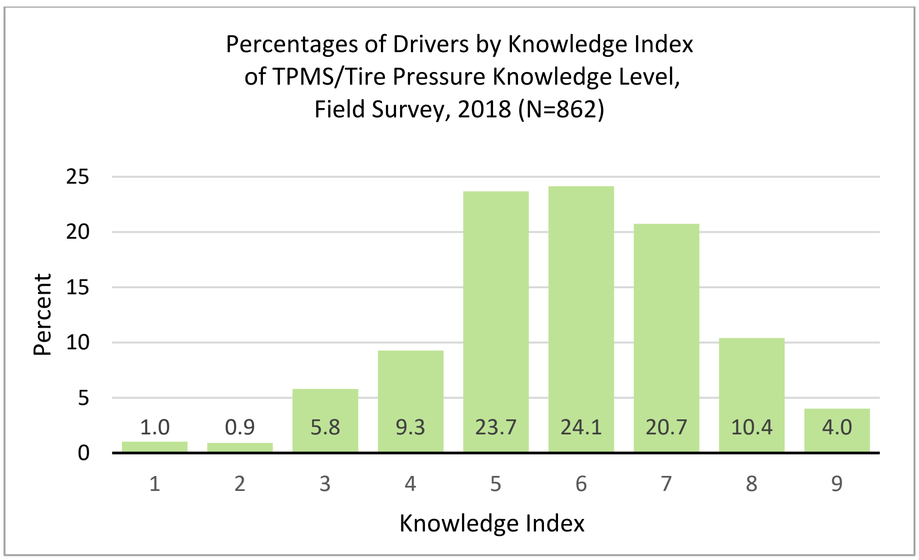

Figure 6-1. Percentage of Drivers by Knowledge Index, Field Survey

The index is intended to give only a general idea of driver knowledge. Limitations are that it assumes drivers were knowledgeable in their answers, guessing is not accounted for, specific meaning of TPMS malfunction light versus low-pressure light was not an available component, and the scoring system had arbitrary human judgment.

6.3 Data Synthesis

Key conclusions extracted from the above data points follow. Discussion points are cross-referenced with the items that contributed to the conclusions.

- Driver knowledge about having a TPMS and recognizing TPMS lights as being related to tire pressure appears to be high. Even some who don't know they have a TPMS know that the icon relates to tire pressure (6a). Similar knowledge in the 2010/2011 survey was also high (6g). As a caveat, drivers knowing or inferring that a survey is about TPMS could influence responses to questions like these.

- Driver knowledge of whether their TPMS uses direct or indirect technology appears to be low. Only 15 percent of drivers identified their TPMS type correctly (6b). However, this knowledge should not be crucial if a driver knows how to maintain tire pressure and respond to TPMS warnings. (Vehicle owners' manuals often do not identify TPMS as "direct" or "indirect," although they usually give a basic explanation of the technology.)
- Driver knowledge of how to add air to tires appears to be high, being reported by 83 percent (6c). It is not clear whether the other 17 percent ignore the pressure or rely on a service facility or other person to add air.
- When a TPMS light is on, driver awareness that it is on, and that it is related to TPMS or tire pressure, is high, but specific understanding of a TPMS malfunction light is under 40 percent with confusion that it is a low-pressure warning (6d, 6f). Specific understanding of a TPMS low-pressure warning light could improve, being under 75 percent (6e). More drivers misinterpreted a malfunction light than a low-pressure light (6d, 6e). Guessing could not be assessed from the data.
- Knowledge about where to look for recommended pressure appears to need improvement. About a third of drivers would incorrectly look at the tire sidewall, but the sidewall gives maximum pressure, not recommended pressure. Knowledge of correctly getting the recommended pressure from the vehicle placard has grown since the placard became required over the last twenty years but is still low at 37 percent (Table 6-1).
- Knowledge about resetting or recalibrating TPMS is low for drivers of both TPMS types (6k, 6l, 6m). The 2010/2011 survey also showed low reset knowledge, so it appears that not much progress has been made on this topic in later model years (6n).
- Despite the individual deficiencies noted for some topics, most drivers showed moderate to high knowledge of basic TPMS and tire pressure issues (Figure 6-1).

6.4 Implications

General driver knowledge about TPMS and tire pressure topics appears to be good, with some exceptions. One concern would be that many drivers think a TPMS malfunction light indicates low pressure or something else. This may lead to driver confusion such as adding unneeded air or not repairing a problem in the TPMS. Some vehicle models may avert this confusion by showing phrases such as "check tire pressure" or "TPMS malfunction" rather than just the flashing or steady tire cross-section icon. Another challenge is that some drivers incorrectly look at the tire sidewall, rather than the vehicle placard, for recommended pressure. The sidewall gives maximum pressure, not recommended pressure, so incorrectly using it as a reference could lead to pressure issues. A potential technology aid could be to have the TPMS tell the recommended pressure. A third challenge is low driver knowledge about TPMS reset and recalibration. There are many terms for this, differences among what it means, different requirements for different vehicle makes and TPMS type, and confusion about who does the reset and when.

Areas of emphasis in driver educational outreach could be interpreting a TPMS light, using the vehicle placard to find recommended tire pressure for a vehicle, and better knowledge about resetting or recalibrating TPMS.

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7. Driver Engagement with Tire Pressure

7.1 Topic Background

Driver engagement with tire pressure refers to drivers taking action to check their tire pressure and adjust it as needed. NHTSA has published recommendations in this area. Research questions proposed for this topic included: Do drivers of vehicles with TPMS have experience and follow recommendations with checking air and putting air in tires?

NHTSA and manufacturer recommendations. NHTSA recommends that drivers, including drivers of vehicles with TPMS, check tire pressure at least once a month and adjust it as needed. A NHTSA web page states:

> Newer vehicles have Tire Pressure Monitoring Systems, but these only activate a warning when a tire is significantly underinflated. You should still conduct a monthly tire pressure check to ensure your tires are always properly inflated. (NHTSA, n.d.-a)

FMVSS No. 138 (2007) requires that owners' manuals for vehicles with TPMS include the following language about the system:

> Each tire, including the spare (if provided), should be checked monthly when cold and inflated to the inflation pressure recommended by the vehicle manufacturer on the vehicle placard or tire inflation pressure label.
>
> As an added safety feature, your vehicle has been equipped with a tire pressure monitoring system (TPMS) that illuminates a low tire pressure telltale when one or more of your tires is significantly under-inflated. Accordingly, when the low tire pressure telltale illuminates, you should stop and check your tires as soon as possible, and inflate them to the proper pressure. Driving on a significantly under-inflated tire causes the tire to overheat and can lead to tire failure. Under-inflation also reduces fuel efficiency and tire tread life and may affect the vehicle's handling and stopping ability.
>
> Please note that the TPMS is not a substitute for proper tire maintenance, and it is the driver's responsibility to maintain correct tire pressure, even if under-inflation has not reached the level to trigger illumination of the TPMS low tire pressure telltale.

7.2 Data Analysis

The survey interviews asked drivers questions about checking and adjusting tire pressure either as a regular habit or after a TPMS warning. Some relevant results were:

7a. In 2018, drivers with indirect TPMS were asked: When was the last time you used a pressure gauge to check the tire pressure in the tires on this vehicle? About 41 percent said in the last month, 28 percent said a longer time frame, 23 percent said never, and 8 percent did not know. (The question was in the indirect TPMS module, so was not asked of drivers with direct TPMS.)[25]

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[25] Field Survey module INDIRECT [IND_CHK]

7b. In 2010/2011 all drivers were asked: When was the last time you or someone else checked the tire pressure on this vehicle? For drivers with TPMS, 43 percent said within the last month, 41 percent said a longer time frame, 7 percent said never, and 9 percent did not know. For drivers without TPMS, 41 percent said within the last month, 47 percent said a longer time frame, 3 percent said never, and 9 percent did not know.[26]

7c. In 2001 drivers were asked: How often do you normally check your tires for proper inflation? About 33 percent said they check at least monthly (includes weekly), 25 percent whenever they seem low, 28 percent when they are serviced, 2 percent before a long trip, 5 percent do not normally check, and 7 percent specified other responses including some "don't know" responses. (Some drivers using "Other" specified time periods that would be at least monthly such as every two weeks, twice monthly, every day, etc. A tally of such "other" responses raised the overall percent that would classify as at least monthly to 34 percent. Responses of checking at certain mileage or when filling the gas tank may have involved checking at least monthly but cannot be certain.)[27]

7d. About half of 2018 drivers with a current low-pressure warning said they had checked tire pressure since the light came on. In half of the vehicles with a pressure warning, the light had been on less than a week, and in another 25 percent, one to two weeks. Eight percent said it had been on over a year. [28]

7e. For 2018 drivers who reported that a low-pressure warning had come on and stayed on sometime in the past, about 92 percent said that they or someone else had added air to the tires when this happened (time frame is unavailable).[29] Of the 8 percent who said they did not add air, 51 percent had a current malfunction warning, 12 percent had a current low-pressure warning, and 37 percent had no current warning.

7f. About 24 percent of 2018 drivers who added air when a pressure warning light came on said the light stayed on even after adding air to the tires and driving. About 20 percent of these respondents had a low-pressure warning at the time of the survey, 12 percent had a malfunction warning, and 66 percent had no warning.[30]

7.3 Data Synthesis

Key conclusions extracted from the above data points follow. Discussion points are cross-referenced with the items that contributed to the conclusions.

- Driver adherence to pressure recommendations appears to be low. In 2018 and 2010/2011, only about 41 to 43 percent of drivers with TPMS said they checked their tire pressure in the last month. The wording of this question said "you" and "with a pressure gauge" in 2018 and "you or someone else" with no specification of pressure gauge in 2010/2011 but still saw similar percentages (drivers in 2018 may have implicitly included other people checking as proxies even though the question did not specify others). Since the 2018 question was only asked of drivers with indirect TPMS, none of them would have had systems that report the individual pressures. Based on these results, about 60

[26] TPMS-SS [LASTSERVICEID]
[27] TPSS [D12]
[28] Field Survey, Module MALFUNCTION#2 [MALF2FIX1], [MALF2AW2]
[29] Field Survey, Module CLOSE [TRYFIX1], [TRYFIX2]
[30] Field Survey, Module CLOSE [TRYFIX3]; and Module INTRO [MALFCODE]

percent of drivers do not follow the recommended practice, and this has not changed much between 2010/2011 and 2018 (7a, 7b).

  - A caution to the 2018 percentages is that they were only from drivers with indirect TPMS, which reduces the sample size, limits by TPMS type, and restricts to newer vehicles. However, the 2010/2011 result included direct TPMS and was similar to the 2018 result.
  - In 2001 about 34 percent said they check at least monthly, but the question wording was specific to how often they normally check air, rather than the last time they checked as was asked in 2010/2011 and 2018. Someone could have checked air in the last month even if they check it rarely. This may account for the differences between 2001 at 34 percent compared to 2010/2011 and 2018 at about 42 percent.

- Having TPMS, at least in 2010/2011 when TPMS was relatively new, appeared to neither encourage nor discourage drivers from checking air proactively (7b). (A comparison was not available in 2018 data because the survey only included vehicles with TPMS.)
- Completely ignoring tire pressure may be increasing over time. In 2018, about 31 percent never check air or don't know when they last did. This is higher than the percentages seen in 2010/2011 or 2001 (7a,7b,7c).
- Driver reactions to a low-pressure warning light also show a lack of urgency, although most drivers eventually take care of it. In 2018 about half of drivers with a current low-pressure light had checked the pressure, and the light had been on longer than a week for half of the vehicles (7d). However, those results do not include drivers who did respond quickly to a warning. Most drivers who reported having a past low-pressure warning eventually corrected the pressure problem in an unspecified time frame (7e).
- Of drivers who had a past low-pressure warning light, about 8 percent said they did not act to correct the warning at all. This is a safety concern, but also, half of them had a current TPMS malfunction warning. It is possible that some of these drivers confused the light meaning or that they prefer to ignore TPMS in general (7e).
- Low-pressure warning lights staying on after adding air and driving could be a concern (7f). It could result from incorrect resetting or recalibration, incorrect inflation, the light being a malfunction light mistaken as a low-pressure light, or other problems. Some drivers that reported this occurring did not have a current warning light (7f), so the reported past light had to have gone off at some point, but it is not clear how.

7.4 Implications

Based on results and conclusions from this section, driver habits for checking air show a lack of urgency. The recommended practice is to check it once a month whether the vehicle has a TPMS or not, but less than half of drivers with TPMS or without TPMS reported doing this. Responding to TPMS warnings also show a lack of urgency in some drivers. The recommended practice is to address a TPMS warning light as soon as possible, but half of drivers with a current TPMS pressure warning light said it had been on over a week. Not responding quickly to a low-pressure warning is a concern because a potential safety issue exists until the pressure is corrected.

Education and public outreach could focus on the need for drivers to check air once a month rather than relying on TPMS to check it, to act on a TPMS pressure warning as soon as possible rather than waiting, and to be mindful of proper procedures for adding air and resetting or recalibrating. A technology enhancement that could help and appears to be in use already in some manufacturers is to have TPMS included in the smartphone application that connects to the vehicle.

Implications for questionnaire design. Each of the following questions was trying to get at the driver's habit for checking air:

- (2018) When was the last time you used a pressure gauge to check the tire pressure in the tires on this vehicle?
- (2010/2011) When was the last time you or someone else checked the tire pressure on this vehicle?
- (2001) How often do you normally check your tires for proper inflation?

The three surveys were designed independently, so the questions were not harmonized and are difficult to compare. A recommendation for future surveys would be to standardize wording. Questionnaire design for the driver habit question could consider whether to concentrate on the driver habit of checking air in general or the last time air was checked (or ask both for response comparison).

8. TPMS Malfunction Reasons and Repairs

8.1 Topic Background

FMVSS No. 138 requires that a TPMS malfunction be warned to the driver with an indicator lamp. The lamp can be separate from the pressure telltale lamp or combined with it. Although a malfunctioning TPMS will give a malfunction telltale, it cannot receive the information needed to generate a low-pressure warning, with the result that the system will not be useful. Research questions proposed for this topic included: What are the reasons that TPMS need repairs, and what component parts are commonly replaced?

8.2 Data Analysis

The surveys asked about events, reasons, and repairs around TPMS malfunctions. Field Survey driver responses are essentially for direct TPMS as indirect TPMS malfunction was very rare in the survey. RFS questions were separate for direct and indirect TPMS. Some results were:

8a. About 31 percent of drivers with TPMS malfunction said that they had installed one or more new tires or wheels before the malfunction. Other responses were rotated tires (12%), switched out specialty tires such as seasonal or off-road tires (11%), and installed or replaced tire valve stems (5%). Replacing sensors, brake work, and crash incidents were almost never selected, and 28 percent said none of the listed options had happened. The question allowed multiple responses.[31]

8b. About 78 percent of drivers with a malfunction who consulted someone about it (usually a dealership, auto repair shop, or mechanic) said they were told that sensors would need to be repaired or replaced. Other responses were recalibration (7%) and other unspecified response (12%). The question allowed multiple responses.[32]

8c. The source of direct TPMS malfunction most cited by repair facilities was sensors (81%). On-board hardware and on-board software were each cited by 7 percent. The most cited service to fix direct TPMS malfunctions was installing new sensors at 62 percent (21% rim-mounted, 41% stem-mounted). Others were recalibration (27%), repairing or replacing on-board hardware (2%) or on-board software (1%). Responses are for the most frequently seen option, not the percentage at which the option occurred.[33]

8d. Events before a direct TPMS malfunction most cited by repair facilities were worn out batteries (51%), tire replacement (28%), weather including flood or snow (21%), and vehicle age (19%). Sensors were not a given option, but were frequently mentioned in "other, specify" responses. The question allowed up to three selections.[34]

8e. Sources of indirect TPMS malfunction that repair facilities most often cited were chassis-mounted sensors such as wheel speed sensors (69%), on-board hardware (11%) and on-board software (11%). Cited services to fix indirect TPMS malfunctions were installing new chassis-mounted sensors (58%), recalibration (27%), repairing or replacing on-board

[31] Field Survey, Module MALFUNCTION#1 [MALF1AF1A/B]
[32] Field Survey, Module MALFUNCTION #1 [MALFIX1], [MALFIX2], [MALFIX3]
[33] Repair Facilities Survey [MALSRCD], [MALSVCD]
[34] Repair Facilities Survey [MALEVENTD], [MALEVENTD_OTHER]

hardware (6%) or on-board software (2%). Responses are for the most frequently seen option, not the percentage at which the option occurred.[35]

8f. The most cited events preceding indirect TPMS malfunctions were vehicle age (28%), electrical interference (16%), vehicle accident (14%) and weather including flood or snow (14%). Wheel sensors were frequently mentioned in “other, specify” responses. The question allowed up to three selections.[36]

8g. The median estimate given by repair facilities for overall direct TPMS lifespan before it needs service of some kind was 4 years, and for a direct TPMS rim-mounted or stem-mounted sensor, 5 years.[37]

8h. The median estimate given by repair facilities for overall indirect TPMS lifespan before it needs service of some kind was 5 years, and for an indirect TPMS chassis-mounted sensor such as a wheel speed sensor, 6 years.[38]

8.3 Data Synthesis

Conclusions drawn from the topic data points were:

- Tire events such as being installed, rotated, switched, or having stems replaced may precede TPMS malfunction. They were mentioned by more than half of drivers with a current malfunction as events preceding the malfunction. The next most cited event was “nothing” at almost 30 percent (8a). The “nothing” would likely mean internal causes not perceptible to the driver.
- Replacing tire pressure sensors is the most common repair for direct TPMS as cited by drivers and by repair facilities. Worn out batteries in the sensors were cited as a leading cause (8b,8c,8d,8f).
- Sensors were also mentioned for indirect TPMS, but these are wheel speed sensors (8e). They are not inside tires so are considered less likely to break.
- Repair facility responses that sensor problems start to occur after about 5 years (8g) align with Field Survey dashboard check findings that showed TPMS malfunction presence rising as vehicles age past 5 years and particularly after vehicles are seven years old (Figure 3-1). It is possible that some older vehicles being driven with TPMS malfunctions had the malfunction for some time.

8.4 Implications

Tire pressure sensors in direct TPMS appear to be the most often needed repair in direct TPMS as systems age. They are estimated to have an average lifespan of about 5 years. Wheel-mounted sensors may be problems in indirect TPMS.

The many types of reset and recalibrations offered may contribute to driver confusion and lack of knowledge about reset/recalibration, as seen in Section 6.

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[35] Repair Facilities Survey [MALSRCI], [MALSVCI]
[36] Repair Facilities Survey [MALEVENTI], [MALEVENTI_OTHER]
[37] Repair Facilities Survey [LSD_OVERALL], [LSD_RSENSOR], [LSD_SSENSOR]
[38] Repair Facilities Survey [LSI_OVERALL], [LSI_SENSOR]

9. TPMS Repair Costs

9.1 Topic Background

Repair costs for a malfunctioning TPMS may influence the vehicle owner's decision about correcting the problem. Research questions proposed for this topic included: What are the maintenance and repair costs of TPMS, as related to the diagnosed problem?

In Section 8, tire pressure sensors were the most cited repair needed for direct TPMS. Online tire industry sites often recommend that when one sensor is replaced, they all should be replaced. For example, one site states:

> If a single sensor has reached the end of its lifespan, it is highly recommended to replace all sensors at the same time. Similar to headlights, once one sensor dies, the rest are likely to be close behind. The same is true for a corroded valve stem or other non-impact sensor replacement (Gruenzner, 2017).

9.2 Data Analysis

The Field Survey asked drivers with current malfunctions about costs to repair based on their ad hoc perception or from having work priced. As before, Field Survey responses are dominated by direct TPMS.

The Repair Facilities Survey asked average total price charged for repairing various direct and indirect TPMS components, including parts and labor, independent of tire replacement.

Some relevant results were:

9a. About 43 percent of drivers who had a current malfunction and had priced the work to have it repaired, of which 78 percent said the needed work was to replace tire pressure sensors, reported that it was priced at about $50 to $99, 38 percent reported it was more than $100, 15 percent reported it was more than $300, and 6 percent said it would be no charge. Of those who had not priced the work, about 70 percent did not have a general idea of what the price would be. (The sample size for those who did have an idea of the price was too small for estimates of the price.)[39]

9b. Most drivers who said the cost would be zero had a warranty in effect (80%).[40]

9c. Repair facilities median estimates for average prices charged to customers to repair components in a TPMS, including parts and labor, independent of tire replacement, are shown in Table 9-1. The rows are separated by TPMS type and ordered by lowest to highest price. The percent of facilities that offer the service is also shown. Estimates are from 2016 and do not reflect any inflation since then.

9d. As seen in Table 9-1, the median estimated cost for parts and labor of replacing one direct TPMS tire pressure sensor was $96 to 99 and for a chassis-mounted sensor such as a wheel speed sensor used in indirect TPMS, $145.

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[39] Field Survey, Module MALF. #1 [MALFIX3], [MALCOST1A/1B], [MALCOST2A/2B]
[40] Field Survey, Module CLOSE [MAINT2A]

Table 9-1. Percentage That Offers and Median Prices, Including Parts and Labor, Estimated by Repair Facilities for TPMS Services by TPMS Type, Least Expensive to Most Expensive

INTERVIEWER: In the following questions I'll ask about the average price you charge customers to repair specific components in a TPMS system. Please provide your best estimate of the total price you charge for this work, including both parts and labor. What is the average price you charge for replacing each of the following, independent of tire replacement? Your best estimate is fine.[41]	% Facilities That Offer	Respondent Median Estimated Price
Direct TPMS		
Auto-relearn recalibrations of direct TPMS systems, which do not require tools but do require driving the vehicle to register new sensor IDs*	76%	$17
Stationary recalibrations of direct TPMS systems, which do not require tools but do require a series of steps such as button presses, pumping the brake pedal, and cycling the ignition before deflating each tire to register the new sensor IDs*	84%	$18
Recalibrations of direct TPMS systems that require an activation tool with the vehicle in relearn mode to register new sensor IDs, but do not require driving the vehicle*	89%	$29
Recalibrations of direct TPMS systems that require an activation tool in conjunction with a scan tool to register new sensor IDs, but do not require driving the vehicle*	84%	$38
Updating the software on a direct system*	78%	$49
Replacing the onboard dash lights, direct TPMS	68%	$81
One stem-mounted sensor, direct TPMS	100%	$96
One rim-mounted sensor, direct TPMS	98%	$99
Replacing the on-board electrical wiring, direct TPMS	63%	$132
Replacing the on-board processing unit, direct TPMS	65%	$293
Replacing the on-board receiver hardware, direct TPMS	66%	$325
Indirect TPMS		
Recalibrations of indirect TPMS systems that require pushing buttons or using the vehicle control panel to update the tire pressures, but do not require driving the vehicle*	86%	$17
Recalibrations of indirect TPMS systems that require the use of magnets to update the tire pressures, but do not require driving the vehicle*	66%	$18
Auto-relearn recalibrations of indirect TPMS systems, which do not require tools but do require driving the vehicle to register new sensor IDs*	100%	$18
Updating the software on an indirect system*	77%	$57
Replacing the dash lights, indirect TPMS	65%	$83
Replacing the electrical wiring, indirect TPMS		$125
One chassis-mounted sensor (such as a wheel speed sensor), indirect TPMS	93%	$145
Replacing the on-board receiver hardware, indirect TPMS	67%	$250
Replacing the on-board processing unit, indirect TPMS	64%	$280
*Some respondents reported price of zero. Zeroes are included in median price. Source: NHTSA TPMS-ORRC, Repair Facilities Survey		

[41] Repair Facilities Survey [PRICED_xxx], [PRICEI_xxx]

9.3 Data Synthesis

Key points extracted from the results of this section were:

- When drivers estimated the cost of repair at $50 to 99 and the repair was for sensors, it is not clear whether the cost estimates included four sensors or just one. Per repair facilities, about $99 would be a cost for one sensor replacement, so doing four at once could approach $400 (9a, 9d).
- Replacing the on-board hardware or processing unit had considerably high expense with costs up to $325, but this is still less than four sensors at almost $400 (Table 9-1). From Section 8, replacing the on-board hardware or processing unit were infrequently mentioned as needed repairs.
- Recalibrations and resets were the least expensive service and sometimes were cited as zero cost, apparently being complimentary or part of another service (Table 9-1). Recalibrations or resets should not involve replacing any parts.

9.4 Implications

Direct TPMS tire pressure sensors have been identified as the most frequently needed repair for direct TPMS. Following recommendations to replace four sensors when the first one fails would give a cost of around $400 in 2016 dollars. Section 10 will look at how drivers react to TPMS malfunctions and repair costs.

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10. Driver Acceptance of TPMS and Reaction to Malfunction

10.1 Topic Background

Driver acceptance of TPMS can be seen as general receptiveness to having the system in the vehicle and using it, while willingness to pay for system maintenance may point to a higher degree of acceptance. Acceptance can be seen as degraded when drivers decline to repair the system or seek to disable it. Research questions proposed for this topic included: What is drivers' acceptance of the TPMS? Do owners repair TPMS, and if not, why not? How often and for what reasons are TPMS disabled?

Malfunction recommendations. FMVSS No. 138 requires owners' manuals to describe the malfunction telltale and lists some reason that TPMS may malfunction. Owner manuals typically instruct owners to seek service if a malfunction warning appears. From an example manual:

> Driver display: The TPMS will not function properly if one or more of the TPMS sensors are missing or inoperable. When the system detects a malfunction, the low tire pressure warning light, defined above, flashes for about one minute and then stays on for the remainder of the ignition cycle. … If the TPMS is not functioning properly, it cannot detect or signal a low tire pressure condition. See your dealer for service if the TPMS malfunction light and DIC message, if equipped, come on and stay on. (Buick, p. 246)

Make inoperative. The "make inoperative" provision of the Motor Vehicle Safety Act (49 USC 30122[b]) states:

> a manufacturer, distributor, dealer, or motor vehicle repair business may not knowingly make inoperative any part of a device or element of design installed on or in a motor vehicle or motor vehicle equipment in compliance with an applicable motor vehicle safety standard prescribed under this chapter unless the manufacturer, distributor, dealer, or repair business reasonably believes the vehicle or equipment will not be used (except for testing or a similar purpose during maintenance or repair) when the device or element is inoperative.

In a 2011 response to an inquiry from the Tire Industry Association, NHTSA issued clarifications about the "make inoperative" provision as applied to TPMS, including:

> According to NHTSA, if the pressure sensor was inoperative before the customer presented the vehicle to the retailer, "a motor vehicle repair business would not be violating 49 USC 30122(b) by removing an inoperative or damaged TPMS sensor and replacing it with a standard snap-in rubber valve stem…However, a motor vehicle repair business that goes on to make any other element of the TPMS system inoperative, for example, by disabling the malfunction indicator lamp, would violate the "make inoperative" provision. (Consolacion, 2012)

Another industry article interprets the "make inoperative" provision to its users as "If you turn off the light without fixing the issue, you are violating the NHTSA's "make inoperative" provision, which then leaves shops legally responsible for disabling the TPMS." (Gruenzner, 2017)

In the Repair Facilities Survey, facilities were asked about driver requests to disable a malfunctioning TPMS or leave it unrepaired. Having a driver request does not imply the facility fulfilled the request. Per the “make inoperative” provision, service facilities presumably would not fulfill requests to disable the TPMS.

10.2 Data Analysis

TPMS-ORRC areas addressing TPMS acceptance included a question about TPMS preference for a next vehicle and questions in the Field Survey and Repair Facilities Survey about driver reaction and follow-up to TPMS malfunction. Field Survey drivers with a current malfunction light entered an extended interview including Module MALFUNCTION #1.

Relevant results included:

10a. In 2018, about 88 percent of drivers with TPMS said they’d strongly or somewhat prefer to have a TPMS on their next vehicle, less than 3 percent would prefer somewhat or strongly not to have it, and 8 percent were neutral or didn’t know.[42]

10b. The dashboard check found 0.5 percent of vehicles had an unclear TPMS status or no TPMS light in the ON position, two conditions that could reflect disabled TPMS. When asked, none of the involved drivers responded that the TPMS had been disabled.[43]

10c. About one percent of vehicles were observed to have some obstruction such as tape on the dashboard, but these vehicles were recorded as having a valid TPMS operational status, so the obstruction presumably was not blocking the TPMS light.[44]

10d. For drivers with a current TPMS malfunction warning who were aware that a TPMS light was on, 96 percent said the light had been on more than a week, 68 percent more than a month, and 24 percent more than a year.[45]

10e. About 56 percent of drivers with a current malfunction light who were aware of it said they planned to correct the malfunction, 37 percent did not plan to correct it, and 7 percent were undecided. About 36 percent had priced the work that would correct it.[46]

10f. About 42 percent of drivers who did not plan to correct a current malfunction said their reason was cost. Other reasons were that TPMS is a luxury and not needed for vehicle operation (22%), the State does not require the TPMS to be working (19%), the driver will be selling or getting rid of car soon (6%), the driver is not sure the indicator is accurate (2%), and it is too inconvenient or just a nuisance (9%).[47]

10g. About 91 percent of drivers with TPMS who have never had a TPMS malfunction said that if they did, they would have it repaired or repair it themselves. Eight percent would take some other unspecified action or didn't know. One percent said they'd disable the system and under one percent said they'd do nothing. Of those who said they'd fix it,

[42] Field Survey, Module INTRO [NEXTVEH]
[43] Field Survey, Inspection Module 2 [TPMSMALF], Module INTRO [DISABLE2]
[44] Field Survey, Inspection Module 2 [TPMSTAPE]
[45] Field Survey, Module MALFUNCTION #1 [MALF1AW2]
[46] Field Survey, Module MALFUNCTION #1 [MALFIX4], [MALCOST1A]
[47] Field Survey, Module MALFUNCTION #1 [MALFIX6]

about 91 percent said they'd try to fix it as soon as possible, 6 percent would let the timing depend on cost, and 3 percent would wait for the next scheduled maintenance.[48]

10h. Willingness to pay for a TPMS repair, as collected in Field Survey extended interviews, is shown in Figure 10-1. About 5 percent of drivers with TPMS said they would not be willing to pay anything to repair a TPMS, 55 percent said the most they'd be willing to pay would be between $1 and $99, 15 percent would pay between $100 and $299, 2 percent were willing to pay more than $300, and 22 percent were not sure.[49] (A comparison by vehicle age groups did not find statistically significant differences. Since almost zero percent of drivers overall were willing to pay more than $300 dollars, this was also true of drivers in newer or older vehicles.)

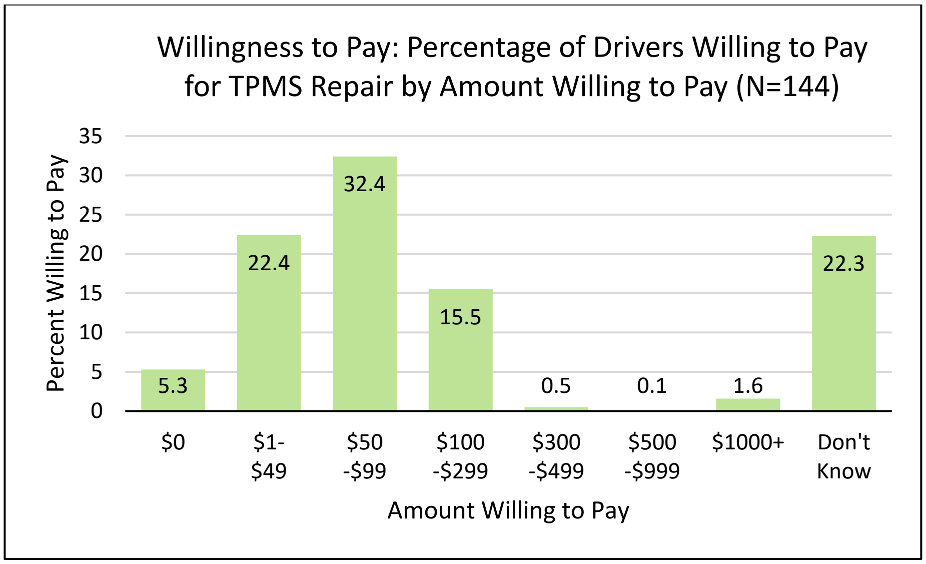

Figure 10-1. Percentage of Drivers Willing to Pay for TPMS Repair by Amount Willing to Pay

10i. About 65 percent of repair facilities reported having seen disabled direct TPMS infrequently or never in the last 90 days (for indirect, 78%).[50]

10j. When repair facilities were asked how often drivers with a malfunctioning direct TPMS in the last 90 days had asked for it to be disabled or left unrepaired, 70 percent reported having such requests to some degree, and 30 percent said never. For a malfunctioning indirect TPMS, 60 percent reported requests of that nature to some degree, and 40 percent said never.[51]

10k. Repair facilities reported that when vehicle owners who came in with a malfunctioning TPMS asked for it to be disabled or left unrepaired, the most common reason they gave was "It costs too much" (73% for those with direct TPMS and 66% for those with indirect). Other reasons were "It isn't necessary for the operation of the vehicle" (15% direct, 17% indirect) and "it's not accurate or reliable" (9% direct, 10% indirect).[52]

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48 Field Survey [HYPMAL2], [HYPMAL3]
49 Field Survey [PAYFIX2], Repair Facilities Survey [MALSRCD/I],[MALSRVCD/I]
50 Repair Facilities Survey [DISABLED], [DISABLEI]
51 Repair Facilities Survey [ASKDISABD1], [ASKDISABI1]
52 Repair Facilities Survey [ASKDISABD2], [ASKDISABI2]

10l. Of drivers who were not experiencing a current malfunction but recalled a past malfunction, about 84 percent said they took some action to correct it. About 16 percent of these drivers said the needed action was to repair or replace sensors or another component, 6 percent said recalibration, and 72 percent fell into "repairs other than above," "other repairs, specifics unknown," or "other."[53] Overall, about 20 percent of drivers not experiencing a current malfunction reported a past malfunction, ranging from 18 percent for vehicles up to 4 years old to 21-23 percent for vehicles from 5 to 13 years old as listed in Table 10-1. [54]

Table 10-1. Percentage of Drivers Reporting Past TPMS Malfunction, 2018

Vehicle age group	Percentage of drivers reporting past malfunction (95% CI)
0-4 years	18% (9,32)
5-7 years	21% (14,31)
8-10 years	23% (16,31)
11-13 years	23% (13,39)

Source: NHTSA TPMS-ORRC, Field Survey

10m. In 2010/2011, about 23 percent of drivers with TPMS (vehicles up to 7 years old at the time of the survey) said they had experienced a TPMS malfunction light in the past. Of those, 92 percent said they took some sort of action.[55]

10.3 Data Synthesis

Key conclusions drawn from the above data points were:

- Most drivers appear to like the idea of TPMS in general, as evidenced by preference to have it on another vehicle and lack of trying to cover the icon or disable the system (10a,10b,10c). Most drivers say they would repair a hypothetical TPMS malfunction when cost is not proposed (10g).
- Although responses showed drivers accepting the TPMS in general, drivers with a current TPMS malfunction aren't enthused about repairing it, as evidenced by the amount of time the light had been on - at least a week for almost all, and at least a year for a quarter (10e). Repair facilities also noted owner reticence to repair a TPMS malfunction (10j). Drivers with current malfunctions and repair facilities that have had owners request to leave TPMS unrepaired cited cost as the top reason. Another reason widely mentioned is TPMS is not required for operation of the vehicle (10f,10k).
- Disabling TPMS does not appear to be common. Few vehicles had dashboard results that might reflect disabled TPMS (10b). It was not attested to by the few drivers who had those results. Repair facilities reported seeing disabled TPMS infrequently (10i) but noted getting some requests to disable a malfunctioning TPMS or leave it unrepaired (10k). The "Make Inoperative" provision should prevent service facilities from disabling TPMS, so disabling would have to be done by the owner or another individual.

[53] Field Survey, Module PAST MALFUNCTION#1 [LASTACT2]
[54] Field Survey, Module PAST MALFUNCTION#1 [MALEVER]
[55] TPMS-SS [MALFACTIONID], [MALFEVERONID]

- **Willingness to pay.** Driver willingness to pay for TPMS repair was usually low to moderate, and rarely high (10h). The economic concept "willingness to pay," according to the Harvard Business School, is

  > the maximum price a customer is willing to pay for a product or service. It's typically represented by a dollar figure or, in some cases, a price range. … While potential customers are likely willing to pay less than this threshold, it's important to understand that, in most cases, they won't pay a higher price. … When a customer has an urgent need that your product or service can address, they may be willing to pay a higher price than when their need is less urgent (Stobierski, 2020).

  The most cited repair for TPMS was new sensors as seen in Section 8. Sensors have a limited lifespan (Section 8), and maintenance websites suggest replacing all sensors when one goes bad (Section 9). The cost of parts and labor for installing four new sensors was estimated by repair facilities to be about $400 (Section 9), but only about two percent of drivers with TPMS expressed willingness to pay $300 or more to repair a TPMS (10h). Drivers with current malfunctions who do not intend to repair it, and repair facilities that have had owner requests to leave TPMS unrepaired, both cited cost as the top reason. Another reason widely mentioned is TPMS is not required for operation of the vehicle (10f,10k). Per the Harvard citation above, perceiving a need as less urgent can decrease willingness to pay.

- Some drivers who hesitate to repair TPMS due to cost may eventually repair it anyway. This is evidenced by recalled past malfunctions being repaired at a higher percentage (84%) than the percentage of drivers with a current malfunction who said they would fix it or weren't sure (63%) while the percentage who said they would repair a hypothetical malfunction was 91 percent. However, drivers with past malfunctions who had them quickly repaired may have different willingness to pay or ability to pay than the drivers who were driving with a current malfunction warning, most of whom (96%) had the warning for at least a week (10l, 10d).

- Percentages of past malfunctions (Table 10-1) may seem high compared to the finding of overall current malfunctions at 4 percent, but vehicles with current malfunctions do not cover all malfunctions that occurred and got repaired, which may help explain the difference.

- Since repairs conducted for a past malfunction were often categorized as unknown, and the knowledge of what a TPMS malfunction warning light means has been seen to be low (Section 6), it is possible that some of the reported past malfunctions were mistakenly recalled low-pressure incidents. However, taking the vehicles in for service should confirm what the light was, so drivers reporting a past malfunction that was serviced may have a more accurate understanding of the malfunction warning than drivers with a current unresolved malfunction or drivers who put air in their tires and thought it was curing a malfunction (10l).

- Findings from 2010/2011 and 2018 showed the percentage of drivers correcting past TPMS malfunctions to be high, with 84 percent in 2018 and 92 percent in 2010/2011 (10l, 10m).

Limitations. One limitation for data on this topic was that some repair facility questions asked about owner requests to either disable a malfunctioning TPMS or to leave it unrepaired, so responses on those questions could be about either. Another was that some repair facility questions asked if situations had been seen in the last 90 days on a scale of [never, 2,3,4, almost always], which different respondents could interpret in different ways and does not convert to a percentage of vehicles. Another was that disabled TPMS could be underestimated in the Field Survey if drivers with disabled TPMS felt uncomfortable with the survey and declined to be surveyed, or if surveyed drivers with disabled TPMS did not want to say that the TPMS had been disabled. (This would not be a problem in the repair facilities survey, where the respondents were facility representatives rather than drivers. Also, the "make inoperative" provision should preclude service facilities from disabling a TPMS, so instances of disabling would have to have been done by the driver or another individual.) A limitation on "willingness to pay" is that it was hypothetical and could go higher when a driver is faced with a need to repair.

10.4 Implications

The findings indicate that drivers perceive value in TPMS as a general concept. However, cost of repair becomes an issue when a TPMS malfunctions. Many drivers with current malfunctions were not enthusiastic to repair it and cited the cost as the main reason. The most common repair for direct TPMS, new tire pressure sensors, is estimated at around $400 for four, but only about two percent of drivers said they'd be willing to spend more than $300 to repair a malfunctioning TPMS (note again that these costs are from 2016 to 2018 surveys and subject to inflation). Drivers also noted that TPMS is not required to operate the vehicle, which may reduce willingness to pay. Differences between responses to past malfunction and current malfunctions may show that a certain set of drivers is willing to repair TPMS and another set is not willing. Behavioral research could look more closely at differences in driver attitudes about tire pressure and TPMS.

11. Indirect TPMS

11.1 Topic Background

Most findings in preceding sections were dominated by direct TPMS because it is the more prevalent TPMS type in the applicable fleet. The share of indirect TPMS in the U.S. fleet has been small but growing. Table 11-1 shows the proportion of indirect TPMS in nationwide registrations in calendar year 2018 for vehicles compliant to FMVSS No. 138 by model year groups. Sample sizes achieved for the 2018 Field Survey are also shown. As seen in the table, the sample proportions of indirect TPMS by model year group closely tracked the vehicle population but left smaller sample sizes for analysis.[56]

Table 11-1. Indirect TPMS Fleet Portion and Sample Sizes by Model Year Group, TPMS-ORRC

Model Year	Vehicle Age at Survey	Indirect TPMS Fleet Share at Survey*	Sample Size, Indirect TPMS	Sample Size, Direct TPMS	Indirect TPMS Sample Share, Unweighted
2006-2008	11-13 yrs	0%	0	517	0.0%
2009-2011	8-10 yrs	1.0%	5	912	0.5%
2012-2013	6-7 yrs	4.9%	50	875	5.4%
2014-2015	4-5 yrs	10.8%	103	956	9.7%
2016-2019	0-3 yrs	12.7%	134	925	12.7%
Overall	0-13 yrs	7.3%	292**	4185	6.5%

*Fleet of FMVSS No. 138-compliant vehicles. Does not include some earlier versions of indirect TPMS.
Sources:
Registration data: 2018 National Vehicle Population Profile, IHS Markit Co.
TPMS type by model and model year: NHTSA Office of Vehicle Safety Compliance
TPMS survey data: NHTSA TPMS-ORRC Field Survey, 2018
**Five of these entered the survey as direct TPMS but were later found to be indirect TPMS.

As mentioned in Section 2, indirect TPMS does not sense the actual tire pressures; rather, it derives its conclusion from other inputs. For indirect TPMS, the terms “calibrate,” “recalibrate,” “reset,” “store tire pressure,” or others, are used to mean the process where the system learns the current inputs to the TPMS and sets them as the baseline. To give correct TPMS warnings, indirect TPMS must be recalibrated after tire maintenance activities such as adjusting pressure or rotating tires. Calibrating an indirect TPMS usually involves some combination of pressing a button or a touch screen menu option and driving at a certain speed for a certain time. If indirect TPMS is not calibrated after a tire activity, including the driver adding air, the system may have incorrect baseline values. NHTSA noted during the rulemaking process that a reset button might invite human error, such as recalibrating instead of adjusting tire pressure to clear a low-pressure telltale or calibrating when tires are underinflated, but not underinflated enough to trigger the TPMS telltale (FMVSS 138).

Indirect TPMS was targeted in the research topics because of the calibration issues described above and implied in the language of the FAST Act (Section 1). Research questions proposed for this topic included: Do drivers of vehicles with indirect TPMS have knowledge and experience with recalibrating the system?

[56] As noted in Section 3.1.1, the 2018 Field Survey tried to oversample indirect TPMS by approaching any vehicle make known to use indirect TPMS off the focal island, but the proportion of indirect TPMS in the sample was not much different than in the population.

11.2 Data Analysis

The extended interview survey module for drivers of vehicles with indirect TPMS (module INDIRECT) asked several questions about calibration. Key results were:

11a. About 40 percent of drivers with indirect TPMS knew that their TPMS had to be recalibrated on occasion.[57]

11b. Of those who knew recalibration had to be done, 70 percent knew they could do it themselves.[58]

11c. Of those who knew they could do the recalibration themselves, 83 percent said they knew how to do it; of those, 80 percent said they had done it in the past.[59]

11d. The most common reason for recalibrating indirect TPMS was after checking pressure or adding air to tires (52%); other reasons were after tire replacement or rotation (34%) and the TPMS warning light was on (15%).[60]

11e. About 43 percent of all drivers with indirect TPMS said that when the system or tires were serviced, the facility recalibrated the TPMS, while 42 percent did not know.[61]

TPMS detection check. To look at possible indications of incorrect calibration in indirect TPMS, the survey added a check for vehicles with working indirect TPMS to measure each tire's pressure and temperature. The recommended tire pressure was also recorded from the vehicle placard. The results allow a check of telltale status by true pressure. Tire pressure, temperature, and recording of recommended pressure were achieved for all four tires in 135 vehicles with indirect TPMS. (Appendix O shows the procedure for the measurements and calculations.)

The measured pressure and telltale status were statistically associated (F=15.3(1,16), p=.0012). An association would be expected since the telltale presence should depend on the system inputs.

To describe the possible outcomes of the checks in an intuitive way, terminology borrowed from the field of Signal Detection Theory (for example, Hanover, n.d.) was helpful, as follows: if measured pressure in at least one tire is at least 25 percent under recommended pressure (the threshold for FMVSS No. 138), and the low-pressure telltale is illuminated, the situation is called a "hit" (true positive) and if the telltale is not illuminated, a "miss" (false negative). When no tires meet the threshold of warning and the low-pressure telltale illuminates, the situation is called a "false alarm" (false positive), and if it is not illuminated, it is a "correct rejection" (true negative). The percentage results from the check are shown as table cells with 95 percent confidence intervals in Table 11-2. The overall agreement rate from the check was (hit + correct rejection cell percentages) = 5.3 + 85.5 = 90.8 percent. The overall disagreement rate was (false alarm + miss cell percentages) = 4.8 + 4.4 = 9.2 percent. The difference of the disagreement cells was (false alarm cell – miss cell) = 4.8 – 4.4 = 0.4 percent, a very small difference showing no special tendency toward one kind of disagreement over the other.

[57] Field Survey, Module INDIRECT [IND_RECB]
[58] Field Survey, Module INDIRECT [IND_AWARE]
[59] Field Survey, Module INDIRECT [IND_KNOW]
[60] Field Survey, Module INDIRECT [IND_RCBY]
[61] Field Survey, Module INDIRECT [IND_SVC]

Table 11-2. TPMS Dash Status by Tire Pressure, Indirect TPMS, Percentages (95% CI)

TPMS Detection by Measured Tire Pressure in Indirect TPMS (*n*=135)		**Measured Tire Pressure Status***		
		Tire pressure is low	**Tire pressure is not low**	**Total**
TPMS Dashboard Status	Low-pressure telltale is illuminated.	**Hits** 5.3% (2.1,12.9)	**False Alarms** 4.8% (2.1,10.8)	9.7% (5.7,15.8)
	Low-pressure telltale is not illuminated.	**Misses** 4.4% (1.7,10.7)	**Correct Rejections** 85.5% (77.4,91.0)	90.3% (84.2,94.2)
	Total	10.1% (5.6,17.6)	90.3% (84.2,94.2)	100

Source: NHTSA, TPMS-ORRC Field Survey, 2018

*defined as low if at least one tire is 25% below recommended pressure (adjusted for temperature).

Other considerations for the tire pressure check. Recommendations often say to take tire pressure when the tires have not been driven on for at least three hours ("cold pressure") (NHTSA, n.d. -a), but the survey by its design was taking pressure for vehicles that had been driven to the station. The tire temperature adjustment should make up for this difference. A check found that if the temperature adjustment is ignored, most cases did not change detection status. Another check found that mean ambient temperature ranged from 66 to 73 in the cells, and the mean temperature differences were not found to be statistically significant, so influence of ambient temperatures should not be a factor. It is also not clear whether temperature is even a factor in indirect TPMS, since the detection is not based on tire pressure sensors.

As with any measurement, chance measurement error could occur. The survey had practices in place to avert measurement error, such as using high-quality pressure gauges and pyrometers and having detailed training and practice for data collectors. Data checks did not find any obvious outliers or unusual PSUs that could indicate data collection anomalies.

Summary and limitations. In these results, indirect TPMS detection accuracy was about 91 percent and in the other 9 percent, false negatives and false positives were about equally likely. Although calibration could be involved, it is not possible to definitively pinpoint the cause of these discrepancies. For instance, the data cannot tell us whether a system was correctly calibrated at the time of the check. It can take driving some miles before a telltale correctly goes off after calibrating, or correctly comes on after pressure reaches the threshold for a warning, situations that also cannot be known from the data. Another limitation is that the results are from a sample size of 135, much smaller than the full sample, leading to wider confidence intervals, allowing for potentially influential cases, and restricting additional breakouts.[62] A control group for comparison, such as direct TPMS vehicles or indirect TPMS vehicles known to be correctly calibrated, was also not available to help assess the results. For these reasons, caution may be warranted in interpreting Table 11-2.

[62] For example, survey responses within Hit, Miss, and False Alarm cells are not broken down by other factors because their cell size did not meet the denominator threshold of 30 mentioned in Section 1.5. If the cell percentages of about 5 percent in the Hit, Miss and False Alarm cells hold, then having at least 30 in each cell would require a sample size of 30/.05=600 vehicles with indirect TPMS getting complete needed measurements (only about half of the indirect TPMS vehicles in the Field Survey achieved complete needed measurements).

11.3 Data Synthesis

Conclusions about indirect TPMS issues extracted from this and other sections were:

- Knowledge and experience with indirect TPMS recalibration appear to be low. In Section 6, drivers with indirect TPMS appeared to have somewhat better knowledge about TPMS reset than drivers with direct TPMS, but knowledge was still low with almost 60 percent of drivers with indirect TPMS saying they do not know how to reset it. A similar result is seen in this section, with 60 percent of drivers with indirect TPMS not knowing it must be recalibrated on occasion (11a). Some drivers know the driver can recalibrate the TPMS but don't know how to do it (11b). Based on bullets 11a to 11c, the estimated proportion of drivers with indirect TPMS who have ever recalibrated their systems is .40*.70*.83*.80 = 19 percent.
- An issue may exist if drivers with indirect TPMS do not recalibrate their systems correctly after adding air. This could result in incorrect stored baseline settings. Based on check results, about 9 percent of vehicles with indirect TPMS may have an incorrect warning or lack of warning for low pressure (Table 11-2).
- An issue may exist if drivers with indirect TPMS recalibrate the system to get rid of a low-pressure warning (11d). This could result in incorrect stored baseline settings. The situation was cited by about 15 percent of the 19 percent of drivers who have ever recalibrated, so would be only about 3 percent of all drivers with indirect TPMS, but this is low only because less than 20 percent have ever recalibrated at all. (Drivers who said they recalibrated to make a light go off could also have meant they recalibrated after adding air to make a light go off, although "after adding air" was an available option.)
- Many drivers do not know whether a service facility recalibrates the TPMS after service (11e). This could be a problem if the driver leaves the facility not knowing whether the TPMS is properly calibrated or needs to be recalibrated.
- TPMS operational status for direct and indirect TPMS (regardless of measured pressure) was compared in Figure 3-2 for vehicles up to 7 years old, the only ages with enough indirect TPMS for analysis. The results suggested that TPMS malfunction is rare in newer vehicles of either indirect or direct TPMS, but rates for indirect TPMS appeared to be lower (almost zero). See Section 12.2.1 for an elaboration of Figure 3-2 in which the differences in percentages for low pressure by TPMS type were not found to be statistically significant.

11.4 Implications

Indirect TPMS is growing as a share of the passenger vehicle fleet and was up to almost 13 percent in model year group 2016 to 2019. Lack of driver knowledge and follow-up on recalibrating an indirect TPMS after adding air or other tire maintenance appear to be issues. Driver education for drivers with indirect TPMS could add emphasis to the need to recalibrate and how to do it, either in general outreach or at the point of sale. Further detection checks could be suggested with larger sample sizes as indirect TPMS grows as a share of the population. Such a follow-up would ideally include both indirect and direct TPMS for comparison. Perhaps working with repair facilities that service TPMS could enable a future data collection effort in this area.

12. Related Factors

12.1 Topic Background

In Section 5, surveys from 2001, 2010/2011, and 2018 showed prevalence of on-road vehicles having a TPMS warning light or measured low pressure varying with vehicle age. This section looks at other factors that may be associated. For this section, "TPMS event" means driving with a TPMS malfunction or low-pressure warning and "tire pressure event" means driving with low pressure. Some factors may be related to vehicle age but may be of interest if they point out conditions around vehicle age that relate to the events. Research questions proposed for this topic included: Does tendency to have an unresolved TPMS malfunction or low-pressure warning differ by vehicle age, type, or mileage, or by demographics? Who are the drivers and what are the vehicles more likely to benefit from added attention to tire pressure?

12.2 Data Analysis

Vehicle factors considered included vehicle age, mileage, body type, unusual valve situations, and spare tire situation. Driver factors included driver age, sex, education level, language, home ZIP median income, belief on whether TPMS is required to be working, preference for TPMS, and TPMS knowledge level. Other factors of interest included ambient temperature at the time of the check, whether the vehicle was under warranty, and how long the driver has had the vehicle. The comparisons start with 2018 data, but if similar comparisons are available from the earlier surveys, they are presented for historical perspective.

For 2018 data TPMS operational status [1], [3] and [5] (as translated in Table 3-4) were mapped to the event "TPMS not functional." Status [1], TPMS malfunction indicator, is by far the dominant status in this mapping. The rarely seen statuses [3] and [5] mean that no indication of TPMS was seen in a vehicle known to have been equipped with TPMS, so TPMS is mapped as not functioning properly. Status [2] was mapped to the event "TPMS low-pressure warning" (severe underinflation warning). For either event, the denominator is the full set of vehicles.

Events were coded as zero when the event was not observed and one when it was, allowing the percentage of vehicles with the event to be the mean of the zeroes and ones. This allowed statistical comparisons of means in SAS PROC SURVEYMEANS, which has an option DIFFTEST to make pairwise comparisons of means within domains with a *t*-test for the difference of the means. The option ADJUST=BON (Bonferroni adjustment) was used to adjust the *p*-values by multiplying the original *p*-value for the t-test by the number of pairwise comparisons being tested. For instance, in a comparison variable with four categories, there are six comparisons to make (1-2,1-3,1-4,2-3,2-4,3-4), so the multiplier would be 6.[63] The adjusted *p*-value is still assessed for being below 0.05. The BON adjustment increases the threshold for significance results, so differences noted are more likely to be meaningful, but it also increases the chances that a meaningful difference is not found to be statistically significant.[64] The BON adjustment was applied within the comparison variable, not across all comparisons.

In this section, pairwise comparison test results are presented if the difference in percentages was statistically significant (alpha=.05). No difference in means would give a *t*-statistic of zero, but the *t*-statistic is not simply the difference in percentages, since *t* also involves the standard error

[63] In mathematical notation this is (*n* choose 2) where *n* is the number of categories.
[64] PROC SURVEYFREQ offers a chi-squared test for overall association but does not offer pairwise comparisons.

of the difference. Degrees of freedom (*df*), which contribute to the *t*-statistic's distribution and *p*-value, are, for these tests, the number of PSUs minus the number of strata. The sign of the *t*-statistic comes from subtracting the second listed category's percentage from the first, so it indicates the direction of the significant difference. If a pairwise difference was not statistically significant, the comparison is not shown in the presented table or text. If there are only one or two differences, they may be described in the text rather than a table. Comparisons are done within malfunction or low pressure, not across them.

If any statistically significant differences were found, the full data is shown on a chart for visual assessment. In 2018 charts the result labeled "total" above the column is the sum of malfunction and low-pressure rates. The components of the total are shown as stacked columns The full height of the stacked column corresponds to the total, tracked on the left axis. The tests for differences were conducted for the events, not the totals. Since pairwise comparison tests were done and presented when significant, confidence intervals for percentages are not added.

Comparisons are done within surveys, not across them. Note that when results are from different surveys, they have different universes and data collection methods as detailed in Appendix M, so are shown for historical perspective, but are not appropriate for statistical tests of differences.

12.2.1 Vehicle Age and TPMS Type

Vehicle age. Vehicle age was looked at in Section 3 and Section 5, but the discussion is expanded here. Vehicle age at the time of the survey was derived from the vehicle's model year. In the 2018 survey, vehicles up to 13 years old were surveyed. In the 2010/2011 survey, only vehicles up to 7 years old were surveyed, and in the 2001 survey, vehicles of any age were allowed. For better cell sizes and to match the weighting in the 2018 survey, vehicles were grouped into age groups 0 to 4, 5 to 7, 8 to 10, and 11 to 13 years old.

Table 12-1 shows the categories for which significant differences in event percentages were detected and the accompanying test statistics.

Table 12-1. Significant Differences in Pressure Event Percentages by Vehicle Age

Survey	Domain	Event	Comparison (vehicle age in years)		*t* statistic (*df*)	Adj. *p*-value
2018	With TPMS	TPMS Malfunction	**0-4**	**8-10**	***t*=6.85 (16)**	***p*<.0001**
			0-4	**11-13**	***t*=5.95 (16)**	***p*=.0001**
			5-7	**8-10**	***t*=7.79 (16)**	***p*<.0001**
			5-7	**11-13**	***t*=5.57 (16)**	***p*=.0003**
		TPMS Low Warning	**0-4**	**11-13**	***t*=4.47 (12)**	***p*=.0023**
2010/2011	With TPMS	Low Pressure	**0-4**	**5-7**	***t*=4.90 (12)**	***p*=.0004**
2001	Without TPMS	Low Pressure	**0-4**	**5-7**	***t*=5.49 (12)**	***p*=.0014**
			0-4	**8-10**	***t*=4.42 (12)**	***p*=.0083**
			0-4	**11-13**	***t*=6.51 (12)**	***p*=.0003**
			0-4	**14+**	***t*=11.70 (12)**	***p*<.0001**
			5-7	**14+**	***t*=10.49 (12)**	***p*<.0001**
			8-10	**11-13**	***t*=4.01 (12)**	***p*=.0173**

The event percentage point estimates for each survey are charted in Figure 12-1.

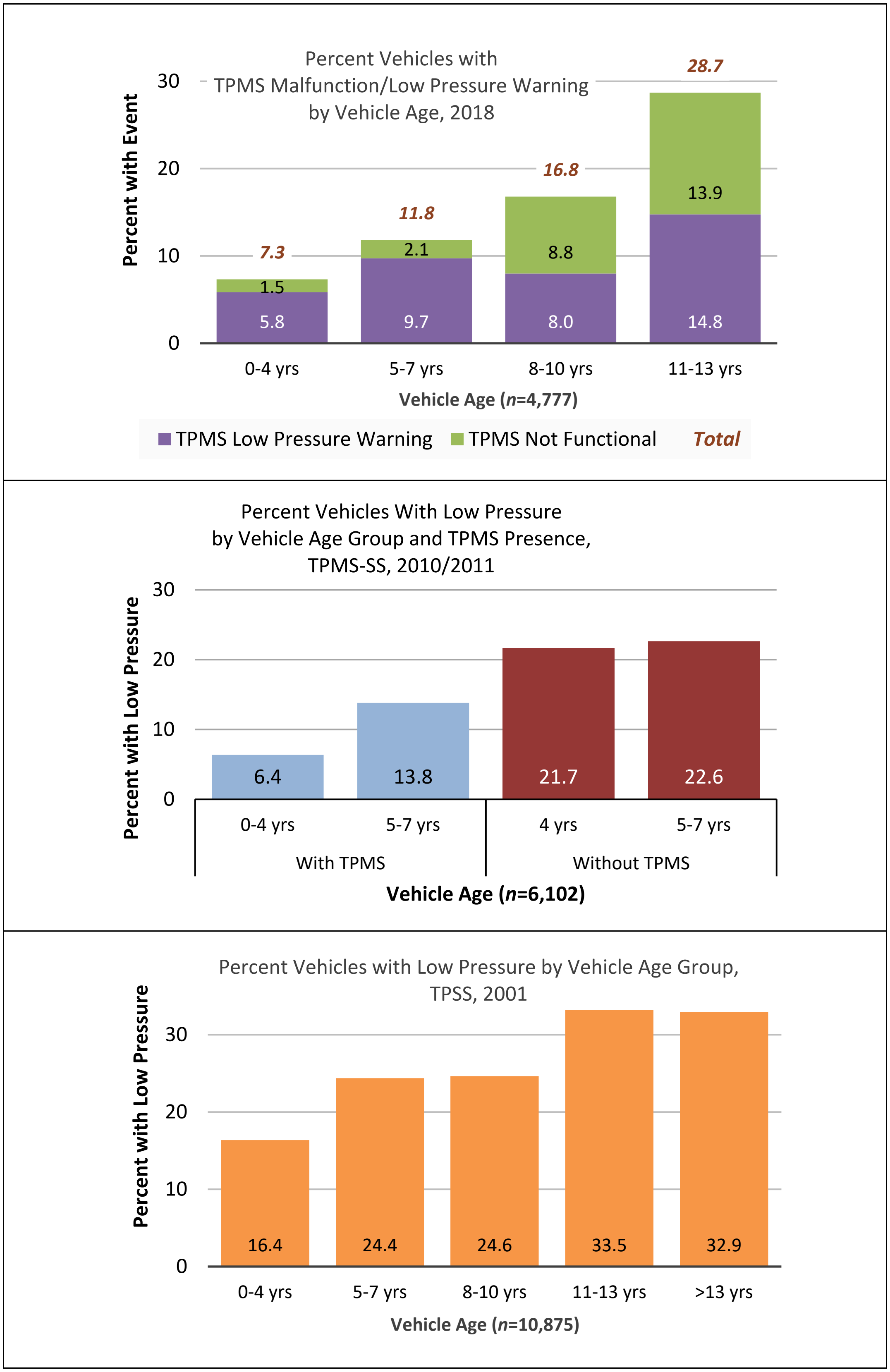


Figure 12-1. Survey Percentages of TPMS or Tire Pressure Events by Vehicle Age

TPMS type. The 2018 results in Figure 12-1 were over both direct and indirect TPMS but were largely dominated by direct TPMS, since indirect TPMS was relatively rare in the population and sample (Table 11-1). Comparing by TPMS type was done with vehicles up to 7 years old, since vehicles 8 and older at the time of the survey had very few indirect TPMS in the sample (*n*=5, Table 11-1). Table 12-2 shows the comparisons that were found to have statistically different percentages and their test statistics. Figure 12-2 shows the chart of the data.

Table 12-2. Significant Differences in Pressure Event Percentages by TPMS Type

Survey	Events	Domain	Category Comparison	*t* statistic (*df*)	Adj. *p*-value
2018	TPMS Malfunction	Vehicles Age 0-4	**Indirect vs. Direct TPMS**	***t*=-3.02 (16)**	***p*=.0492**
		Vehicles Age 5-7	**Indirect vs. Direct TPMS**	***t*=-3.43 (16)**	***p*=.0207**
		Indirect age 0-4 vs. Direct age 5-7		***t*=-3.10 (16)**	***p*=.0416**
		Indirect age 5-7 vs. Direct age 0-4		***t*=-3.75 (16)**	***p*=.0104**

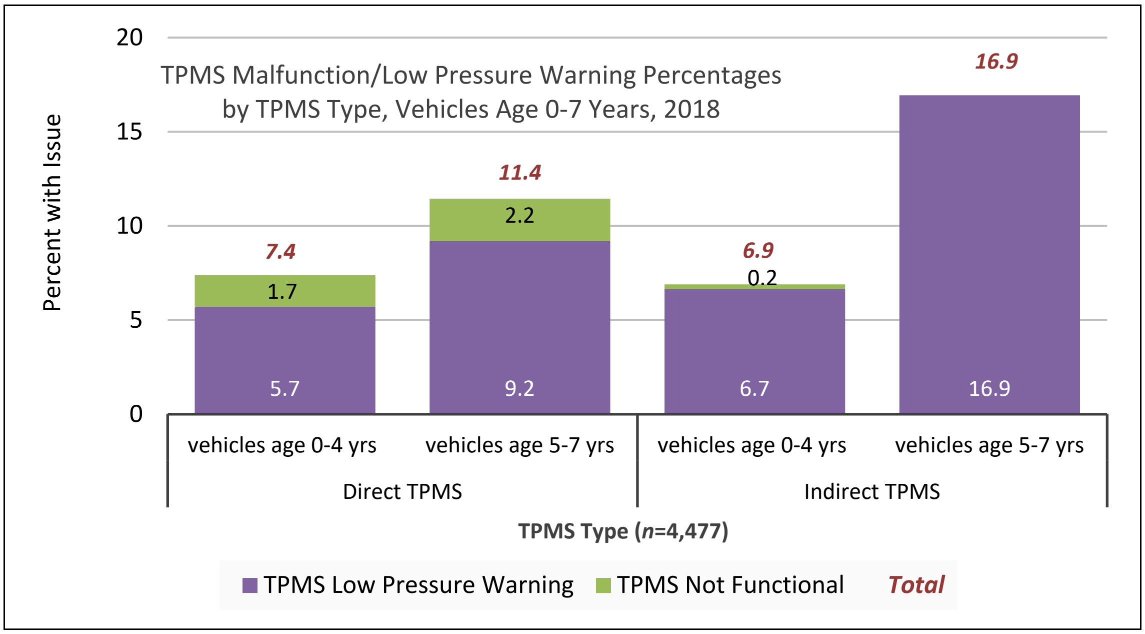


Figure 12-2. Survey Percentages of Tire Pressure Events by TPMS Type

12.2.2 Other Related Factors

For the next factors, analyzing within broader age groups should give a better idea of a factor influence without a strong confounding effect of vehicle age. To do this, vehicles are grouped into domains of vehicles up to 7 years old and vehicles of higher age when possible. At the end of the section, the factors are assessed for association with vehicle age within the age groups. The 2010/2011 data only included vehicles up to 7 years old, but it had vehicles with and without TPMS, so is split by TPMS presence. The 2018 data comparisons in the following results are over indirect and direct TPMS but largely dominated by direct TPMS.

Vehicle mileage. In 2018, TPMS event percentages were significantly different between some mileage groupings in newer vehicles. Differences were not found in the 2011 data. The 2001 survey did not collect mileage. Table 12-3 shows categories where significant differences were detected and test statistics. Figure 12-3 shows the results for 2018 and 2011 by recorded mileage.

Table 12-3. Significant Differences in Pressure Occurrence Percentages by Vehicle Mileage

Survey	Occurrence	Domain	Categories With Significant Difference		*t* statistic (*df*)	Adj. *p*-value
2018	TPMS Malfunction	Vehicles Age 0-7	**3-31,999**	**32,000-62,999**	***t*=-3.15 (16)**	***p*=.0373**
			32,000-62,999	**63,000-99,999**	***t*=-4.23 (16)**	***p*=.0038**
			32,000-62,999	**100,000-299,999**	***t*=-4.03 (16)**	***p*=.0059**
	TPMS Low Warning	Vehicles Age 0-7	**3-31,999**	**100,000-299,999**	***t*=-3.14 (16)**	***p*=.0381**
			63,000-99,999	**100,000-299,999**	***t*=-3.77 (16)**	***p*=.0101**

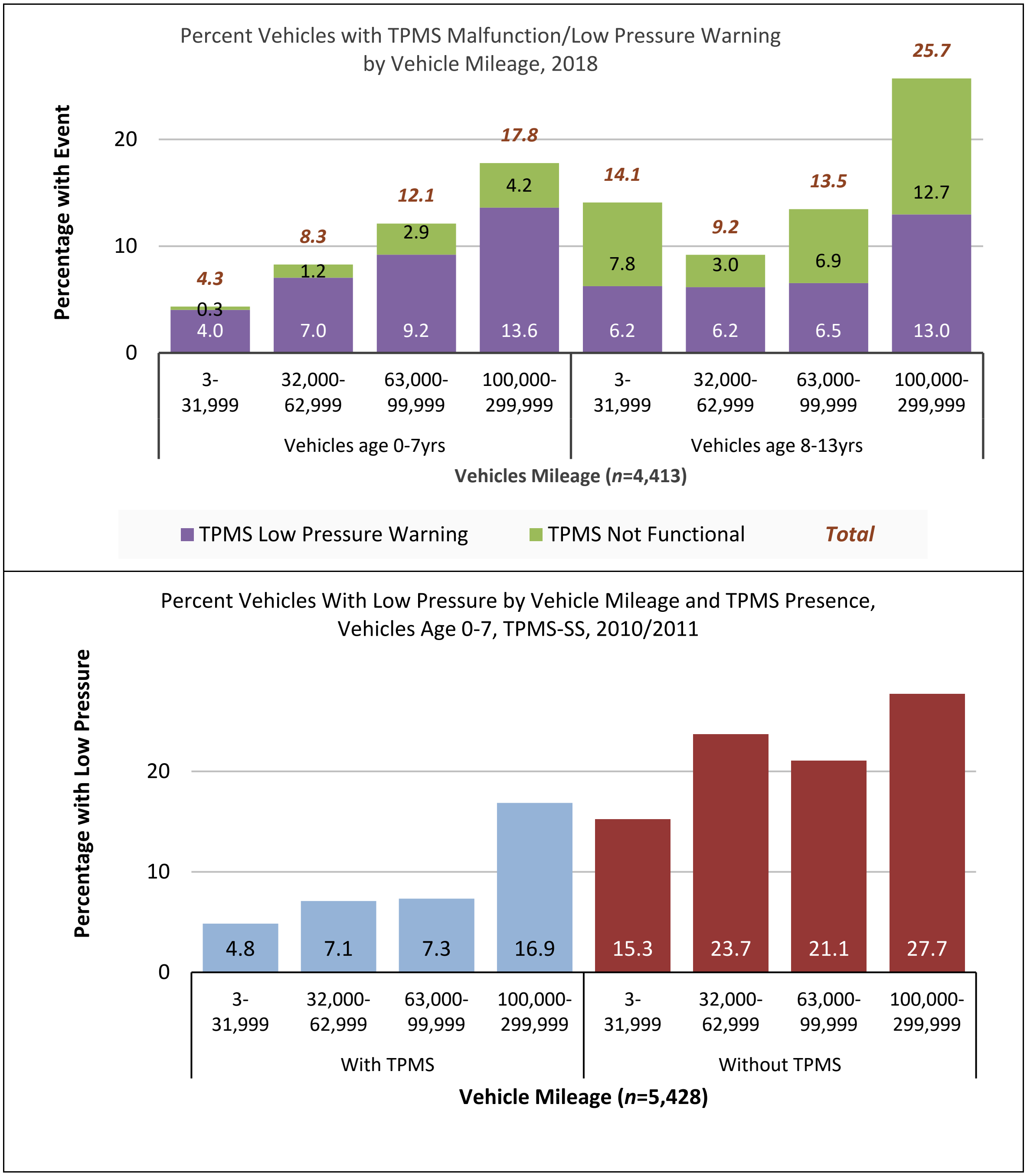


Figure 12-3. Survey Percentages of TPMS or Tire Pressure Events by Vehicle Mileage

Vehicle type. TPMS malfunction in 2018 data did not significantly differ by vehicle type, but underinflation warning percentages were found to be significantly different by vehicle type within newer vehicles (t=-3.16, df=16, adjusted p=.0061). Significant differences by vehicle type were not found in the earlier surveys. Figure 12-4 charts event percentage estimates by vehicle type for the three surveys.

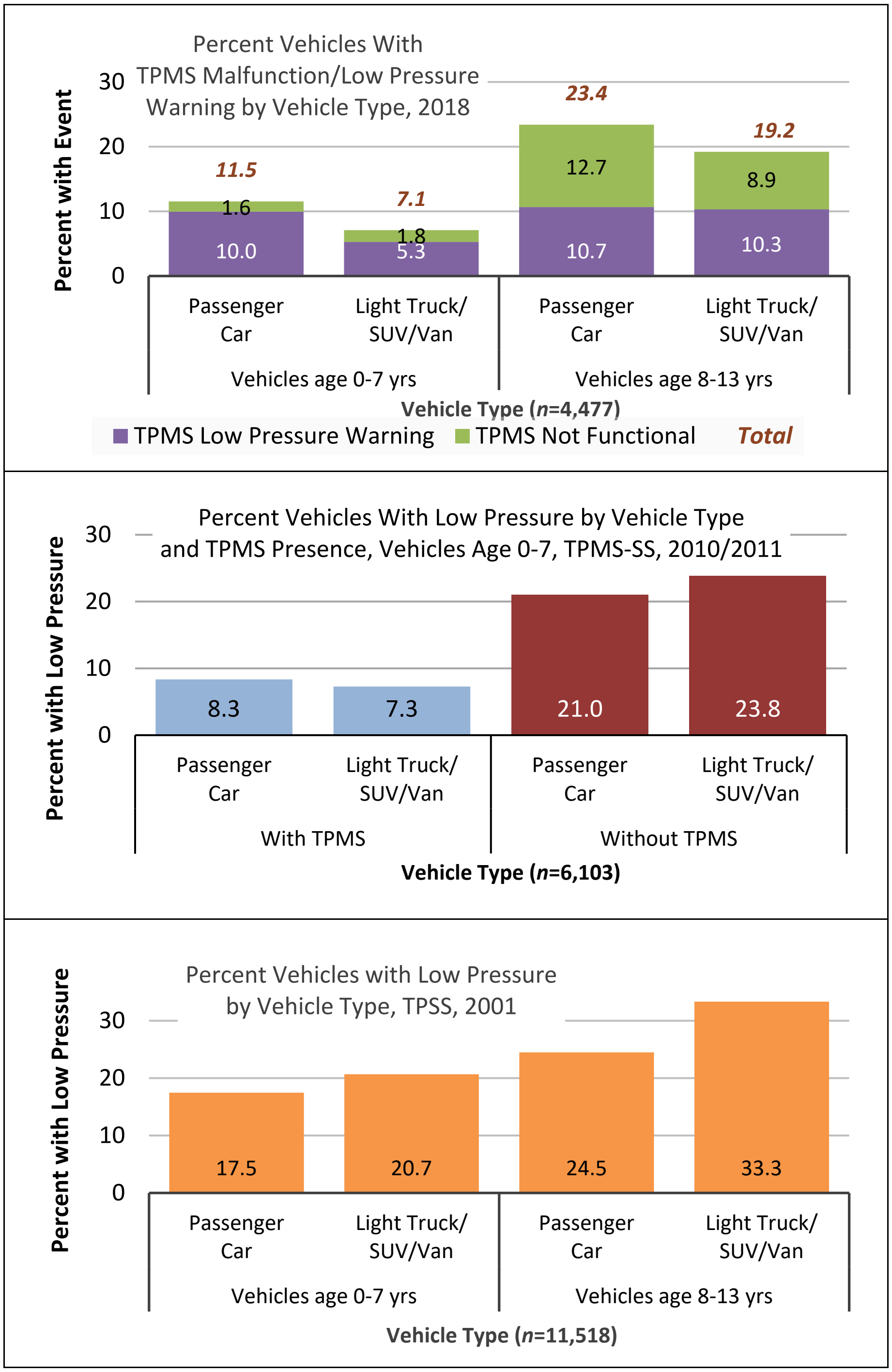


Figure 12-4. Survey Percentages of TPMS or Tire Pressure Events by Vehicle Type

Driver age group. In the 2018 Field Survey, participating drivers were asked to give their ages either as a number or in a group option, but the response was only entered into the group options.

- 25 years old or younger
- 26-44 years old
- 45-64 years old
- 65+ years old

Driver age group was also estimated by data collector observation for all approached vehicles but only into three groups: young adult, adult, and senior adult. For this comparison, 8 cases that were missing in reported age were mapped from observed age for young adult (mapped to 25 or younger) and senior (mapped to over 65). Cases where reported age was missing and observed age was "adult" were not mapped because the adult designation is too vague to assume as 26-44 or 45-64. Those cases are not included in this comparison analysis.

In the 2010/2011 TPMS-SS survey, driver age was asked and recorded as number, not a grouping. For this comparison, the ages are grouped to match the groups in the 2018 survey. In the 2001 TPSS survey, driver age was estimated into three groups by data collector observation only: young adult (16-24), adult (25-69) and senior (70+).

Table 12-4 shows the categories for which significant differences by driver age group were detected and the accompanying test statistics.

Table 12-4. Significant Differences in Pressure Event Percentages by Driver Age

Survey	**Event**	**Domain**	**Categories With Significant Difference**		***t* statistic (*df*)**	**Adjusted *p*-value**
2018	TPMS Malfunction	Veh. age 8-13 yrs.	**26-45**	**65+**	***t*=3.76 (16)**	***p*=.0103**
	TPMS Low Warning	Veh. age up to 7 yrs.	**<=25**	**65+**	***t*=3.72 (16)**	***p*=.0111**
			46-64	**65+**	***t*=3.04 (16)**	***p*=.0471**
		Veh. age 8-13 yrs.	**<=25**	**65+**	***t*=3.87 (16)**	***p*=.0082**
			26-45	**65+**	***t*=5.08 (16)**	***p*=.0007**
			46-64	**65+**	***t*=3.81 (16)**	***p*=.0093**
2010/2011	Low Pressure	With TPMS	**<=25**	**26-45**	***t*=4.61 (12)**	***p*=.0036**
		Without TPMS	**<=25**	**65+**	***t*=3.19 (12)**	***p*=.0468**
			46-64	**65+**	**t=7.64 (12)**	***p*<.0001**

The charts in Figure 12-5 show event percentage estimates by the driver age groups that were available in the three surveys.

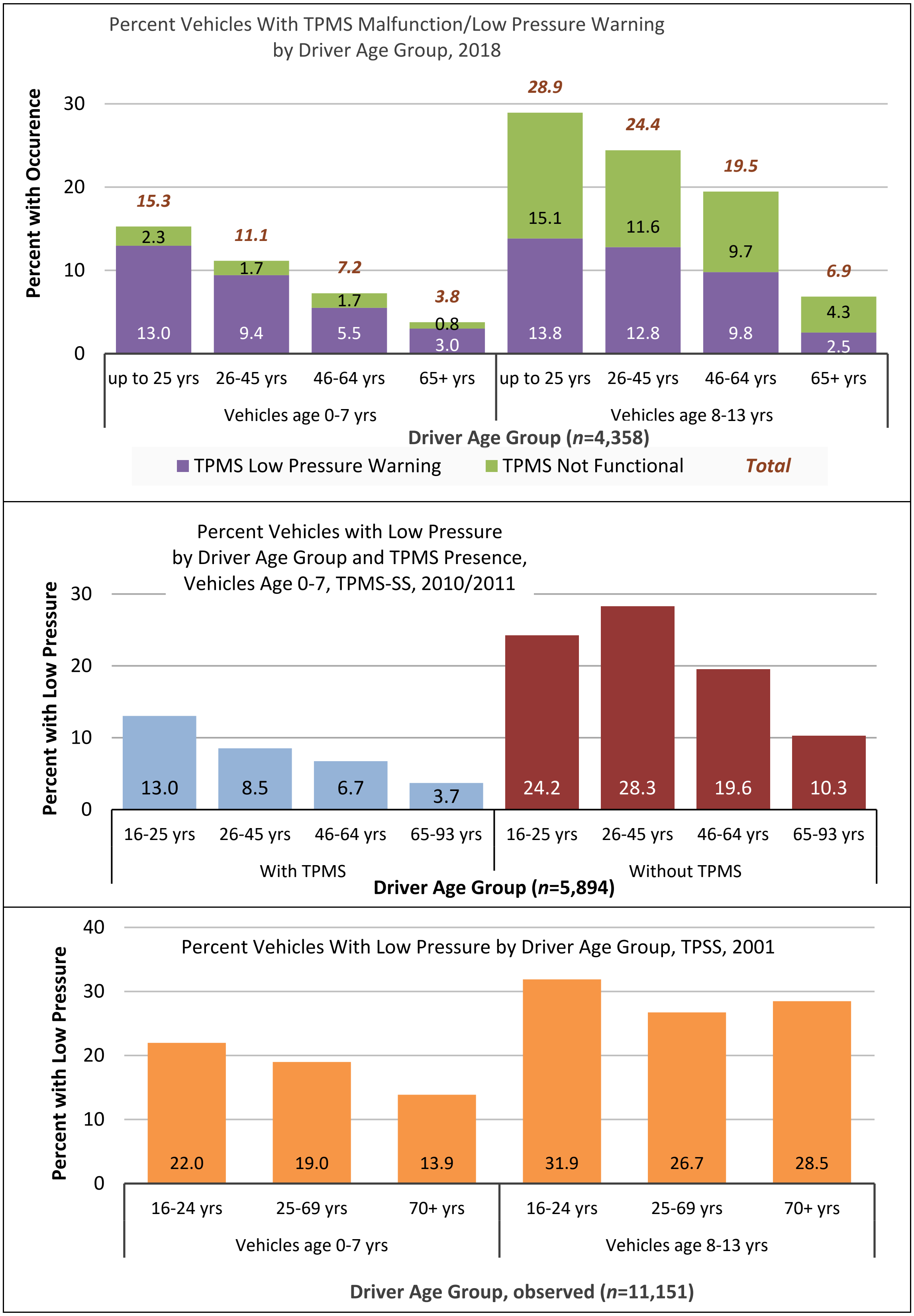


Figure 12-5. Survey Percentages of Tire Pressure Events by Driver Age Group

Driver education level. Drivers in 2018 and 2010/2011 were asked their highest level of education. Some differences were detected between groups for malfunction percentages in the 2018 data. Significant differences were not detected in 2010/2011 data, but the estimates showed a slight direction consistent with 2018. The 2001 survey did not collect education level. Table 12-5 shows the categories for which significant differences were detected and the accompanying test statistics. Figure 12-6 graphs the percentage estimates from the results.

Table 12-5. Significant Differences in Pressure Event Percentages by Driver Education Level

Survey	Event	Domain: Vehicle Age	Categories With Significant Difference		*t* statistic (*df*)	Adjusted *p*-value
2018	TPMS Malfunction	Up to 7 years	**HS or less**	**Bach or Grad**	***t*=5.50 (16)**	***p*=.0001**
		8-13 years	**HS or less**	**Some College**	***t*=3.69 (16)**	***p*=.0059**
			Some College	**Bach or Grad**	***t*=9.83 (16)**	***p*<.0001**

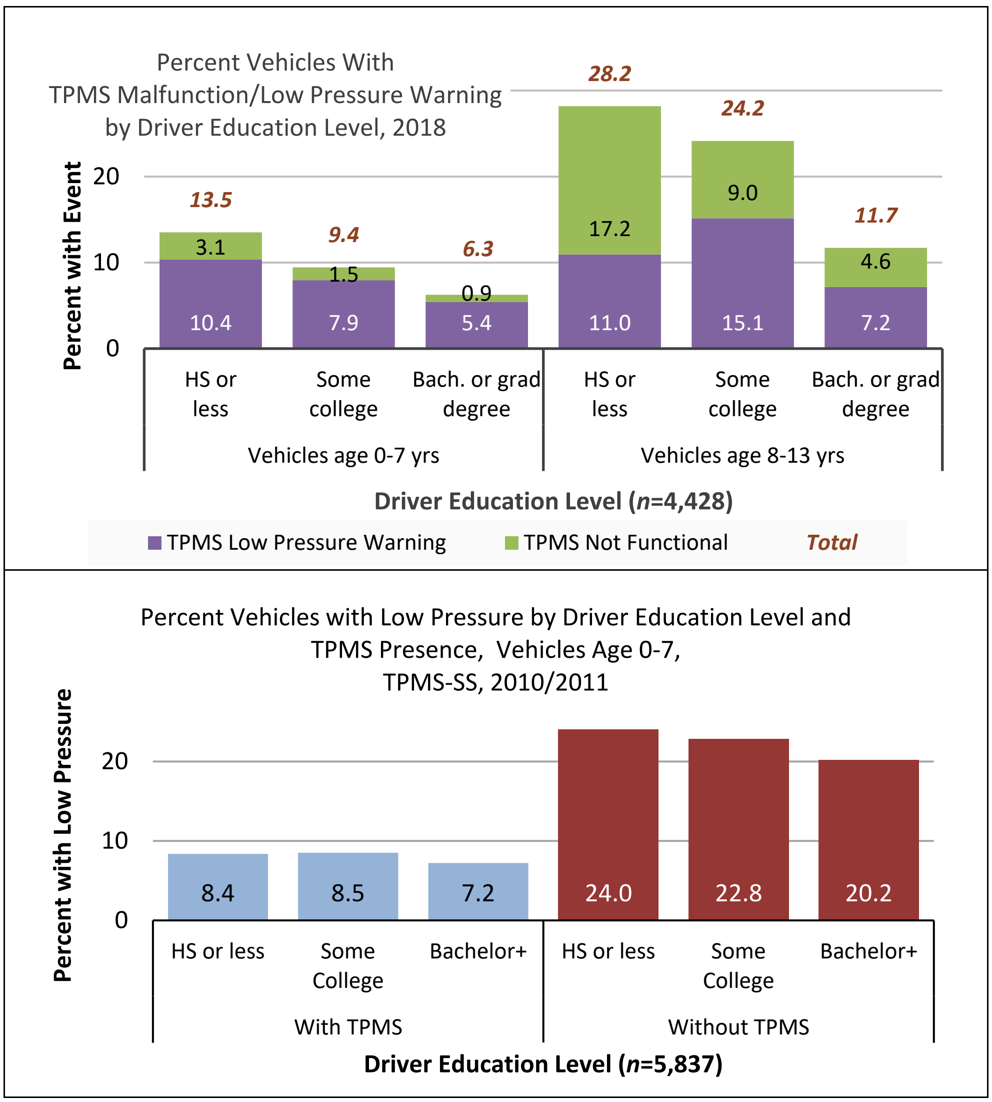


Figure 12-6. Survey Percentages of Tire Pressure Events by Driver Education Level

Driver language. Tests detected some differences in tire pressure events by driver's language used in the 2018 and 2010/2011 data. Language used was not recorded in the 2001 survey. Table 12-6 shows the categories for which significant differences were detected and the accompanying test statistics, and Figure 12-7 graphs the percentage estimates.

Table 12-6. Significant Differences in Tire Pressure Event Percentages by Driver Language

Survey	Event	Domain	Categories With Significant Difference		*t* statistic (*df*)	Adj.*p*-value
2018	TPMS Malfunction	Veh. Age 8-13	**English**	**Other**	***t*=-2.13 (16)**	***p*=.0492**
	TPMS Low Warning	Veh. Age 8-13	**English**	**Other**	***t*=-4.45 (16)**	***p*=.0004**
2010/2011	Low Pressure	Without TPMS	**English**	**Other**	***t*=-10.32 (12)**	***p*<.0001**

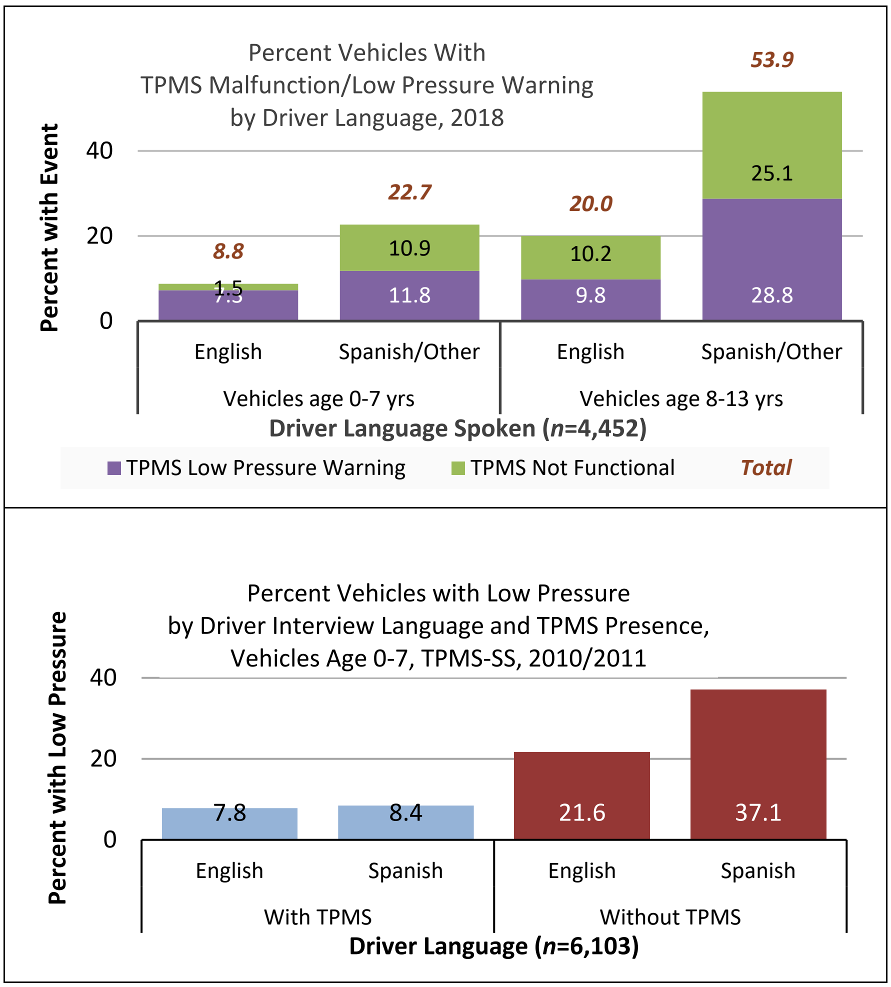


Figure 12-7. Survey Percentages of Tire Pressure Events by Driver Language

A limitation is the small proportion of non-English speakers in the samples (in 2018, 2.6 percent of the weighted sample; in 2010/2011, 3.0 percent of the weighted sample) allowing fewer cases for comparison. It is also possible that if a driver's first language was not English, the interview still could have been conducted in English. The Census Bureau reports that in 2019, 5.8 percent of the U.S. population age 5 years and older did not speak English at all (Dietrich & Hernandez, 2022).

Ambient temperature. Ambient temperature refers to the current surrounding air temperature. For the tire surveys, it means the current air temperature at the site of the data collection.

A frequently cited rule-of-thumb says, with some variations, that tire pressure in passenger vehicles changes by 1 psi for a change in 10 °F in temperature. According to one industry site,

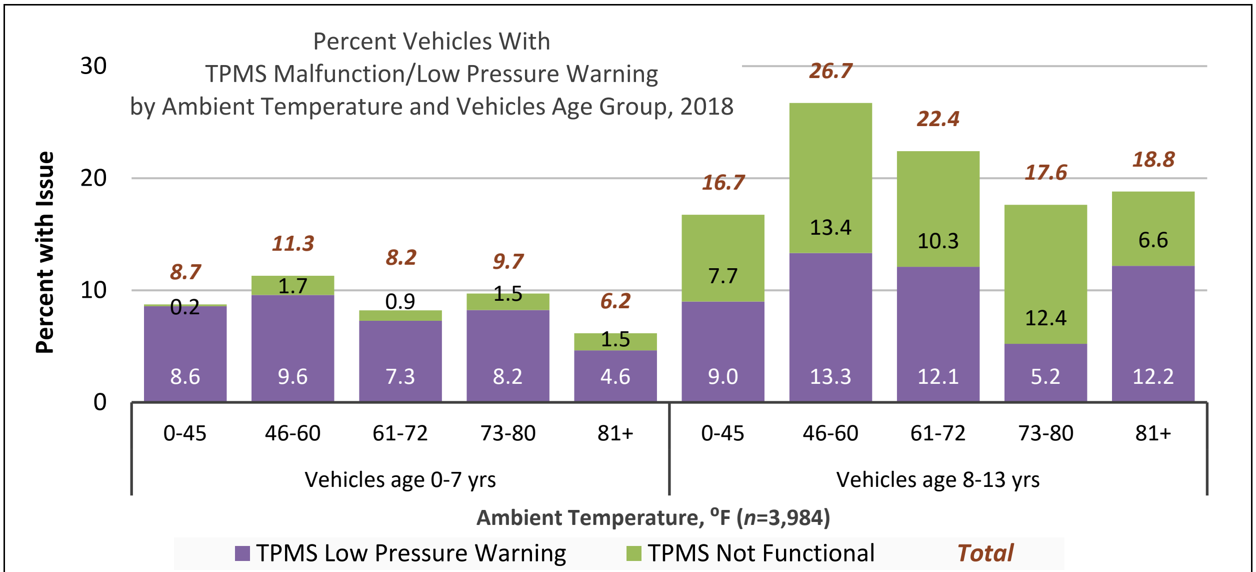
> The rule-of-thumb is for every 10° F change in air temperature, tire pressures will change about 2 percent (up with higher temperatures and down with lower). This means that light-duty, standard-pressure tires (typically inflated to 30 to 50 psi) used in applications on cars, vans and light trucks will change by about 1 psi…
>
> In most parts of North America, the difference between average summer and winter temperatures is about -50° F…which results in a potential loss of about 5 psi as winter's temperatures set in… enough to sacrifice handling, traction, and durability!
>
> Additionally, the difference between cold nighttime temperatures and hot daytime temperatures in most parts of the country is about 20° F. This means that after setting tire pressures first thing in the morning, the vehicle's tire pressures will be almost 2 psi higher when measured in the afternoon (if the vehicle was parked in the shade). While that is expected, the problem is when you set your vehicle's tire pressures in the heat of the day, their cold pressures will probably be 2 psi low the following morning.
>
> And finally, if the vehicle is parked in the sun, the sun's radiant heat will artificially and temporarily increase tire pressures. (Tire Rack, n.d.)

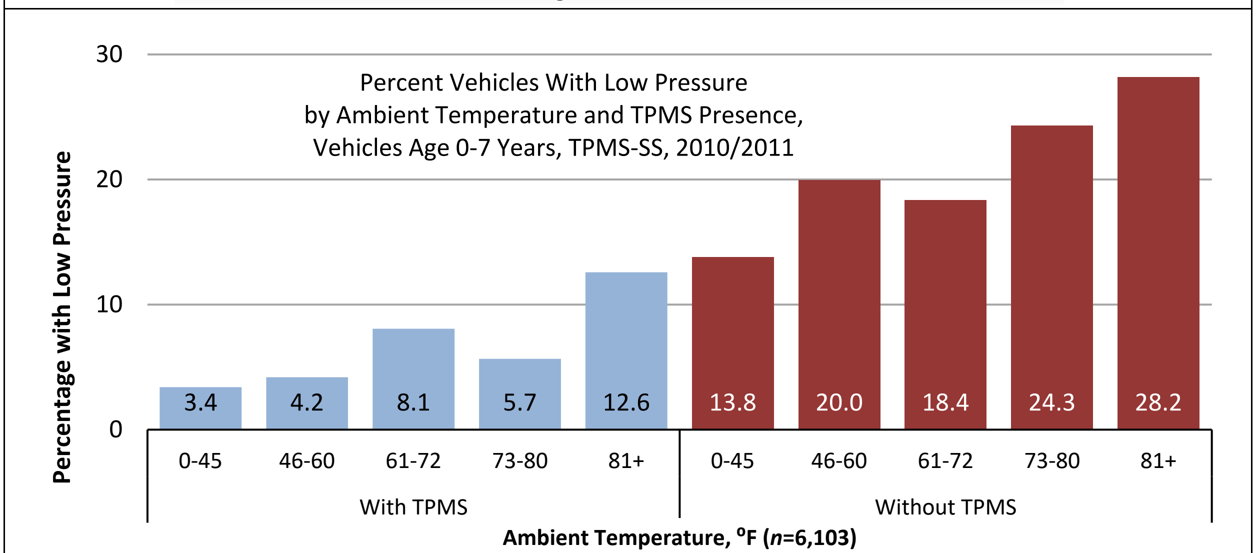
Tire pressure readings entered in the three surveys were adjusted for tire temperature for the analyses in this report and the 2012 evaluation report (Appendix O). All three surveys recorded the ambient temperature at the site at the time of data collection. The temperature distributions varied greatly by survey because each survey was conducted at different times of the year (2018: June-November; 2011: August 2010-April 2011; 2002: February.) For comparisons, temperatures have been grouped as (° F) 0-45, 46-60, 61-72, 73-80, and 81+ to give each category a workable sample size in all three surveys.

TPMS warnings in 2018 did not show significant differences by ambient temperature but is covered here because of differences seen in 2010/2011 and 2001 and general interest in the topic. Table 12-7 shows the categories for which significant differences were detected. The charts in Figure 12-8 show the percentage point estimates from the three surveys.

Table 12-7. Significant Differences in Pressure Event Percentages by Ambient Temperature

Survey	Event	Domain	categories with significant difference		t statistic (df)	Adjusted p-value
2010/2011	Low Pressure	With TPMS	**<=45°**	**81°+**	**t=4.44 (16)**	**p=.0080**
			46°-60°	**81°+**	**t=-5.31 (16)**	**p=.0018**
2001	Low Pressure	Vehicles Age 0-7 yrs	**<=45°**	**73°-80°**	**t=-5.42 (16)**	**p=.0015**
			73°-80°	**81°+**	**t=5.05 (16)**	**p=.0029**
		Vehicles Age 8+ yrs	**<=45°**	**81°+**	**t=-7.08 (16)**	**p=.0001**
			46°-60°	**81°+**	**t=-4.04 (16)**	**p=.0164**
			61°-72°	**81°+**	**t=-4.25 (16)**	**p=.0112**





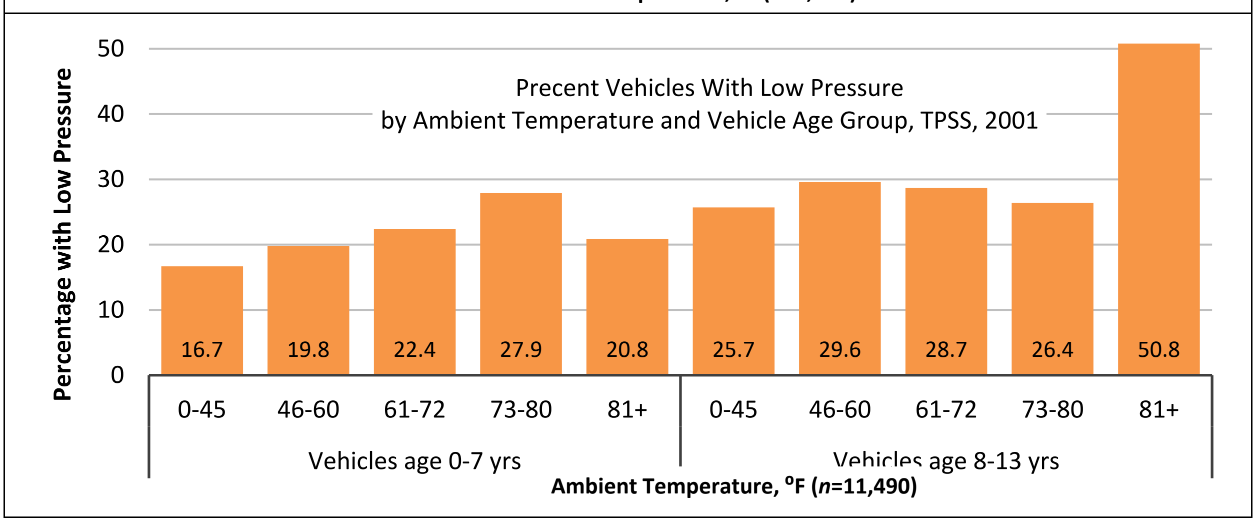


Figure 12-8. Survey Percentages of Tire Pressure Events by Ambient Temperature

Remaining comparison factors tested from the 2018 data did not have available similar factors in the earlier surveys, so only 2018 data is shown.

Tire valve situation (direct TPMS only). The Field Survey inspected tire valve stems and caps for condition and material on all four tires for vehicles with direct TPMS. For this comparison, an irregular valve situation means at least one stem or cap is in poor condition, at least one cap is missing, or either the caps or stems are of mixed materials (metal or rubber/plastic). Table 12-8 shows the categories for which significant differences were detected and the accompanying statistics. Figure 12-9 charts the results for the valve comparison.

Table 12-8. Significant Differences in Pressure Event Percentages by Valve Situation

Survey	Event	Vehicle Age	categories with significant difference		*t* statistic (*df*)	Adjusted *p*-value
2018	TPMS Malfunction	Up to 7 years	**No**	**Yes**	**t=3.81 (16)**	**p=.0015**
		8-13 years	**No**	**Yes**	**t=2.82 (16)**	**p=.0015**
	TPMS Low Warning	Up to 7 years	**No**	**Yes**	**t=3.06 (16)**	**p=.0075**
		8-13 years	**No**	**Yes**	**t=6.43 (16)**	**p<.0001**

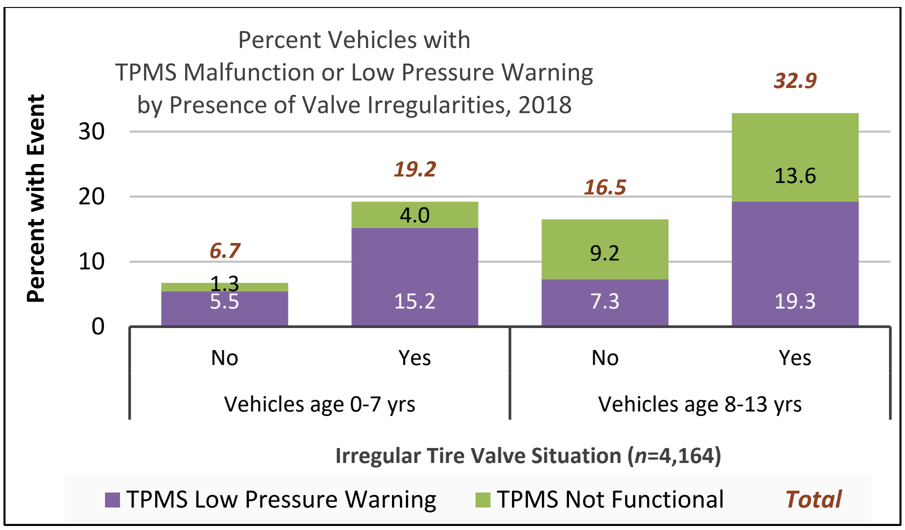


Figure 12-9. Survey Percentages of TPMS Events by Valve Situation, 2018

Spare tire in use. According to an industry web site, "[n]ot all spare tires have TPMS sensors. Most donut spare tires, which are designed for short-term use, do not have pressure sensors. However, some full-size spare tires do have TPMS sensors, depending on the make and model of the car" (Creech, 2023). Lack of a sensor will usually trigger a direct TPMS malfunction. The Field Survey inspection noted whether a spare tire or non-matching wheel appeared to be in use. Only about one percent had such a situation. With the small sample size for spare tires as a caveat, TPMS malfunction percentages were significantly different by spare tire situation in newer vehicles (t=3.34, df=16, adjusted p<.0064). Although the point estimates were far apart for older vehicles, their differences were not statistically significant. Low-pressure warning rates were not significantly different by spare tire situation. Figure 12-10 shows the point estimates by spare tire status.

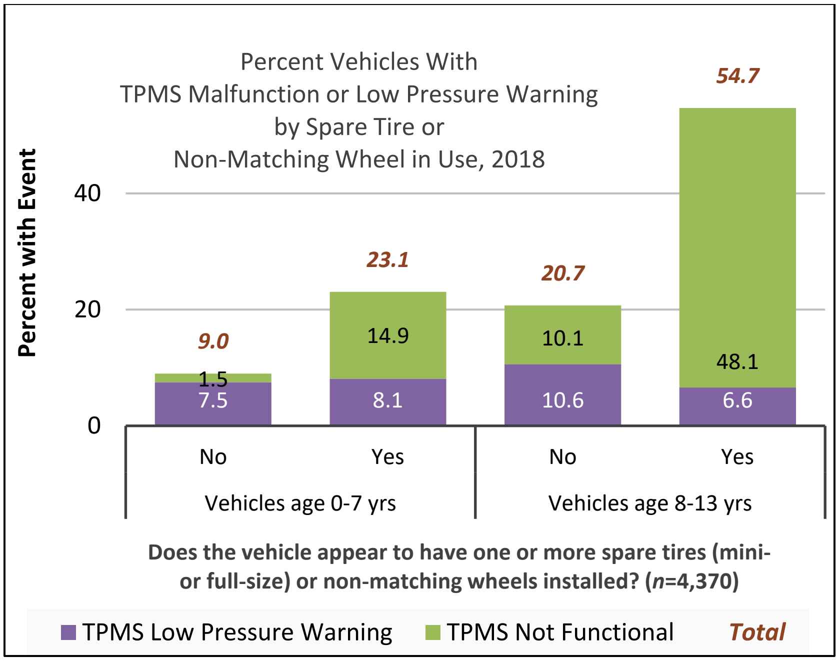


Figure 12-10. Survey Percentages of TPMS Events by Vehicle Tire/Wheel Situation, 2018

Warranty in effect. Drivers in 2018 extended interviews were asked whether the vehicle was under warranty, either original or added. For better sample size, original and added warranties are combined into one warranty status for this comparison. TPMS malfunction rates were significantly different by warranty status in older vehicles (t=2.50, df=16, p=.0236). Figure 12-11 shows the percentage point estimates from the results.

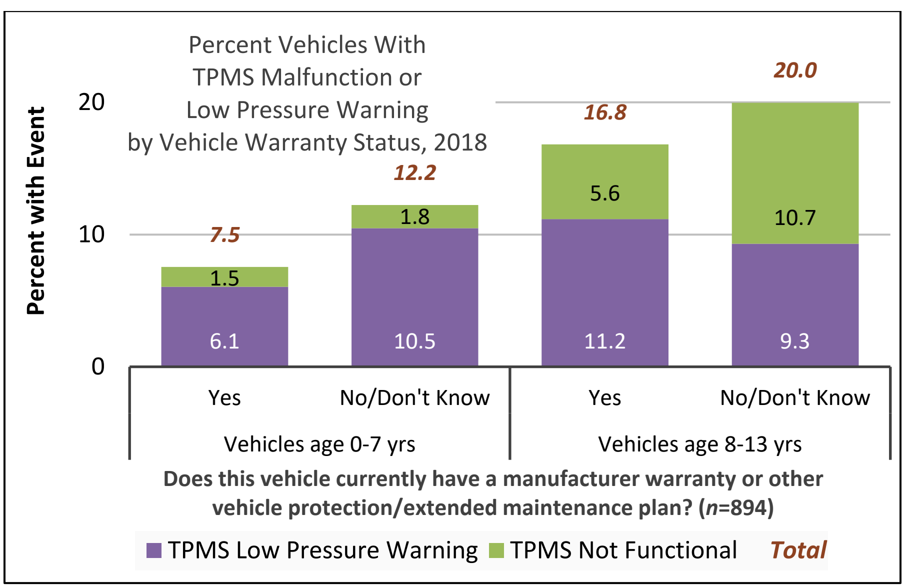


Figure 12-11. Survey Percentages of TPMS Events by Vehicle Warranty Status, 2018

Driver's home ZIP median income. In 2018 drivers were asked to give their home ZIP Codes at the end of the survey. Median incomes for reported ZIPs were added from the 2018 American Community Survey. Table 12-9 shows the categories for which significant differences were detected and the accompanying statistics.

Table 12-9. Significant Differences in Event Percentages by Driver's Home ZIP Median Income

Survey	Event	Vehicle Age	Categories with significant difference		*t* stat. (*df*)	Adj.*p*-value
2018	TPMS Malfunction	Up to 7 years	**\$45,000-\$67,000**	**\$100,000-\$201,000**	***t*=4.23 (16)**	***p*=.0038**
		8-13 years	**\$20,000-\$45,000**	**\$45,000-\$67,000**	***t*=3.19 (16)**	***p*=.0345**
			\$20,000-\$45,000	**\$67,000-\$100,000**	***t*=3.18 (16)**	***p*=.0352**
			\$20,000-\$45,000	**\$100,000-\$201,000**	***t*=4.87 (16)**	***p*=.0010**
			\$45,000-\$67,000	**\$100,000-\$201,000**	***t*=4.31 (16)**	***p*=.0032**
	TPMS Low Warning	Up to 7 years	**\$20,000-\$45,000**	**\$45,000-\$67,000**	***t*=3.61 (16)**	***p*=.0140**
			\$20,000-\$45,000	**\$67,000-\$100,000**	***t*=3.15 (16)**	***p*=.0373**
			\$20,000-\$45,000	**\$100,000-\$201,000**	***t*=3.09 (16)**	***p*=.0418**
		8-13 years	**\$45,000-\$67,000**	**\$100,000-\$201,000**	***t*=3.51 (16)**	***p*=.0173**

Figure 12-12 shows a chart with the percentage point estimates. Limitations for this result are that the median income is not the driver's income and that the median incomes are not adjusted for cost of living in an area. The results are not meant to imply event percentages for the entire ZIP geographic area.

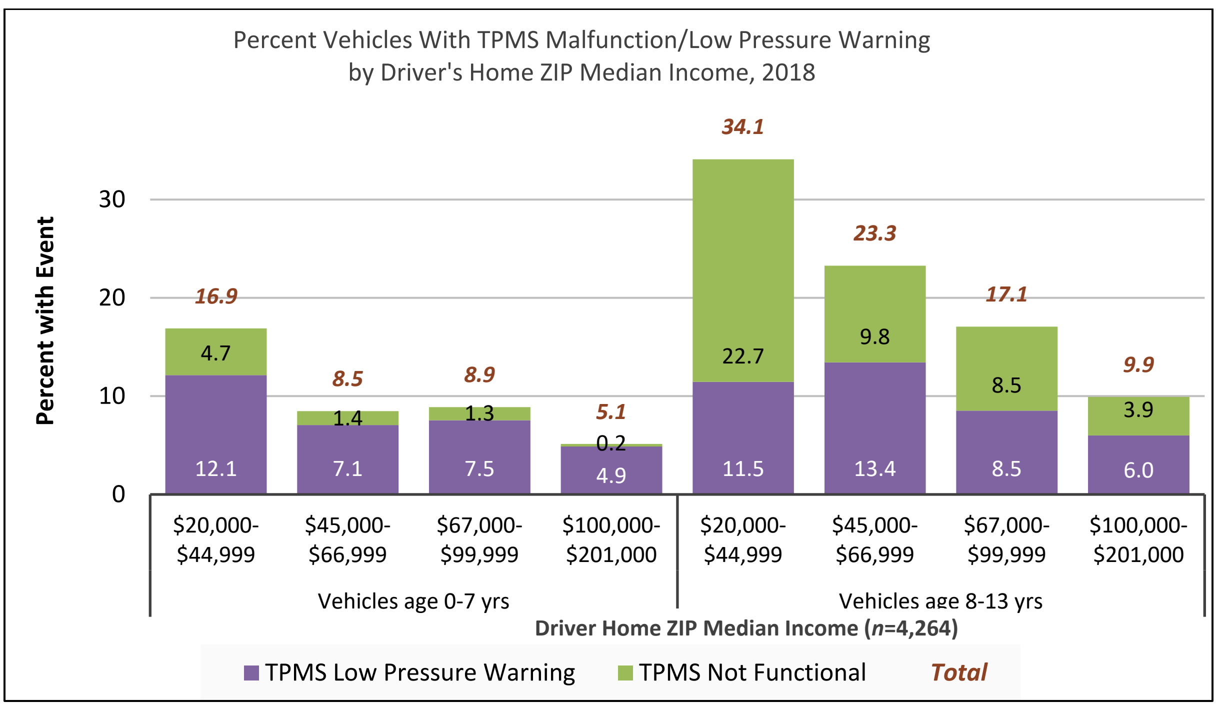


Figure 12-12. Survey Percentages of TPMS Events by Driver's Home ZIP Median Income, 2018

Driver's TPMS law perception. Drivers in 2018 extended interviews were asked whether, to their knowledge, their TPMS was legally required to be functioning properly. No laws in sampled PSUs required TPMS to be working in 2018 (see Section 13.), but since some drivers thought it was required, the responses allow a look at how the belief may influence TPMS maintenance. No differences were statistically significant but point estimates for malfunction in older vehicles were in a noticeable direction of 4.4 percent versus 11.9 percent (t=-2.06, df=16, p=.0561). Figure 12-13 charts the percentage point estimates.

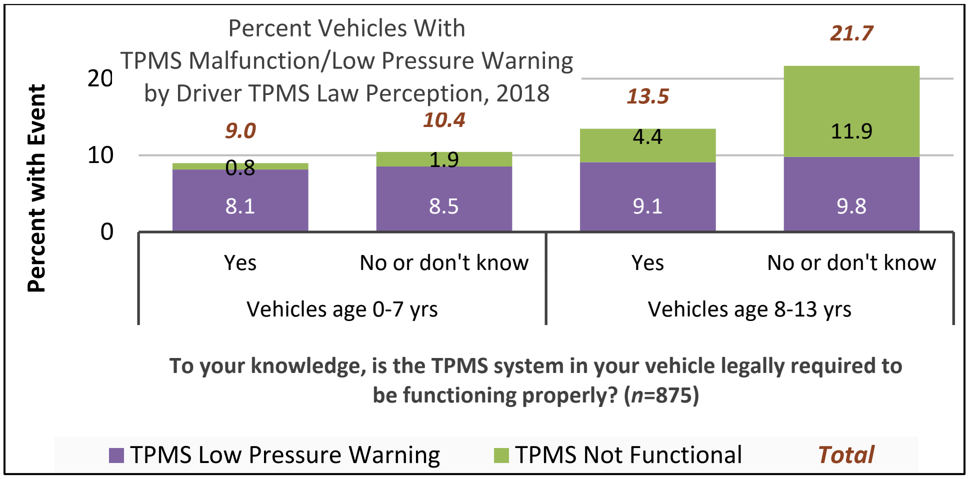


Figure 12-13. Survey Percentages of TPMS Events by Driver TPMS Law Perception, 2018

Driver's TPMS preference. Drivers in 2018 were asked their preference for TPMS on their next vehicle. Responses have been mapped to (somewhat or strongly) prefer, neutral or don't know, or (somewhat or strongly) do not prefer. TPMS malfunction occurrence percentages were significantly different by driver's TPMS preference in older vehicles for "prefer" versus "neutral" (t=-3.03, df=16, p=.0239) and "prefer" versus "not prefer" (t=-2.88, df=16, p=.0328). Figure 12-14 charts the percentage point estimates.

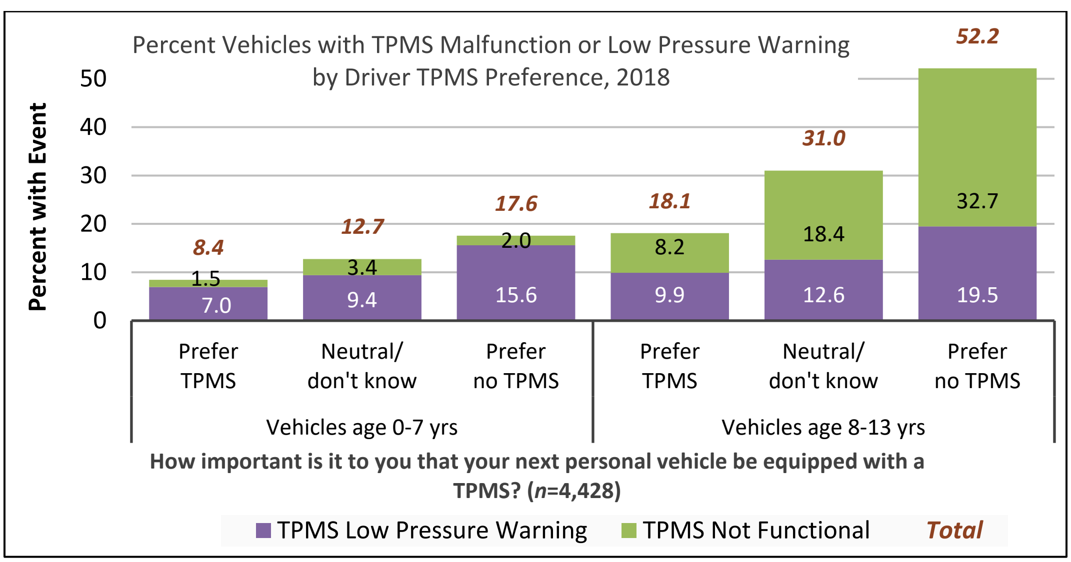


Figure 12-14. Survey Percentages of TPMS Events by Driver TPMS Preference, 2018

12.2.3 Factors Not Significant

Tested factors that showed no associations with TPMS operational status or with tire pressure status were driver sex/gender (all survey years), driver knowledge index and how long driver has had the vehicle (only available in 2018), and driver race (only available in 2001).

12.2.4 Associations Between Significant Factors and Vehicle Age

The preceding comparisons were split by vehicle age groups of up to 7 years and 8 to 13 years to help mitigate any vehicle age effect when looking at other factors. There could still be some statistical associations between factors and vehicle age within the age groups. Tests cited in this section use the *F* statistic described in Section 1.5. If the *p*-value is less than the significance level of .05, the association between them is considered statistically significant at the .05 level. In other words, if the *p*-value is under .05, the data suggest association between the named factor and vehicle age.

These association tests are drawn from 2018 data. Within the vehicle age groups, the original groups of 0-4 versus 5-7 (newer group) and 8-10 versus 11-13 (older group) were used for the association tests to have larger cell sizes and because the sample weights are post-stratified to those four groups.

Table 12-10 shows the F value, numerator and denominator degrees of freedom, and *p*-value for the tests of significant associations with vehicle age within the specified vehicle age groups. Bold type means the test found a statistically significant association (*p*-value greater than .05).

Table 12-10. Tests of Association, Significant Comparison Factors and Vehicle Age

Factor test for association with vehicle age (within vehicle age groups of 0-7 years or 8-13 years in 2018)	Vehicles up to 7 years old		Vehicles 8-13 years old	
	Significant *F*-test (*df*)	*p*-value	Significant *F*-test (*df*)	*p*-value
Vehicle type	***F*=24.2 (1,16)**	***p*=.0002**	*F*=0.7 (1,16)	*p*=.4288
Vehicle mileage	***F*=332.1 (3,48)**	***p*=<.0001**	***F*=15.9 (3,48)**	***p*=<.0001**
Driver age group	*F*=0.6 (3,48)	*p*=.6028	*F*=2.4 (3,48)	*p*=.0781
Driver education	***F*=9.9 (2,32)**	***p*=.0005**	*F*=0.5 (2,32)	*p*=.6108
Driver language	*F*=0.1 (1,16)	*p*=.8081	*F*=.0 (1,16)	*p*=.9876
Ambient temperature	***F*=13.3 (4,60)**	***p*=<.0001**	*F*=0.6 (4,60)	*p*=.6733
Driver home ZIP median income	*F*=2.3 (3,48)	*p*=.0866	*F*=1.3 (3,48)	*p*=.2845
Tire valve situation	***F*=12.1 (1,16)**	***p*=.0031**	*F*=3.3 (1,16)	*p*=.0876
Spare tire in use	*F*=1.4 (1,16)	*p*=.2523	*F*=0.7 (1,16)	*p*=.4039
Driver TPMS law perception	*F*=1.2 (1,16)	*p*=.2803	*F*=0.0 (1,16)	*p*=.9423
Warranty status	***F*=41.9 (1,16)**	***p*=<.0001**	*F*=1.8 (1,16)	*p*=.1987
Driver TPMS preference	*F*=1.2 (2,32)	*p*=.3224	***F*=4.7 (2,32)**	***p*=.0161**

Source: NHTSA TPMS-ORRC Field Survey, 2018

The tests of Table 12-10 within vehicle age groups could give different results if tested over the entire range of vehicle ages. This was true for driver home ZIP median income, which over the entire age range was significantly associated with vehicle age (*F*=2.6, *df*=9,144, *p*=.0087).

A bold row in Table 12-10 does not mean the factor is "more" significant as related to TPMS warning lights. In fact, the non-bold rows are the factors that were related to TPMS warning occurrence without showing a relationship to vehicle age, so could be seen as the factors of higher interest along with the overall vehicle age factor.

12.3 Data Synthesis

Key conclusions extracted from this section were:

- Although a TPMS malfunction and a low-pressure warning cannot occur at the same time, so cannot be calculated as directly correlated, they often are seen to rise and fall together within other associated circumstances.
- Factors that were related to driving with TPMS telltale lights on (either malfunction or low pressure) and were not related to vehicle age were driver age (younger drivers more likely to have warning light), driver language (non-English more likely), driver home ZIP median income (lower income more likely), driver TPMS law perception (don't think TPMS required), and spare tire status (spare tire or non-matching tire in use more likely to have TPMS malfunction).
- Factors that were related to driving with TPMS telltale lights illuminated but also related to vehicle age (in either newer vehicles, older vehicles, or both) were vehicle type (passenger car higher more likely to have warning light), higher mileage (more likely), lower driver education level (more likely), ambient temperature (varying results), problem tire valve situation (more likely), warranty in effect (less likely), and driver high TPMS preference (less likely). With many tests being conducted, and the mentioned factors showing at least some relationship vehicle age, some of these may be spurious relationships. Also, some may be related because of other factors associated with vehicle age (confounding factors); however, it can be of interest to know the various related factors to help identify situations that could be remedied. These factors may also have interaction effects, which were not tested here.

12.4 Implications

Drivers and vehicles that may best benefit from educational outreach about tire pressure maintenance appear to be younger drivers, drivers with lower income and education, drivers whose first language is not English, and drivers with older vehicles (who may tend to have some of the other noted characteristics). Vehicles that may tend to have more TPMS malfunctions are older vehicles, vehicles with a spare or non-matching tire, and vehicles with poor condition valves or caps. Conditions that may encourage drivers to repair TPMS malfunctions may be having a vehicle warranty and having a legal requirement that TPMS be working. Drivers with higher preference for having a TPMS appear to have fewer incidents of driving with a TPMS warning light of either kind. Further research could examine whether the vehicle age effect is simply tires losing air over time while driver interest level is rather constant or is due to drivers paying less attention to air pressure as the vehicle ages. Further analysis could also examine interaction effects between the comparison factors.

13. State Requirements

13.1 Topic Background

State requirements were not part of the TPMS-ORRC survey design or research questions, and the national survey data is not amenable to State estimates. However, the topic was of interest to check for possible influence of State requirements on national survey estimates.

NHTSA guidelines state that each State should have a program for periodic inspection of all registered vehicles (NHTSA, 2014). Although State requirements are subject to periodic updates, as of July 2015 a Government Accountability Office study found that 11 States require annual vehicle safety inspections, 3 require biannual inspections, and 2 have some other kind of inspection requirement (GAO, 2016). These tallies do not include emissions inspections.

13.2 Do States Have TPMS Requirements in Safety Inspections?

Some tire-related websites have been seen to state that some State vehicle safety inspections require TPMS to be working, specifically citing Hawaii, Rhode Island, Vermont, and West Virginia as having this requirement. This list is apparently unverified and inaccurate. Follow-up online searching found the following information about the four cited States:

Hawaii. Online sources gave no indication that Hawaii has ever had a TPMS inspection requirement. A service provider's online checklist shows tires and wheels, but not TPMS, in the inspection (Midas Hawaii, n.d.). Hawaii DOT documentation dated 2013 and revised 2018 also specify inspection of tires and wheels but not TPMS (Hawaii DOT, 2013, 2018). The tire inspection apparently checks air pressure but as an advisory only. A commercial service provider's manual for Hawaii safety inspections instructs "Advise owner if the tire pressure does not match the motor vehicle manufacturer's recommendations" (Lex Brodie's, 2017).

Rhode Island. The Rhode Island vehicle inspection manual revised June 2019 does not have TPMS as an inspection item. Tires are inspection points, but the inspection is for the condition of the tires (Rhode Island Department of Revenue, 2019; Rhode Island Emissions and Safety Testing, 2022). An earlier version from 2008 also did not mention TPMS or have a tire pressure advisory (Ditomasso, 2008).

West Virginia. According to the West Virginia motor vehicle inspection manual, 2010 revision, air pressure is taken and, if not correct, generates a driver advisory but not rejection. TPMS is not mentioned. Tire damage including an audible air leak are grounds for rejection (West Virginia State Police, 2010). A 2023 online training presentation for vehicle inspectors also does not mention TPMS (West Virginia Department of Motor Vehicles, 2023).

Vermont. Vermont had a TPMS requirement as early as 2008 (Vermont State Vehicle Inspection, 2008), but it was dropped in 2020. According to an online news article from 2018, as the vehicle safety inspection was revised "[o]ne other item has prompted a lot of debate — the tire pressure monitoring system, or TPMS. Federal rules require new vehicles to have TPMS, which alerts drivers to low tire pressure. Vermont's current inspection manual does not allow the TPMS light to be activated." The chief inspector for the Vermont Department of Motor Vehicles stated that "... the DMV advisory group has been intensely researching the tire pressure question" (McCullum, 2018). In another article, a manager of a tire and service center said "[t]o just replace a sensor, you're probably looking at $115 give or take depending on the vehicle, and that's on the easy side." He explained that "[i]f it happens to be the control module, the price goes way up." The article stated that “in the new proposed manual, auto shops would recommend a customer fix the issue, rather than failing the car” (Garris, 2018). According to the new inspection manual dated 2020, the new procedure is to “[a]dvise customer if: 1. The tire pressure monitoring system (TPMS) low-pressure air-warning light/indicator is activated and may be malfunctioning. The inspection mechanic must recommend repair” (Vermont Agency of Transportation, 2020).

Other practices. New York State’s Department of Motor Vehicles website states “[t]ire pressure - You will be informed if the vehicle's tire pressure in not within the manufacturer's recommendation. This is an advisement only, and not cause for rejection” (New York State, 2011). In Massachusetts, “[t]he TPMS lamp and/or digital pressure values on the dashboard visually indicate if one or more tires are low on pressure. This safety feature visually alerts the motorist of a tire pressure problem, but is not a part of the Massachusetts Vehicle Check safety inspection. Vehicles cannot be failed if a TPMS Lamp is illuminated” (Massachusetts Vehicle Check, 2013). It is not clear whether the Massachusetts inspection informs the driver of an illuminated TPMS telltale.

13.3 California Air Resources Board Mandate

In 2010 the California Air Resources Board (CARB) implemented a mandatory pressure check and fill with any vehicle service performed in California. From the CARB website:

> On September 1, 2010, (CARB’s) Tire Pressure Regulation took effect. The purpose of this regulation is to reduce greenhouse gas emissions from vehicles operating with under inflated tires by inflating them to the recommended tire pressure rating. The regulation applies to vehicles with GVWR up to 10,000 lb. Automotive service providers must meet the regulation’s following requirements:

- Check and inflate each vehicle’s tires to the recommended tire pressure rating, with air or nitrogen, as appropriate, at the time of performing any automotive maintenance or repair service.
- Indicate on the vehicle service invoice that a tire inflation service was completed and the tire pressure measurements after the service were performed.
- Perform the tire pressure service using a tire pressure gauge with a total permissible error no greater than + two (2) pounds per square inch (psi).
- Have access to a tire inflation reference that is current within three years of publication.
- Keep a copy of the service invoice for a minimum of three years, and make the vehicle service invoice available to the ARB, or its authorized representative upon request.

CARB mandate influence on national estimates. The California regulation is of interest for the 2018 Field Survey because 4 of the PSUs in the sample frame are in California. About 17 percent of the unweighted survey cases were done in California, but with weighting, the percentage becomes 13 percent. In 2018, California had about 13.5 percent of the registered vehicles in the nation (FHWA, 2021). Thus, the California cases in the TPMS-ORRC should not unduly influence, but rather should properly influence, the national estimates.

The TPMS-SS of 2010/2011 had one PSU in California. In that survey, California cases did not have lower rates of underinflation than the rest of the cases. The TPMS-SS survey started in

August 2010 and the CARB requirement took effect on September 1, 2010. It could be expected to take some time for the influence of the regulation to be seen in the vehicle population as vehicles are serviced.

CARB mandate influence on tire pressure in California. The CISS national sample of PSUs used in the Field Survey is not designed for comparative estimates by State. A rudimentary check, not valid for statistical inference, is to look at unweighted cases in California compared to all other cases. This check found that about five percent of unweighted cases in California had a low-pressure warning compared to 8 percent of all other cases. About 1.6 percent of California cases had TPMS malfunction compared to about 4 percent of all other cases. Vehicle age is not confounding these results: The average vehicle age in California cases was 6.7 years old compared to 5.9 years in the rest of the cases. By vehicle age groups, California had lower percentages with a low-pressure warning in every vehicle age group: 0 to 4 years old (California 4.4%, others 5.3%); 5 to 7 years old (California 3.4%, others 8.8%); 8 to 10 years (California 5.4%, others 8.0%); and 11 to 13 years (California 9.1%, others 15.2%).

13.4 Implications

State policies such as checking tire pressure during a safety inspection or during service visits could be a topic for further research on driving with underinflated tires. The California regulation that tire pressure must be checked and brought to proper level at every service visit could be of high interest for further study.

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14. Summary

Applying the survey results to the identified research topics led to key findings and suggestions for further activity as discussed in the report sections and summarized below.

14.1 Key Findings

Key findings from this report reveal information on TPMS functionality, effectiveness, and driver interaction with TPMS, as follows:

14.1.1 TPMS Effectiveness and Functionality

- **TPMS operational status.** In on-road passenger vehicles with TPMS compliant to FMVSS No. 138, the prevalence of TPMS malfunction was about 4 percent and of low-pressure warning, 8 percent - giving a combined TPMS warning prevalence of 12 percent. Vehicles with TPMS malfunction may or may not be experiencing low pressure, with results from earlier surveys suggesting that a substantial proportion of them may. Presence of either warning tended to increase with vehicle age.
- **TPMS effectiveness.** Low pressure in 8 to 12 percent of passenger vehicles with TPMS (above bullet) is an improvement over the 20 to 25 percent of passenger vehicles without TPMS found to have low pressure in earlier surveys. Similar findings in 2010/2011 generated an estimate that TPMS reduced the likelihood of severe underinflation by about 56 percent. A related earlier finding that TPMS effectiveness may be lower in older vehicles appears related to unresolved TPMS malfunction as vehicles age, but also to a general tendency for tire pressure to be low more frequently in older vehicles.
- **TPMS malfunctions and repair costs.** Tire pressure sensor failure including battery failure appears to be the most common contributor to direct TPMS malfunctions. Wheel-mounted sensors may be a contributor in indirect TPMS. Malfunctions in indirect TPMS appear to be rarer than in direct TPMS, but the fleet is also newer. The most common repair for direct TPMS was for new tire pressure sensors, estimated to cost around $400 for four sensors (2016 dollars).
- **Indirect TPMS.** Vehicles with indirect TPMS are a smaller but growing share of the U.S. passenger vehicle fleet. Drivers with indirect TPMS were found to have low knowledge and experience in recalibrating the TPMS after adjusting pressure or other tire events, a requirement for indirect TPMS. Tire checks found about 9 percent of vehicles with indirect TPMS showing a warning or lack of warning inconsistent with the measured pressure; this result could be related to calibration, but this cannot be definitively known from the available data.

14.1.2 Driver and Vehicle Factors

- **Driver acceptance and willingness to pay.** Most drivers prefer to have a TPMS, but many have concerns about the cost of TPMS repair. Many drivers whose vehicles showed TPMS malfunction said they do not plan to repair it, noting cost and that TPMS is not needed to operate the vehicle. Although the most common repair for direct TPMS was new tire pressure sensors at about $400 for four, under two percent of drivers said they would be willing to spend more than $300 on a hypothetical TPMS repair.

- **Driver knowledge.** Drivers have high levels of general knowledge about having a TPMS, knowing the light is related to tire pressure, and how to add air, but a smaller portion of drivers with a current malfunction light knew what the light means. To find a vehicle's recommended air pressure, about a third of drivers incorrectly look at the tire sidewall rather than the vehicle placard - a concern because the sidewall gives the tire's maximum pressure, not the recommended pressure. Driver awareness about the vehicle placard has improved since the placard became required but is still under 40 percent. For either direct or indirect TPMS, driver knowledge about TPMS reset and recalibration appears to be low. Reset terminologies, displays, and procedures vary across vehicle makes, and many drivers are not sure who can do a reset and when it needs to be done.
- **Drivers following recommendations.** NHTSA recommends that drivers check their tire pressure once a month, regardless of whether their vehicle has TPMS, but less than half of drivers with TPMS reported that they had checked their pressure in the last month. NHTSA also recommends that a TPMS warning light be given attention as soon as possible, but half of drivers with a pressure warning and most drivers with a malfunction warning said the warning had been on over a week.
- **More likely to be driving with a TPMS warning.** Driving with a TPMS low-pressure warning or malfunction warning was more prevalent among younger drivers, drivers of lower income and education, drivers whose first language is not English, and drivers of older vehicles or vehicles with higher mileage. Vehicles being driven with higher occurrences of TPMS malfunction were older vehicles, vehicles with a spare or non-matching tire, and vehicles with irregular tire valve stems or caps. Having a vehicle warranty or believing there is a legal requirement for TPMS to be working was associated with lower prevalence of driving with a TPMS malfunction light.

14.1.3 State Practices

- No State vehicle safety inspections were found that currently require TPMS to be working or tire pressure to be correct, but some check the tire pressure and give a driver advisory. However, a California regulation mandating a pressure check at every vehicle service visit may be reducing incidences of low pressure in the State compared to other States.

14.2 Suggestions for Future Activities

Some possible activities suggested by the findings were:

- **Driver education and outreach** could emphasize what a TPMS light means, using the placard rather than the sidewall to find recommended pressure, improving knowledge about resetting or recalibrating TPMS especially in indirect TPMS, checking air once a month rather than relying on TPMS to monitor it and acting on a TPMS pressure warning as soon as possible. A public campaign about driving with underinflated tires could be targeted to all drivers or focus on younger drivers, drivers whose first language is not English, drivers of older vehicles, and drivers in lower income areas or who have lower education levels.
- **Further signal detection research** could expand TPMS vehicle pressure checks to assess the accuracy of TPMS warnings compared to measured pressure, comparisons

between direct and indirect TPMS signal detections, and low-pressure rates in vehicles with TPMS malfunction. A possible alternative way to get more data could be to partner with automotive repair facilities.

- **Behavioral research** could examine how drivers react to TPMS warning lights and tire pressure in general and as vehicles age, to develop countermeasures to driving with underinflated tires.
- **Tracking surveys** such as a periodic vehicle and driver survey could incorporate the added signal detection checks and behavioral questions mentioned above. Recommendations would be to standardize the surveys, variables, and analysis programs; expand signal detection checks to all TPMS types and situations; and expand extended interviews to include all drivers with low pressure.
- **State regulations** could be compared in a special study of low pressure in different States with varying practices, including the California regulation requiring air service at all service visits, or other State policies such as checking pressure during a safety inspection.

14.3 Limitations

In some sections of this report, limitations and cautions were noted when warranted. A general summary of the limitations is:

- The NHTSA surveys and the Omnibus Survey referenced or analyzed in this report each had different methods, question wording, and sampling schemes, so the results do not lend themselves to statistical analysis of differences or trends; comparisons among the different surveys are intended only for historical perspective in subject matter issues.
- Some driver responses or willingness to participate could have been influenced by the driver knowing or surmising that the survey was about tire pressure or TPMS.
- The knowledge index was developed by human judgment, does not account for guessing, and does not test for true knowledge in some components.
- "Willingness to pay" was hypothetical and could change when a driver is confronted with an actual repair need.
- The TPMS detection check was only performed on vehicles with indirect TPMS, so the sample size was small and no comparison group of direct TPMS was available.
- In repair facility questions, the percentage citing the circumstance most often seen is not the same as the prevalence of the circumstance.
- Vehicles with current issues do not reflect all vehicles that had issues corrected. In other words, the surveys cannot estimate an annual overall rate of TPMS malfunctions or severe underinflation occurrences.

14.4 Survey Potential Learned

An interesting side result from the Field Survey and earlier surveys was that surveying at fuel stations proved useful for nationally representative estimates. Station surveys such as these may be useful for other traffic safety questions and for estimating exposure proportions for drivers and vehicles on the road.

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Appendix A. Field Survey Sampling and Weighting

This appendix explains the sampling and weighting for the Field Survey.

Universe. The Field Survey sampled vehicles from the universe of U.S. registered passenger vehicles (car, SUV, light truck, van) under 10,000 lb GVWR that have TPMS compliant to FMVSS No. 138 and TPMS malfunction indicator;[65] and their drivers or maintainers. The universe starts to exist in MY 2006 with the TPMS rule phase-in. NHTSA's Office of Vehicle Safety Compliance provided internal compilations of which models had which type of TPMS equipment (direct or indirect) in MY 2006 and later.

The survey used a complex sample design with stages as follows.

Primary Sampling Units (PSUs). The survey used the 24-PSU design of NHTSA's CISS, in which 24 U.S. geographic areas are sampled from 8 strata. The PSUs are shown mapped in Figure A-1.

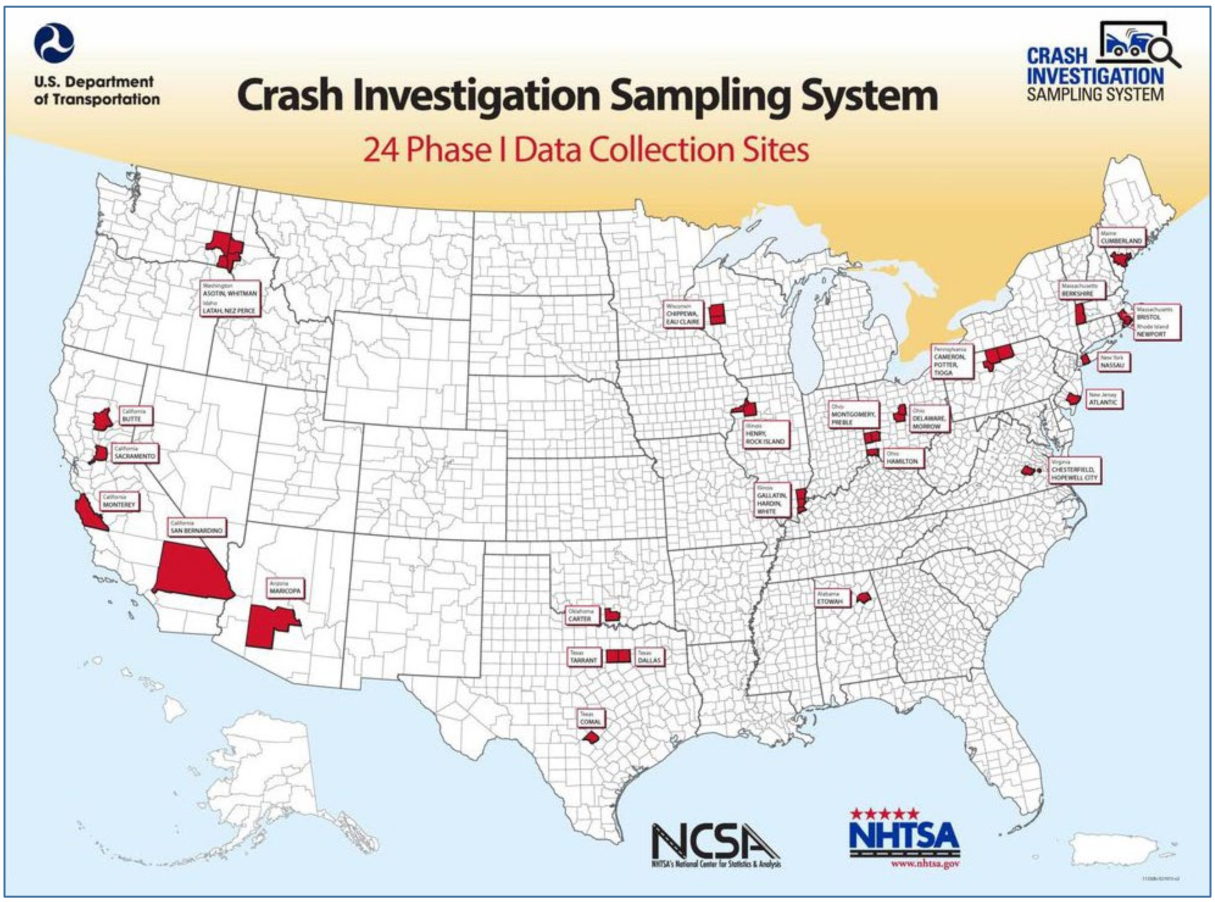

Figure A-1. NHTSA's Crash Investigation Sampling System, 24-PSU design

[65] TPMS malfunction indicator was not required until MY 2008, although some phase-in vehicles in MY 2006/2007 had it. Vehicles without it were not useful to the survey topic of TPMS malfunction so were not sampled. This reduced the pool of eligible vehicles from MY 2006/2007.

A list of the PSUs with their strata and 2015 populations[66] is shown in Table A-1.

Table A-1. CISS 24-PSU Design Primary Sampling Units

STATE	COUNTY	STRATUM	Pop. (2015 est.)
AL	ETOWAH	SOUTH RURAL	103,057
AZ	MARICOPA	WEST URBAN	4,167,947
CA	BUTTE	WEST RURAL	225,411
CA	MONTEREY	WEST URBAN	433,898
CA	SACRAMENTO	WEST URBAN	1,501,335
CA	SAN BERNARDINO	WEST URBAN	2,128,133
ID, WA	ID: LATAH, NEZ PERCE; WA: ASOTIN, WHITMAN	WEST RURAL	149,108
IL	GALLATIN, HARDIN, WHITE	MIDWEST RURAL	23,727
IL	HENRY, ROCK ISLAND	MIDWEST URBAN	453,476
MA	BERKSHIRE	NORTHEAST RURAL	127,828
MA, RI	MA: BRISTOL; RI NEWPORT	NORTHEAST URBAN	639,195
ME	CUMBERLAND	NORTHEAST URBAN	289,977
NJ	ATLANTIC	NORTHEAST URBAN	274,219
NY	NASSAU	NORTHEAST URBAN	573,587
OH	DELAWARE, MORROW	MIDWEST URBAN	228,087
OH	HAMILTON	MIDWEST URBAN	807,598
OH	MONTGOMERY, PREBLE	MIDWEST URBAN	573,587
OK	CARTER	SOUTH RURAL	27,158
PA	CAMERON, POTTER, TIOGA	NORTHEAST RURAL	63,702
TX	COMAL	SOUTH URBAN	129,048
TX	DALLAS	SOUTH URBAN	2,553,385
TX	TARRANT	SOUTH URBAN	1,982,498
VA	CHESTERFIELD, HOPEWELL CITY	SOUTH URBAN	358,065
WI	CHIPPEWA, EAU CLAIRE	MIDWEST RURAL	165,636

A CISS PSU is a geographic area defined by a county or group of counties. The CISS sample design allows a scalable sample size of from 16 to 73 PSUs, where the PSU sample is designed for national representativeness. The measure of size for selecting the CISS PSUs was a composite involving crash counts, registration proportions, and populations, and favored newer vehicles, which was also advantageous to this survey. The CISS PSUs were formed as groups of adjacent counties with end-to-end distance no more than 65 miles for urban areas and 130 miles for rural areas and are stratified by 4 Census Bureau regions (North, Midwest, South, and West) and by rural or urban area. The selected 24-PSU sample was drawn with probabilities proportional to size with two rural and 4 urban PSUs from each region (Zhang et.al., 2019).

The sample size of 24 PSUs for the TPMS-ORRC survey was chosen as the largest affordable PSU sample size from the available scalable CISS PSU sample sizes. NHTSA provided CISS PSU weights for TPMS-ORRC weight calculations.

Operationally, the CISS sample was advantageous to the TPMS-ORRC because NHTSA already had a current presence in these geographic areas through CISS. However, CISS crash investigators were not involved in TPMS-ORRC data collection.

[66] Census Bureau estimates

Two ZIP Codes within each PSU. One ZIP[67] code was sampled with probability proportional to ZIP population[68] out of all PSU ZIPs. The median income of the first selected ZIP was compared to the median of all ZIP median incomes in the PSU.[69] The second ZIP was chosen as a simple random sample of one from ZIPs that were no more than 20 miles away from the first ZIP[70] (for operational requirements with a traveling supervisor) and were on the other side of the PSU ZIP median income.[71] The ZIP median income division was used to foster more variability in coverage, but the ZIPs and income groups were not treated as strata or analytical domains.

Two fuel stations within each selected ZIP. The data collection subcontractor listed the general passenger-vehicle fuel stations in each selected ZIP using online maps and a commercial database (MELISSA). The completed list was sorted by a random number generated for each station. The first sampled station was the first station in the random sort that fulfilled sampling and operational viability requirements: station traffic flow enables vehicle sampling requirements (sufficient flow of vehicles MY 2006 or newer) and periodic flow counts; adequate visibility and space exist to safely conduct the interviews and observations; station clientele has reasonable local representation; permission can be obtained from the site's proprietor or manager to conduct the survey; and there exists at least one other viable station within a 15-minute driving distance. The second station sampled was the next viable station in the random sort that was within 15 driving minutes of the first station.[72]

Vehicles at the selected stations. When the data collection supervisor and team set up operations at a selected station in cooperation with the station manager, a particular pump island was selected as the focal sampling area based on criteria such as traffic, accessibility, and station manager input. The team approached all potentially eligible passenger vehicles that pulled up to the focal island in the order in which they arrived and presented information to the driver about the survey. Exceptions to approaching every driver included safety issues, surplus vehicle volume where a vehicle departs while the team is busy surveying another vehicle, out-of-State vehicles,[73] and vehicles that were obviously older than MY 2006 or not passenger vehicles.

Beyond the focal island, the hierarchy of approach was as follows:

1. Focal island – first in hierarchy when (2) and (3) not in effect
2. Indirect TPMS vehicle off the island (based on known makes and models such as VW, Audi, newer Honda) – as many as seen, since indirect are uncommon but needed for the survey.
3. Diesel pump – if one is available, approach when used, since rarer in survey population but may have indirect TPMS.
4. If focal island empty, other islands in pre-determined order.
5. If all islands empty, convenience store customers and inspection line if available.

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[67] "ZIP" in this appendix refers to Census Bureau ZIP Code Tabulation Areas.
[68] Population by ZIP is available in public data from the American Community Survey, US Census Bureau.
[69] Median income by ZIP is available in public data from the American Community Survey, US Census Bureau.
[70] ZIP-to-ZIP distance used a 20-mile great-circle distance threshold, found in the 2016 ZIP Code Tabulation Area (ZCTA) Distance Database, published by the National Bureau of Economic Research.
[71] If ZIPs proved infeasible or unproductive, some were replaced.
[72] If stations lost cooperation or were unproductive, some were replaced.
[73] If a PSU was in two States, a plate from either of the two States was acceptable.

When an approached driver agreed to participate, a few more questions screened the driver in if the vehicle model year was in scope per the driver's knowledge, the vehicle was not a short-term rental or Zipcar, and the driver or another present person was the primary driver or main upkeep person for the vehicle. If screen-in conditions were met, a team member scanned the VIN from the doorjamb placard or could enter it manually if necessary. The tablet entered the VIN into NHTSA's vPIC online VIN translator to identify model year, make and model. From those, the tablet used lookup tables to confirm eligibility: vehicles in MY 2008 to 2019[74] and phase-in vehicles in MY 2006-07 with a TPMS malfunction indicator were eligible. Lookup tables also identified an eligible vehicle's TPMS type for routing in the inspection and interview.

The survey contractor and NHTSA monitored vehicle sampling daily by vehicle type and model year group. The protocol had a provision to purposefully rebalance vehicle selections if a need became apparent, but it was never needed.

Working hours were daytime shifts under the assumption that topics of the study are well-represented in daytime fuel-buyers and would not vary by fuel-buying outside of daytime hours.[75] Weekend shifts were included to have more varied coverage of drivers fueling.

Subsample for extended interviews. All participating vehicles were given the vehicle inspection and all drivers were given a brief "basic" interview with core questions. All cases where the vehicle had either TPMS malfunction or an indirect TPMS went to an extended interview. For cases where the vehicle had working direct TPMS, expected to be the largest group, cases were subsampled for extended interview by the data collection tablet at a goal of about one per daypart (morning, afternoon) per station for about 360 overall. The tablet selected the first such case of the morning and of the afternoon. If the extended interview did not complete (refused or dropped out), the tablet assigned the next one until the daypart quota was reached. Position of a case as first in a daypart was considered quasi-random.

Traffic counts. At intervals during the day, the tablet prompted data collectors to stop sampling and for 15 minutes count passenger vehicles arriving at the station, visually splitting them by vehicle type (passenger cars or LTV) based on provided training. They visually omitted larger trucks and buses but were not asked to visually restrict by model year or other eligibility factors. The tablet distributed the count times evenly through the 8-hour day.[76] The counts were collected for later extrapolation to sampling denominators.

Case weighting. Cases were weighted based on probability of selection in each sampling stage and post-stratification using known totals at some stages. NHTSA provided CISS weights for Stage 1. The survey contractor provided design weights (the inverse of the selection probability) for stages 2-4. Known totals for ZIP populations, PSU populations, PSU vehicle registrations, and national vehicle registrations by model year, vehicle type, FMVSS No. 138 compliance status, and TPMS type[77] were also available for weight post-stratification.

[74] Originally, the specification was MY 2006-2016. Later it was changed to MY 2006-2019.
[75] A similar assumption was made in Sivinski (2012).
[76] Originally, there were 8 counting periods per 8 hours at a station. It was reduced to five count periods per 8 hours starting on July 23 to open more time for collecting cases.
[77] The nationwide registration data is from the National Vehicle Population Profile (NVPP), a proprietary dataset purchased annually at national and State levels by NHTSA from IHS Markit Inc. The PSU registration data were from a special purchase of 2018 NVPP subset data made from IHS Markit Inc. Vehicle TPMS status and type were added to the NVPP data using data from NHTSA's Office of Vehicle Safety Compliance.

Weighting basic and extended interview questions. Every case got a vehicle inspection[78] and the core questions that made up the basic interview. Groups 1 and 3 (malfunctioning or disabled TPMS of either type) and 4 (working indirect TPMS) were subsampled for extended interviews at 100 percent and got group-specific extended interview modules plus two general extended interview modules (PAST MALFUNCTION#1 and CLOSE). Group 2 (functioning direct TPMS) was subsampled at a rate much lower than 100 percent: of 4006 cases (after correcting four cases for misclassified TPMS type), 483 got extended interviews. The subsample from Group 2 always got the two general extended interview modules and would get Module MALFUNCTION#2 if the low-pressure warning light was on. The final data consist of 4,477 cases where 3527 had only a basic interview and 950 had extended interviews.

For weighting, the distinction is not as much by the case as by the question. Basic interview questions have n=4,477 drawn from all cases. Extended interview questions have much smaller sample sizes drawn only from extended interviews. Because the extended interviews were not all selected at random, using basic interview weights on extended interview questions gives incorrect proportion point estimates for questions from the two general extended interview modules (where malfunctioning TPMS and indirect TPMS will be heavily over-represented). It also became apparent that the subsample weight had to be applied before post-stratification. These issues meant that separate weighting calculations for basic interview questions and extended interview questions were needed.

Developing special weights for the extended interview questions caused some special needs. Also, since some gas stations were non-productive and replaced, not every gas station in the sample achieved extended interviews in the Group 2 subsample. There were also small sample sizes for extended interview questions in other sampling stages, and when post-stratifying by the preferred variables (PSU, vehicle type, model year group, TPMS type), some cells would be empty. To work with these issues, weights were calculated at the PSU level. For consistency, it was desirable to use the same weighting procedures for the two concepts, so the PSU level weighting was also used for the basic interview weights.

The following steps were thus used for basic and extended interviews, the only differences being the presence of a subsampling stage for extended interview and the set of cases used in post-stratification.

1. **PSU weights.** The PSU weights were the same as those used in the CISS 24-PSU sample. The CISS 24-PSU weights give national representation to the 24 selected PSUs.
2. **ZIP Code weights**. For ZIPs selected in a PSU, the ZIP weight was calculated as the sum of the populations of all ZIPs in the PSU divided by the sum of the populations of selected ZIPs.
3. **Station weights.** For all selected stations in a PSU, the station weight was calculated as the number of stations listed in the selected ZIPs divided by the number of selected stations in the selected ZIPs.
4. **Vehicle weights.** For all vehicles selected in a PSU, the vehicle weight was calculated as the extrapolated number of eligible vehicles arriving during survey hours at all stations in the PSU divided by the number of vehicles entering the survey in the PSU. The total arriving was extrapolated from the periodic traffic counts taken at the stations. The

[78] There were no extended inspections. The inspection branched for all cases depending on TPMS type.

extrapolation formula had to change for cases done starting July 23 because the traffic counts were originally done 8 times a day, but on July 23 changed to five.[79] The traffic counts were also adjusted for eligibility by applying the proportion of survey-eligible vehicles in the PSU passenger vehicle registrations (needed because the traffic counts did not try to distinguish by model year or other aspects of survey eligibility beyond limiting to passenger vehicles).[80]

5. **Subsample weights.** For extended interview weights, Groups 1, 3 and 4 had a subsample weight of one. For Group 2, the subsample weight was calculated as the number of Group 2 cases in the PSU divided by the number of Group 2 extended interviews in the PSU. For basic interview weights, there was no subsampling stage.
6. **Within-PSU weight.** The within-PSU case weight was calculated as the product of the ZIP Code weight, station weight, vehicle weight, and subsample weight.
7. **Post-stratification 1.** Registration counts for the PSU for 2018 were adjusted to counts of vehicles eligible for the survey. Ratio 1 was calculated for each PSU as the number of survey-eligible vehicles registered in the PSU in 2018 divided by the sum of the within-PSU weights for the cases in the PSU.
8. **Within-PSU post weight**. The within-PSU post-weight was calculated as the product of the within-PSU weight and Ratio 1. This scales each within-PSU weight equally so that the within-PSU post weights will sum to the number of survey-eligible registered vehicles in the PSU in 2018.
9. **National weight.** The national weight was calculated as the product of the PSU weight and within-PSU post weight.
10. **Post-stratification 2.** National registration counts for 2018 were adjusted to counts of vehicles eligible for the survey. They were then divided into cells by model year group (2006-2008, 2009-2011, 2012-2014, 2015-2019) and TPMS type (indirect, direct) forming eight cells. For each cell, Ratio 2 was calculated as the number of survey-eligible vehicles registered in the nation in 2018 divided by the sum of the national weights for each case in the survey. This gives a different Ratio 2 for each cell.
11. **Final weight.** Cases were divided into groups matching the cells of post-stratification 2. For each group, the final weight was calculated as the product of the national weight and Ratio for the cell. This scales each national weight so that the final weights for each cell will sum to the number of eligible registered vehicles in the cell in 2018. The overall sum of the final weights will also match the number of nationwide survey-eligible registered vehicles.

[79] Sampling was suspended during traffic counts, so originally an 8-hour day had 45*8=360 minutes of sampling time and 15*8=120 minutes of counting time, for a multiplier of 360/120=3. Starting on July 23, the multiplier is (480-75)/75=5.4. Even if a day at a station is cut short, these proportions should be valid because the tablets were programmed to call for counts at proportionally timed intervals. One PSU was used both before and after July 23, so it is important to apply the multiplier by date rather than by PSU.

[80] Although the traffic counts were split into passenger car or LTV by data collector observation, the distinction was ultimately not used in weighting.

Why Ratio 2 was used. The PSU registration counts multiplied by the PSU weights give an estimated total very close to the actual national registration counts. This can be seen as a strong validation of the of the CISS sample design. In the survey, earliest cases accepted only MY 2006-2016. This was changed to MY 2006-2019 on September 10. Because there were fewer MY 2017-19, they were grouped with MY 2016-2017 for weighting and analysis. This made MY group 2015-2019 under-represented in the final sample. Also, the survey tried to oversample indirect TPMS by approaching them off the focal island. Ratio 2 adjusted weights to compensate for those issues. Ratio 2 was not used at the PSU level because the cells were sometimes too small or empty, especially for extended interviews.

Analysis of weighted responses. In analyzing basic and extended interview questions, basic interview question weights were used for all basic interview questions even if the case had an extended interview. A dataset was created of just extended interviews to calculate the extended interview weights. The resulting weights were used only for the extended interview questions in this report. Validation testing found that when using the two sets of weights on basic interview variables, the point estimates were quite close. See Appendix C for comparison results.

Smoothing. Along with the previously cited reasons for calculating weights at the PSU level, another benefit was that it smoothed weights and averted overly influential data points.

Registered vehicles. Low-sales vehicle makes were excluded from the registration counts per common ORAE practice. For this analysis, low sales was defined as a make that did not have at least 10,000 registered passenger vehicles nationwide in at least one model year during 2018. Removing low-sales vehicles reduced the national total for 2018 by 0.13 percent and had no practical effect on weighting or estimates.[81] No low-sales vehicle makes entered the survey.

Identifying subsampled cases. The data had no special flag for Group 2 subsampled cases, so they had to be identified by a combination of variables starting with disposition codes. Group 2 cases could only have one of these disposition codes:

67=Complete: TPMS low-pressure warning (Group 2 or 3 extended interview)
68=Complete: TPMS functioning properly (Group 2 or 3 extended interview)
77=At Quota: TPMS low-pressure warning (Group 2 basic interview)
78=At Quota: TPMS functioning properly (Group 2 basic interview)
38=End Survey, terminated early (can be any group, basic or extended)

In these codes, "Complete" means extended interview completed and "At Quota" means a basic only interview conducted because the extended interview quota for the daypart had been met. There was no "At Quota" for Group 3 because indirect TPMS always had an extended interview. As can be seen, disposition code alone wasn't enough to identify Group 2 subsampled cases. For further indications, the first questions from each of the three modules given to extended Group 2 interviews were checked for non-missing responses. The specific logic used to identify subsampled Group 2 interviews was: if Disposition Code is one of (38, 67, 68) and TPMS type is direct ([IND_TPMS]=2) and TPMS is working ([TPMSMALF]=2 or 4) and at least one of [MALEVER] (first question in Module PAST MALFUNCTION #1), [MAL2AW1] (first question in Module MALFUNCTION #2) or [TDRIVE] (first question in Module CLOSE) is not missing, the cases was considered to be a Group 2 subsampled case. Early terminations are possible, so extended interviews can have empty fields in the extended interview questions.

[81] The reduction was about 200,000 of about 157,300,000 or about 0.13%.

Appendix B. Field Survey Data Anomalies and Adjustments

The following summaries describe data anomalies and other circumstances found in the TPMS-ORRC Field Survey data and any related adjustments that were made during analysis.

Early termination. The dataset has 114 cases with disposition code "Early Termination." This occurred if a respondent chose to stop responding before the end of the survey. If that happened, the data collector exited the survey with a special tablet button. All cases with this situation went through at least the dashboard check. Responses for questions after the point of termination are missing in the data. (This is different from the response "Refused," which is applied on a question-by-question basis.) Twenty-one early terminations only have data through the dashboard check. Six early terminations had indirect TPMS. No adjustments were made.

Vehicle body type. Vehicle body type (passenger car or LTV) was assigned after the survey using ORAE VIN translator. ORAE NVPP translators related to the VIN translator were applied to NVPP registration data for the same body type classifications. In a very few cases, an NVPP "Trim" variable is used by the ORAE programs to help determine body type classification. Trim was used as needed in the national NVPP data, but the PSU registration data didn't have it, so where it was needed, national percentages of trim in NVPP were applied to the PSU registration data. Ultimately vehicle body type was not used in weighting, but for a few models, trim was needed in assigning registration data TPMS type, which was used in weighting.

Truck class. NVPP light truck data include Class 3 trucks, which are 10,000-14,000 GVWR, but the survey scope includes GVWR only up to 10,000 lb A few truck models can be either Class 2 (GVWR 6001-10,000 lb) or Class 3. When developing the NVPP survey-eligible vehicle data used for post-stratification Ratio 2, Class 3 trucks were easily omitted. For Ratio 1, the PSU registration data didn't have a GVWR field, so for the few models in question, the PSU totals were multiplied by (1 - the NVPP proportion of trucks that are Class 3).

Ineligible vehicles. The ORAE VIN translator found three trucks in the survey that had GVWR over 10,000 lb These are not in the survey universe so were dropped from weighted analysis. The sample size of 4,477 used in this report is for the data without these trucks.

Misclassified TPMS type. The tablet accessed NHTSA's vPIC online VIN decoder for on-the-spot assignment of make, model, and model year from the VIN scan. Lookup tables in the tablet assigned an eligible vehicle to indirect TPMS if the combination of make, model, and model year had indirect TPMS; otherwise, the eligible vehicle was assigned to direct TPMS. This meant if a VIN did not decode to a make and model exactly as spelled and capitalized in the lookup table, or didn't decode at all, it was classified as direct TPMS. Twenty vehicles had this situation. The ORAE VIN decoder and/or inspection data collector observation of vehicle make helped determine the TPMS type. Four vehicles in this situation had indirect TPMS. Per the default classification they had all been classified as direct TPMS. One of them was subsampled for a Group 2 extended interview. For weighting and analysis in this report, they are handled as indirect TPMS. Table B-1 shows the four misclassified vehicles.

Table B-1. Field Survey Vehicles Corrected from Direct to Indirect TPMS

MASTERID	Truncated VIN	MODEL YEAR	vPIC Make	vPIC Model	ORAE VIN decode make	ORAE VIN decode model	Data collector observed make
181015-50-0472	IFARW1H87HE	2017			12 FORD	99999 UNKNOWN	10=HONDA*
181029-22-1525	WA1VFBFL3DA	2013	AUDI	allroad	32 AUDI	32307 AUDI ALLROAD**	1=AUDI
180711-35-0384	WVWDA9AJ5BW	2011			30 VOLKSWAGEN	30042 VW GOLF/CABRIOLET **	21=VOLKSWAGEN
181107-50-1101	1HGCT2B48FA	2015	HONDA		37 HONDA	37032 HONDA ACCORD**	10=HONDA

*Data collector observed the vehicle type as SUV, leading to the conclusion that it is indirect TPMS because all Honda SUVs were indirect TPMS for model year 2017.
**The make and model decoded from the ORAE VIN decoder for the vehicle's model year had indirect TPMS.

Since the tablet routed these four vehicles as direct TPMS, they are missing the tire pressure inspection and interview Module INDIRECT. Since the other 16 vehicles in the situation had direct TPMS, no adjustment was needed for them.

Observed body type. In traffic counts, data collectors visually classified passenger vehicles by body type (passenger car or LTV) per training conducted. They also assessed body type in the observational non-response variable [BODY_OBS]. Comparing [BODY_OBS] to body type from the ORAE VIN decoder found that 97 percent of cars and 90 percent of LTVs were correctly classified in [BODY_OBS]. Some of the errors cancel each other in the aggregate, so that the net difference was about 4 percent. However, as there was no special sampling by body type and it was generally reflective of the population, body type was not separated in weighting. The observed body type was not used for case analysis since the ORAE VIN decoder assigned body type by VIN rather than observation. Observed body type was used in non-response analysis since the VINs of non-responding vehicles could not be known.

ZIP Code anomalies. ZIP selection was not always able to achieve a balance by income group in the two selected ZIPs. Five PSUs had both ZIPs with median income below the PSU median income. One PSU had both ZIPs above the median income. The other 18 PSUs had ZIPs on each side of the median income. In overall weighted case distribution, 56 percent are in ZIPs with median income at or below the PSU median income and 44 percent in ZIPs with median income above the PSU median income (true for basic interview weights or extended interview weights).

In PSUs 1 and 2, three ZIPs were used rather than the design plan of two. In both situations, the PSU had two second selected ZIPs that were used on different sets of days. It's possible that cooperation or viability issues forced a move to another ZIP or that the two stations were originally thought to be in the same ZIP.

PSU 6 had a misidentification for the ZIP of one of the stations used. The station was identified as being in the first selected ZIP but was in the second. As a result, the first selected ZIP had one station, and the second selected ZIP had three stations, instead of the intended balance of two stations per ZIP.

A ZIP labeled 00000 was not a legitimate ZIP so was not included in the sample frame.

Some ZIPs in California were dropped from the sample frame, apparently due to very small or sparse populations or other unknown reasons.

ZIP Code residency. Using PSU registrations to post-stratify weights would be most representative if all case vehicles were registered in the PSU, and an indication of this could be if the driver's home is in the PSU. The survey didn't prescreen for residency, but it only took in-State vehicles and asked all respondents for their home ZIP at the end. Home ZIP was missing or invalid (bad ZIP) in 138 cases for a 97 percent response rate. From the ZIP sampling frame, ZIPs were mapped to PSUs and respondent home ZIPs were checked for being in the PSU. Among respondents who gave a home ZIP, 80 percent lived in the PSU in which they were surveyed (the percentage varies by PSU and some rural PSUs had smaller percentages). Analysis also found no significant differences in the key variable of the dashboard check result [TPMSMALF] between in-PSU respondents and out-of-PSU respondents. Post-screening the respondents to only those with in-PSU home ZIPs would reduce the sample size from 4,477 to 3475. Because of these results and because each out-of-PSU respondent was at least from the same State as the PSU, out-of-PSU respondents were accepted as viable proxies for in-PSU respondents and were included in analysis.

State requirements. One PSU had counties in Massachusetts and Rhode Island. The survey-eligible registration counts were about 489,000 for the Massachusetts portion and about 73,000 for the Rhode Island portion giving Rhode Island about 13 percent of the survey-eligible registered vehicles in the PSU. At the time of the survey, it was believed that Rhode Island had a vehicle safety inspection requirement for working TPMS. Such a requirement would likely influence TPMS malfunction rates making them not reflective of nationwide rates, so ZIP sampling in the PSU was limited to Massachusetts ZIPs. Later checking found that Rhode Island did not have a TPMS requirement. No weighting adjustment was undertaken for the anomaly since the Massachusetts cases should represent the entire PSU and the PSU weight applies to the entire PSU. (Although the anomaly caused some confusion in the Field Survey, it was unavoidable since the survey was using the CISS PSU sample design.)

No information was found about any State having a TPMS requirement or air pressure requirement to pass State inspection in 2018 (or later, as of 2023). Some States require that State inspections check tire pressure and give the driver an advisory if pressure is low. California, starting in late 2010, requires that service facilities conduct a tire pressure check and air fill, if needed, on all service visits. Such mandates could influence low-pressure rates, and even malfunction rates if the pressure check raises awareness of a malfunction in the TPMS. See Section 13. for added information on State practices.

PSU situations. Sample subsets with low counts sometimes did not occur in every PSU. For instance, vehicles with a malfunction light occurred in 23 of the 24 PSUs, so all estimates for questions asked of drivers with a malfunction light are drawn from 23 PSUs rather than 24. SAS PROC SURVEYFREQ adjusts its estimates accordingly.

Mileage. It is possible that vehicles that are driven more would be more likely to get into a survey done at fuel stations, but the mileage of the vehicles in the Field Survey was rather evenly distributed. No adjustment was made for vehicle mileage.

Appendix C. Field Survey Sample Validation

Non-response data collection. Field Survey teams approached vehicles per the focal island hierarchy described in Appendix A. In inspection Module 1, the inspector entered 10 fields by observation whether the driver entered the survey or refused it. These were recorded for later non-response analysis. If these variables had noteworthy differences in the distributions between respondents (drivers who entered the survey) and non-respondents (drivers who refused the survey), it could warrant a concern about bias in the results and a need for possible adjustments or cautions.

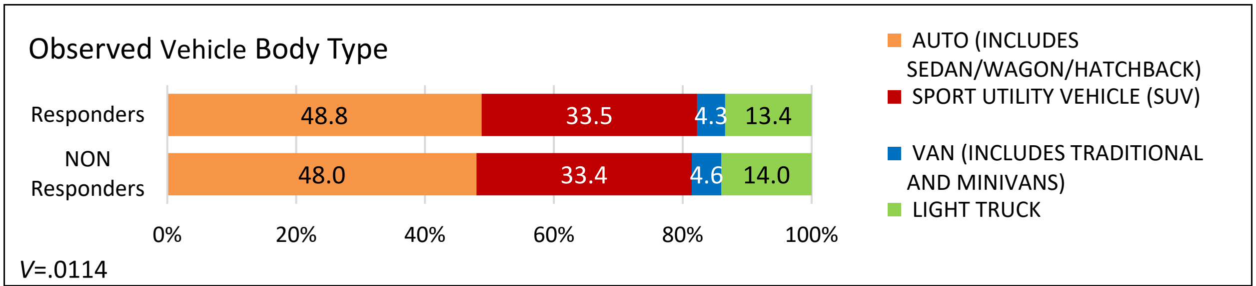
The observational variables collected were:

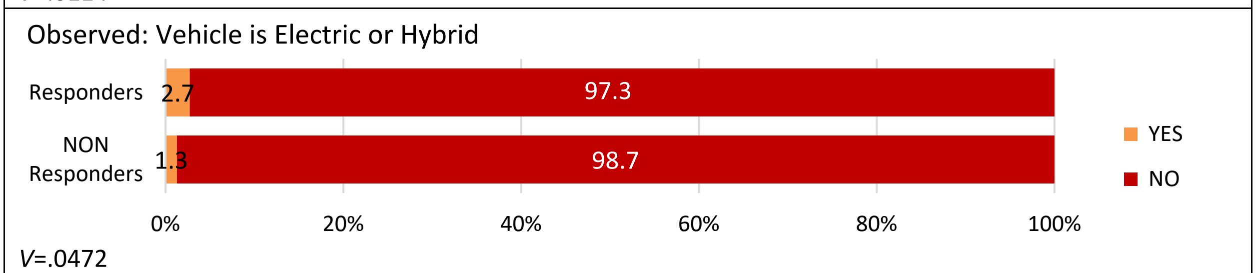
- body type of vehicle
- make of vehicle
- driver language spoken
- age group of driver (up to 25, 25-69, 70+)
- sex of driver
- number of adult occupants
- number of child occupants
- is there damage to the vehicle?
- is the vehicle equipped with a rear hitch?
- is the car a hybrid or electric?

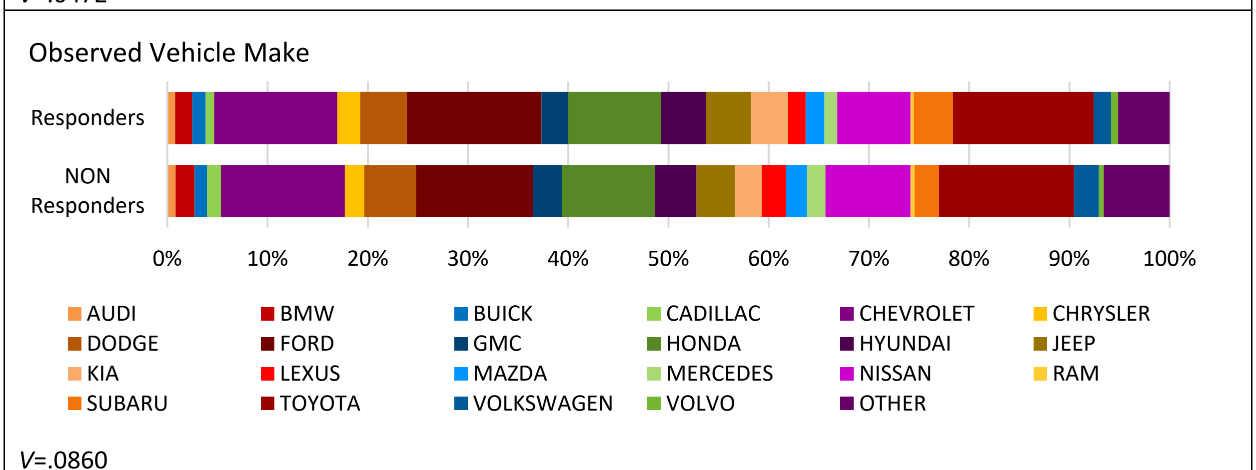
The file of non-responding cases had 2,722 observations, compared to 4,477 observations in the completed case file. The non-response file is unweighted, so comparisons between the two files are unweighted.

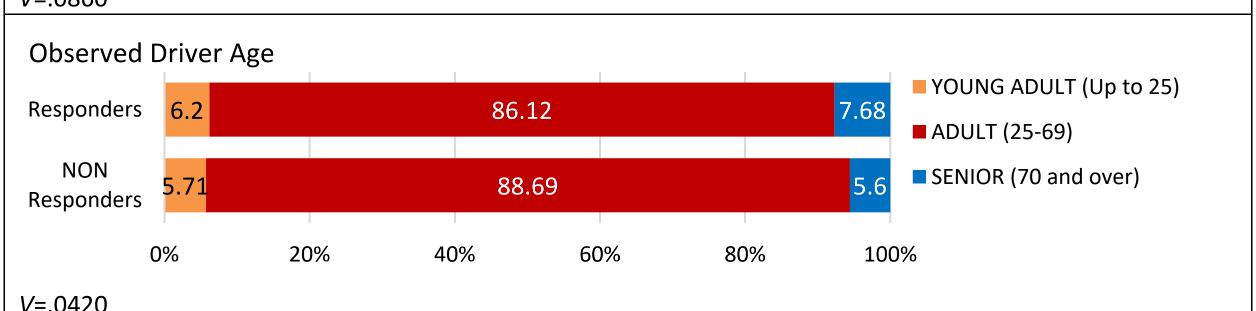
Analysis. To check for indications of non-response bias, the unweighted data for respondents and non-respondents were combined into one dataset for comparing variable distributions between the two groups. Relative bar charts of the results are shown in the figures inside Table C-1 for visual assessment. For a measure of effect size, SAS PROC FREQ was run on the combined data noting output statistic Cramér's V, a measure based on the chi-squared test of independence. If the smaller dimension of a cross-tabulation is two (true for all tested variables since respondent status has only two levels), Cramér's V (called Cramér's ϕ' by Cohen) matches Cohen's w, which ranges from 0 to 1 with the following interpretations suggested by Cohen: 0.10 to 0.30 is a small effect size, 0.30 to 0.50 a medium effect size, and greater than 0.50 a large effect size (Cohen, 1988). This leaves 0 up to 0.10 as a negligible effect size. Here, the "effect" is the effect of being a respondent or non-respondent, so that a negligible V implies a negligible effect of the difference. The V effect size is shown beneath the bar charts. All comparisons had V less than 0.10 (negligible), so the results did not find evidence to suggest non-response bias.

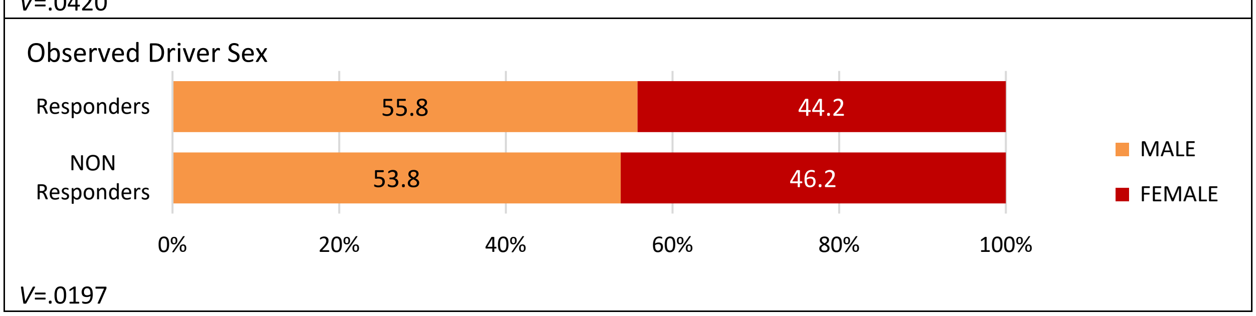
Table C-1. Figures, Non-Respondent Distributions Compared to Respondents, Field Survey

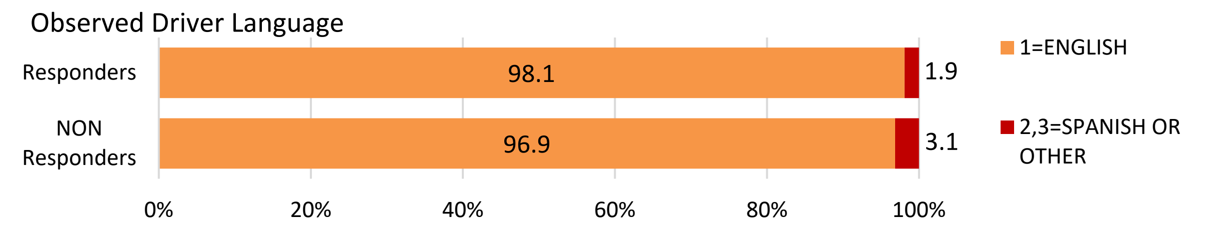












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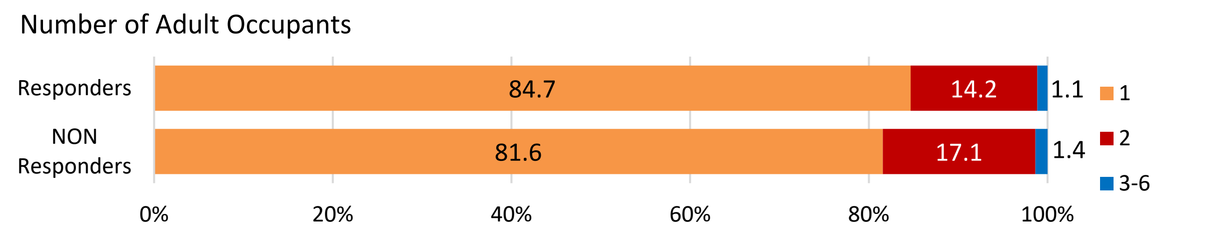

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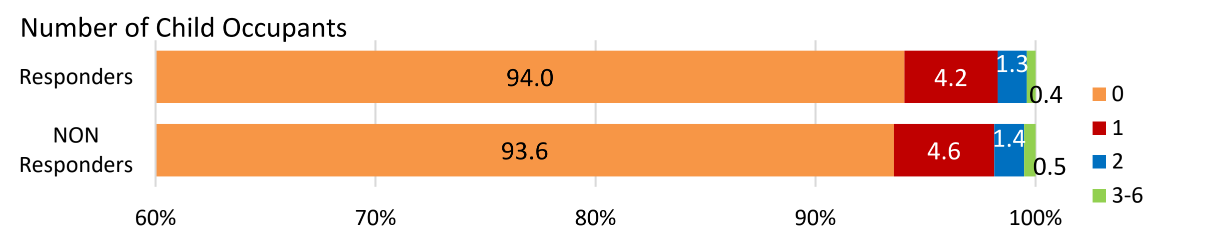
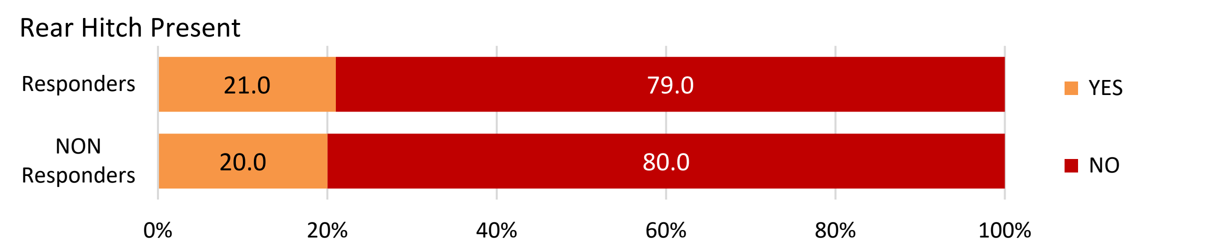
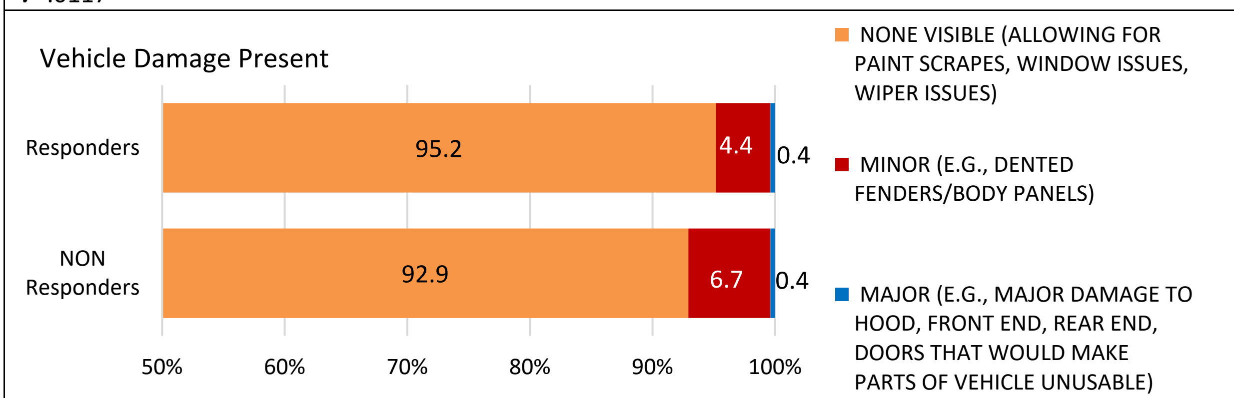


V=.0115



V=.0117



V=.0484

Vehicle make distributions in the weighted survey and in the population. Model year group and TPMS type totals in the Field Survey were post-stratified to the eligible vehicle population in the National Vehicle Population Profile (NVPP) for 2018, so their proportions in the weighted sample will by design match the proportions in the population. This is not so for vehicle make, which is available in the NVPP but was not a post-stratification factor since it would have too many cells. Vehicle make is thus a useful check on the sample proportions being representative of the population. Table C-2 shows the proportions for vehicle make in the weighted survey data and the NVPP. Figure C-1 shows the comparative proportions graphically.

Table C-2. Weighted Vehicle Make Proportions in Field Survey and National Registrations for Eligible Vehicles

Make	Survey Weighted %	2018 National Eligible Registered Vehicles %	Difference
ACURA	0.94	1.05	0.11
AUDI	0.94	1.05	0.11
BMW	1.73	1.93	0.2
BUICK	1.21	1.29	0.08
CADILLAC	0.83	1.08	0.25
CHEVROLET	12.68	12.23	-0.45
CHRYSLER	1.69	1.71	0.02
DODGE/RAM	5.31	5.43	0.12
FIAT	0.16	0.16	0
FORD	14.08	14.04	-0.04
GMC	2.74	3.02	0.28
HONDA	8.87	8.93	0.06
HYUNDAI/GENESIS	4.60	4.24	-0.36
INFINITI	0.74	0.74	0
JAGUAR	0.12	0.10	-0.02
JEEP	4.36	4.01	-0.35
KIA	3.91	3.36	-0.55
LAND ROVER	0.34	0.38	0.04
LEXUS	1.85	2.10	0.25
LINCOLN	0.66	0.66	0
MAZDA	2.02	1.80	-0.22
MERCEDES-BENZ	1.36	1.95	0.59
MERCURY	0.15	0.19	0.04
MINI	0.24	0.28	0.04
MITSUBISHI	0.53	0.53	0
NISSAN	7.50	7.23	-0.27
OTHER	0	0.29	0.29
PONTIAC	0.39	0.31	-0.08
PORSCHE	0.08	0.25	0.17
SATURN	0.21	0.18	-0.03
SMART	0.07	0.05	-0.02
SUBARU	3.16	2.94	-0.22
SUZUKI	0.04	0.11	0.07
TOYOTA/SCION	13.99	13.75	-0.24
VOLKSWAGEN	1.75	2.09	0.34
VOLVO	0.75	0.54	-0.21

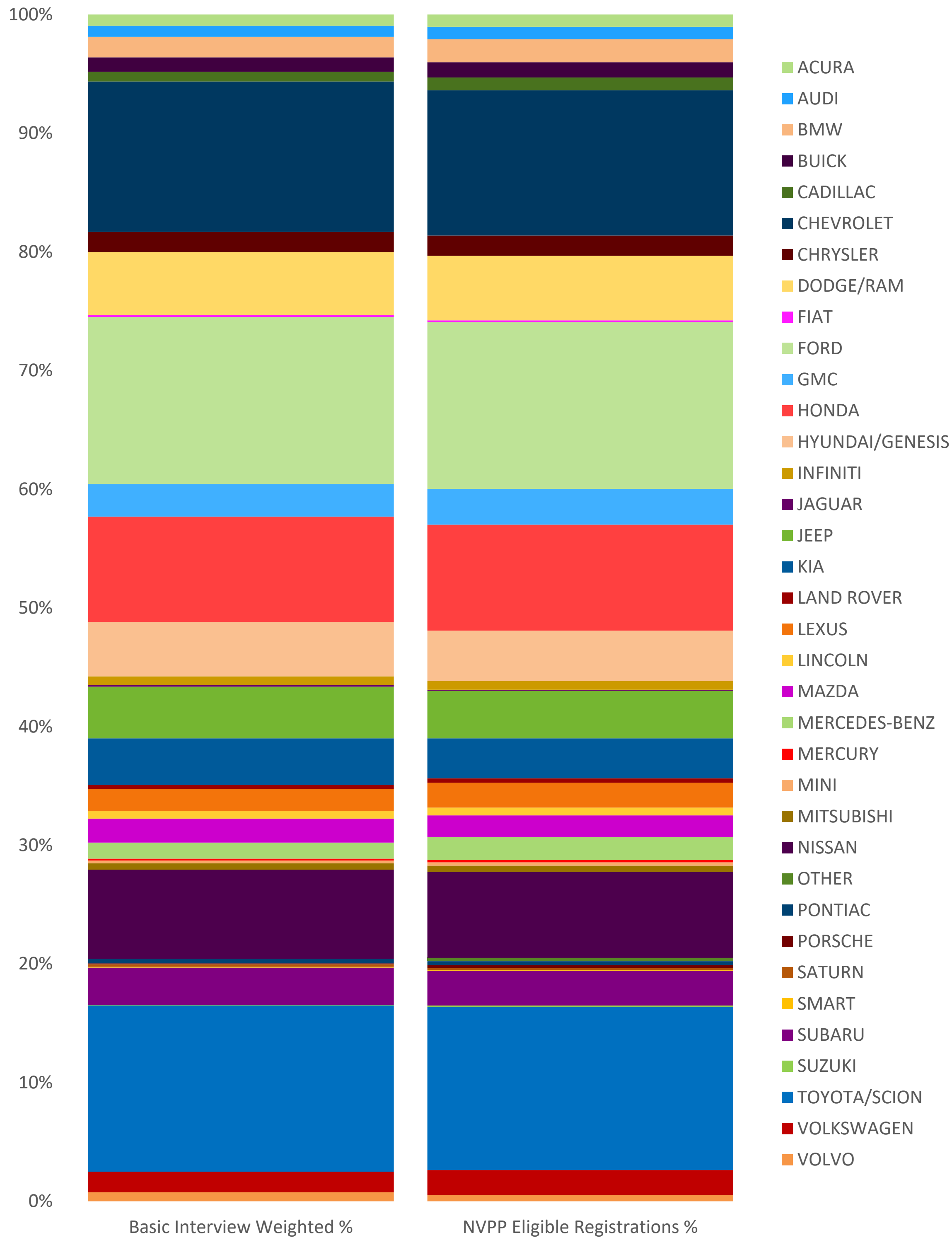
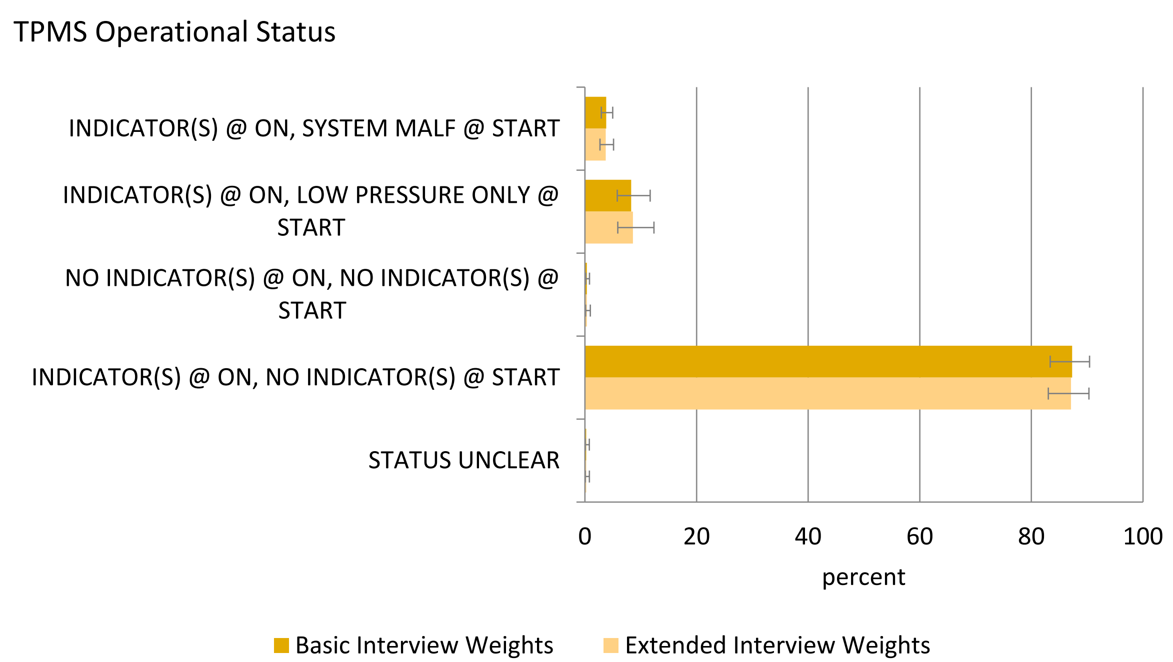
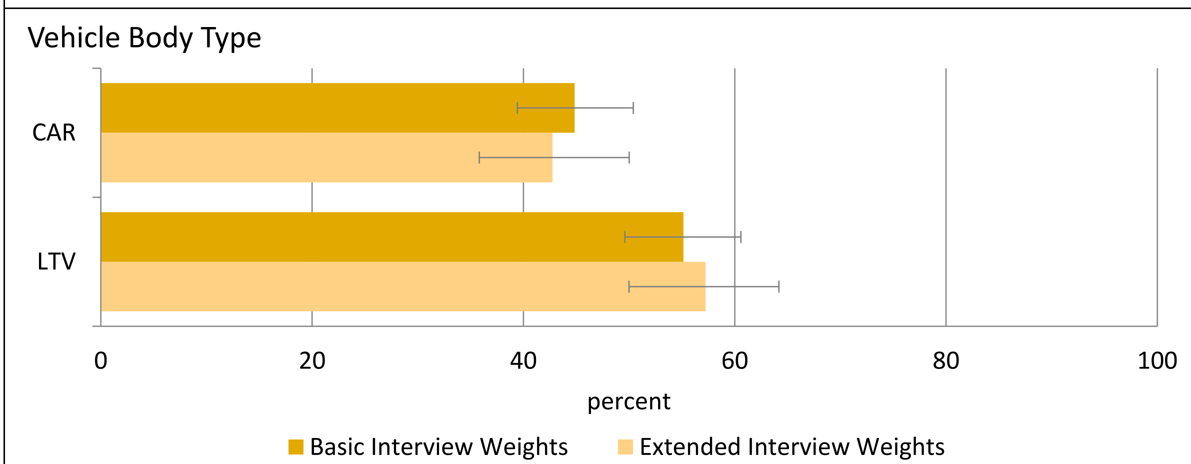


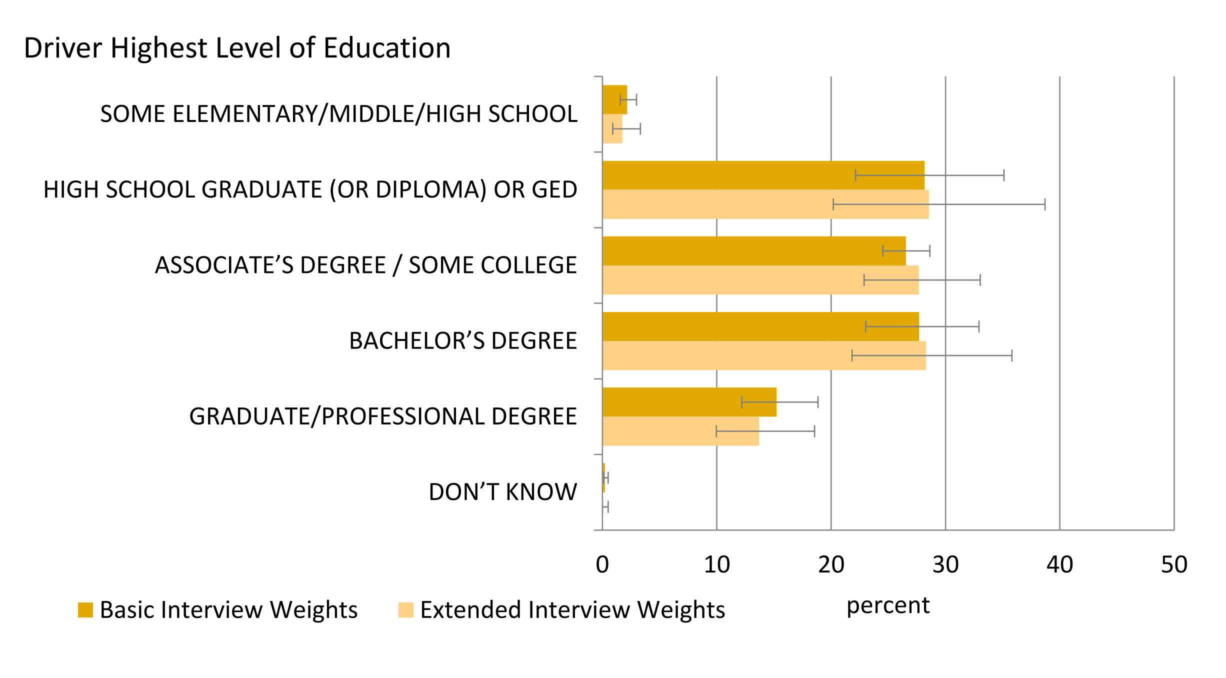
Figure C-1. Weighted Vehicle Make Proportions in Field Survey and National Registrations for Eligible Vehicles

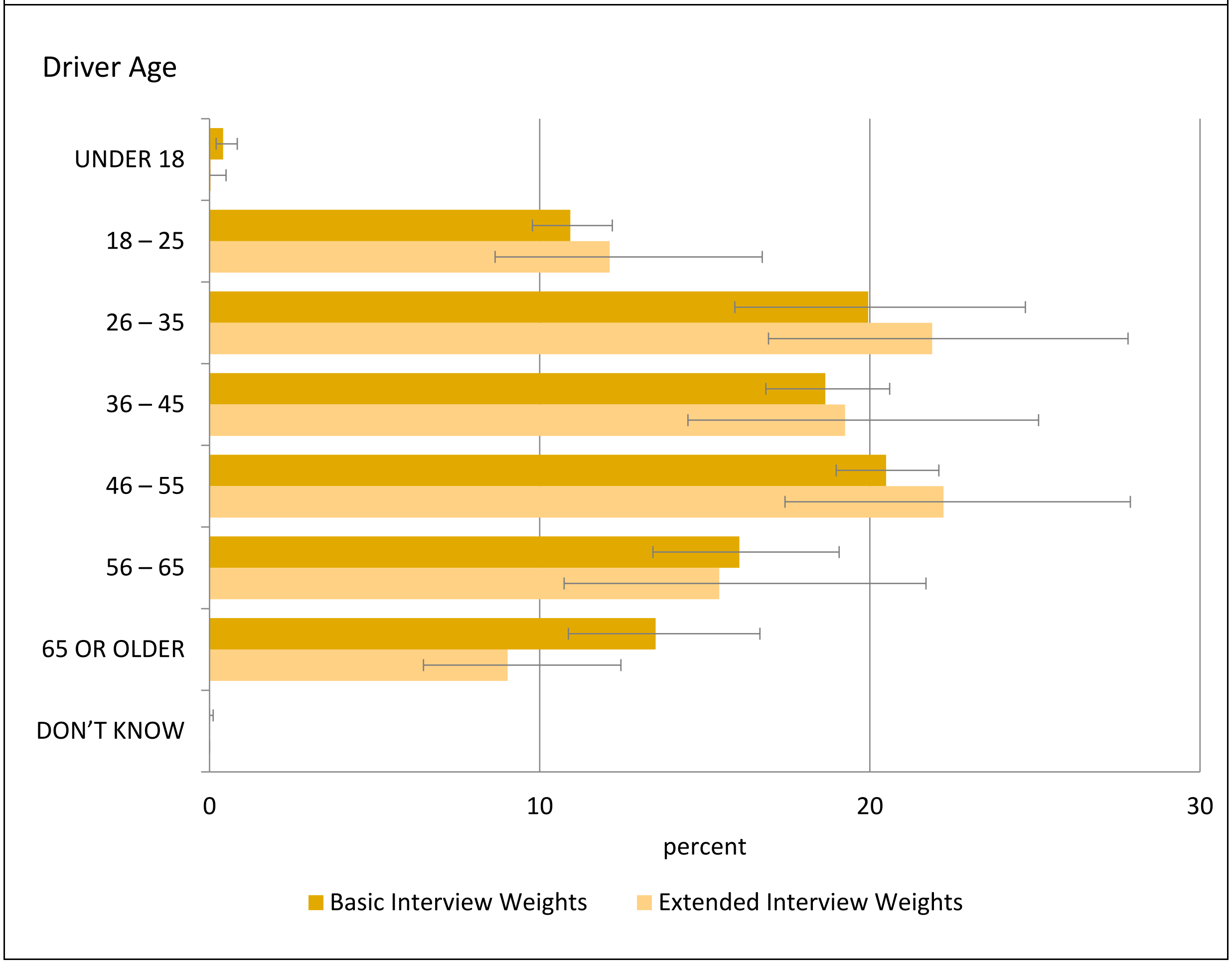
Weighted estimates from basic interview and extended interview. Weights for extended interviews were developed separately from weights for basic interviews (Appendix A). All basic interview variables are also in the extended interviews. If only analyzing basic interview variables, there is no need to use the extended interview weights, but if comparing a basic to an extended variable, it is necessary to use the extended interview weights. Checking weighted estimates is a way to help validate the extended interview weights as compared to the basic interview weights. Figures in Table C-3 show four basic interview variable response percentages estimated using the basic and extended interview weights. The confidence interval is often wider when using the extended interview weights since the sample size for extended interviews is much smaller.

Table C-3. Field Survey Example Weighted Estimates Using Basic or Extended Interview Weights






Driver Highest Level of Education
SOME ELEMENTARY/MIDDLE/HIGH SCHOOL
HIGH SCHOOL GRADUATE (OR DIPLOMA) OR GED
ASSOCIATE'S DEGREE / SOME COLLEGE
BACHELOR'S DEGREE
GRADUATE/PROFESSIONAL DEGREE
DON'T KNOW
0
10
20
30
40
50
percent
Basic Interview Weights
Extended Interview Weights


Driver Age
UNDER 18
18 – 25
26 – 35
36 – 45
46 – 55
56 – 65
65 OR OLDER
DON'T KNOW
0
10
20
30
percent
Basic Interview Weights
Extended Interview Weights

Most respondents lived in the PSU where their survey was conducted, and the others did not have substantially different response patterns. Ideally, drivers in the TPMS-ORRC would be residents of the PSU, but this was not required. Having an in-State plate was required, but this could have been overlooked in some sampled vehicles. The driver was asked home ZIP at the end of the survey. Table C-4 shows the sample makeup of respondent home ZIP situation. About 78 percent lived in the PSU.

Table C-4. Field Survey, Driver Home ZIP Code Situations

(category) **Home ZIP situation**	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
(1) Home ZIP is sample ZIP	1,855	41.43	1,855	41.43
(2) Home ZIP is a good other ZIP in the PSU	1,617	36.12	3,472	77.55
(3) Home ZIP is a good ZIP in the same State and not in a PSU	716	15.99	4,188	93.54
(4) Home ZIP is a good ZIP in another PSU in the same State	28	0.63	4,216	94.17
(5) Home ZIP is a good ZIP in another PSU in a different State	3	0.07	4,219	94.24
(6) Home ZIP is a good ZIP not in a PSU but in a PSU State	18	0.40	4,237	94.64
(7) Home ZIP is a good ZIP not in a PSU State	34	0.76	4,271	95.40
(8) Home ZIP is not a good ACS ZIP	68	1.52	4,339	96.92
(9) Home ZIP is missing or unknown	138	3.08	4,477	100.00

As a check example, Figure C-2 shows TPMS operational status [TPMSMALF] by respondents who lived in the PSU (categories 1 and 2 in Table C-4) and those who reported a good ZIP not in the PSU (categories 3-7). The effect size statistic Cramér's V was negligible at 0.048. Based on such checks, drivers who lived outside of the PSU were retained in the survey and were considered feasible proxies for PSU residents.

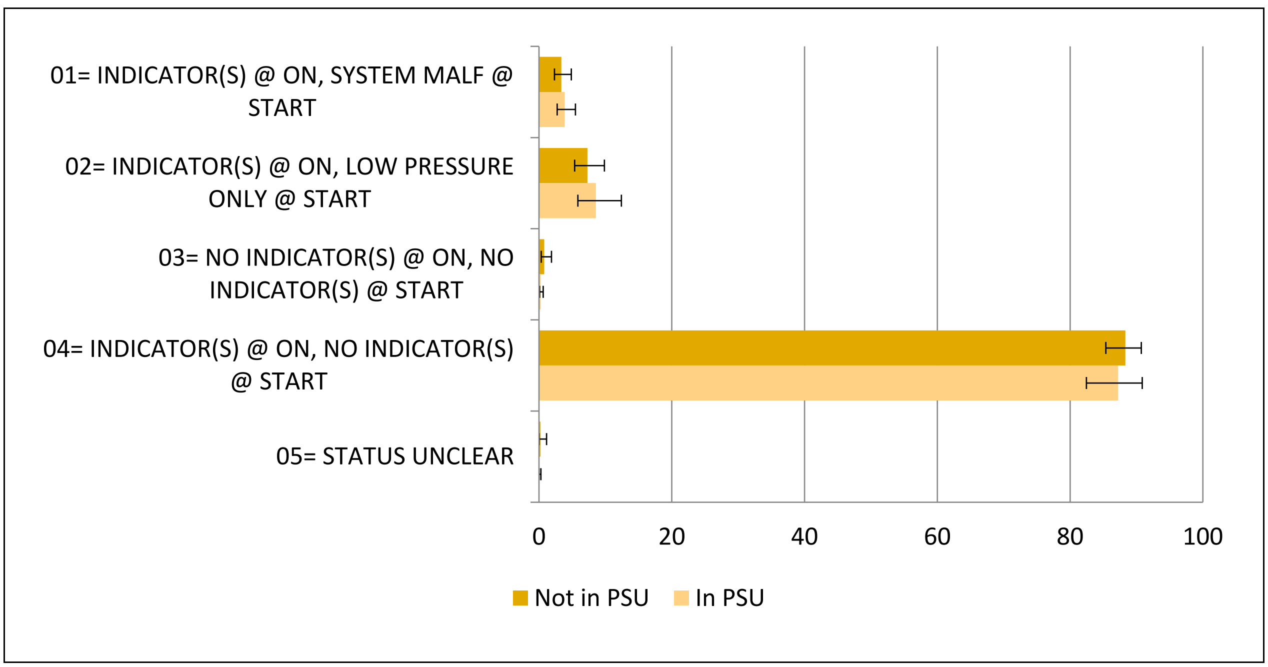


Figure C-2. Field Survey, TPMS Operational Status by Whether Driver Lived in the PSU

Appendix D. Field Survey Sample Makeup

Pie charts show the Field Survey unweighted sample makeup counts.

Figure D-1 shows sample counts for vehicle characteristics.

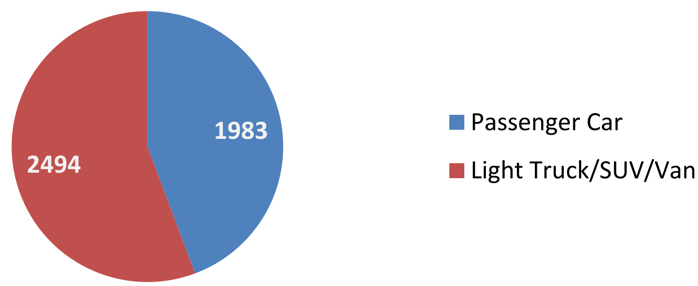
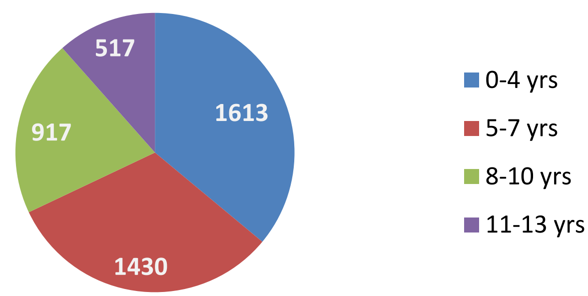
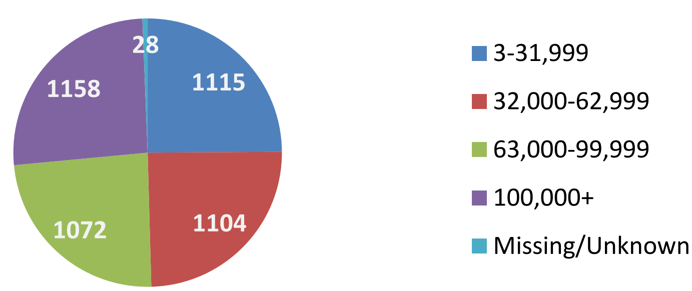
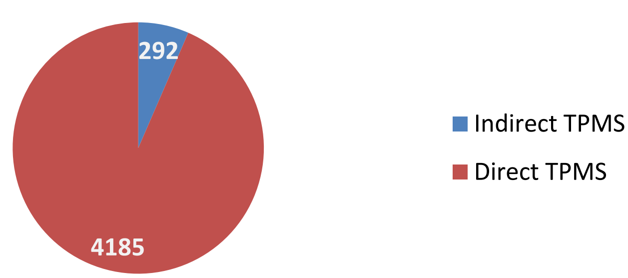
Characteristic	Sample Counts
Vehicle body type As classified in ORAE's VIN translating programs.	
Vehicle age In years. Derived as 2019 minus vehicle model year MY 2019=0 yr. MY 2018=1 yr. … Model year from VIN.	
Vehicle mileage Read from the odometer.	
TPMS type Mapped to the vehicle from tables provided by NHTSA's Office of Vehicle Safety Compliance.	

Figure D-1. Field Survey Sample Makeup, Vehicle Characteristics

Figure D-2 shows Field Survey sample counts for driver characteristics.

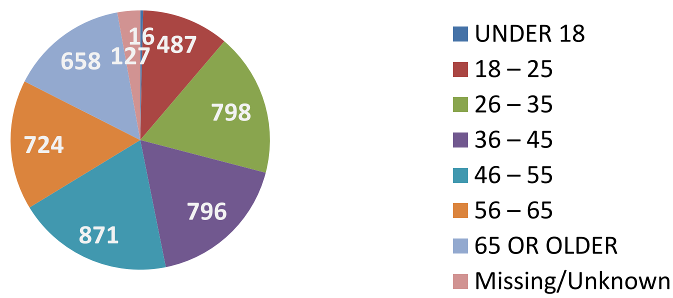
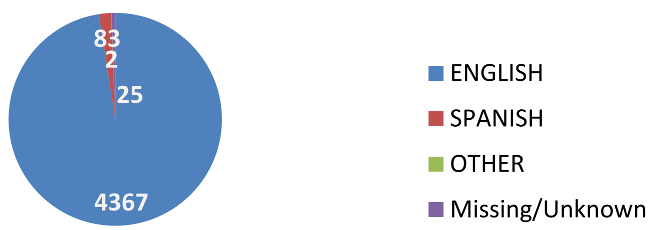
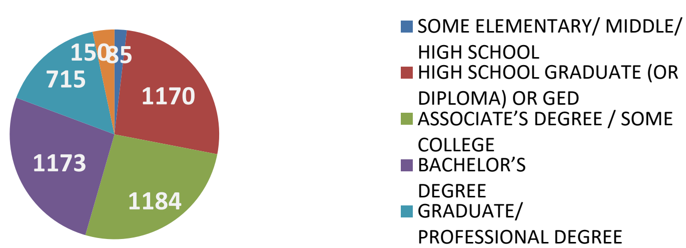
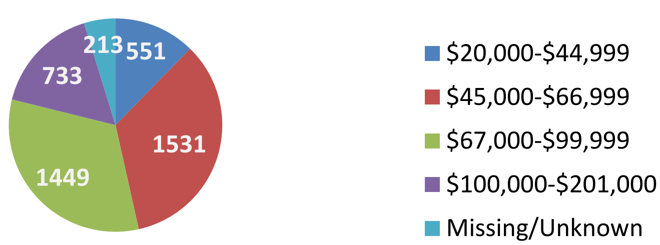
<table>
<tr><th>Characteristic</th><th>Sample Counts</th></tr>
<tr><td>Driver age group
In years. Respondents were asked age at the end of the interview or could point at an age group. Data were recorded in age groups only.</td><td>
</td></tr>
<tr><td>Driver sex
The surmised sex of the respondent per data collector observation.</td><td>
</td></tr>
<tr><td>Language
The primary language used by the driver, per data collector observation.</td><td>
</td></tr>
<tr><td>Education
Respondents were asked their highest level of education completed at end of interview.</td><td>
</td></tr>
<tr><td>Home ZIP median income
Respondents were asked their home ZIP Code at end of interview. 2018 median income by ZIP was added from Census Bureau data.</td><td>
</td></tr>
</table>

Figure D-2. Field Survey Sample Makeup, Driver Characteristics

Figure D-3 shows Field Survey sample counts for external characteristics.

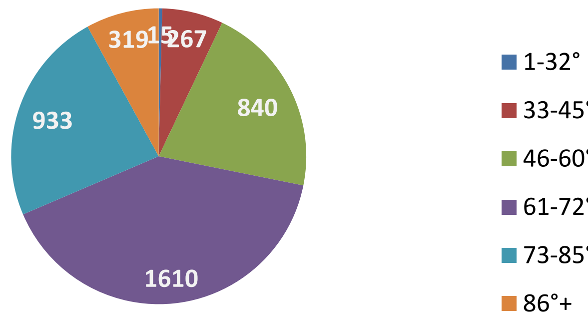
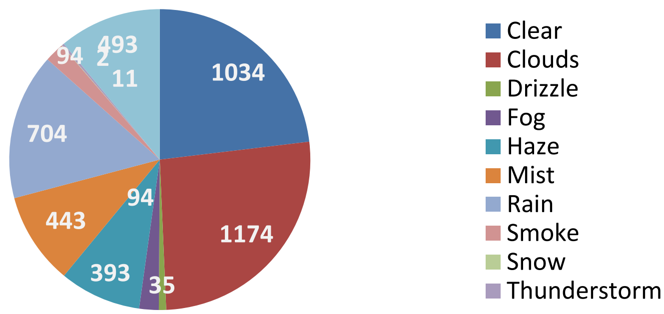
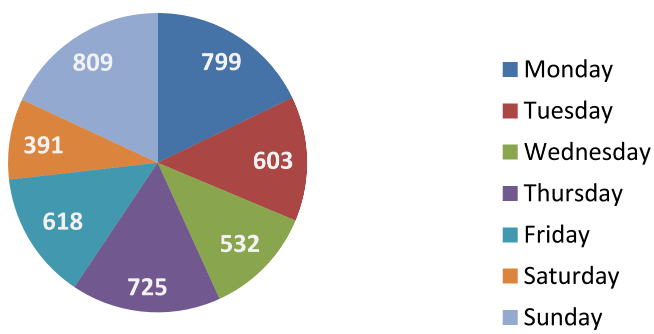
<table>
<tr><th>Characteristic</th><th>Sample Counts</th></tr>
<tr><td>Ambient air temperature at time of interview
Degrees F.
Measured at the data collection site with a pyrometer. (The survey was conducted June-November 2018)</td><td>
</td></tr>
<tr><td>Weather condition at time of interview
Recorded by observation at the site at the time of data collection.</td><td>
</td></tr>
<tr><td>Day of week
Recorded internally by the tablet.</td><td>
</td></tr>
</table>

Figure D-3. Field Survey Sample Makeup, Weather Conditions and Day of Week

Appendix E. Field Survey Response Tables

This appendix reports the percentage responses to each subject matter question in the TPMS-ORRC Field Survey. For ease of reading, bar charts are shown for each table with details as follows:

Bar graph. For each question, the bar end marks the point estimate for the response percentage. Error bars mark the start and end of 95 percent confidence intervals. Table entries at the end of bars give the point estimates and confidence intervals that generated the bars.

Domain. The domain is the subset of respondents eligible for the question. The "*n*" specified for the domain is the number of respondents that fell in that domain. The character string in brackets is the name of the variable in the data set, and the "*n*" below the variable name is the number of responses. The response "*n*" would ideally equal the domain "*n*" but may be less due to item non-response.

Inspection or interview. Questions marked as INSPECTION were observational variables not asked of the respondent. Question not marked as INSPECTION are interview questions.

Survey modules. As explained in Section 3.1, the survey had different modules that applied to different domains, depending on the case's TPMS situation, or on random selection. Skip patterns in the tablet programming sent the tablet interface to the appropriate module. The response tables are shown in survey order by module.

Other skip patterns. Some questions within modules had different domains depending on previous question within the module. For example, a respondent would be asked the cost of previous braking work only if the respondent reported having previous braking work. Such situations are explained in the domain description.

Lower or upper case. In interview questions, response options in lower case were read or shown to the respondents; response options in upper case were not read aloud and were coded from the respondent's open answer. In inspection questions, no questions or answers were read aloud as the inspector silently recorded the observations.

Weighted data. All response results are based on weighted data.

Questions. The questions shown start after the non-response observational module and the initial screening questions.

A module flow chart for the survey is shown in Figure E-1.

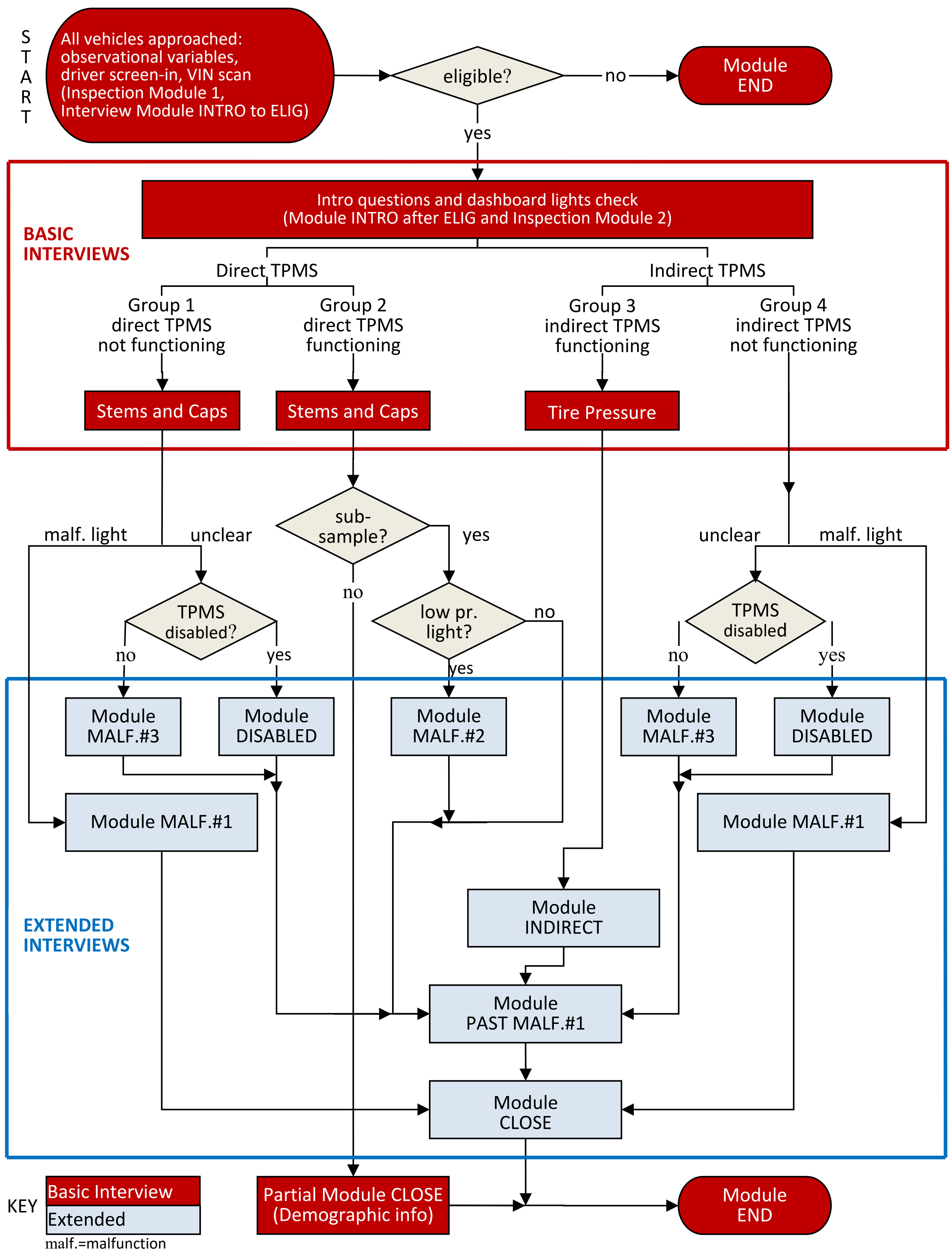


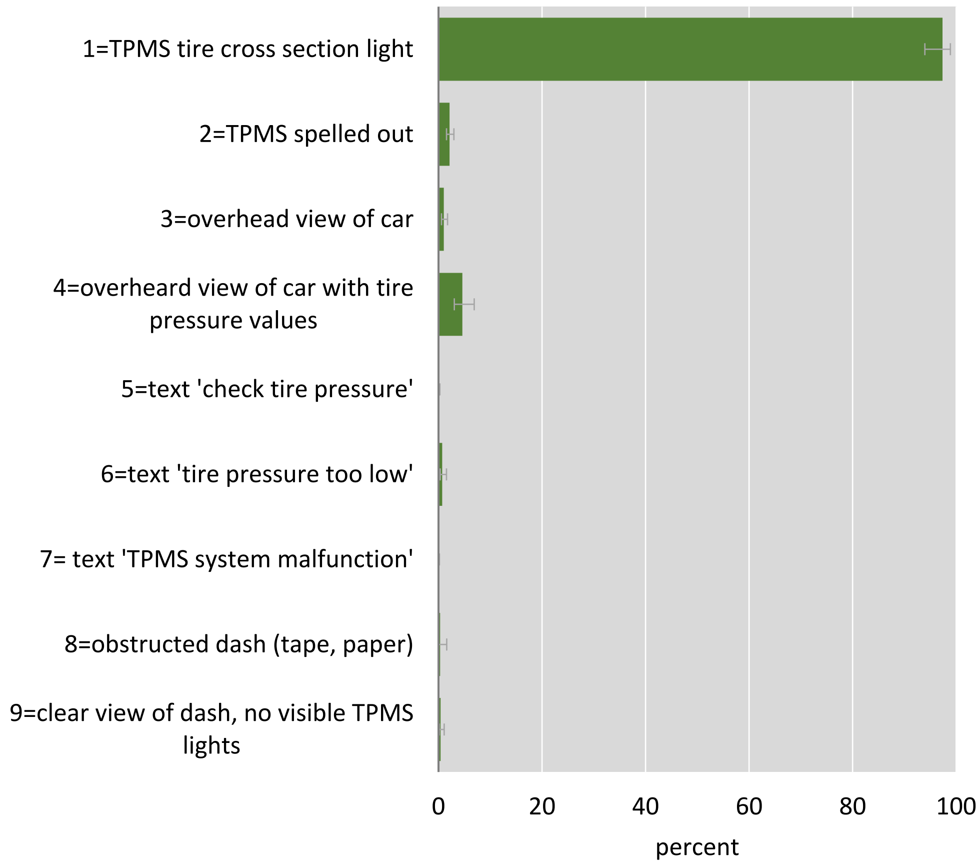
Figure E-1. Flow Chart of the TPMS-ORRC Field Survey

INSPECTION MODULE 1 – Non-response data (Appendix C).

INSPECTION MODULE 2 – Entered by all vehicles participating in the survey.

IGNITION TEST, ON POSITION. INSPECTOR: TURN KEY FROM LOCK (0) TO ON (II) POSITION AND PAUSE 5 SECONDS. SELECT ALL TPMS-RELATED INDICATOR LIGHTS OR READOUTS VISIBLY ILLUMINATED ON THE DASH (ALLOWING FOR MINOR STYLISTIC VARIATIONS OR DIFFERENCES IN WORDING).

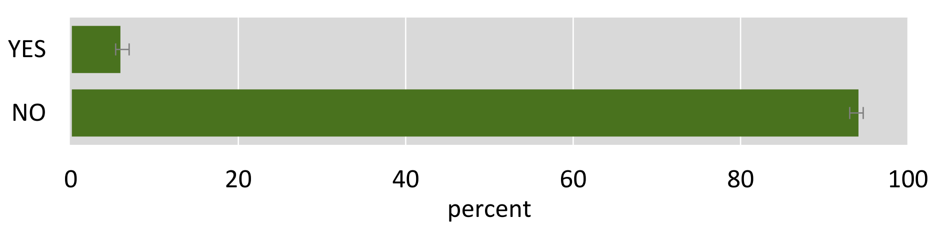
DOMAIN: All (n=4477)



	pct	95% C.I.
1=TPMS tire cross section light	97.4	(94.0, 98.9)
2=TPMS spelled out	2.2	(1.5, 3.0)
3=overhead view of car	1.0	(0.6, 1.8)
4=overheard view of car with tire pressure values	4.6	(3.1, 6.9)
5=text 'check tire pressure'	0.1	(0.0, 0.3)
6=text 'tire pressure too low'	0.7	(0.3, 1.5)
7= text 'TPMS system malfunction'	0.1	(0.0, 0.2)
8=obstructed dash (tape, paper)	0.3	(0.1, 1.6)
9=clear view of dash, no visible TPMS lights	0.4	(0.2, 1.1)

Insp. Module 2
[TPMSON]
n=4477

INSPECTION: Are ANY indicator lights (other than TPMS indicators) illuminated in ON (II) position? *DOMAIN: All (n=4477)*



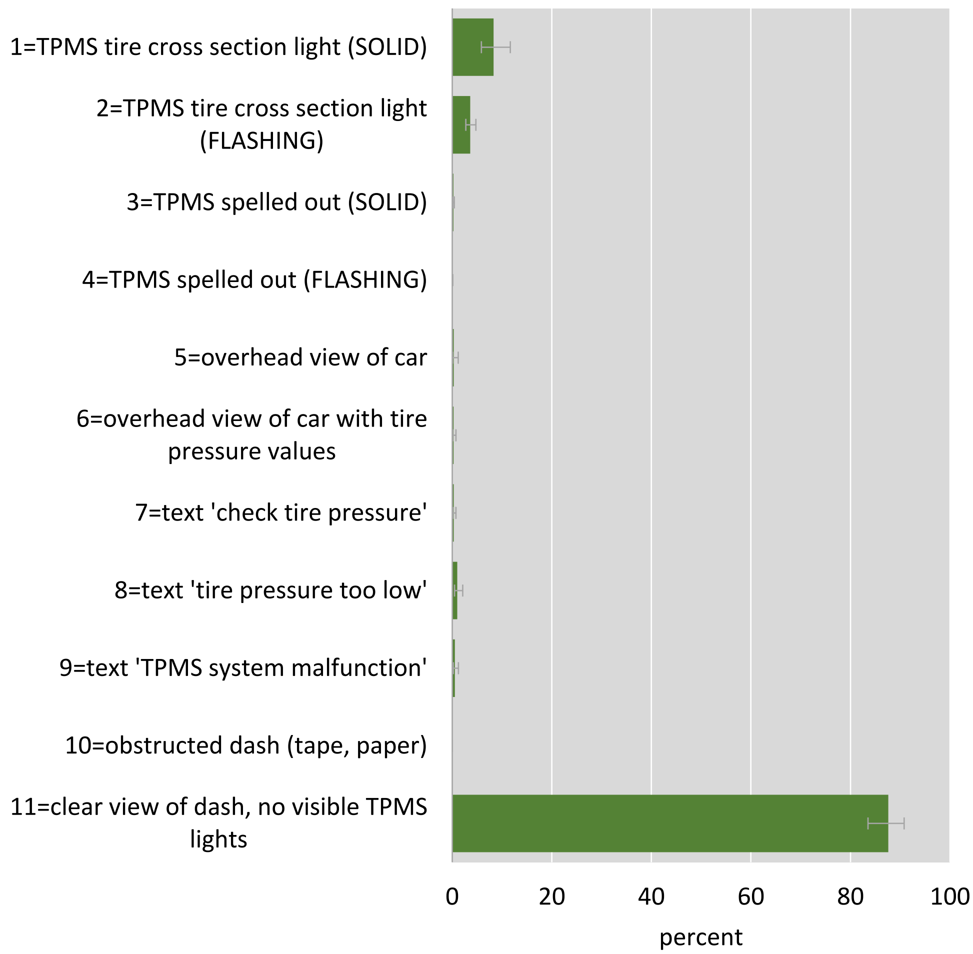
	pct	95% C.I.
YES	5.9	(2.5, 13.4)
NO	94.1	(86.6, 97.5)

Insp. Module 2
[WARN1]
n=4452

Source: NHTSA TPMS-ORRC, 2018

(IGNITION TEST, START POSITION) INSPECTOR: TURN KEY FROM ON (II) TO START (III) POSITION AND PAUSE 5 SECONDS. SELECT ALL TPMS-RELATED INDICATOR LIGHTS OR READOUTS VISIBLY ILLUMINATED ON THE DASH (ALLOWING FOR MINOR STYLISTIC VARIATIONS OR DIFFERENCES IN WORDING).

DOMAIN: All (n=4477)

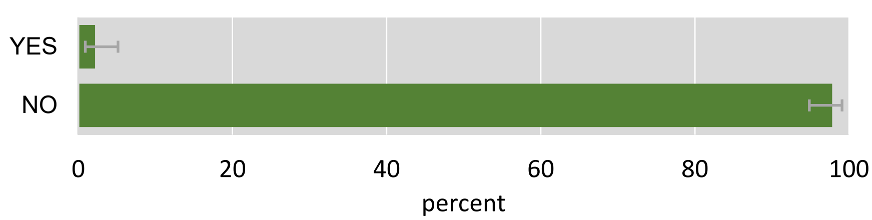


	pct	95% C.I.
1=TPMS tire cross section light (SOLID)	8.3	(5.9, 11.7)
2=TPMS tire cross section light (FLASHING)	3.6	(2.7, 4.7)
3=TPMS spelled out (SOLID)	0.2	(0.1, 0.4)
4=TPMS spelled out (FLASHING)	0.0	(0.0, 0.1)
5=overhead view of car	0.3	(0.1, 1.2)
6=overhead view of car with tire pressure values	0.3	(0.1, 0.7)
7=text 'check tire pressure'	0.3	(0.1, 0.7)
8=text 'tire pressure too low'	1.0	(0.5, 2.1)
9=text 'TPMS system malfunction'	0.5	(0.2, 1.2)
10=obstructed dash (tape, paper)	0.0	
11=clear view of dash, no visible TPMS lights	87.6	(83.5, 90.8)

Insp. Module 2
[TPMSSTART]
n=4477

INSPECTION: Are ANY indicator lights (other than TPMS indicators) illuminated in START (III) position?

DOMAIN: All (n=4477)



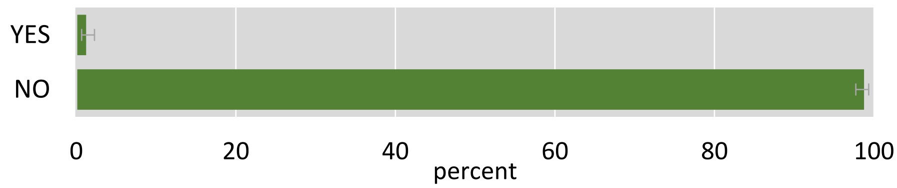
	pct	95% C.I.
YES	2.2	(0.9, 5.1)
NO	97.8	(94.9, 99.1)

Insp. Module 2
[WARN2]
n=4,379

Source: NHTSA TPMS-ORRC, 2018

INSPECTION: Has an attempt been made to cover up any indicator lights on the dash (e.g., with tape)?

DOMAIN: All (n=4477)



	pct	95% C.I.
YES	1.2	(0.7, 2.3)
NO	98.8	(97.7, 99.3)

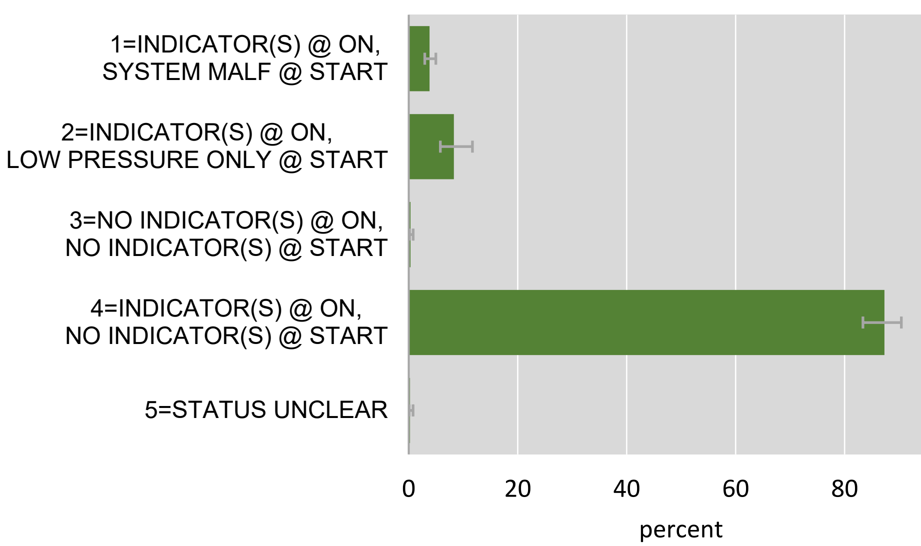
Insp. Module 2
[TPMSTAPE]
n=4,453

Source: NHTSA TPMS-ORRC, 2018

TPMS DASH INSPECTION RESULT set in tablet

DOMAIN: All (n=4477)

Condition	TPMS Situation [TPMSMALF]
IF TPMSON NE 9 AND TPMSSTART IN 2,3,4,9	1=INDICATOR(S) @ ON, SYSTEM MALF @ START (malfunction indicator illuminated)
ELSE IF TPMSON NE 9 AND TPMSSTART IN 1,6,7,8	2=INDICATOR(S) @ ON, LOW PRESSURE ONLY @ START (low-pressure indicator illuminated)
ELSE IF TPMSON=9 AND TPMSSTART=11	3=NO INDICATOR(S) @ ON, NO INDICATOR(S) @ START (no lights, possibly disabled, indeterminate)
ELSE IF TPMSON NE 9 AND TPMSSTART=5,11	4=INDICATOR(S) @ ON, NO INDICATOR(S) @ START (normal situation, TPMS is working, pressure is OK)
ELSE	5=STATUS UNCLEAR (indeterminate, but can't be functioning right)



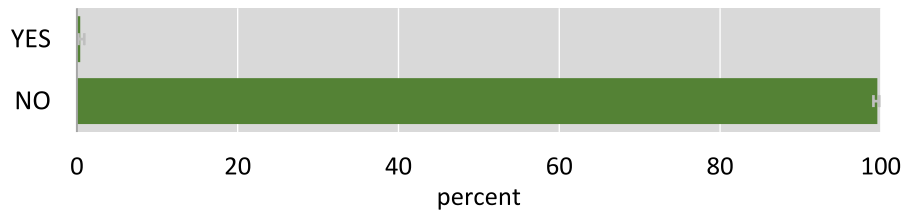
	pct	95% C.I.
1=INDICATOR(S) @ ON, SYSTEM MALF @ START	3.8	(2.9, 5.0)
2=INDICATOR(S) @ ON, LOW PRESSURE ONLY @ START	8.3	(5.8, 11.7)
3=NO INDICATOR(S) @ ON, NO INDICATOR(S) @ START	0.3	(0.1, 0.8)
4=INDICATOR(S) @ ON, NO INDICATOR(S) @ START	87.3	(83.4, 90.4)
5=STATUS UNCLEAR	0.2	(0.1, 0.8)

Insp. Module 2
[TPMSMALF]
n=4,477

Source: NHTSA TPMS-ORRC, 2018

INSPECTION: Does the vehicle contain visible equipment that could cause electromagnetic interference (e.g., radar detector)? [Toll collection tags do NOT count as electromagnetic interference equipment]

DOMAIN: All (n=4477)



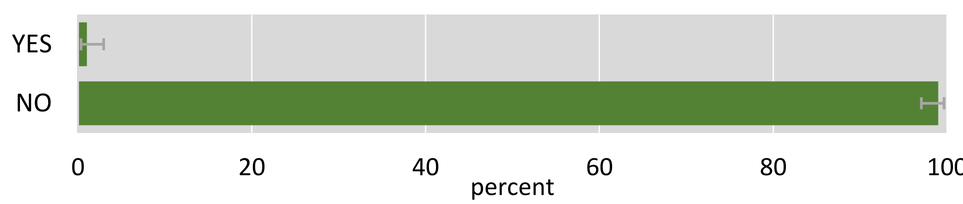
	Pct	95% C.I.
YES	0.4	(0.2, 0.9)
NO	99.6	(99.1, 99.8)

Insp. Module 2
[EMAG]
n=4,355

Source: NHTSA TPMS-ORRC, 2018

INSPECTION: Does the vehicle appear to have one or more spare tires (mini- or full-size) or non-matching wheels installed?

DOMAIN: All (n=4477)



	pct	95% C.I.
YES	1.0	(0.3, 3.0)
NO	99.0	(97.0, 99.7)

Insp. Module 2
[SPARE]
n=4,370

Source: NHTSA TPMS-ORRC, 2018

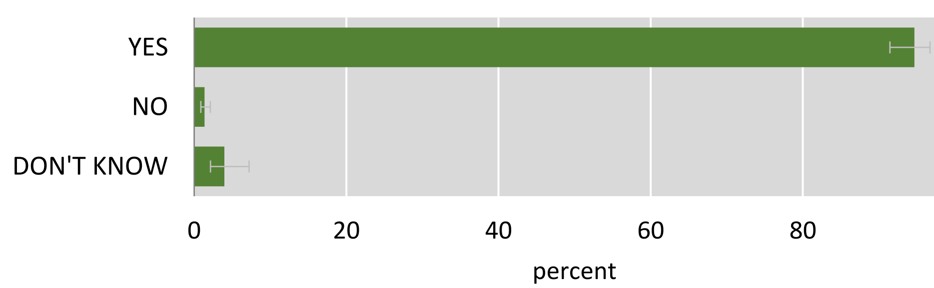
End Inspection Module 2

(All modules from this point on are interview modules.)

Module INTRO – entered by all respondents.

To your knowledge, is this vehicle equipped with a tire pressure monitoring system, known as TPMS—whether or not it is currently working?

DOMAIN: All (n=4477)



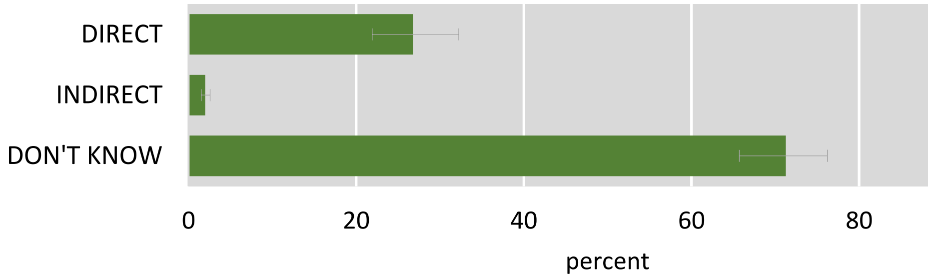
	pct	95% C.I.
YES	94.7	(91.5, 96.7)
NO	1.4	(0.9, 2.1)
DON'T KNOW	4.0	(2.1, 7.2)

Module INTRO
[TPMSEQ]
n=4,450

Source: NHTSA TPMS-ORRC, 2018

To your knowledge, is the TPMS system in this vehicle “direct,” using sensors in the wheels, or “indirect,” using sensors in the antilock braking system?

DOMAIN: Respondent reports vehicle is equipped with TPMS (n=4230)



	pct	95% C.I.
DIRECT	26.8	(21.9, 32.2)
INDIRECT	2.0	(1.5, 2.6)
DON'T KNOW	71.3	(65.7, 76.2)

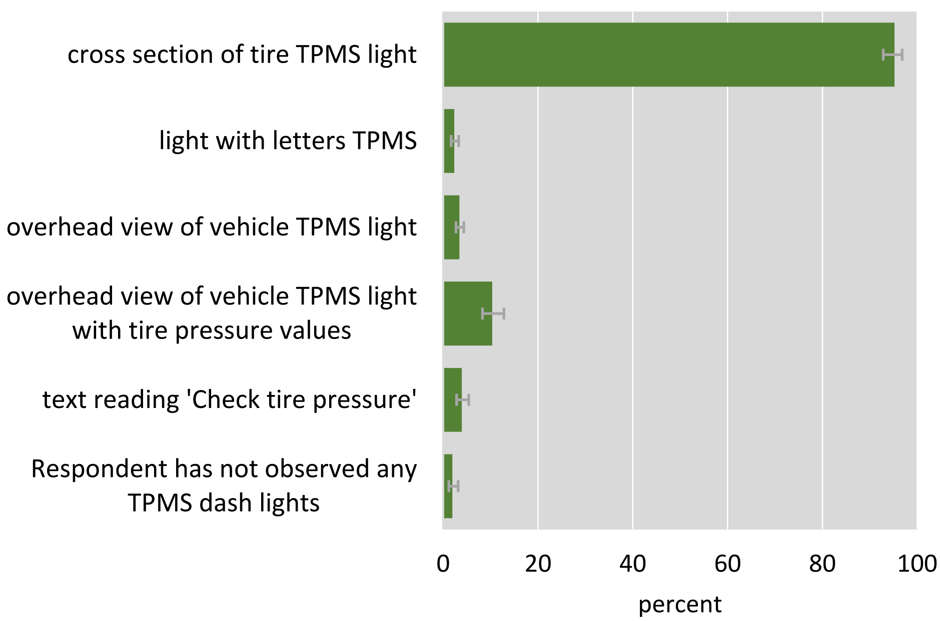
Module INTRO
[TPMSTYPE]
n=4,223

Source: NHTSA TPMS-ORRC, 2018

Looking at these pictures – and allowing for minor variations in style – please point to those items that you have seen on your vehicle’s dash at any time in the past, either when starting the engine or later when the vehicle was running. SELECT ALL THAT APPLY

[INTERVIEWER: SHOW RESPONDENT IMAGES OF TPMS SYMBOLS]

DOMAIN: All (n=4477)



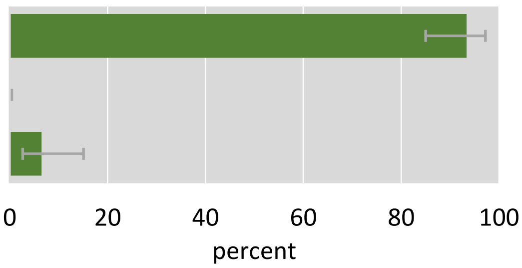
	pct	95% C.I.
cross section of tire TPMS light	95.2	(92.8, 96.8)
light with letters TPMS	2.3	(1.7, 3.3)
overhead view of vehicle TPMS light	3.4	(2.7, 4.3)
overhead view of vehicle TPMS light with tire pressure values	10.3	(8.3, 12.8)
text reading 'Check tire pressure'	3.9	(2.8, 5.4)
Respondent has not observed any TPMS dash lights	1.9	(1.2, 3.2)

Module INTRO
[TPMSDASH]
n=4,432

What does this light/these lights mean to you?

[INTERVIEWER: BACKCODE RESPONSE; IF NECESSARY, ASK WHAT LIGHT(S) MEAN WITH REGARD TO SPECIFIC VEHICLE SYSTEMS]

Domain: All (n=4477)



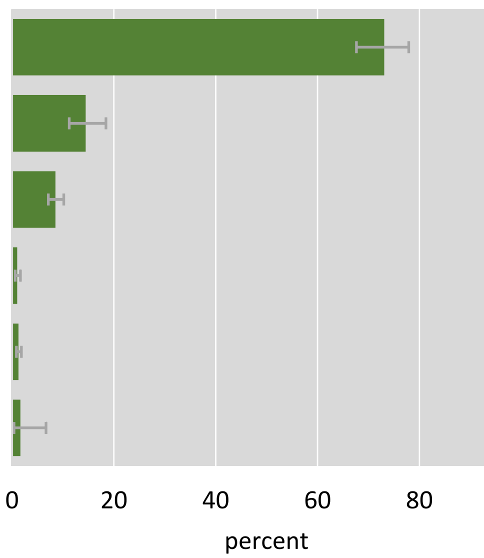
	pct	95% C.I.
RELATED TO TIRE PRESSURE/TPMS	93.4	(85.0, 97.2)
OTHER	0.1	(0.0, 0.4)
DON'T KNOW	6.5	(2.6, 15.1)

Module INTRO
[TPMSDASHA]
n=4,436

Source: NHTSA TPMS-ORRC, 2018

How important is it to you that your next personal vehicle be equipped with a TPMS system? Would you…

DOMAIN: All (n=4477)



	pct	95% C.I.
Strongly prefer the vehicle be equipped with TPMS?	73.1	(67.6, 77.9)
Somewhat prefer the vehicle be equipped with TPMS?	14.5	(11.2, 18.4)
Have no preference whether the vehicle is equipped with TPMS?	8.5	(7.1, 10.2)
Somewhat prefer the vehicle NOT be equipped with TPMS?	1.0	(0.6, 1.6)
Strongly prefer the vehicle NOT be equipped with TPMS?	1.3	(0.9, 1.8)
DON'T KNOW	1.6	(0.4, 6.7)

Module INTRO
[NEXTVEH]
n=4,428

Source: NHTSA TPMS-ORRC, 2018

Based on the model year of your vehicle, it should have been manufactured with a TPMS system, but during our vehicle inspection we were not able to confirm that your vehicle has a functioning TPMS system. Has the TPMS system in this vehicle been disabled?

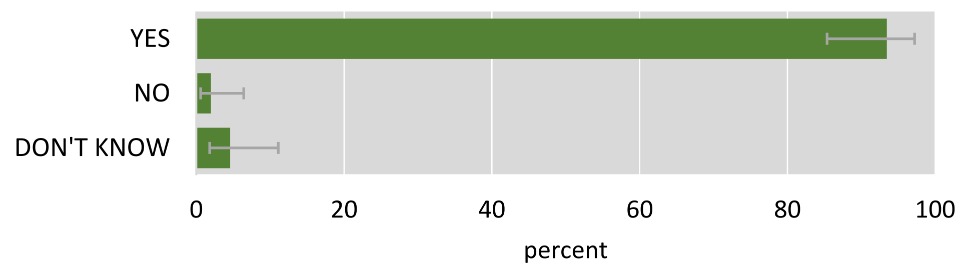
DOMAIN: Vehicle is known to be equipped with TPMS, but no TPMS indicator lights illuminate in ON position (MALFCODE= 3 or 5) (n=15) Domain size too small for estimates.

End Module INTRO

Module MALFUNCTION #1 - entered by all respondents experiencing a TPMS malfunction indicator currently illuminated.

Are you aware that a TPMS dash light is currently on in your vehicle?

DOMAIN: TPMS malfunction indicator is currently illuminated (TPMSMALF=1) (n=159)



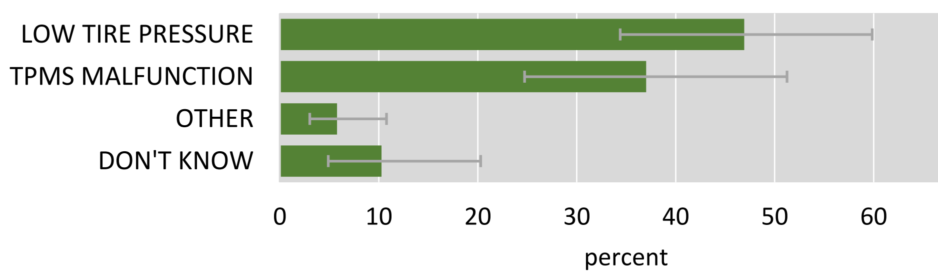
	pct	95% C.I.
YES	93.4	(85.4, 97.2)
NO	2.0	(0.6, 6.4)
DON'T KNOW	4.6	(1.8, 11.1)

Module MALF. #1
[MALF1AW1]
n=157

Source: NHTSA TPMS-ORRC, 2018

What does this light mean to you? [INTERVIEWER: BACKCODE RESPONSE; IF NECESSARY, ASK WHAT LIGHT MEANS WITH REGARD TO SPECIFIC VEHICLE SYSTEMS]

DOMAIN: Aware that light is on (n=148)



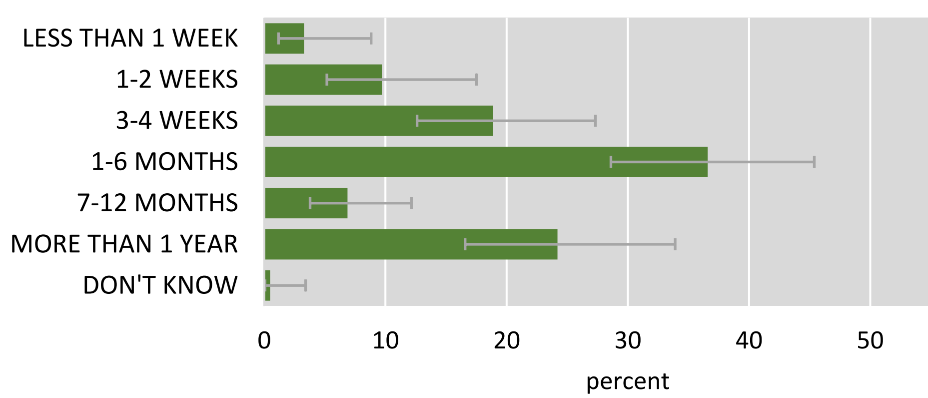
	pct	95% C.I.
LOW TIRE PRESSURE	46.9	(34.4, 59.9)
TPMS MALFUNCTION	37.0	(24.7, 51.3)
OTHER	5.8	(3.0, 10.8)
DON'T KNOW	10.3	(4.9, 20.3)

Module MALF. #1
[MALF1AW1A]
n=148

Source: NHTSA TPMS-ORRC, 2018

How long has this malfunction light been on? If the light has been turning on and off intermittently, please think back to the first time you noticed that the light was on.

DOMAIN: Aware that light is on (n=148)



	pct	95% C.I.
LESS THAN 1 WEEK	3.3	(1.2, 8.8)
1-2 WEEKS	9.7	(5.2, 17.5)
3-4 WEEKS	18.9	(12.6, 27.3)
1-6 MONTHS	36.6	(28.6, 45.4)
7-12 MONTHS	6.9	(3.8, 12.1)
MORE THAN 1 YEAR	24.2	(16.6, 33.9)
DON'T KNOW	0.5	(0.1, 3.4)

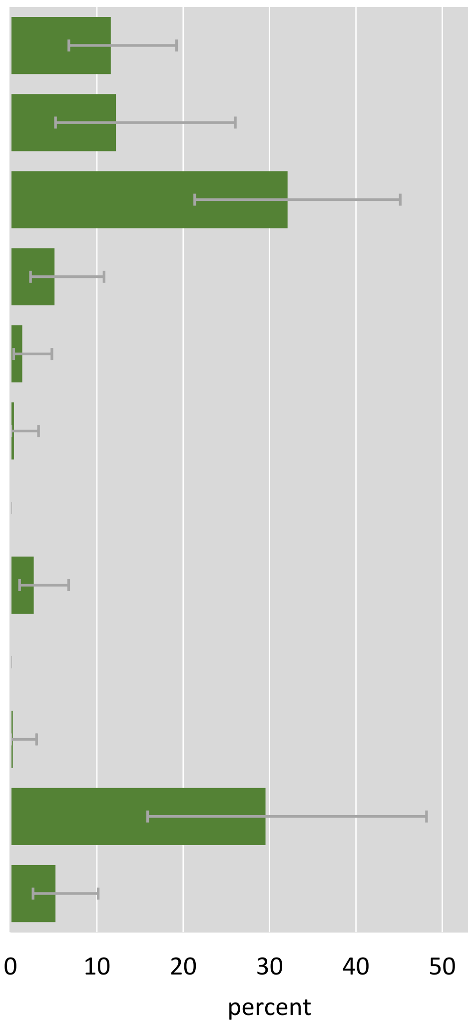
Module MALF. #1
[MALF1AW2]
n=147

Source: NHTSA TPMS-ORRC, 2018

Did any of the following events occur shortly before the TPMS system malfunction light came on? SELECT ALL THAT APPLY
DOMAIN: Light is on, driver is aware (n=148)

Did any of the following events occur recently? SELECT ALL THAT APPLY
DOMAIN: Light is on, driver not aware (n=9)

The above two questions ask the same thing, so are combined in one response table (*n*=157).



	pct	95% C.I.
The tires were rotated	11.8	(6.8, 19.9)
Specialty (e.g. ,seasonal or off-road) tires were switched out	11.4	(5.1, 23.5)
One or more new tires or wheel were installed or replaced	31.0	(21.6, 42.3)
One or more tire stems were installed or replaced	4.8	(2.2, 10.2)
One or more tire pressure sensors were installed or replaced	1.3	(0.3, 4.5)
Work was performed on the braking system	0.4	(0.0, 3.1)
Work was performed on the on-board computer system	0	
The vehicle was involved in an accident	2.5	(1.0, 6.3)
The vehicle experienced an extended period of flooding/snow	0.0	
Anything else	0.2	(0.0, 2.9)
None of the above	27.6	(14.2, 46.8)
DON'T KNOW	9.4	(5.7, 15.2)

Module MALF. #1
[MALF1AF1A/B]
n=157

Source: NHTSA TPMS-ORRC, 2018

Did you install or replace the tire stems or tire pressure sensors yourself? [MALF1AF2]

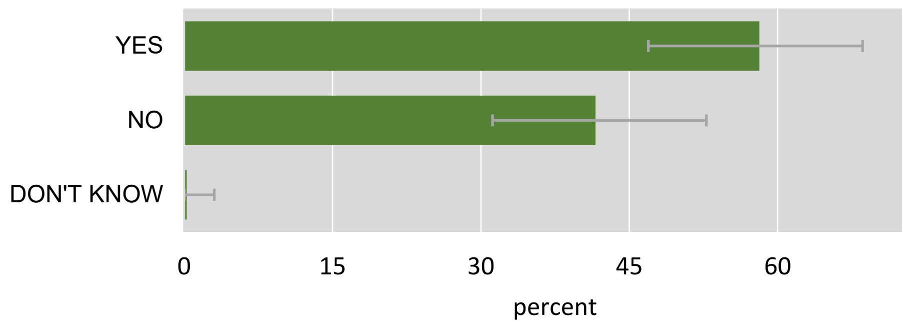
DOMAIN: Tire stems/sensors replaced (n=10) Domain size too small for estimates.

How much did this work cost? [MALF1AF3]

DOMAIN: Tire stems/sensors replaced (n=10) Domain size too small for estimates.

Has anyone explained to you what needs to be done to make the malfunction light turn off?

DOMAIN: Aware that malfunction light is on (n=148)



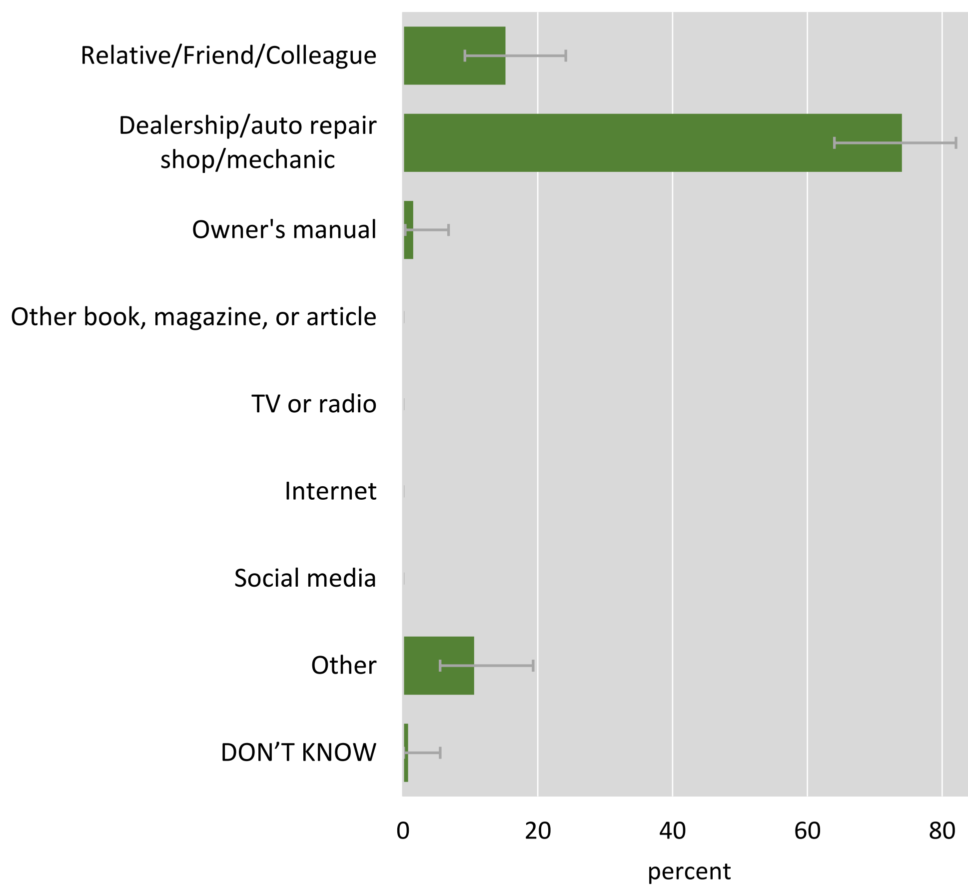
	pct	95% C.I.
YES	58.1	(46.9, 68.6)
NO	41.6	(31.2, 52.8)
DON'T KNOW	0.3	(0.0, 3.0)

Module MALF. #1
[MALFIX1]
n=147

Source: NHTSA TPMS-ORRC, 2018

Who explained this to you? SELECT ALL THAT APPLY

DOMAIN: Someone explained how to correct malfunction (n=88)



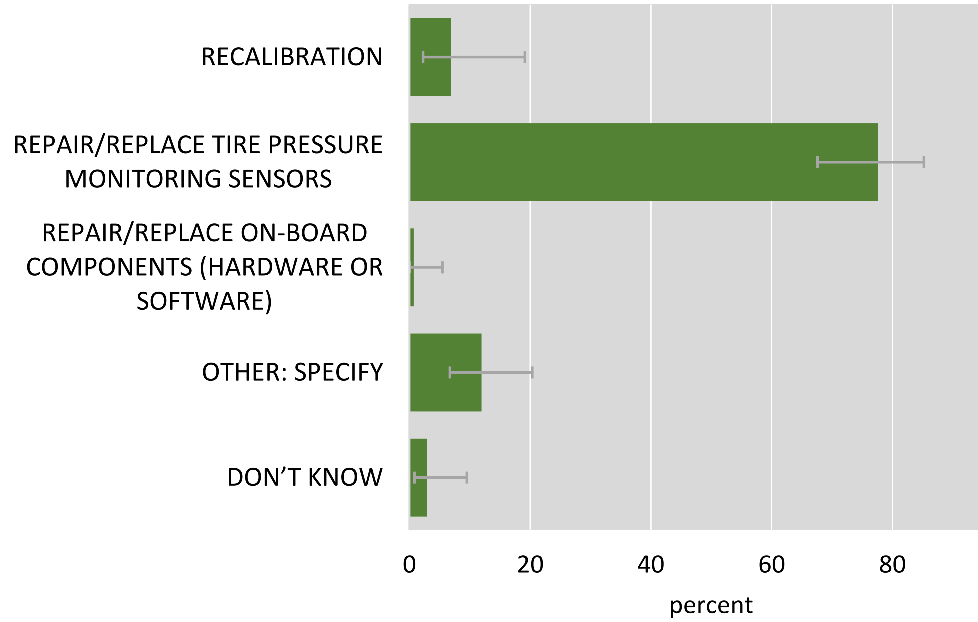
	pct	95% C.I.
Relative/Friend/Colleague	15.2	(9.2, 24.2)
Dealership/auto repair shop/mechanic	74.0	(64.0, 82.1)
Owner's manual	1.5	(0.3, 6.8)
Other book, magazine, or article	0	
TV or radio	0	
Internet	0	
Social media	0	
Other	10.6	(5.5, 19.3)
DON'T KNOW	0.7	(0.1, 5.5)

Module MALF. #1
[MALFIX2_X]
n=88

Source: NHTSA TPMS-ORRC, 2018

What were you told needed to be done to correct the malfunction?

DOMAIN: Someone explained how to correct malfunction (n=88)



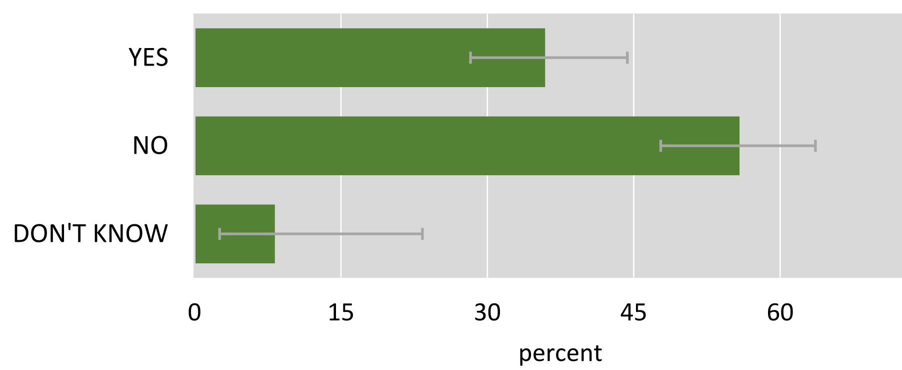
	pct	95% C.I.
RECALIBRATION	6.9	(2.3, 19.1)
REPAIR/REPLACE TIRE PRESSURE MONITORING SENSORS	77.6	(67.6, 85.2)
REPAIR/REPLACE ON-BOARD COMPONENTS (HARDWARE OR SOFTWARE)	0.7	(0.1, 5.5)
OTHER: SPECIFY	11.9	(6.7, 20.3)
DON'T KNOW	2.9	(0.8, 9.5)

Module MALF. #1
[MALFIX3]
n=88

Source: NHTSA TPMS-ORRC, 2018

Have you priced the work required to correct the TPMS system malfunction (whether or not you had the work done)?

DOMAIN: Aware light is on (n=148)



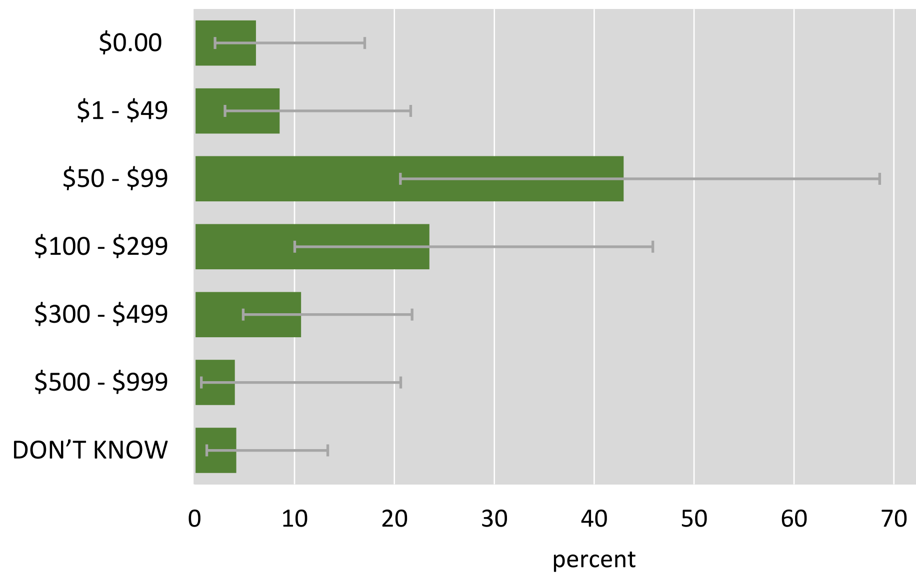
	pct	95% C.I.
YES	35.9	(28.3, 44.4)
NO	55.8	(47.8, 63.6)
DON'T KNOW	8.2	(2.6, 23.4)

Module MALF. #1
[MALCOST1A]
n=147

Source: NHTSA TPMS-ORRC, 2018

What was the price for this work?

DOMAIN: Had the work priced (n=53)



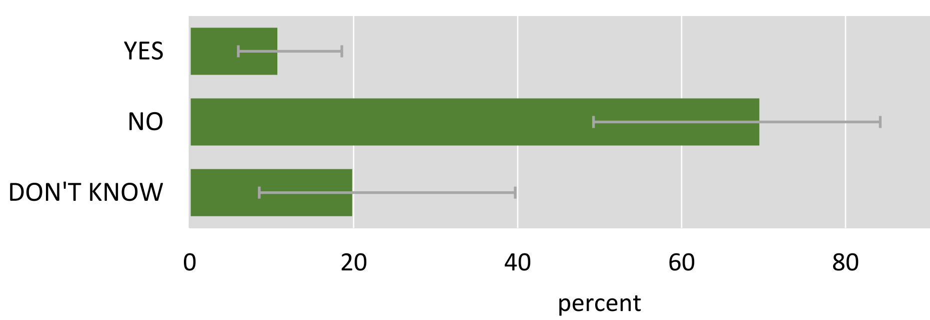
	pct	95% C.I.
$0.00	6.1	(2.0, 17.0)
$1 - $49	8.5	(3.0, 21.6)
$50 - $99	42.9	(20.6, 68.6)
$100 - $299	23.5	(10.0, 45.9)
$300 - $499	10.7	(4.9, 21.8)
$500 - $999	4.0	(0.7, 20.6)
DON’T KNOW	4.2	(1.2, 13.3)

Module MALF. #1
[MALCOST1B]
n=53

Source: NHTSA TPMS-ORRC, 2018

Do you have a general idea of what the price to repair the system would be?

DOMAIN: Hasn’t had repair priced (n=94)



	pct	95% C.I.
YES	10.7	(5.9, 18.6)
NO	69.5	(49.3, 84.2)
DON'T KNOW	19.8	(8.5, 39.7)

Module MALF. #1
[MALCOST2A]
n=94

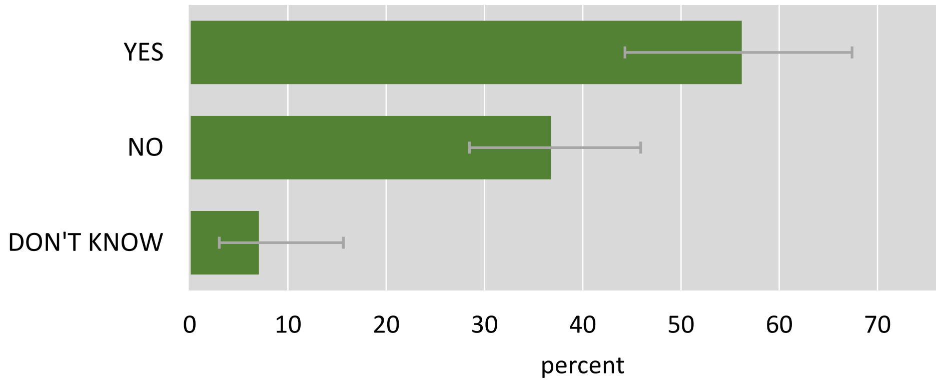
Source: NHTSA TPMS-ORRC, 2018

What is your estimate of the price to perform this repair? [MALCOST2B]

DOMAIN: Has an idea of cost (n=13) Domain size too small for estimates.

Do you plan to correct the current malfunction in the system?

DOMAIN: Aware light is on (n=148)



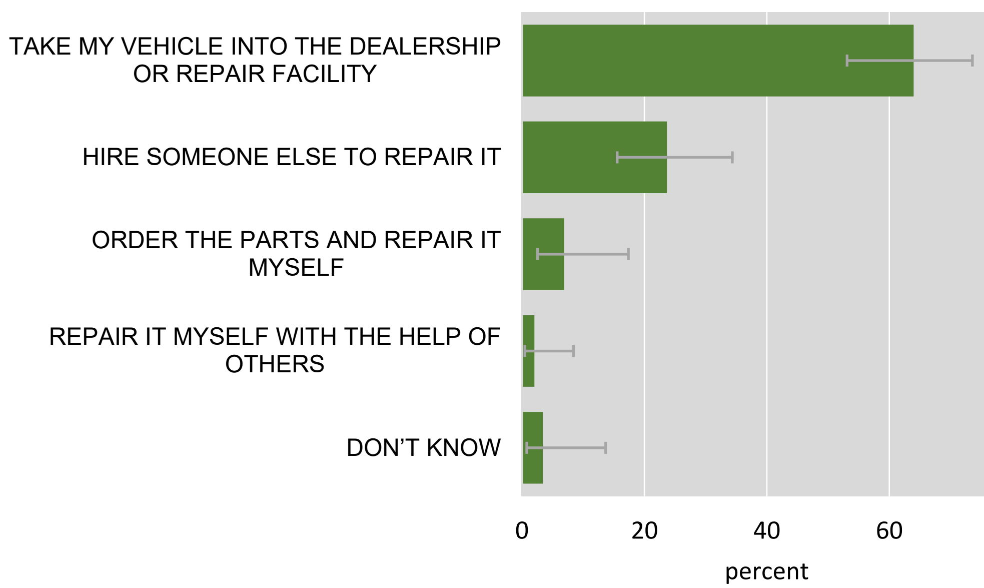
	pct	95% C.I.
YES	56.2	(44.3, 67.4)
NO	36.8	(28.5, 45.9)
DON'T KNOW	7.0	(3.0, 15.6)

Module MALF. #1
[MALFIX4]
n=147

Source: NHTSA TPMS-ORRC, 2018

How do you plan to correct the current malfunction?

DOMAIN: Driver plans to correct (n=81)

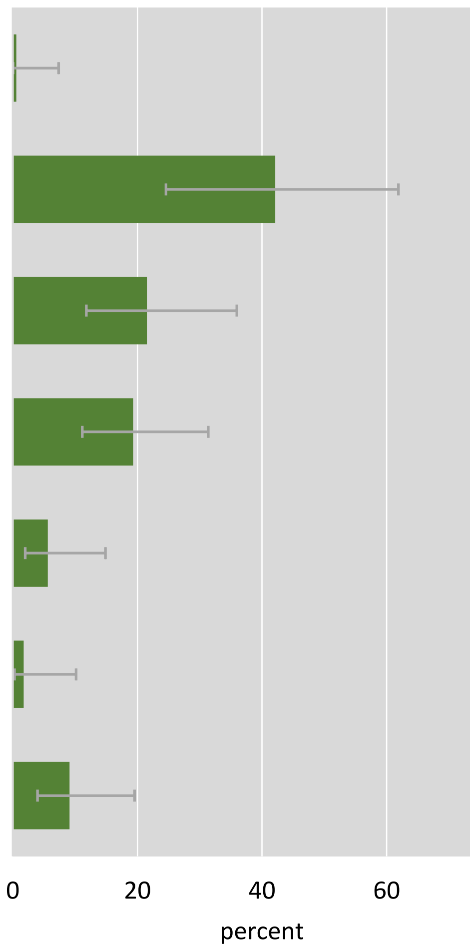


	pct	95% C.I.
TAKE MY VEHICLE INTO THE DEALERSHIP OR REPAIR FACILITY	64.0	(53.1, 73.6)
HIRE SOMEONE ELSE TO REPAIR IT	23.7	(15.5, 34.4)
ORDER THE PARTS AND REPAIR IT MYSELF	6.9	(2.5, 17.4)
REPAIR IT MYSELF WITH THE HELP OF OTHERS	2.0	(0.5, 8.4)
DON'T KNOW	3.4	(0.8, 13.7)

Module MALF. #1
[MALFIX5]
n=81

Source: NHTSA TPMS-ORRC, 2018

What is the primary reason you are not planning to repair the current malfunction in the system?
DOMAIN: Driver does not plan to correct (n=57)



	pct	95% C.I.
CURRENTLY USING SEASONAL TIRES AND WILL SWITCH TIRES OUT WHEN THE WEATHER PERMITS, WHICH SHOULD FIX THE PROBLEM	0.6	(0.0, 7.4)
CANNOT AFFORD THE COST TO REPAIR	42.1	(24.6, 61.9)
TPMS SYSTEM IS A LUXURY AND NOT NECESSARY FOR THE OPERATION OF THE VEHICLE	21.5	(11.8, 36.0)
IT IS NOT MANDATED BY THE STATE THAT I REPAIR THE SYSTEM	19.3	(11.2, 31.4)
WILL BE SELLING / GETTING RID OF THIS CAR SHORTLY	5.6	(2.0, 14.9)
NOT SURE THE TPMS MALFUNCTION INDICATOR IS ACCURATE	1.7	(0.3, 10.2)
TOO INCONVENIENT/ IT'S JUST A NUISANCE	9.1	(4.0, 19.5)

Module MALF. #1
[MALFIX6]
n=57

Source: NHTSA TPMS-ORRC, 2018

Why do you think the TPMS system malfunction indicator is inaccurate? [MALCONF] *DOMAIN: Not sure TPMS indicator is accurate (n=1)* Domain size too small for estimates.

Aside from the current malfunction, have there been any previous malfunctions of the TPMS system? [MALPREV1] *DOMAIN: Driver does not say light is flashing intermittently OR not aware that light is on (n=9)* [82] Domain size too small for estimates.

Other than the current malfunction, how many times has the TPMS system malfunctioned? [MALPREV2] *DOMAIN: Previous malfunction episode reported (n=2)* Domain size too small for estimates

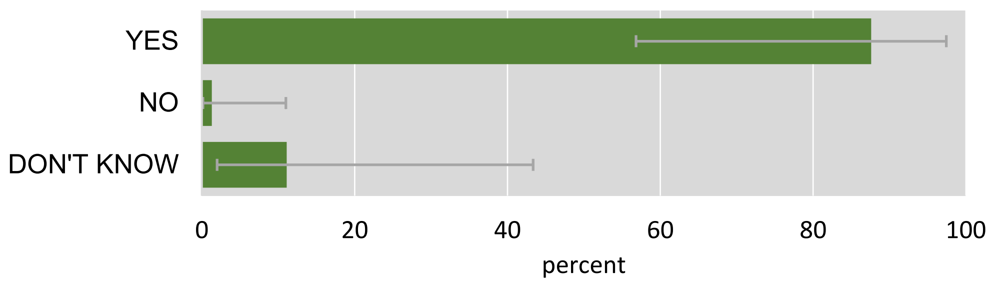
End Module MALFUNCTION #1

[82] This domain condition for [MALPREV1] could perhaps have been expanded, but as it is set is very restrictive, resulting in the small domain size. The small domain carries over into [MALPREV2]. It's possible that "not aware light is on" should have been "aware light is on."

Module MALFUNCTION #2 - Entered by respondents in Group 2 randomly selected extended interview who are currently experiencing TPMS situation #2: TPMS Low Tire Pressure indicator is currently illuminated. Domain sizes are small because it was only applied in extended interviews.

Are you aware that a TPMS dash light is currently on in your vehicle?

DOMAIN: TPMS low-pressure indicator is currently illuminated (n=65)



	pct	95% C.I.
YES	87.6	(56.8, 97.4)
NO	1.3	(0.1, 11.0)
DON'T KNOW	11.1	(2.0, 43.4)

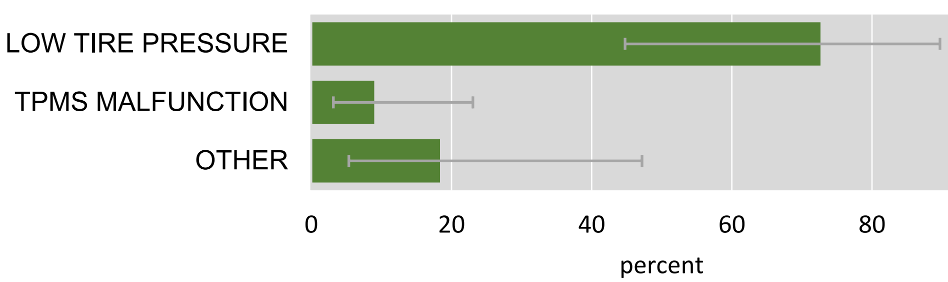
Module MALF. #2
[MALF2AW1]
n=40

Source: NHTSA TPMS-ORRC, 2018

What does this light mean to you?

DOMAIN: Aware that light is on (n=36)

INTERVIEWER: BACKCODE RESPONSE; IF NECESSARY, ASK WHAT LIGHT MEANS WITH REGARD TO SPECIFIC VEHICLE SYSTEMS



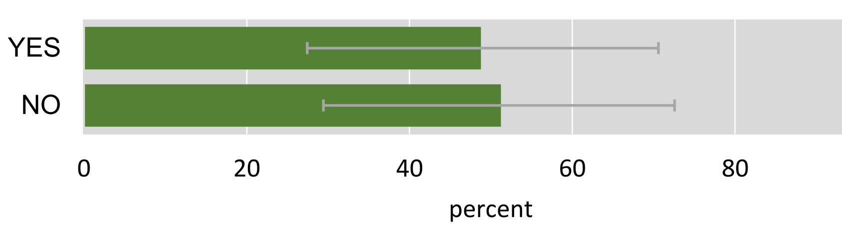
	pct	95% C.I.
LOW TIRE PRESSURE	72.7	(44.8, 89.7)
TPMS MALFUNCTION	9.0	(3.1, 23.1)
OTHER	18.4	(5.4, 47.2)

Module MALF. #2
[MALF2AW1A]
n=36

Source: NHTSA TPMS-ORRC, 2018

Since this light came on, have you checked the pressure in any of your tires?

DOMAIN: Aware that light is on (n=36)



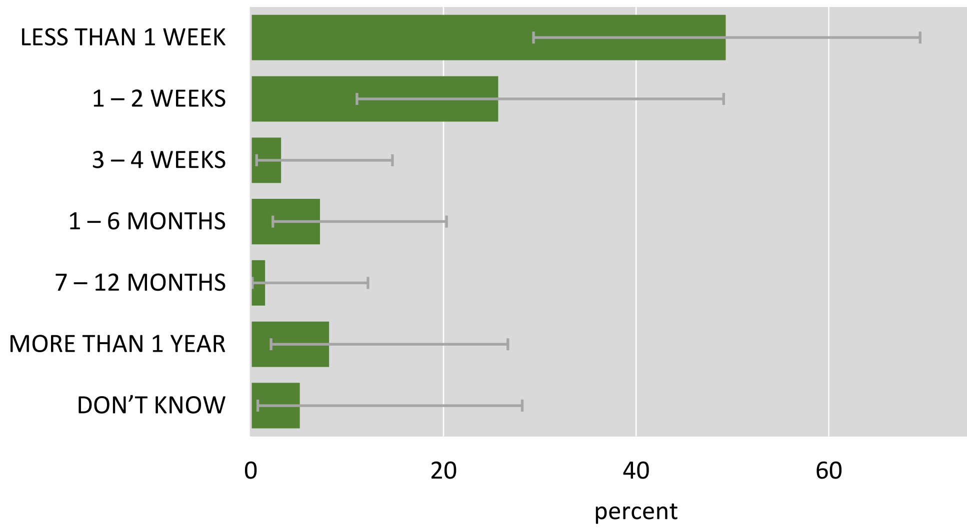
	pct	95% C.I.
YES	48.8	(27.4, 70.6)
NO	51.2	(29.4, 72.6)

Module MALF. #2
[MALF2FIX1]
n=36

Source: NHTSA TPMS-ORRC, 2018

How long has the low pressure light been on? If the light has been turning on and off intermittently, please think back to the first time you noticed that the light was on.

DOMAIN: Aware that light is on (n=36)



	pct	95% C.I.
LESS THAN 1 WEEK	49.3	(29.3, 69.5)
1 – 2 WEEKS	25.7	(11.0, 49.1)
3 – 4 WEEKS	3.1	(0.6, 14.7)
1 – 6 MONTHS	7.2	(2.3, 20.3)
7 – 12 MONTHS	1.5	(0.2, 12.2)
MORE THAN 1 YEAR	8.1	(2.1, 26.7)
DON'T KNOW	5.1	(0.7, 28.2)

Module MALF. #2
[MALF2AW2]
n=36

Source: NHTSA TPMS-ORRC, 2018

Were all of the checked tires properly inflated? *DOMAIN: Driver is aware light is on and has checked pressure (n=20)* Domain size too small for estimates. [MALF2FIX2]

Did any of the following events occur shortly before the low pressure light came on*? DOMAIN: verified all tires are properly inflated (n=14)* Domain size too small for estimates. [MALF2AF1]

Did you install or replace the tire stems or tire pressure sensors yourself? *DOMAIN: Tire stems/sensors replaced (n=2)* Domain size too small for estimates. [MALF2AF2]

How much did this work cost? *DOMAIN: Tire stems/sensors replaced (n=2)* Domain size too small for estimates. [MALF2AF3]

Did you perform the work on the braking system yourself? *DOMAIN: Work done to brake system (n=0)* Domain size too small for estimates. [MALF2AF4].

How much did this work cost? *DOMAIN: Work done to brake system (n=0)* Domain size too small for estimates. [MALF2AF5]

End Module MALFUNCTION #2

Module MALFUNCTION #3 - entered by respondents experiencing TPMS Situation 3: vehicle is known to be equipped with TPMS and respondent denied disabling system, but no TPMS lights are illuminated at ON position.

Eleven respondents entered this module, so none of the questions had enough data for estimates. The three questions in the module were about dash lights and events that might happen prior to a malfunction (the same events that were asked about with regard to TPMS malfunction).

End Module MALFUNCTION #3

Module DISABLED - entered by respondents who reported that the TPMS in their vehicle was disabled.

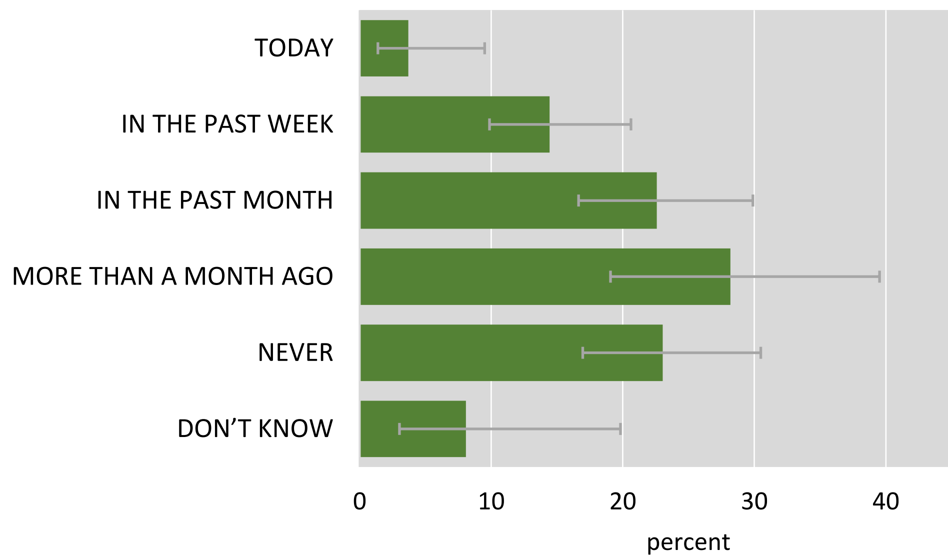
There were no respondents who met the condition to enter this module. The intended questions covered circumstances about disabling TPMS.

End Module DISABLED

Module INDIRECT- entered by respondents who were driving a vehicle with an indirect TPMS system that is FMVSS-compliant and was not malfunctioning or disabled.

When was the last time you used a pressure gauge to check the tire pressure in the tires on this vehicle?

DOMAIN: Functioning indirect TPMS (n=288)



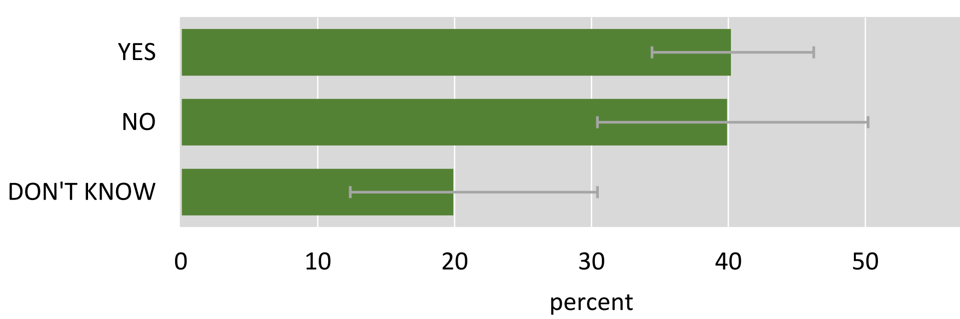
pct	95% C.I.
3.7	(1.4, 9.5)
14.4	(9.9, 20.6)
22.6	(16.6, 29.9)
28.2	(19.1, 39.5)
23.0	(17.0, 30.5)
8.1	(3.0, 19.8)

Module INDIRECT
[IND_CHK]
n=266

Source: NHTSA TPMS-ORRC, 2018

Did you know that the Tire Pressure Monitoring System on this vehicle needs to be recalibrated on occasion?

DOMAIN: Functioning indirect TPMS (n=288)



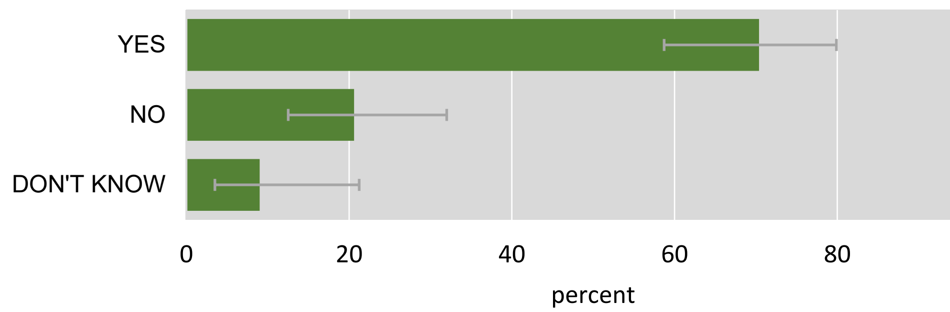
pct	95% C.I.
40.2	(34.4, 46.2)
39.9	(30.4, 50.2)
19.9	(12.4, 30.4)

Module INDIRECT
[IND_RECB]
n=261

Source: NHTSA TPMS-ORRC, 2018

Are you aware that you can recalibrate the Tire Pressure Monitoring System yourself?

DOMAIN: Knows recalibration needed on occasion (n=103)



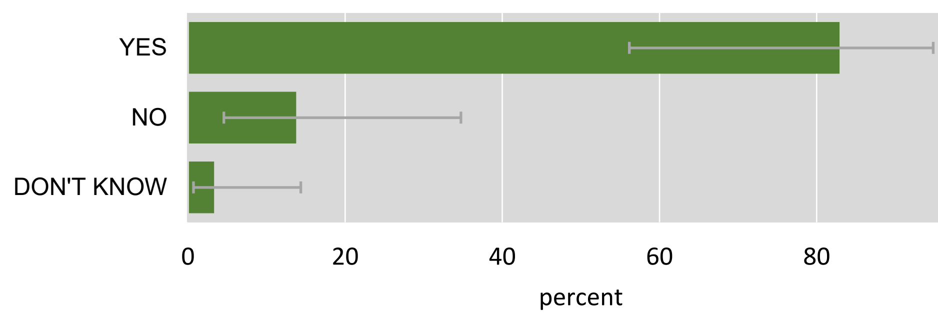
	pct	95% C.I.
YES	70.4	(58.7, 79.9)
NO	20.6	(12.5, 32.0)
DON'T KNOW	9.0	(3.5, 21.2)

Module INDIRECT
[IND_AWARE]
n=103

Source: NHTSA TPMS-ORRC, 2018

Do you know how to recalibrate your Tire Pressure Monitoring System?

DOMAIN: Aware that driver can recalibrate system (n=74):



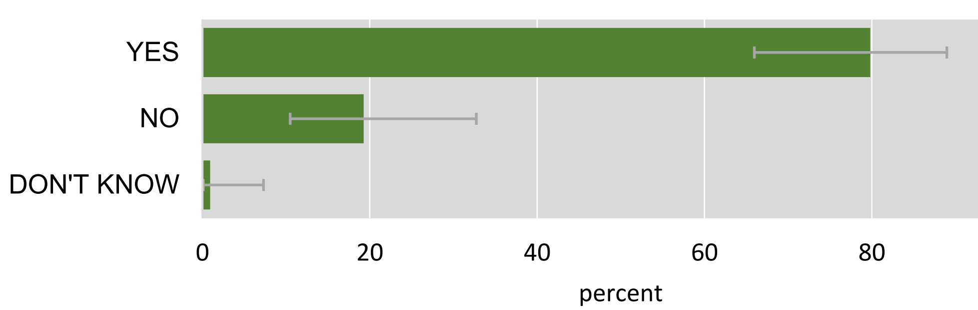
	pct	95% C.I.
YES	82.9	(56.2, 94.8)
NO	13.8	(4.6, 34.7)
DON'T KNOW	3.3	(0.7, 14.4)

Module INDIRECT
[IND_KNOW]
n=74

Source: NHTSA TPMS-ORRC, 2018

Have you ever recalibrated your Tire Pressure Monitoring System on this vehicle in the past?

DOMAIN: Knows how or may know how to recalibrate (n=64)



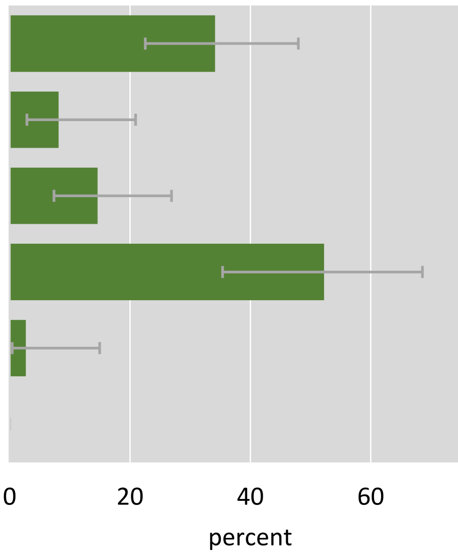
	pct	95% C.I.
YES	79.8	(66.0, 89.0)
NO	19.3	(10.5, 32.7)
DON'T KNOW	0.9	(0.1, 7.3)

Module INDIRECT
[IND_MRECB]
n=64

Source: NHTSA TPMS-ORRC, 2018

Which of the following were reasons that you recalibrated this vehicle's Tire Pressure Monitoring System? SELECT ALL THAT APPLY

DOMAIN: Has recalibrated (n=50)



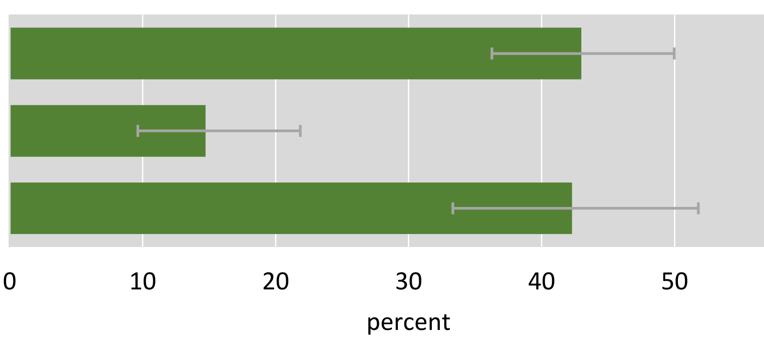
	pct	95% C.I.
After tire replacement or rotation	34.1	(22.5, 48.0)
After changing between winter / summer tires	8.1	(2.9, 20.9)
If the TPMS warning light stayed on after start	14.6	(7.4, 26.9)
After checking tire pressure and/or adding air to tires	52.2	(35.4, 68.6)
After vehicle service performed by dealership, gas station, or repair facility	2.7	(0.4, 15.0)
After you serviced your vehicle	0	

Module INDIRECT
[IND_RCBY]
n=50

Source: NHTSA TPMS-ORRC, 2018

If you have had this vehicle serviced or have had the tires changed, did the facility or dealership recalibrate your Tire Pressure Monitoring System?

DOMAIN: Functioning indirect TPMS (n=288)



	pct	95% C.I.
YES	43.0	(36.3, 50.0)
NO	14.7	(9.6, 21.9)
DON'T KNOW	42.3	(33.3, 51.8)

Module INDIRECT
[IND_SVC]
n=255

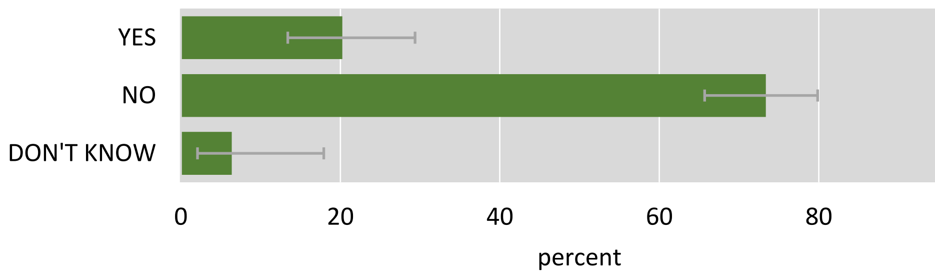
Source: NHTSA TPMS-ORRC, 2018

End Module INDIRECT

Module PAST MALFUNCTION #1 - Entered by all extended interview respondents except those with malfunction light currently illuminated.

Has the TPMS system malfunction dash light ever been on and stayed on while you were driving this vehicle?

DOMAIN: No current malfunction light (n=791)



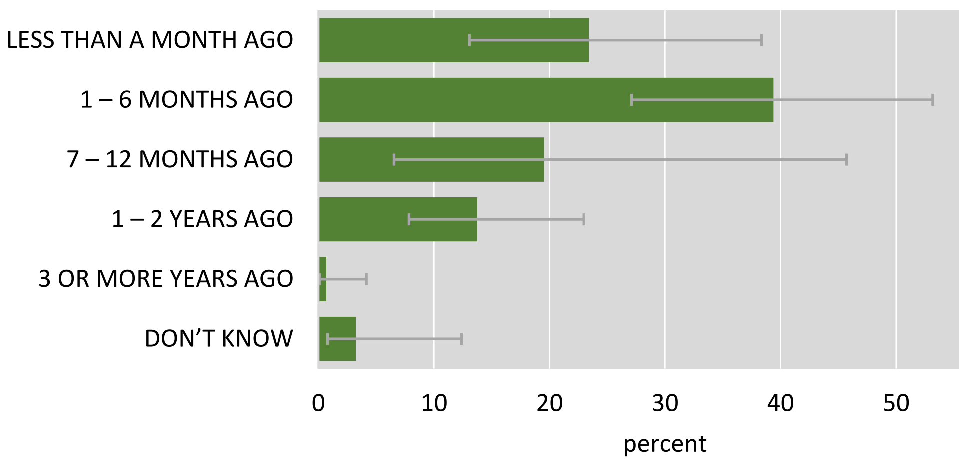
pct	95% C.I.
20.2	(13.4, 29.4)
73.4	(65.7, 79.9)
6.4	(2.1, 17.9)

Mod. PAST MALF#1 [MALEVER] *n*=743

Source: NHTSA TPMS-ORRC, 2018

When was the last time the TPMS system malfunction light was on?

DOMAIN: Malfunction light has been illuminated previously (n=168)



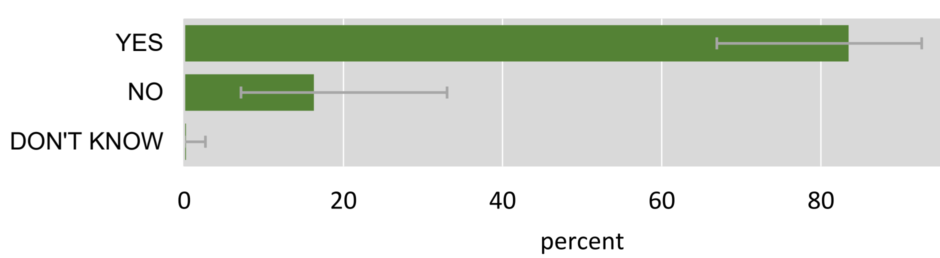
pct	95% C.I.
23.4	(13.1, 38.3)
39.4	(27.1, 53.2)
19.5	(6.5, 45.7)
13.7	(7.8, 23.0)
0.7	(0.1, 4.1)
3.2	(0.8, 12.4)

Mod. PAST MALF#1 [LASTMAL] *n*=168

Source: NHTSA TPMS-ORRC, 2018

Did you take any action in response to the indicator light?

DOMAIN: Malfunction light has been illuminated previously (n=168)



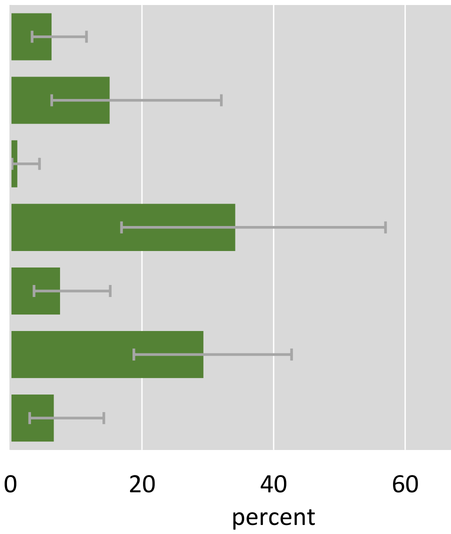
pct	95% C.I.
83.5	(66.9, 92.7)
16.3	(7.1, 33.0)
0.2	(0.0, 2.7)

Mod. PAST MALF#1 [LASTACT1] *n*=168

Source: NHTSA TPMS-ORRC, 2018

What needed to be done to correct the malfunction?

DOMAIN: Took some action in response to malfunction light (n=144)



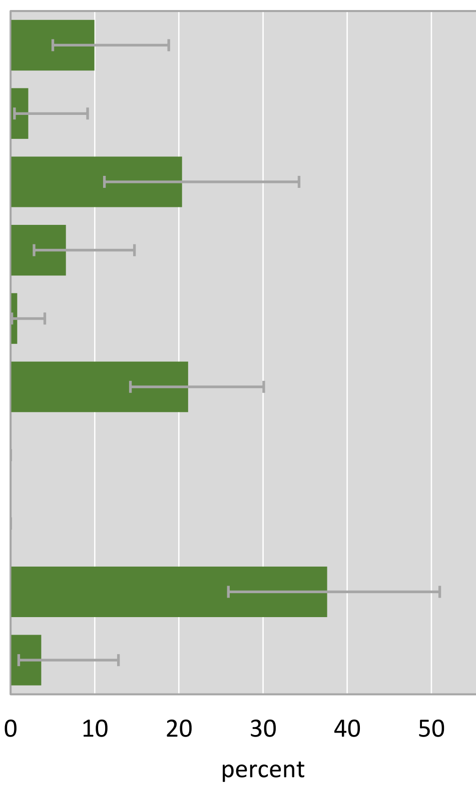
	pct	95% C.I.
RECALIBRATION	6.2	(3.3, 11.6)
REPAIR/REPLACE TIRE PRESSURE MONITORING SENSORS	15.1	(6.3, 32.1)
REPAIR/REPLACE ON-BOARD COMPONENTS (HARDWARE OR SOFTWARE)	1.0	(0.2, 4.4)
REPAIRS, OTHER THAN ABOVE	34.2	(16.9, 57.0)
OTHER REPAIRS, SPECIFICS UNKNOWN	7.5	(3.6, 15.2)
OTHER	29.3	(18.8, 42.7)
DON'T KNOW	6.6	(2.9, 14.2)

Mod. PAST MALF#1
[LASTACT2]
n=143

Source: NHTSA TPMS-ORRC, 2018

What actions did you take in response? SELECT ALL THAT APPLY

DOMAIN: Took some action in response to malfunction light (n=144)



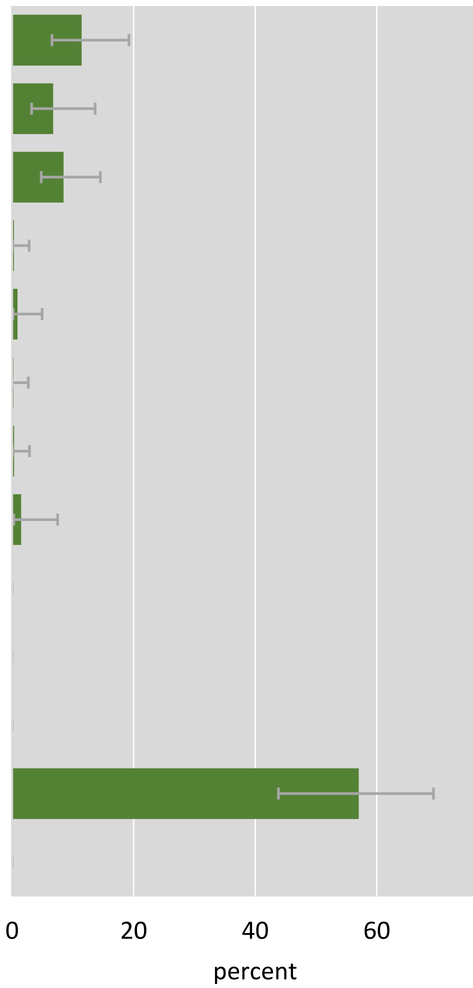
	pct	95% C.I.
Repaired the system myself	10.0	(5.0, 18.8)
Disabled the system	2.1	(0.5, 9.1)
Had the dealer/repair facility repair the system at a cost	20.4	(11.1, 34.3)
Had the dealer/repair facility repair under warranty	6.6	(2.8, 14.7)
Had the dealer/repair facility disable the system	0.8	(0.1, 4.1)
Purchased new tires	21.1	(14.2, 30.1)
Purchased new tire pressure monitoring sensors	0	
NONE, Because the malfunction indicator turned off on its own	0	
OTHER	37.6	(25.9, 51.0)
DON'T KNOW	3.6	(1.0, 12.8)

Mod. PAST MALF#1
[LASTACT3]
n=144

Source: NHTSA TPMS-ORRC, 2018

Did any of the following events occur shortly before the TPMS system malfunction light came on? SELECT ALL THAT APPLY

DOMAIN: Malfunction light has been illuminated previously (n=168)



	pct	95% C.I.
The tires were rotated	11.4	(6.6, 19.2)
Specialty (e.g. ,seasonal or off-road) tires were switched out	6.7	(3.2, 13.7)
One or more tires or wheels were installed or replaced	8.5	(4.8, 14.5)
One or more tire stems were installed or replaced	0.3	(0.0, 2.8)
One or more tire pressure sensors were installed or replaced	0.9	(0.2, 4.9)
Work was performed on the braking system	0.2	(0.0, 2.7)
Work was performed on the on-board computer system	0.3	(0.0, 2.9)
The vehicle was involved in an accident	1.5	(0.3, 7.5)
The vehicle experienced an extended period of flooding/snow	0	
The TPMS system was intentionally disabled	0	
Anything else	0	
NONE OF THE ABOVE	57.0	(43.8, 69.3)
DON'T KNOW	0	

Mod. PAST MALF#1 [LASTAF] *n*=168

Source: NHTSA TPMS-ORRC, 2018

Did you install or replace the tire stems or tire pressure sensors yourself? *DOMAIN: Tire stems/sensors replaced (n=3)* Domain size too small for estimates. [LASTFIX1]

How much did this work cost? *DOMAIN: Tire stems/sensors replaced (n=3)* Domain size too small for estimates. [LASTFIX2]

Did you perform the work on the braking system yourself? *DOMAIN: Work done to brake systems (n=1)* Domain size too small for estimates. [MALF2AF4_2]

How much did this work cost? *DOMAIN: Work done to brake systems (n=1)* Domain size too small for estimates. [MALF2AF5_2]

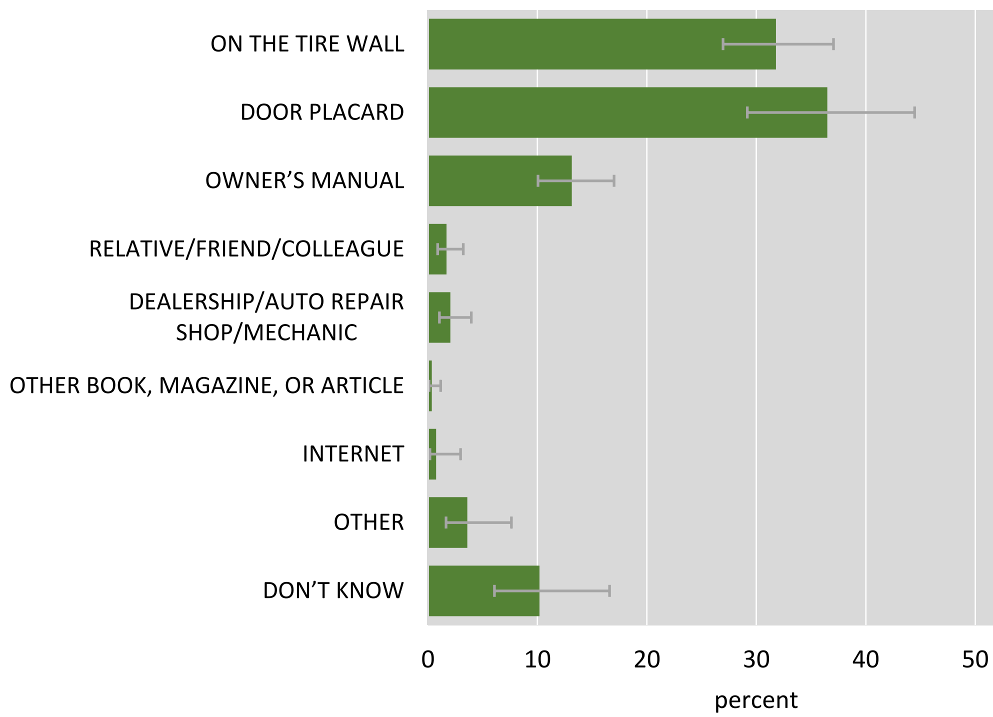
End Module PAST MALFUNCTION #1

Module CLOSE – entered by all extended interviews.

Response percentages in this module are weighted using extended interview weights. Domain "*n*=" is the number of extended interview respondents who were eligible.

Where would you look to find the pressure required for correct inflation of the tires on this vehicle?

DOMAIN: All (n=950)



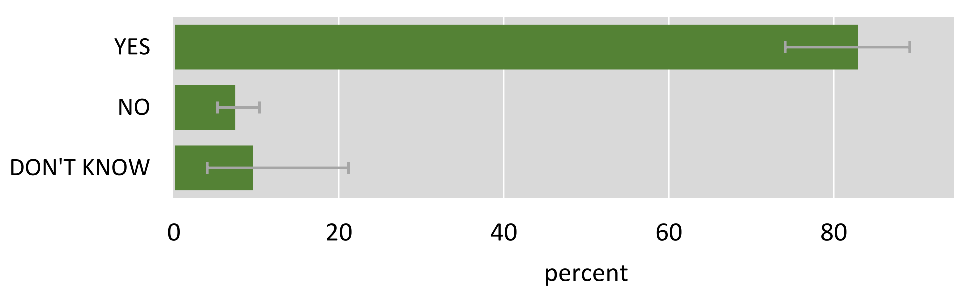
	pct	95% C.I.
ON THE TIRE WALL	31.8	(27.0, 37.0)
DOOR PLACARD	36.5	(29.2, 44.5)
OWNER'S MANUAL	13.1	(10.1, 17.0)
RELATIVE/FRIEND/COLLEAGUE	1.7	(0.9, 3.2)
DEALERSHIP/AUTO REPAIR SHOP/MECHANIC	2.0	(1.0, 4.0)
OTHER BOOK, MAGAZINE, OR ARTICLE	0.3	(0.1, 1.2)
INTERNET	0.7	(0.2, 3.0)
OTHER	3.6	(1.7, 7.6)
DON'T KNOW	10.2	(6.1, 16.6)

Module CLOSE
[AIR1]
n=891

Source: NHTSA TPMS-ORRC, 2018

Do you know how to inflate your tires to the correct pressure?

DOMAIN: All (n=950)



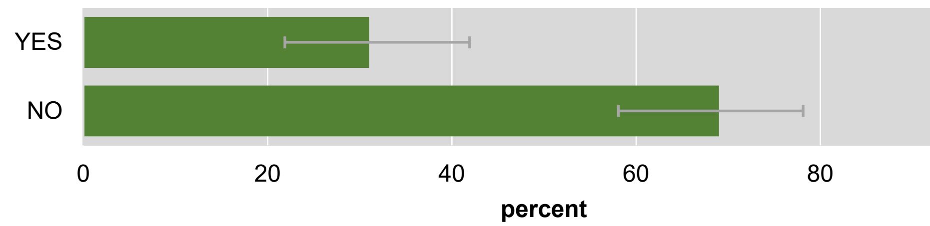
	pct	95% C.I.
YES	82.9	(74.1, 89.2)
NO	7.4	(5.3, 10.4)
DON'T KNOW	9.6	(4.0, 21.2)

Module CLOSE
[AIR2]
n=891

Source: NHTSA TPMS-ORRC, 2018

Before today, has the TPMS low tire pressure light in your dash ever come on and remained on after driving your vehicle?

DOMAIN: All (n=950)



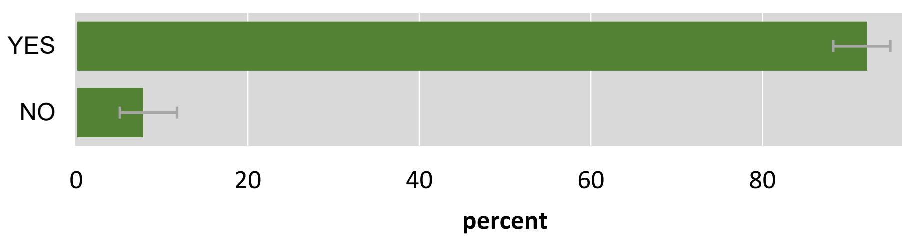
	pct	95% C.I.
YES	31.0	(21.9, 41.9)
NO	69.0	(58.1, 78.1)

Module CLOSE
[TRYFIX1]
n=828

Source: NHTSA TPMS-ORRC, 2018

Did you or someone else add air to one of more tires after this light came on?

DOMAIN: Had low-pressure light come on (n=317)



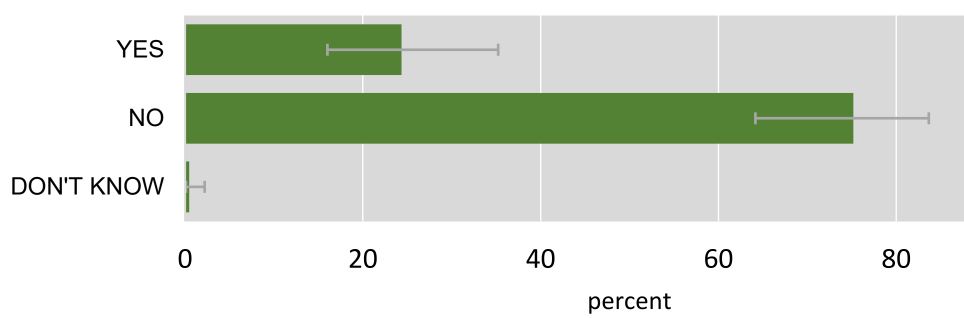
	pct	95% C.I.
YES	92.2	(88.2, 94.9)
NO	7.8	(5.1, 11.8)

Module CLOSE
[TRYFIX2]
n=315

Source: NHTSA TPMS-ORRC, 2018

Did the TPMS low tire pressure light continue to stay on even after adding air to the tires and driving?

DOMAIN: Had low-pressure light come on and then added air to tires (n=286)



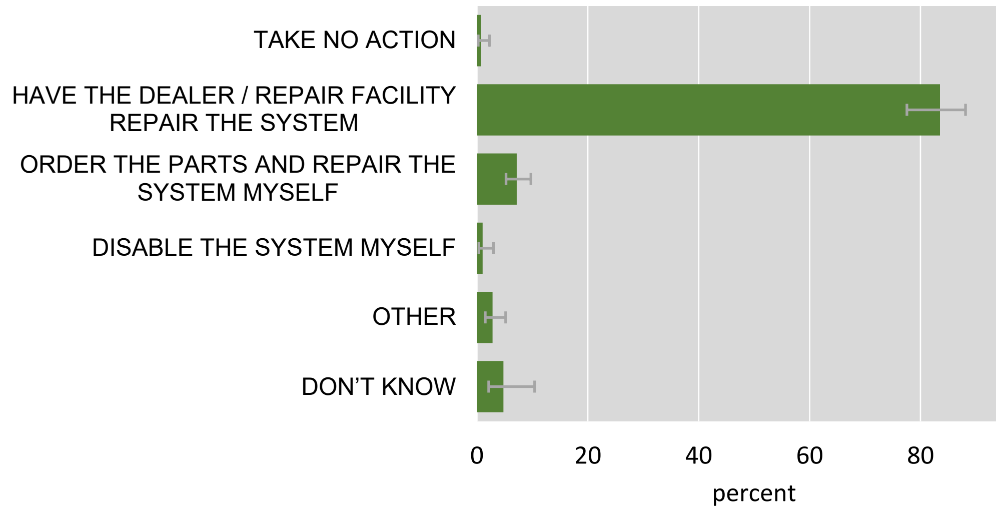
	pct	95% C.I.
YES	24.4	(16.0, 35.2)
NO	75.2	(64.2, 83.7)
DON'T KNOW	0.5	(0.1, 2.2)

Module CLOSE
[TRYFIX3]
n=285

Source: NHTSA TPMS-ORRC, 2018

If the TPMS malfunction light turned on, indicating a problem with the system itself, what action would you most likely take in response?

DOMAIN: Has not experienced a TPMS malfunction (n=534)



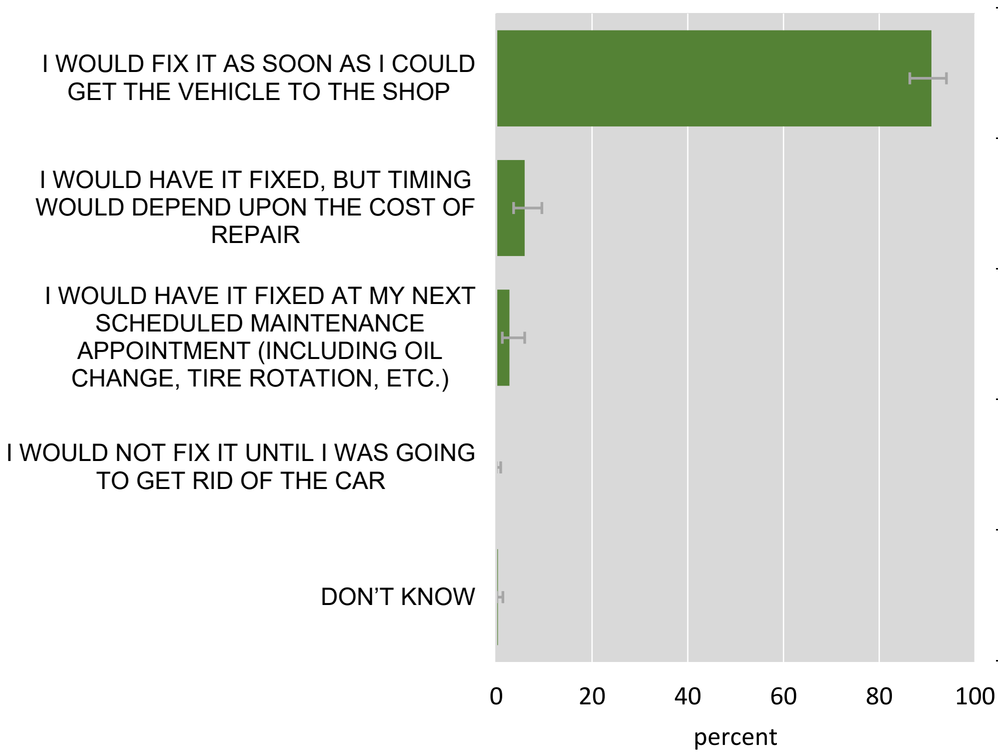
	pct	95% C.I.
TAKE NO ACTION	0.7	(0.2, 2.3)
HAVE THE DEALER / REPAIR FACILITY REPAIR THE SYSTEM	83.5	(77.5, 88.1)
ORDER THE PARTS AND REPAIR THE SYSTEM MYSELF	7.2	(5.2, 9.7)
DISABLE THE SYSTEM MYSELF	1.0	(0.3, 3.0)
OTHER	2.8	(1.5, 5.2)
DON'T KNOW	4.8	(2.1, 10.4)

Module CLOSE
[HYPMAL2]
n=521

Source: NHTSA TPMS-ORRC, 2018

How quickly would you try to get the problem fixed?

DOMAIN: Would take action to fix a TPMS malfunction (n=492)



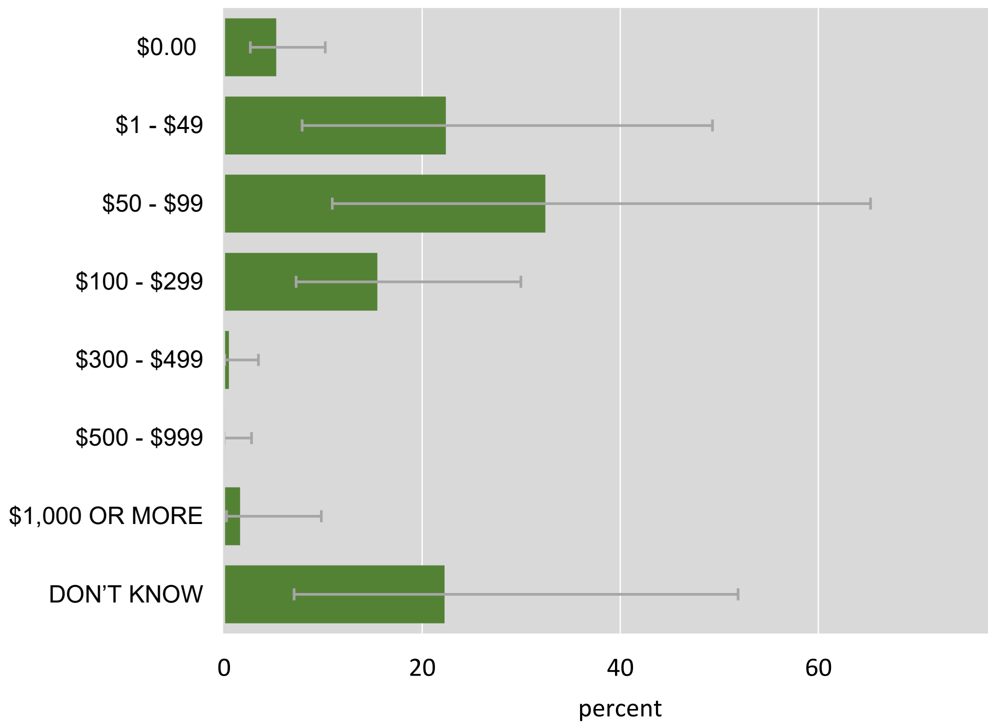
	pct	95% C.I.
I WOULD FIX IT AS SOON AS I COULD GET THE VEHICLE TO THE SHOP	90.9	(86.4, 94.0)
I WOULD HAVE IT FIXED, BUT TIMING WOULD DEPEND UPON THE COST OF REPAIR	5.9	(3.6, 9.5)
I WOULD HAVE IT FIXED AT MY NEXT SCHEDULED MAINTENANCE APPOINTMENT (INCLUDING OIL CHANGE, TIRE ROTATION, ETC.)	2.8	(1.3, 5.9)
I WOULD NOT FIX IT UNTIL I WAS GOING TO GET RID OF THE CAR	0.1	(0.0, 0.9)
DON'T KNOW	0.3	(0.1, 1.4)

Module CLOSE
[HYPMAL3]
n=491

Source: NHTSA TPMS-ORRC, 2018

What is the most you would be willing to spend to repair a malfunctioning TPMS system?

DOMAIN: In other questions, didn't give responses that showed refusal to repair, willingness to repair without condition of cost, or past actual repair of TPMS or tire stems/sensors (n=345)



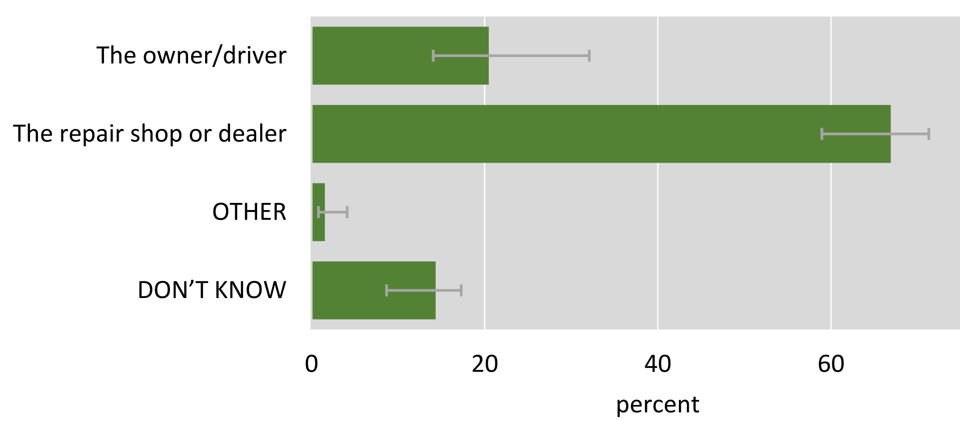
	pct	95% C.I.
$0.00	5.3	(2.6, 10.2)
$1 - $49	22.4	(7.9, 49.3)
$50 - $99	32.4	(10.9, 65.3)
$100 - $299	15.5	(7.3, 30.0)
$300 - $499	0.5	(0.1, 3.5)
$500 - $999	0.1	(0.0, 2.8)
$1,000 OR MORE	1.6	(0.2, 9.8)
DON'T KNOW	22.3	(7.1, 51.9)

Module CLOSE
[PAYFIX2]
n=144

Source: NHTSA TPMS-ORRC, 2018

Who would be able to reset the TPMS system in your vehicle when needed, such as after adding air to the tires or doing work on the tires or wheels? SELECT ALL THAT APPLY

DOMAIN: All (n=950)



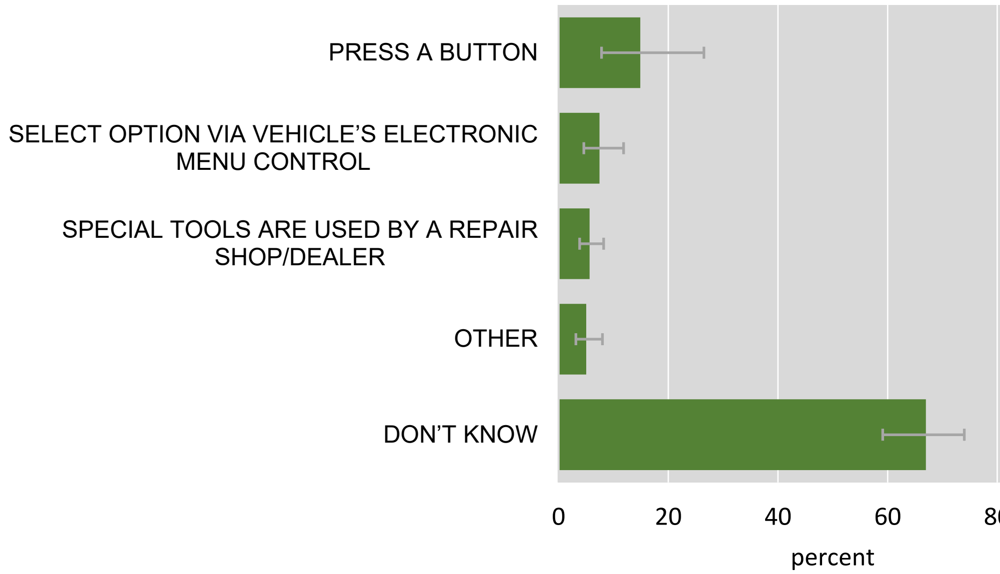
	pct	95% C.I.
The owner/driver	20.5	(14.1, 28.8)
The repair shop or dealer	66.9	(58.9, 74.0)
OTHER	1.5	(0.8, 2.9)
DON'T KNOW	14.3	(8.7, 22.8)

Module CLOSE
[RESET1]
n=929

Source: NHTSA TPMS-ORRC, 2018

What action is required to reset the TPMS system?

DOMAIN: All (n=950)



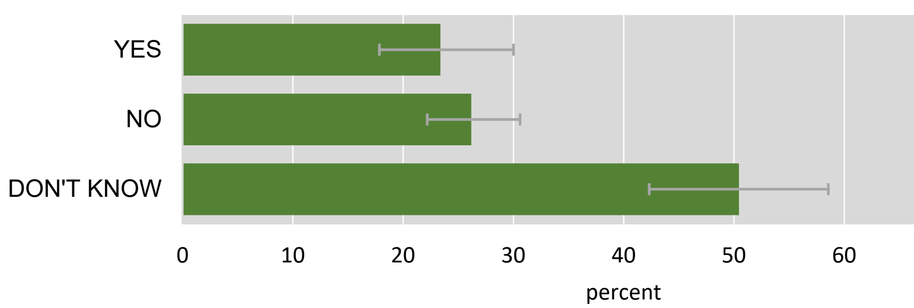
	pct	95% C.I.
PRESS A BUTTON	14.9	(7.8, 26.5)
SELECT OPTION VIA VEHICLE'S ELECTRONIC MENU CONTROL	7.5	(4.6, 11.9)
SPECIAL TOOLS ARE USED BY A REPAIR SHOP/DEALER	5.6	(3.8, 8.2)
OTHER	5.0	(3.2, 8.0)
DON'T KNOW	67.0	(59.1, 74.0)

Module CLOSE
[RESET2]
n=878

Source: NHTSA TPMS-ORRC, 2018

To your knowledge, is the TPMS system in your vehicle legally required to be functioning properly?

DOMAIN: All (n=950)



	pct	95% C.I.
YES	20.5	(14.1, 28.8)
NO	66.9	(58.9, 74.0)
DON'T KNOW	1.5	(0.8, 2.9)

Module CLOSE
[TPMSREQ]
n=875

Source: NHTSA TPMS-ORRC, 2018

End Module CLOSE

End Field Survey.

Appendix F. Repair Facilities Survey Sample Makeup

Pie charts show the Repair Facilities Survey unweighted sample makeup counts.

Figure F-1 shows the sample makeup for facility information.

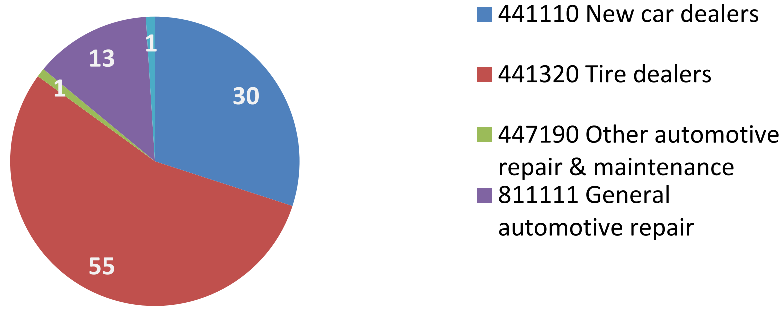
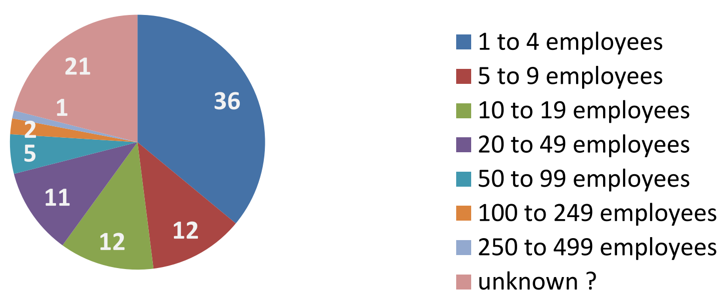
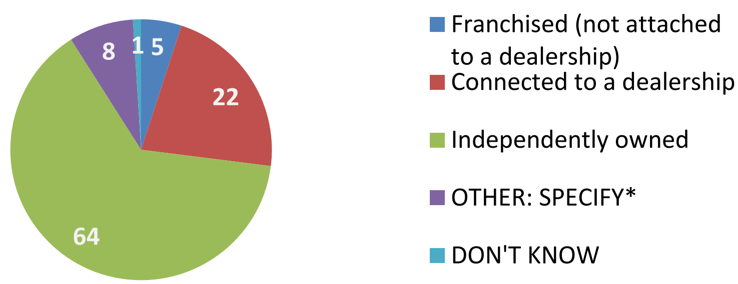
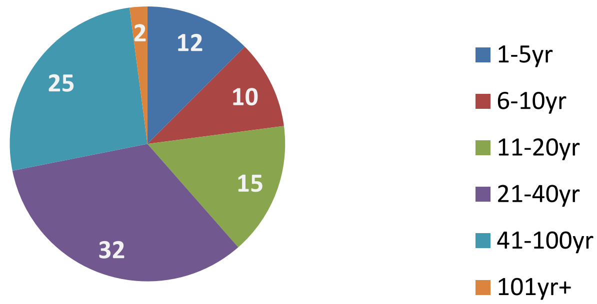
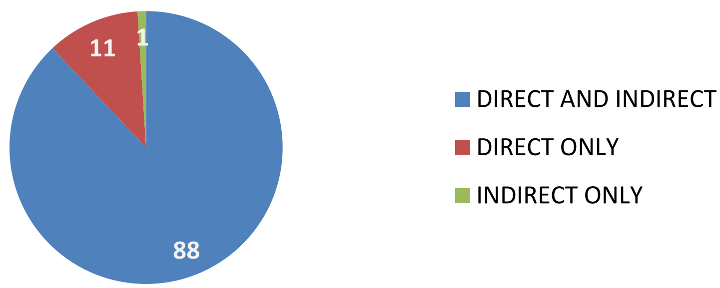
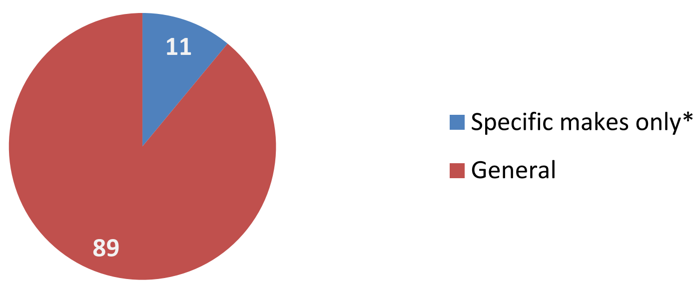
Characteristic	Sample Counts
North American Industry Classification System code [NAICS-DESCRIPTION]	
Annual Sales Volume [SALES_ VOLUME]	
Number of Employees [EMPLOYEE_ TOTAL]	
Facility category [RFTYPE] *co-op, corporate, company owned	

Figure F-1. Repair Facilities Survey Sample Makeup, Business Characteristics

Figure F-2 shows the sample makeup for business years and services offered.

<table>
<tr><th>Characteristic</th><th></th><th>Sample Counts</th></tr>
<tr><td>Years in business (Includes all locations, if the facility has moved)
[RFOPEN1]</td><td></td><td>
</td></tr>
<tr><td>Types of TPMS serviced
[RFTPMS2]</td><td></td><td>
</td></tr>
<tr><td>Vehicle makes serviced
[RFBRAND1]</td><td></td><td>

<table>
<tr><td>*</td><td>GMC, Chevy, Buick, Cadillac</td><td>1</td></tr>
<tr><td></td><td>Hyundai, Isuzu</td><td>1</td></tr>
<tr><td></td><td>Nissan</td><td>1</td></tr>
<tr><td></td><td>Toyota, Chevy, Ford, Nissan, Dodge</td><td>1</td></tr>
<tr><td></td><td>all but BMV, imports</td><td>1</td></tr>
<tr><td></td><td>domestic, Toyota, Nissan, Honda</td><td>1</td></tr>
<tr><td></td><td>Ford Lincoln Mercury</td><td>1</td></tr>
<tr><td></td><td>GMC lines</td><td>1</td></tr>
<tr><td></td><td>Mercedes Benz</td><td>1</td></tr>
<tr><td></td><td>Saab and Volvo</td><td>1</td></tr>
<tr><td></td><td>Volkswagen</td><td>1</td></tr>
</table></td></tr>
</table>

Figure F-2. Repair Facilities Survey Sample Makeup, Years and Service Characteristics

Figure F-3 shows the sample makeup for facilities' reported last 90 days of TPMS activity at the time of the survey.

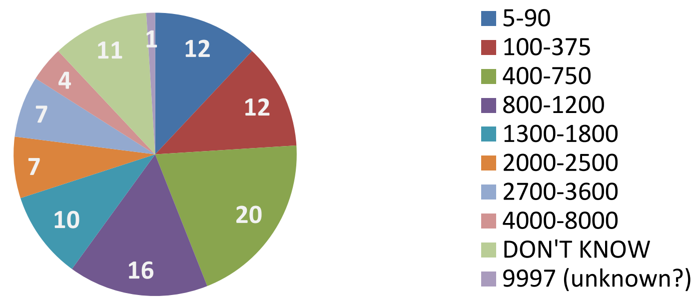
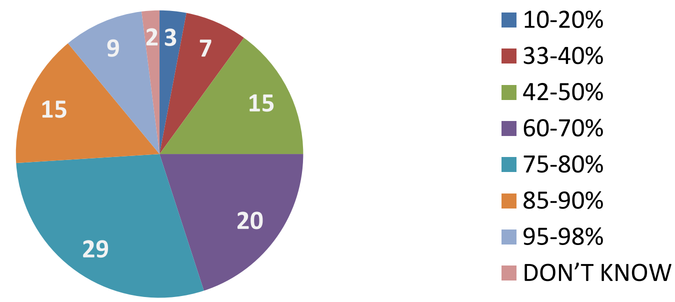
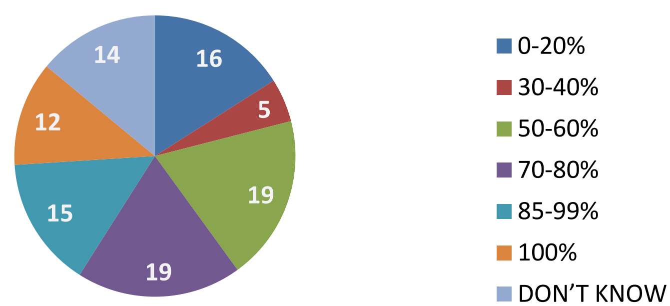
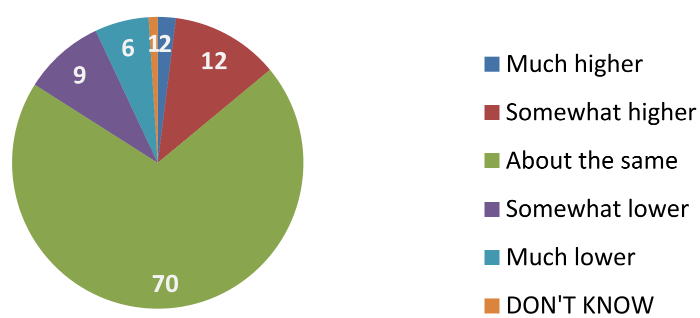
Characteristic	Sample Counts
Number of passenger vehicles this facility serviced in the last 90 days [RFVEHIC]	
Percent passenger vehicles serviced in the last 90 days that were equipped with a TPMS whether or not it was functional [SRVTOT]	
For all facilities, percent of last 90 days TPMS service that was direct TPMS [SRVDIR]	
Volume of TPMS service in this facility in the last 90 days compared to other times of year [TPMSVOL]	

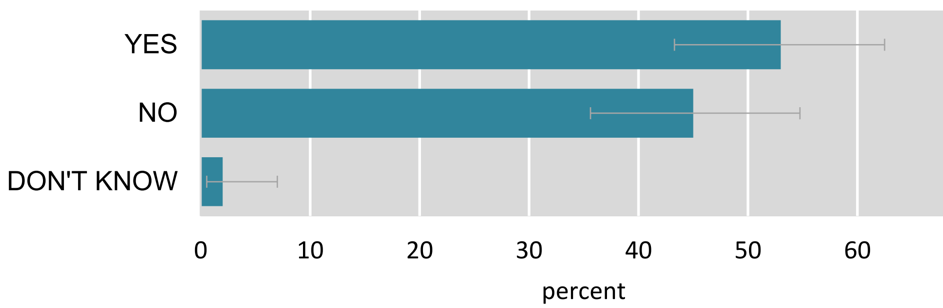
Figure F-3. Repair Facilities Survey Sample Makeup, TPMS Service Activity

Appendix G. Repair Facilities Survey Response Tables

This appendix reports the responses to each subject matter question in the Repair Facilities Survey. For each question, a bar graph is shown where bars mark the point estimate for the response percentage and error bars show 95 percent confidence intervals. Table entries at the right end of bars show the data points and confidence intervals. The domain is the subset of respondents eligible for the question. The character string in brackets (for example, [CHKMALF1]) is the name of the variable in the data set. The "*n*" under the variable name is the number of responses. The response "*n*" would ideally equal the domain "*n*" but may be lower due to item non-response. The questions shown start after the initial screening and population characteristic questions.

As standard practice, does your facility perform a TPMS system inspection on all TPMS-equipped vehicles that come in?

DOMAIN: All (n=100)



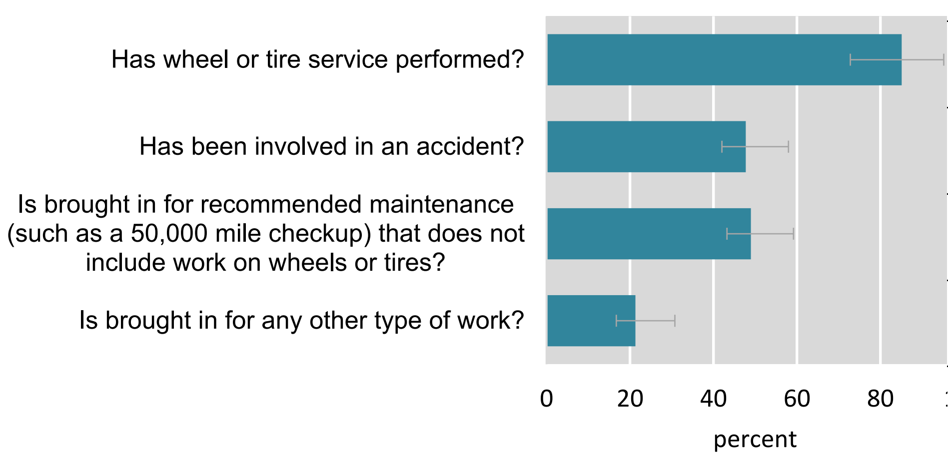
	pct	95% C.I.
YES	53.0	(43.3, 62.5)
NO	45.0	(35.6, 54.8)
DON'T KNOW	2.0	(0.6, 7.0)

[CHKMALF1]
n=100

Source: NHTSA TPMS-ORRC, Repair Facilities Survey

As a standard practice, does your facility check that the TPMS system is working properly each time a TPMS-equipped vehicle... (SELECT ALL THAT APPLY)

DOMAIN: Does not check that TPMS is working for all vehicles (include don't know) (n=47)



	pct	95% C.I.
Has wheel or tire service performed?	85.1	(72.3, 92.6)
Has been involved in an accident?	47.7	(33.8, 62.1)
Is brought in for recommended maintenance (such as a 50,000 mile checkup) that does not include work on wheels or tires?	48.9	(35.3, 62.8)
Is brought in for any other type of work?	21.3	(12.0, 34.9)

[CHKMALF2_A-D]
n=39-47*

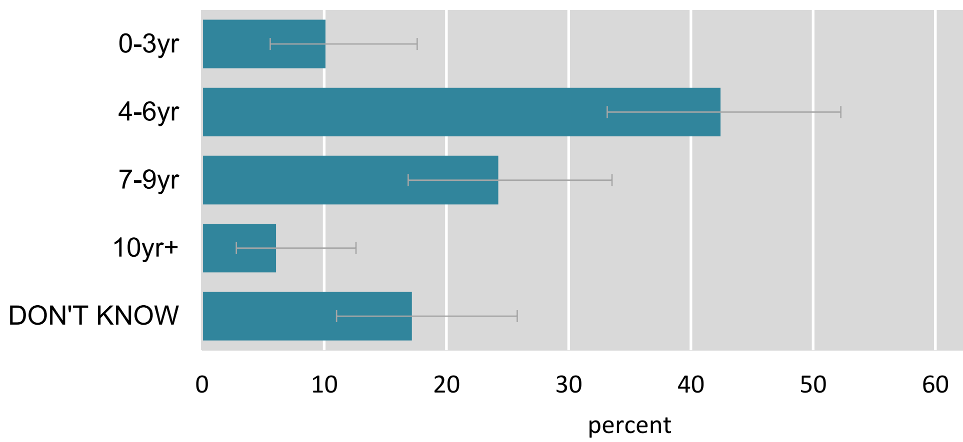
Source: NHTSA TPMS-ORRC RFS, 2016

*Number responding (saying either yes or no) varied by option presented.

INTERVIEWER: In the next set of questions, I'll be asking about the average functional lifespan of TPMS components. Please base your answers on your knowledge about servicing TPMS systems, not on any marketing or other information provided by the suppliers of these products. [INTERVIEWER NOTE: IF LESS THAN 1 YEAR, ENTER 1. IF MORE THAN 10 YEARS, ENTER 11.]

In a direct TPMS system, what is the average functional lifespan of a rim-mounted sensor?

DOMAIN: Facility services direct TPMS in passenger vehicles (n=99)



	pct	95% C.I.
0-3yr	10.1	(5.6, 17.6)
4-6yr	42.4	(33.2, 52.3)
7-9yr	24.2	(16.9, 33.5)
10yr+	6.1	(2.8, 12.6)
DON'T KNOW	17.2	(11.0, 25.8)

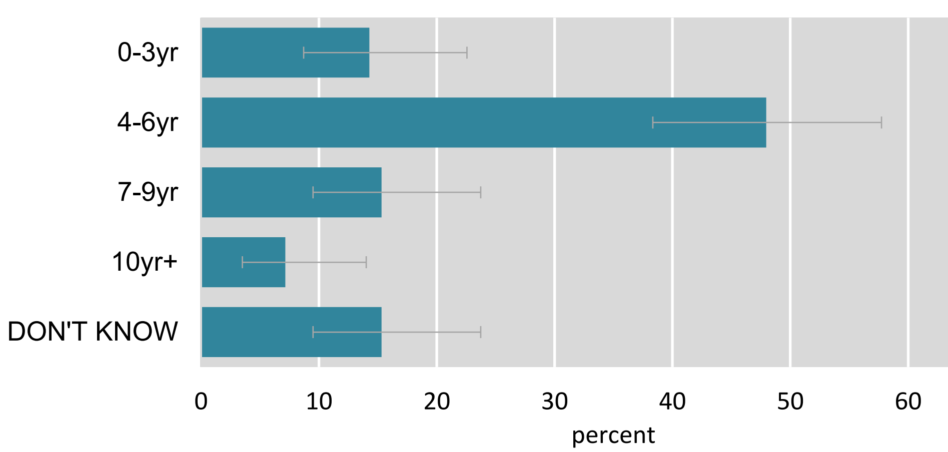
[LSD_RSENSOR]
n=99

Median estimate: 4 years

Source: NHTSA TPMS-ORRC RFS, 2016

In a direct TPMS system, what is the average functional lifespan of a stem-mounted sensor?

DOMAIN: Facility services direct TPMS in passenger vehicles (n=99)



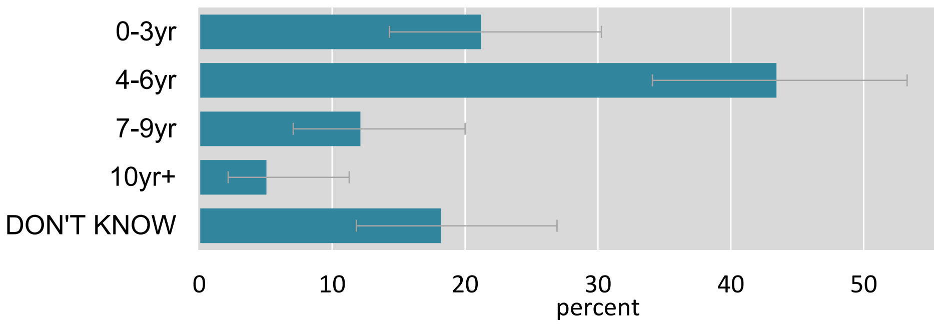
	pct	95% C.I.
0-3yr	14.3	(8.7, 22.6)
4-6yr	48.0	(38.3, 57.7)
7-9yr	15.3	(9.5, 23.7)
10yr+	7.1	(3.5, 14.0)
DON'T KNOW	15.3	(9.5, 23.7)

[LSD_SSENSOR]
n=99

Median estimate: 5 years

Source: NHTSA TPMS-ORRC RFS, 2016

What is the average functional lifespan of a direct TPMS system as a whole, that is, before it requires some kind of service? *DOMAIN: Facility services direct TPMS (n=99)*



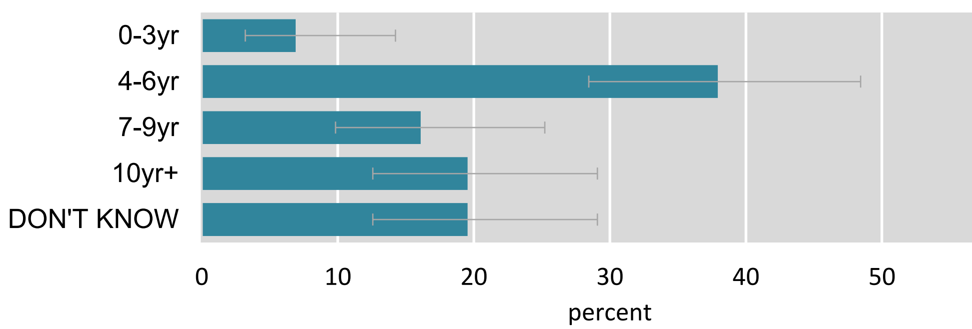
pct	95% C.I.
21.2	(14.3, 30.3)
43.4	(34.1, 53.3)
12.1	(7.1, 20.0)
5.1	(2.2, 11.3)
18.2	(11.8, 26.9)

[LSD_OVERALL]
n=99

Median estimate: 4 years

Source: NHTSA TPMS-ORRC RFS, 2016

In an indirect TPMS system, what is the average functional lifespan of a chassis-mounted sensor (such as a wheel speed sensor)? *DOMAIN: Facility services indirect TPMS (n=89)*



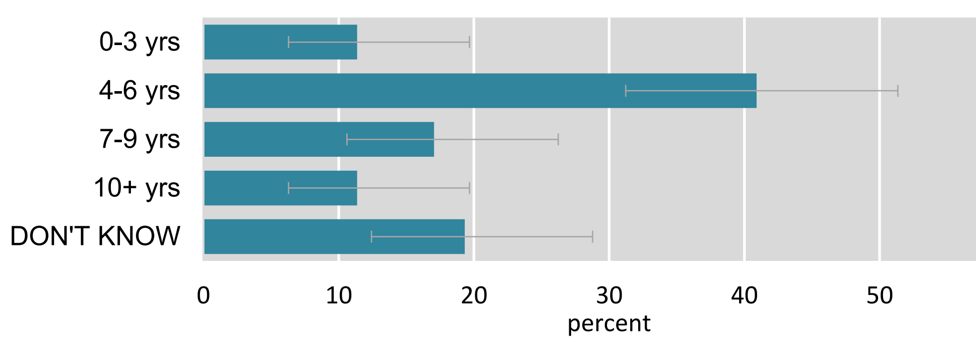
pct	95% C.I.
6.9	(3.2, 14.2)
37.9	(28.5, 48.4)
16.1	(9.8, 25.2)
19.5	(12.6, 29.1)
19.5	(12.6, 29.1)

[LSI_SENSOR]
n=87

Median estimate: 6 years

Source: NHTSA TPMS-ORRC RFS, 2016

What is the average functional lifespan of an indirect TPMS system as a whole, that is, before it requires some kind of service? *DOMAIN: Facility services indirect TPMS (n=89)*



pct	95% C.I.
11.4	(6.3, 19.7)
40.9	(31.2, 51.4)
17.0	(10.6, 26.2)
11.4	(6.3, 19.7)
19.3	(12.4, 28.8)

[LSI_OVERALL]
n=88

Median estimate: 5 years

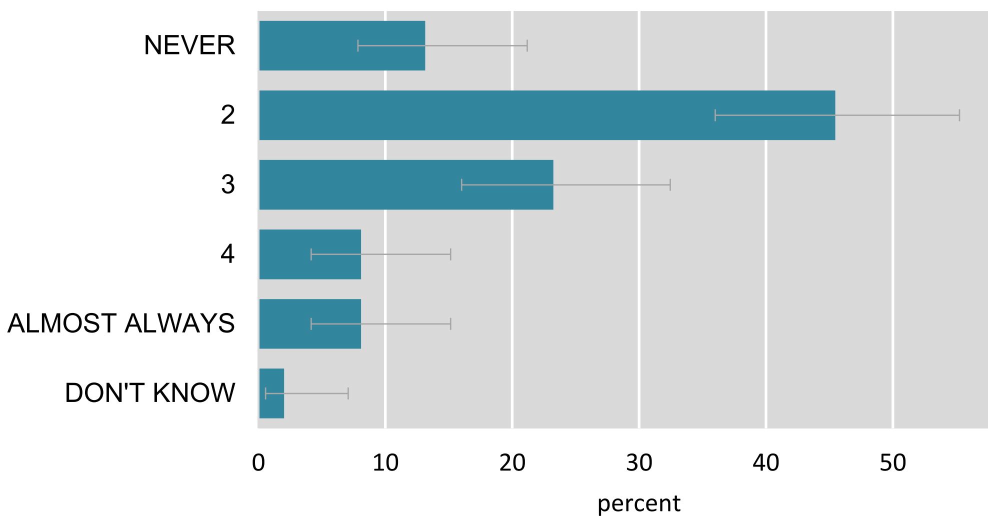
Source: NHTSA TPMS-ORRC RFS, 2016

INTERVIEWER: Now I'd like you to think about TPMS malfunctions in passenger vehicles. For this survey, a TPMS malfunction is defined as any time a TPMS system is not working correctly including problems with the sensors or the on-board components.

(If facility services direct TPMS) The following questions will be specifically about the vehicles with direct TPMS systems that were seen in the last 90 days.

Over the past 90 days, how often did vehicles with direct TPMS come in with a TPMS malfunction whether or not a repair was later done? Please use a 1 to 5 scale where 1 means Never and 5 means Almost Always. [Would you say...]

DOMAIN: Facility services direct TPMS in passenger vehicles (n=99)



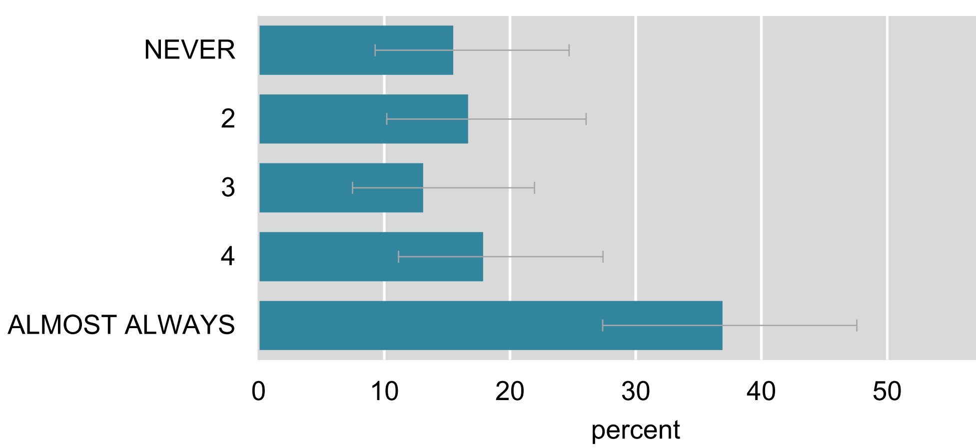
pct	95% C.I.
13.1	(7.8, 21.2)
45.5	(36.0, 55.2)
23.2	(16.0, 32.5)
8.1	(4.2, 15.1)
8.1	(4.2, 15.1)
2.0	(0.6, 7.1)

[MALFREQD]
n=99

Source: NHTSA TPMS-ORRC RFS, 2016

How frequently were these malfunctions originally identified by the owner when the vehicle was first brought in for service? Please use a 1 to 5 scale where 1 means Never and 5 means Almost Always. [INTERVIEWER NOTE: IN PAST 90 DAYS]

DOMAIN: Some direct TPMS malfunctions seen in past 90 days (n=84)



pct	95% C.I.
15.5	(9.3, 24.7)
16.7	(10.2, 26.1)
13.1	(7.5, 21.9)
17.9	(11.1, 27.4)
36.9	(27.4, 47.6)

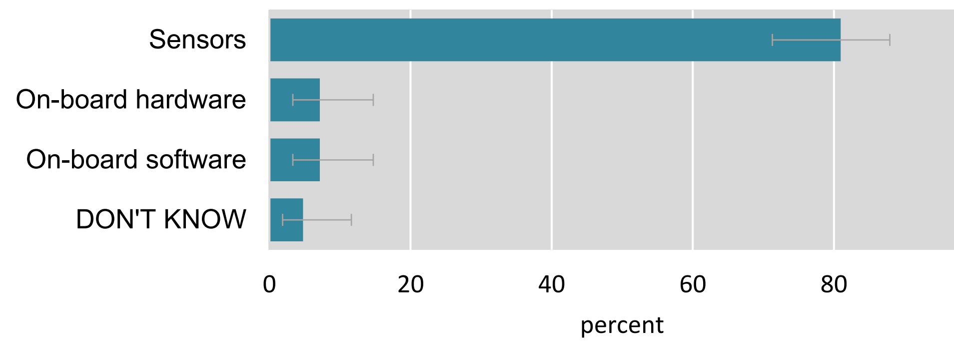
[MALIDENTD]
n=84

Source: NHTSA TPMS-ORRC RFS, 2016

When was the last time a TPMS malfunction was seen in a vehicle with direct TPMS? *DOMAIN: no direct TPMS malfunctions seen in past 90 days (n=13)* The sample size for this question was too small for inferences.

Which of the following was most frequently the source of the TPMS malfunction in these (direct TPMS) vehicles?

DOMAIN: Some direct TPMS malfunctions seen in past 90 days (n=84)



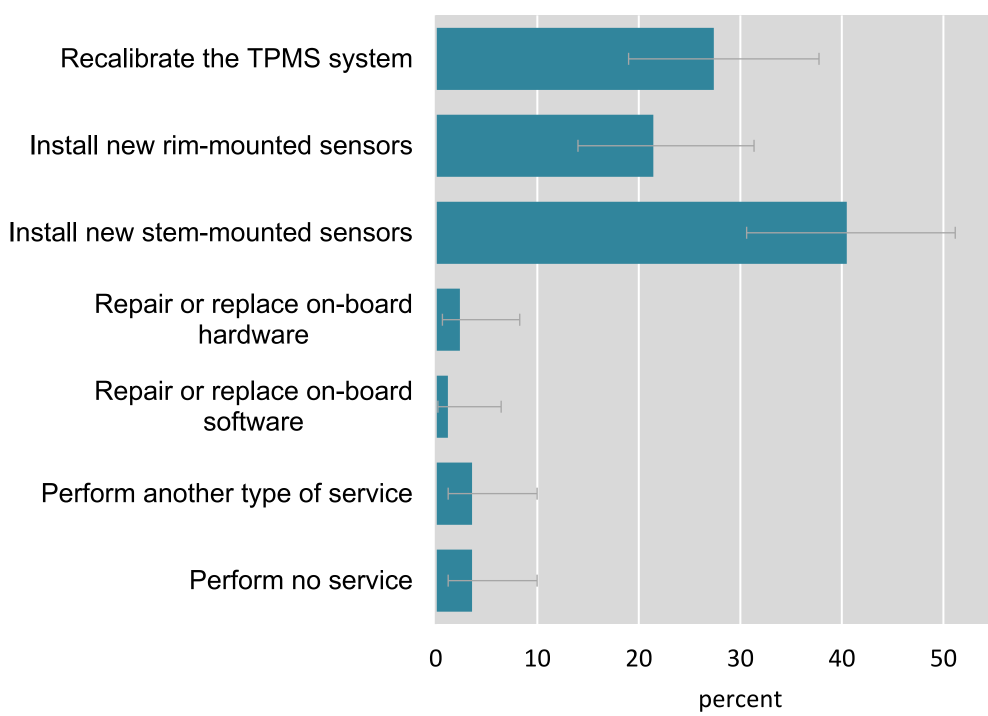
	pct	95% C.I.
Sensors	81.0	(71.3, 87.9)
On-board hardware	7.1	(3.3, 14.7)
On-board software	7.1	(3.3, 14.7)
DON'T KNOW	4.8	(1.9, 11.6)

[MALSRCD]
n=84

Source: NHTSA TPMS-ORRC RFS, 2016

What was the most common service your facility performed to fix the malfunctions in these (direct TPMS) vehicles?

DOMAIN: Some direct TPMS malfunctions seen in past 90 days (n=84)



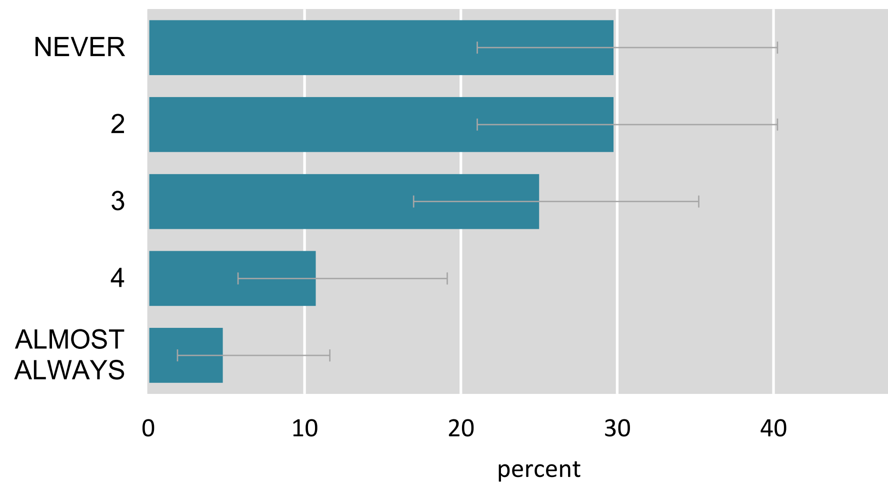
	pct	95% C.I.
Recalibrate the TPMS system	27.4	(19.0, 37.7)
Install new rim-mounted sensors	21.4	(14.0, 31.3)
Install new stem-mounted sensors	40.5	(30.6, 51.2)
Repair or replace on-board hardware	2.4	(0.7, 8.3)
Repair or replace on-board software	1.2	(0.2, 6.4)
Perform another type of service	3.6	(1.2, 10.0)
Perform no service	3.6	(1.2, 10.0)

[MALSRVCD]
n=84

Source: NHTSA TPMS-ORRC RFS, 2016

How frequently did the owners of these vehicles ask you to disable the direct TPMS system or to leave it unrepaired? Please use the same 1 to 5 scale where 1 means Never and 5 means Almost Always. [Would you say...]

DOMAIN: Some direct TPMS malfunctions seen in past 90 days (n=84)



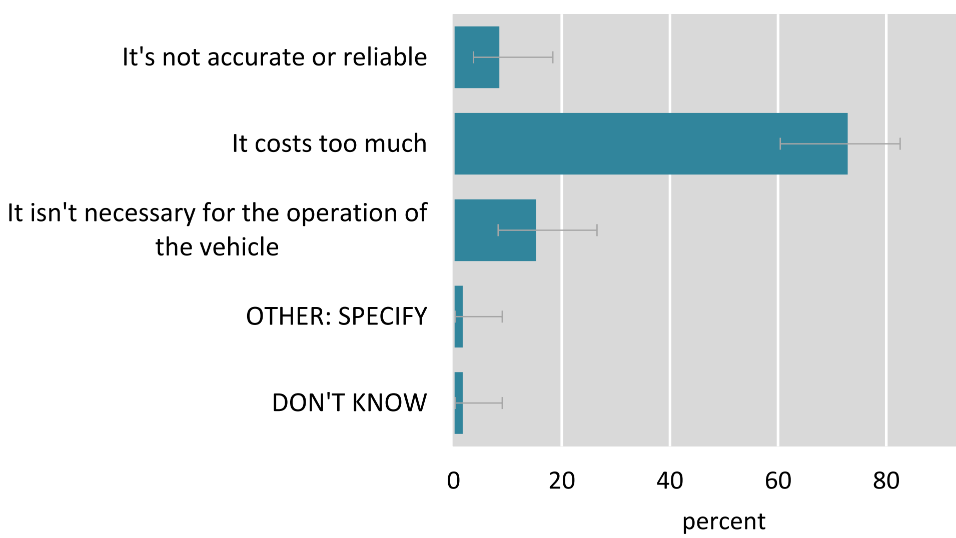
	pct	95% C.I.
NEVER	29.8	(21.0, 40.2)
2	29.8	(21.0, 40.2)
3	25.0	(17.0, 35.2)
4	10.7	(5.7, 19.1)
ALMOST ALWAYS	4.8	(1.9, 11.6)

[ASKDISABD1]
n=84

Source: NHTSA TPMS-ORRC RFS, 2016

What is the most common reason these owners gave for wanting the direct TPMS system in their vehicle disabled or for not wanting it fixed?

DOMAIN: Some customers ask about disabling the direct TPMS system or leaving it unrepaired (n=59)



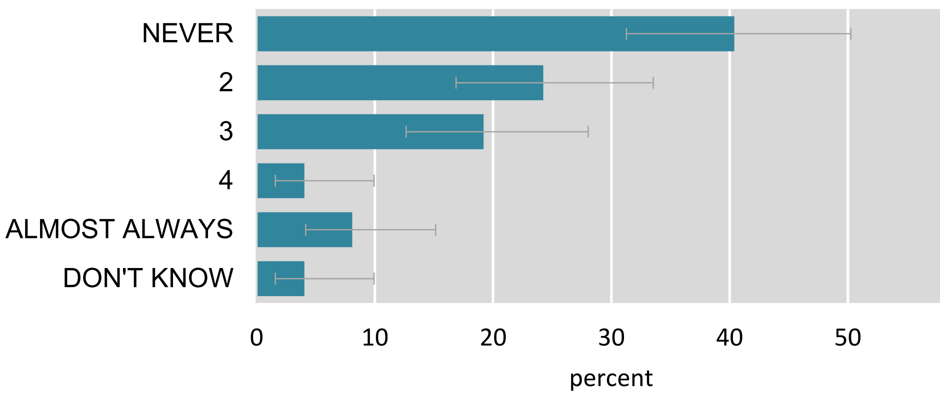
	pct	95% C.I.
It's not accurate or reliable	8.5	(3.7, 18.4)
It costs too much	72.9	(60.4, 82.6)
It isn't necessary for the operation of the vehicle	15.3	(8.2, 26.5)
OTHER: SPECIFY	1.7	(0.3, 9.0)
DON'T KNOW	1.7	(0.3, 9.0)

[ASKDISABD2]
n=59

Source: NHTSA TPMS-ORRC RFS, 2016

Over the past 90 days, how frequently were disabled TPMS systems seen in vehicles with direct TPMS? Please use the same 1 to 5 scale where 1 means Never and 5 means Almost Always. [Would you say...]

DOMAIN: Facility services direct TPMS (n=99)



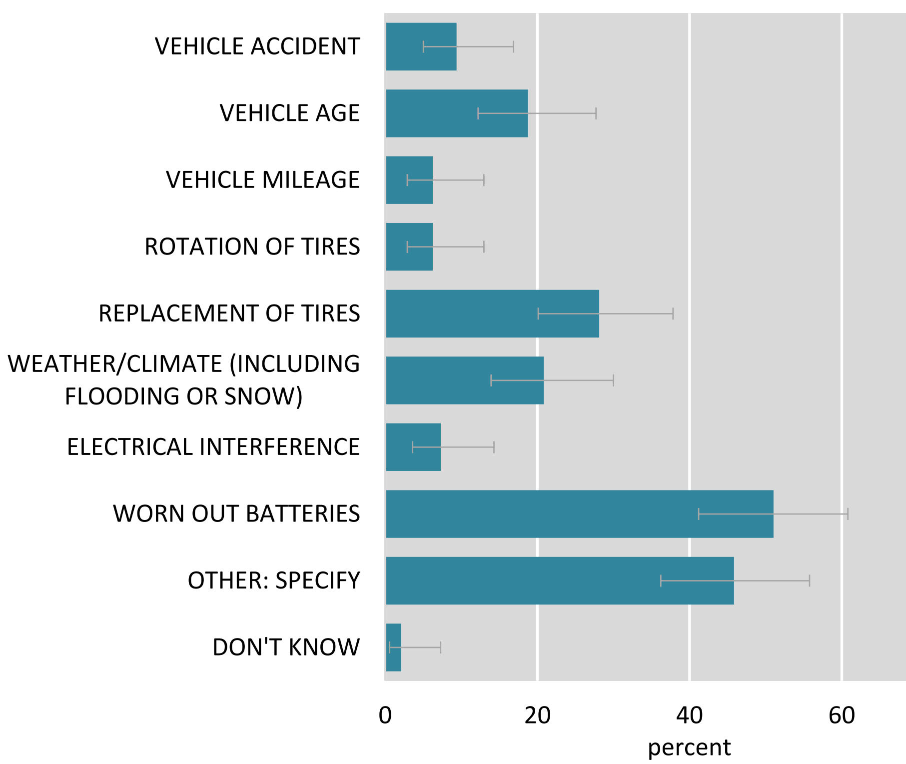
	pct	95% C.I.
NEVER	40.4	(31.3, 50.3)
2	24.2	(16.9, 33.5)
3	19.2	(12.6, 28.0)
4	4.0	(1.6, 9.9)
ALMOST ALWAYS	8.1	(4.2, 15.1)
DON'T KNOW	4.0	(1.6, 9.9)

[DISABLED]
n=99

Source: NHTSA TPMS-ORRC RFS, 2016

Based on your overall experience, what most commonly causes malfunctions in direct TPMS systems? Please include up to three causes. (Percentage sum is not restricted to 100 because respondent could contribute up to three responses)

DOMAIN: has seen direct TPMS malfunctions (n=96)



	pct	95% C.I.
VEHICLE ACCIDENT	9.4	(5.0, 16.9)
VEHICLE AGE	18.8	(12.2, 27.7)
VEHICLE MILEAGE	6.3	(2.9, 13.0)
ROTATION OF TIRES	6.3	(2.9, 13.0)
REPLACEMENT OF TIRES	28.1	(20.1, 37.8)
WEATHER/CLIMATE (INCLUDING FLOODING OR SNOW)	20.8	(13.9, 30.0)
ELECTRICAL INTERFERENCE	7.3	(3.6, 14.3)
WORN OUT BATTERIES	51.0	(41.2, 60.8)
OTHER: SPECIFY	45.8	(36.2, 55.8)
DON'T KNOW	2.1	(0.6, 7.3)

[MALEVENTD_01-10]
n=96

Source: NHTSA TPMS-ORRC RFS, 2016

Other specified responses, most common causes of direct TPMS malfunctions

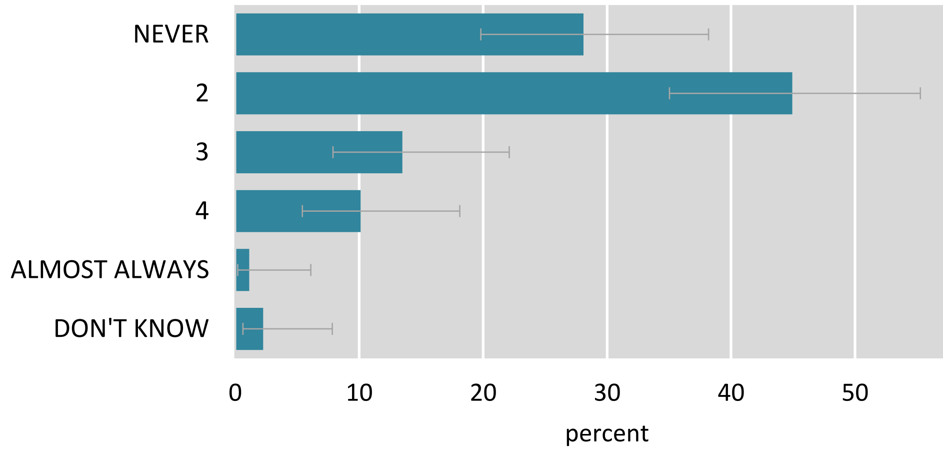
other specified response [MALEVENTD_OTHER]	Count
bad sensor	1
bad sensors	1
broken sensor	1
broken sensor; relearn	1
broken valve stem	1
Charges	1
consumer damage	1
corroded stems	1
Corrosion	1
corrosion of the stem; recalibration	1
corrosion on gm and chryslers, battery, tpms not being reset	1
corrosion, breaks	1
corrosion; broken bands	1
crack rim, direct hit of a curb	1
damaged sensor	1
damaging from fix a flat, chemicals	1
defect in sensor	1
defect sensor and by customer	1
destroyed by flat tire	1
driving on a flat tire	1
fix a flat	1
gasket worn out	1
improper air inflation; damage to tire	1
lack of service	1
low air pressure and damage to sensors	1
low tire pressure	1
low tire pressure, weak stems, bad sensors	1
made cheaply; very fragile; normally 5 lbs off	1
malfunction in sensor, light does not reset, manufacturer tells us to replace all	1
moisture in sensor	1
over or under inflated tires; un-programmed sensors	1
poor maintenance	1
pressure in tires; sensor failure	1
run tire too low for too long time	1
seals deteriorate, debris	1
sensor corrosion, old	1
sensor fails and corrosion	1
sensor failure	1
sensor failure; tire pressure adjustment	1
sensor issues by bending rim, etc	1
sensor was left out after mounting, coil bad	1
tire blow out	1
tire damage	1
wheel sensors	1

Source: NHTSA TPMS-ORRC Repair Facilities Survey

INTERVIEWER: (if facility services indirect TPMS) The following questions will be specifically about the vehicles with indirect systems seen in the last 90 days.

Over the past 90 days, how often did vehicles with indirect TPMS come in with a TPMS malfunction whether or not a repair was later done? Please use a 1 to 5 scale where 1 means Never and 5 means Almost Always. [Would you say...]

DOMAIN: Facility services indirect TPMS (n=89)



	pct	95% C.I.
NEVER	28.1	(19.8, 38.2)
2	44.9	(35.0, 55.3)
3	13.5	(7.9, 22.1)
4	10.1	(5.4, 18.1)
ALMOST ALWAYS	1.1	(0.2, 6.1)
DON'T KNOW	2.2	(0.6, 7.8)

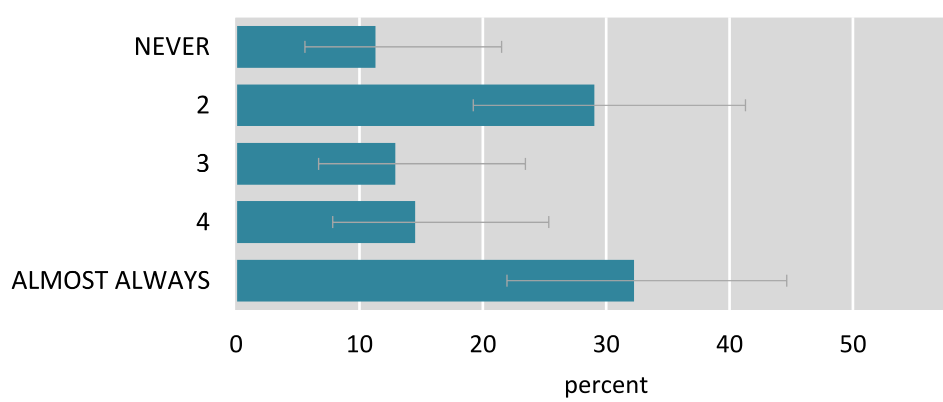
[MALFREQI]
n=89

Source: NHTSA TPMS-ORRC RFS, 2016

When was the last time a TPMS malfunction was seen in a vehicle with indirect TPMS? *DOMAIN: no indirect TPMS malfunctions seen in past 90 days (n=25)* Domain size too small for inferences. [MALFREQI2]

How frequently were these (indirect TPMS) malfunctions originally identified by the owner when the vehicle was first brought in for service? [Please use a 1 to 5 scale where 1 means Never and 5 means Almost Always.] [INTERVIEWER NOTE: IN PAST 90 DAYS]

DOMAIN: Some indirect TPMS malfunctions seen in past 90 days (n=62)



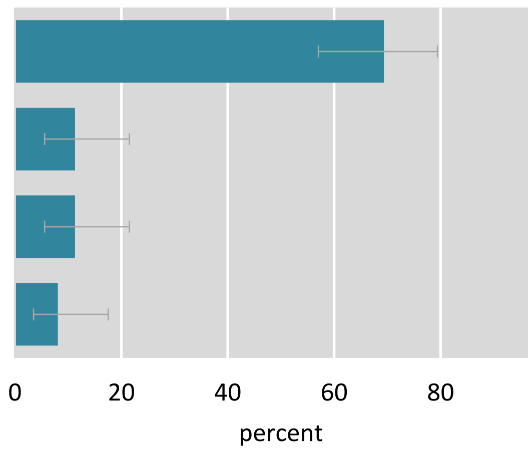
	pct	95% C.I.
NEVER	11.3	(5.6, 21.5)
2	29.0	(19.2, 41.3)
3	12.9	(6.7, 23.4)
4	14.5	(7.8, 25.3)
ALMOST ALWAYS	32.3	(22.0, 44.6)

[MALIDENTI]
n=62

Source: NHTSA TPMS-ORRC RFS, 2016

Which of the following was most frequently the source of the TPMS malfunction in these (indirect TPMS) vehicles?

DOMAIN: Some indirect TPMS malfunctions seen in past 90 days (n=62)



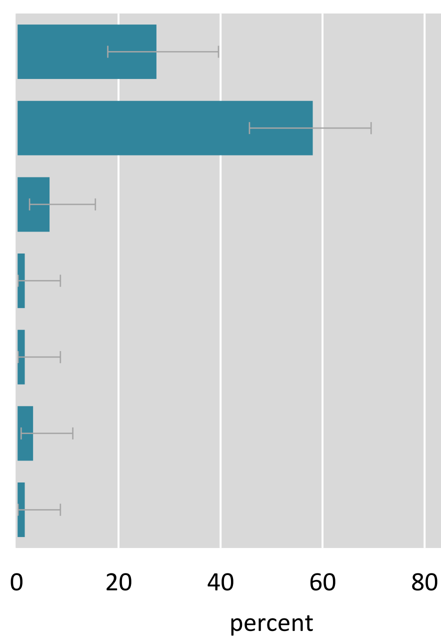
	pct	95% C.I.
Chassis-mounted sensor (such as a wheel speed sensors)	69.4	(57.0, 79.4)
On-board hardware	11.3	(5.6, 21.5)
On-board software	11.3	(5.6, 21.5)
DON'T KNOW	8.1	(3.5, 17.5)

[MALSRCI]
n=62

Source: NHTSA TPMS-ORRC RFS, 2016

What was the most common service your facility performed to fix the malfunctions in these (indirect TPMS) vehicles?

DOMAIN: Some indirect TPMS malfunctions seen in past 90 days (n=62)



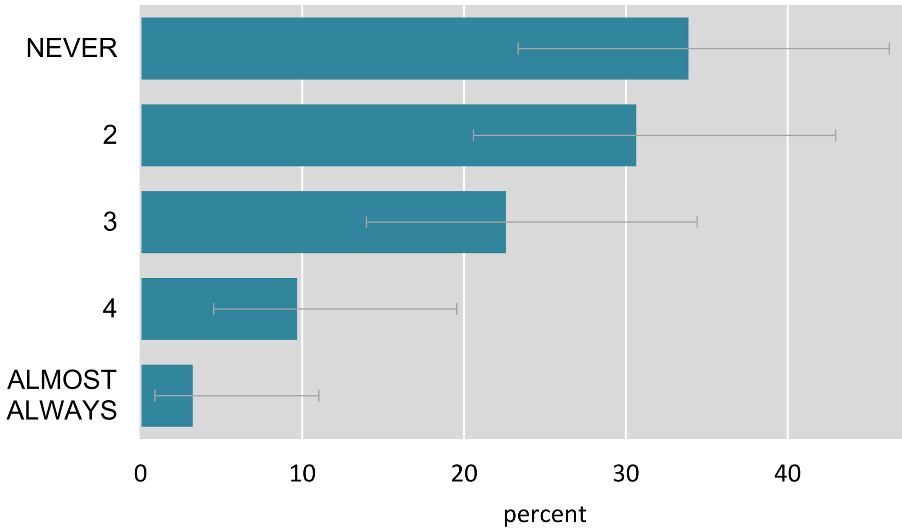
	pct	95% C.I.
Recalibrate the TPMS system	27.4	(17.9, 39.6)
Install new chassis-mounted sensors (such as wheel speed sensors)	58.1	(45.7, 69.5)
Repair or replace on-board hardware	6.5	(2.5, 15.4)
Repair or replace on-board software	1.6	(0.3, 8.6)
Perform another type of service	1.6	(0.3, 8.6)
Perform no service	3.2	(0.9, 11.0)
DON'T KNOW	1.6	(0.3, 8.6)

[MALSRVCI]
n=62

Source: NHTSA TPMS-ORRC RFS, 2016

How frequently did the owners of these vehicles ask you to disable the indirect TPMS system or to leave it unrepaired? Please use the same 1 to 5 scale where 1 means Never and 5 means Almost Always. [Would you say...]

DOMAIN: Some indirect TPMS malfunctions seen in past 90 days (n=62)



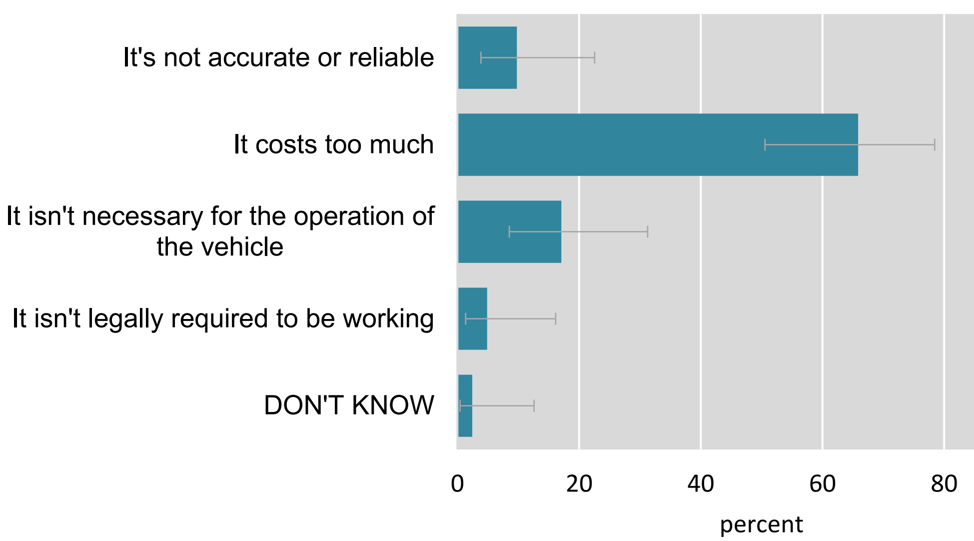
	pct	95% C.I.
NEVER	33.9	(23.3, 46.3)
2	30.6	(20.6, 43.0)
3	22.6	(14.0, 34.4)
4	9.7	(4.5, 19.5)
ALMOST ALWAYS	3.2	(0.9, 11.0)

[ASKDISABI1]
n=62

Source: NHTSA TPMS-ORRC RFS, 2016

What is the most common reason these owners gave for wanting the indirect TPMS system in their vehicle disabled or for not wanting it fixed?

DOMAIN: Some customers ask about disabling the indirect TPMS system or leaving it unrepaired (n=41)



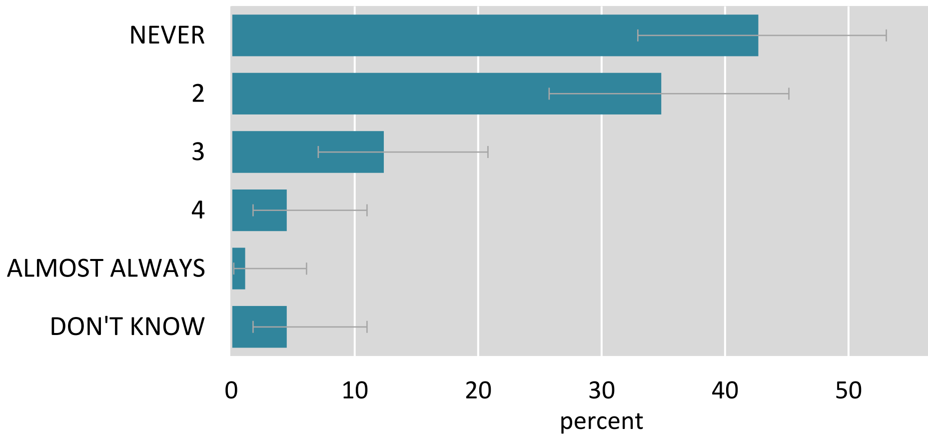
	pct	95% C.I.
It's not accurate or reliable	9.8	(3.9, 22.5)
It costs too much	65.9	(50.5, 78.4)
It isn't necessary for the operation of the vehicle	17.1	(8.5, 31.3)
It isn't legally required to be working	4.9	(1.3, 16.1)
DON'T KNOW	2.4	(0.4, 12.6)

[ASKDISABI2]
n=41

Source: NHTSA TPMS-ORRC RFS, 2016

Over the past 90 days, how frequently were disabled TPMS systems seen in vehicles with indirect TPMS? Please use the same 1 to 5 scale where 1 means Never and 5 means Almost Always. [Would you say...]

DOMAIN: Facility services indirect TPMS (n=89)



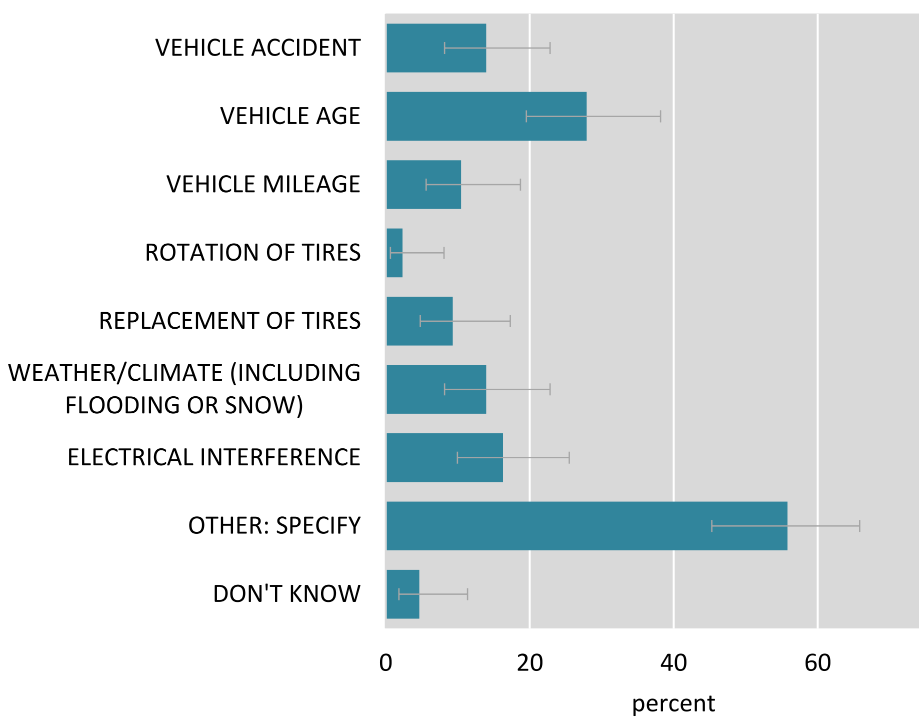
	pct	95% C.I.
NEVER	42.7	(32.9, 53.1)
2	34.8	(25.7, 45.2)
3	12.4	(7.0, 20.8)
4	4.5	(1.8, 11.0)
ALMOST ALWAYS	1.1	(0.2, 6.1)
DON'T KNOW	4.5	(1.8, 11.0)

[DISABLEI]
n=89

Source: NHTSA TPMS-ORRC RFS, 2016

Based on your overall experience, what most commonly causes malfunctions in indirect TPMS systems? Please include up to three causes. (Percentages do not add to 100 because respondent could contribute up to three responses)

DOMAIN: has seen indirect TPMS malfunctions (n=86)



	pct	95% C.I.
VEHICLE ACCIDENT	14.0	(8.2, 22.8)
VEHICLE AGE	27.9	(19.5, 38.2)
VEHICLE MILEAGE	10.5	(5.6, 18.7)
ROTATION OF TIRES	2.3	(0.6, 8.1)
REPLACEMENT OF TIRES	9.3	(4.8, 17.3)
WEATHER/CLIMATE (INCLUDING FLOODING OR SNOW)	14.0	(8.2, 22.8)
ELECTRICAL INTERFERENCE	16.3	(10.0, 25.5)
OTHER: SPECIFY	55.8	(45.3, 65.8)
DON'T KNOW	4.7	(1.8, 11.4)

[MALEVENTI_01-10]
n=86

Source: NHTSA TPMS-ORRC RFS, 2016

Other specified responses, what most commonly causes indirect TPMS malfunctions?

other specified response [MALEVENTI_OTHER]	Count
bad bearing, bad sensor	1
bad sensor	2
bad sensor, bad battery	1
bad wheel bearing	1
bad wheel speed sensor	1
baring failure	1
battery	4
battery in sensor, speed sensor faulty	1
corrosion	3
cost	1
damage to the unit	1
damaged sensor, wrong tire size, system not reset	1
dirty sensors, damage on sensor	1
faulty speed sensors	1
internal problem with sensor	1
internal wear of bearing	1
lack of service	1
low tire pressure, bad sensor	1
maintenance	1
needs to be reset	1
normal ware, corrosion	1
old sensors	1
recalibration	1
rim leak, fix a flat	1
road debris,	1
sensor gets cut, defective sensor	1
sensor goes bad	1
sensor itself failed-battery failure	1
sensors	2
software	1
software, the sensor goes bad	1
software; hardware	1
something hits sensor; customer drives on the wheel flat	1
tire damage, batteries	1
tire pressure adjustment	1
tire wear	1
valve stem, someone breaking the stem, some don't take air, overtighten the valve	1
wheel bearings	1
wheel speed sensor	1
wheel speed sensor is bad, two different kinds of tires	1
wheel speed sensors	1

Source: NHTSA TPMS-ORRC Repair Facilities Survey

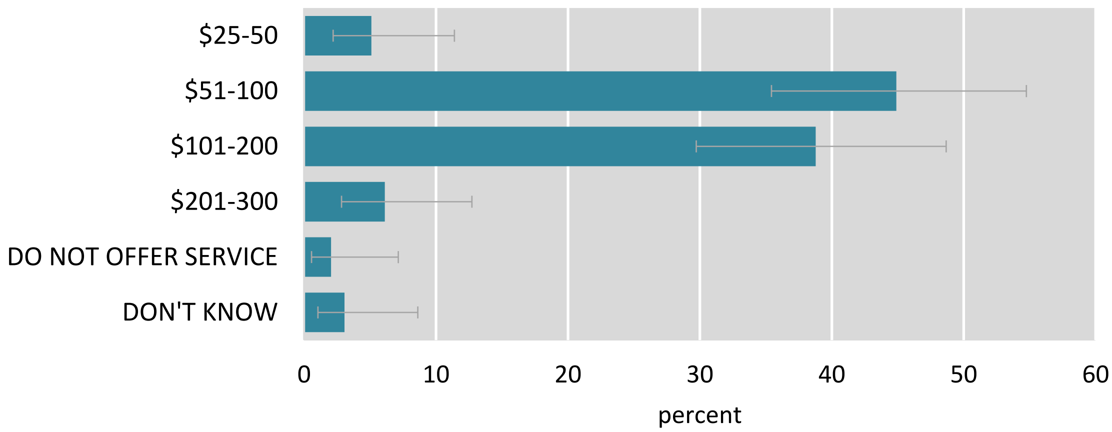
Domain for questions about direct TPMS component pricing: Facilities that service direct TPMS (n=99)

INTERVIEWER: In the following questions I'll ask about the average price you charge customers to repair specific components in a direct TPMS system. Please provide your best estimate of the total price you charge for this work, including both parts and labor.

What is the average price you charge for replacing each of the following, independent of tire replacement? Your best estimate is fine.

One rim-mounted sensor?

[PRICED_RSENSOR] (*n*=99)

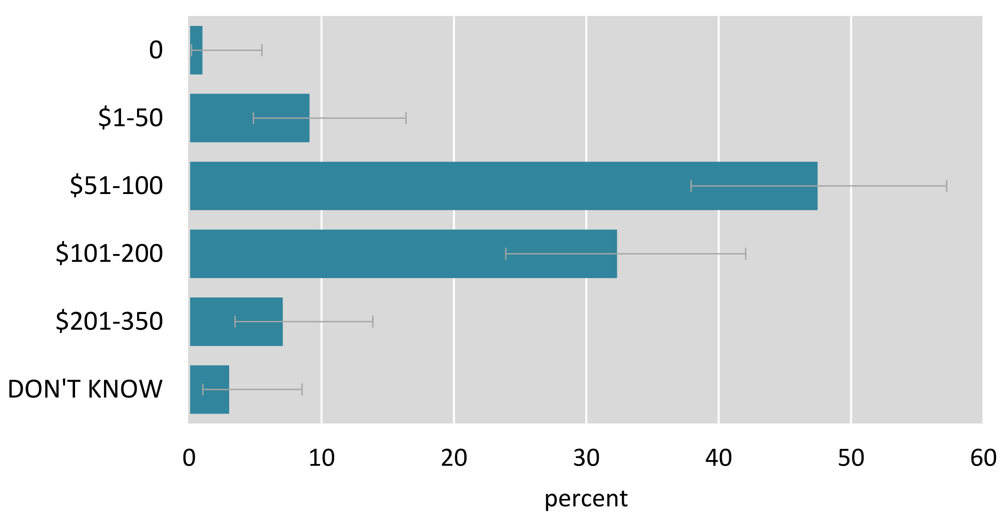


Median estimate: $99

Source: NHTSA TPMS-ORRC Repair Facilities Survey

One stem-mounted sensor?

[PRICED_SSENSOR] (*n*=99)

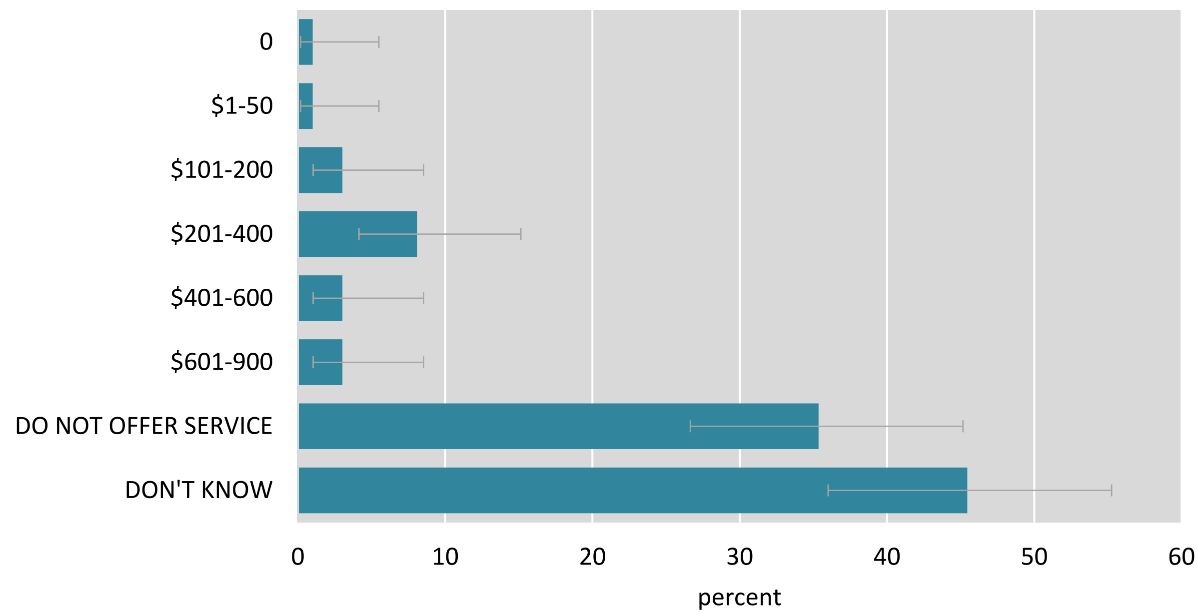


Median estimate: $96

Source: NHTSA TPMS-ORRC Repair Facilities Survey

The on-board processing unit?

[PRICED_HWARE_A] *n*=99

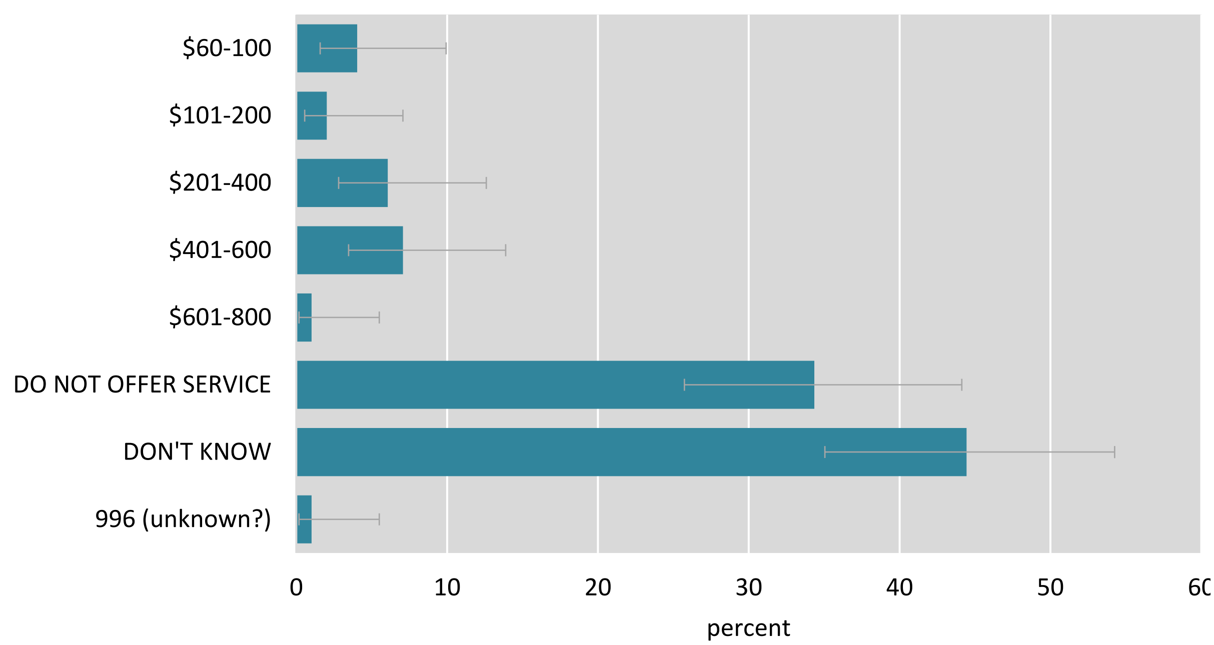


Median estimate: $293

Source: NHTSA TPMS-ORRC Repair Facilities Survey

The on-board receiver hardware?

[PRICED_HWARE_B] (*n*=99)

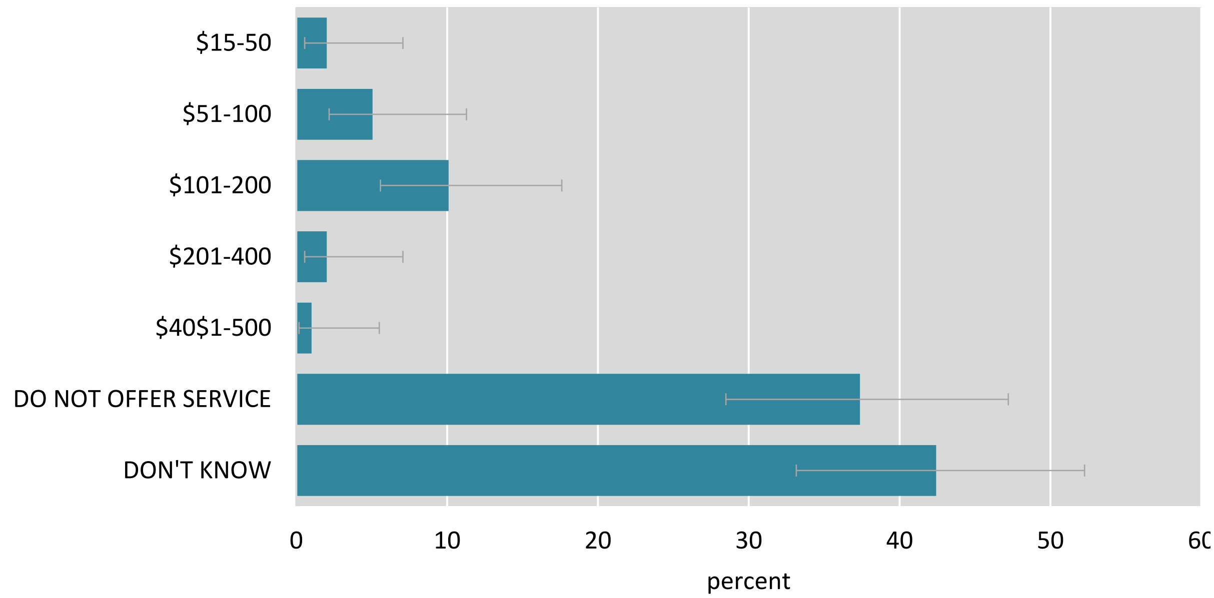


Median estimate: $325

Source: NHTSA TPMS-ORRC Repair Facilities Survey

The on-board electrical wiring?

[PRICED_HWARE_C] (*n*=99)

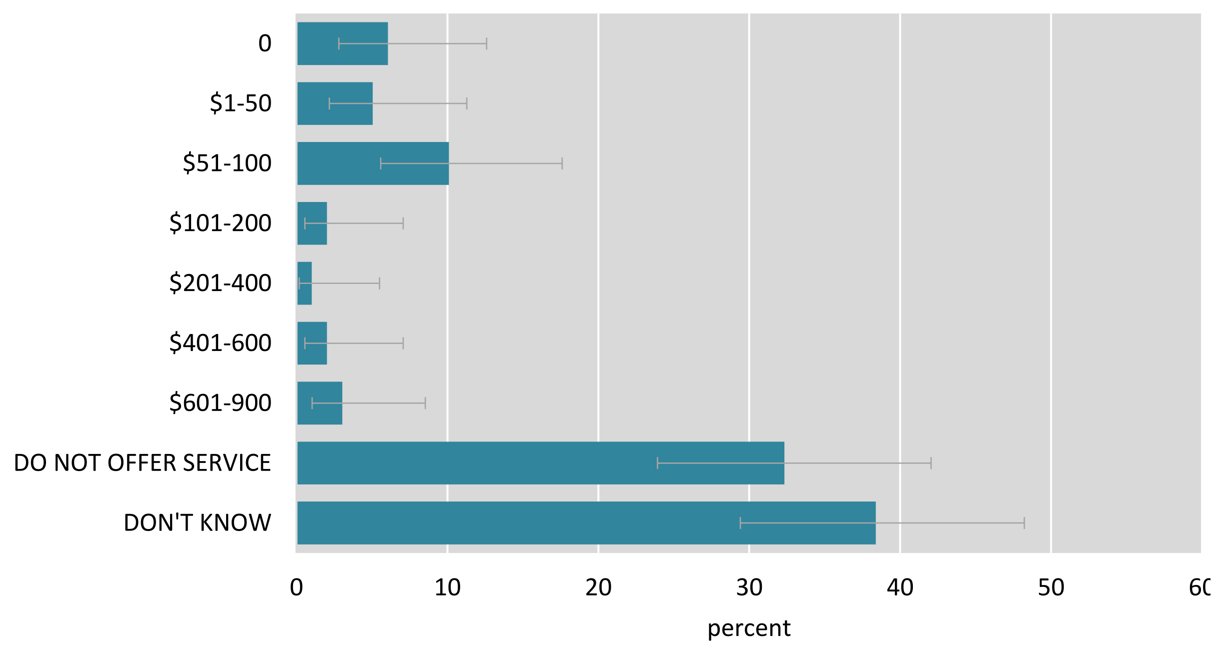


Median estimate: $132

Source: NHTSA TPMS-ORRC Repair Facilities Survey

The onboard dash lights?

[PRICED_HWARE_D] (*n*=99)

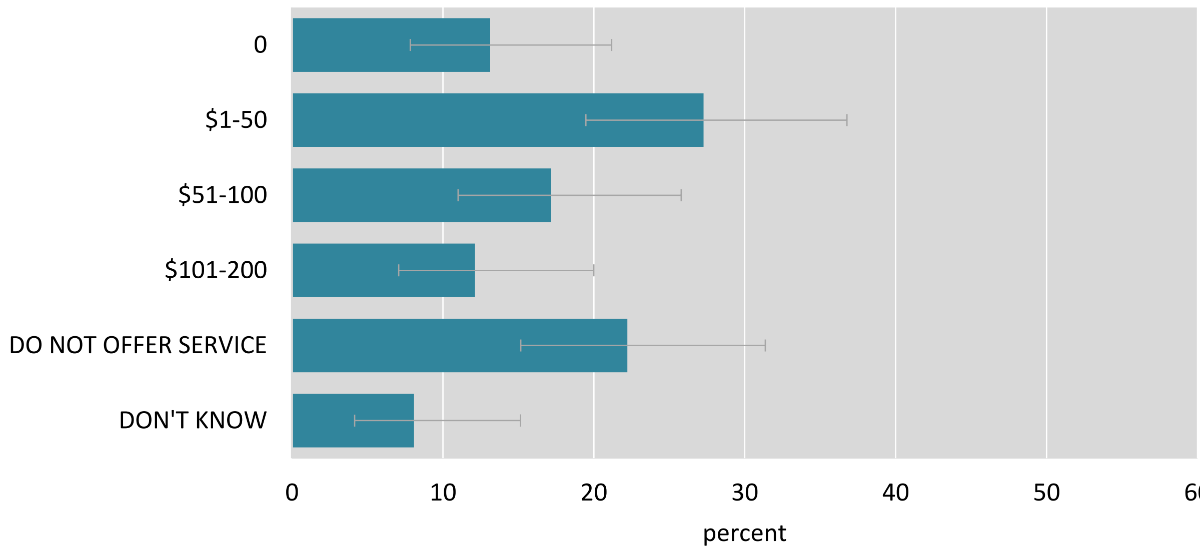


Median estimate: $81

Source: NHTSA TPMS-ORRC Repair Facilities Survey

Updating the software on a direct system?

[PRICED_SWARE] (*n*=99)



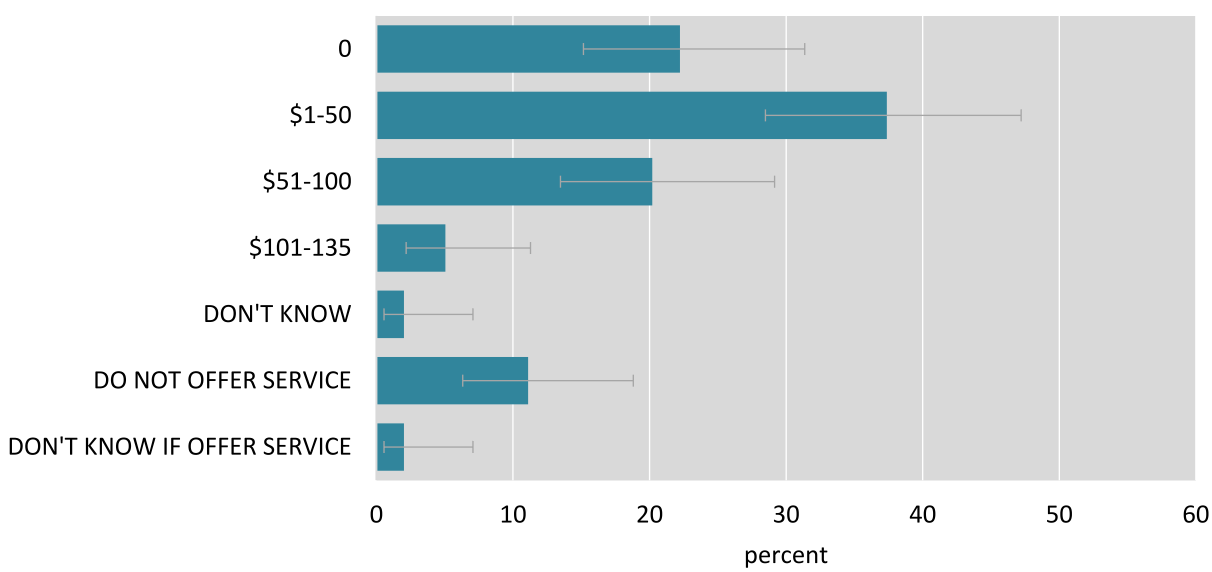
Median estimate: $49

Source: NHTSA TPMS-ORRC Repair Facilities Survey

[Note: Questions about recalibration pricing were asked in two parts – do you offer the service, and if so, what is the price. The two have been combined into one for these tables, consistent with the other pricing questions.]

Recalibrations of direct TPMS systems that require an activation tool with the vehicle in relearn mode to register new sensor IDs, but do not require driving the vehicle?

[PRICED_RECAL1A/B]

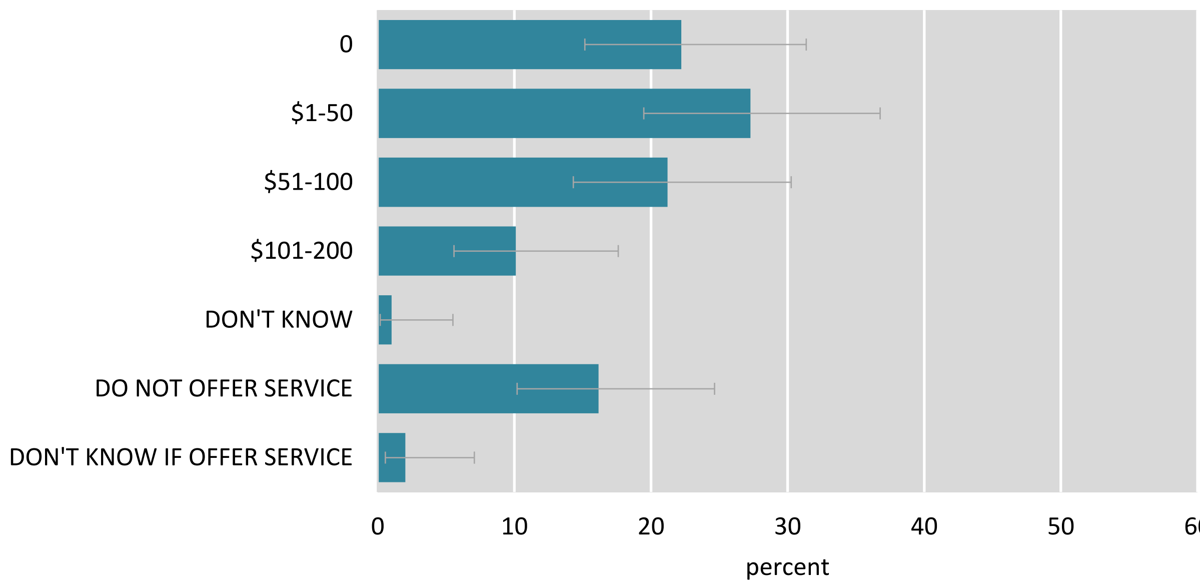


Median estimate: $29

Source: NHTSA TPMS-ORRC Repair Facilities Survey

Recalibrations of direct TPMS systems that require an activation tool in conjunction with a scan tool to register new sensor IDs, but do not require driving the vehicle?

[PRICED_RECAL2A/B]

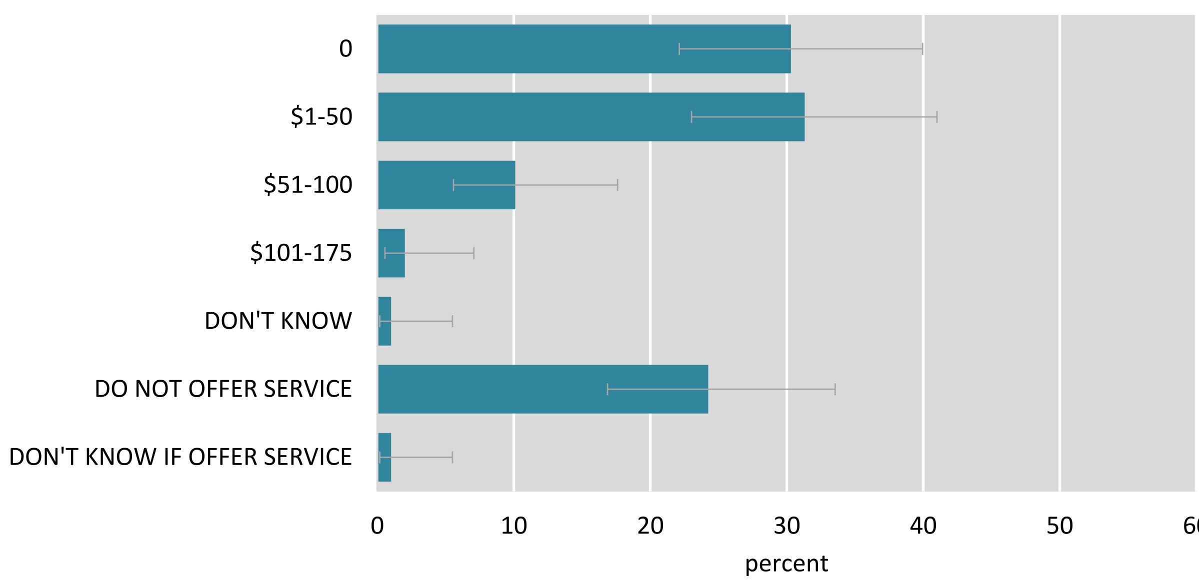


Median estimate: $38

Source: NHTSA TPMS-ORRC Repair Facilities Survey

Recalibrations of direct TPMS systems, which do not require tools but do require driving the vehicle to register new sensor IDs?

[PRICED_RECAL3A/B]

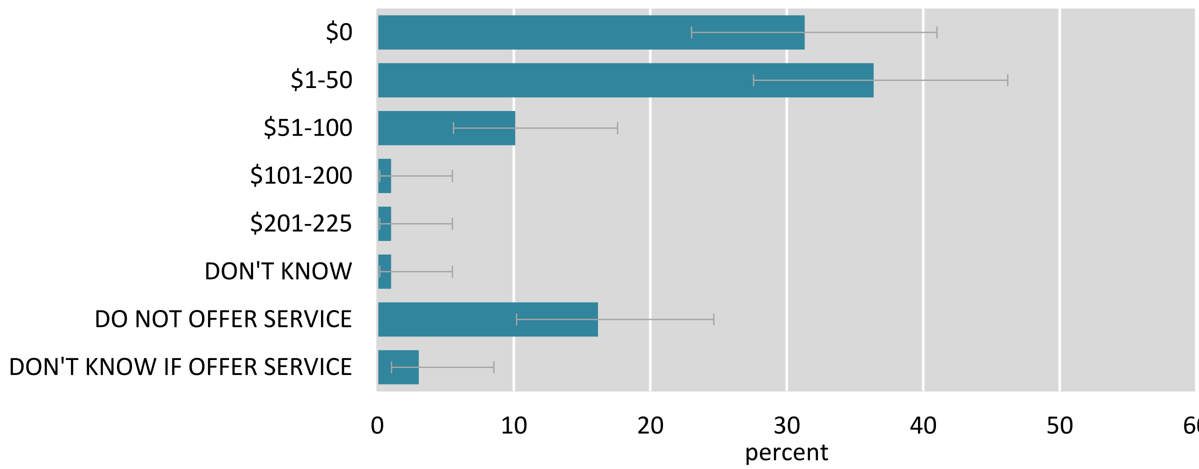


Median estimate: $17

Source: NHTSA TPMS-ORRC Repair Facilities Survey

Stationary recalibrations of direct TPMS systems, which do not require tools but do require a series of steps - such as button presses, pumping the brake pedal, and cycling the ignition - before deflating each tire to register the new sensor IDs?

[PRICED_RECAL4A/B]



Median estimate: $18

Source: NHTSA TPMS-ORRC Repair Facilities Survey

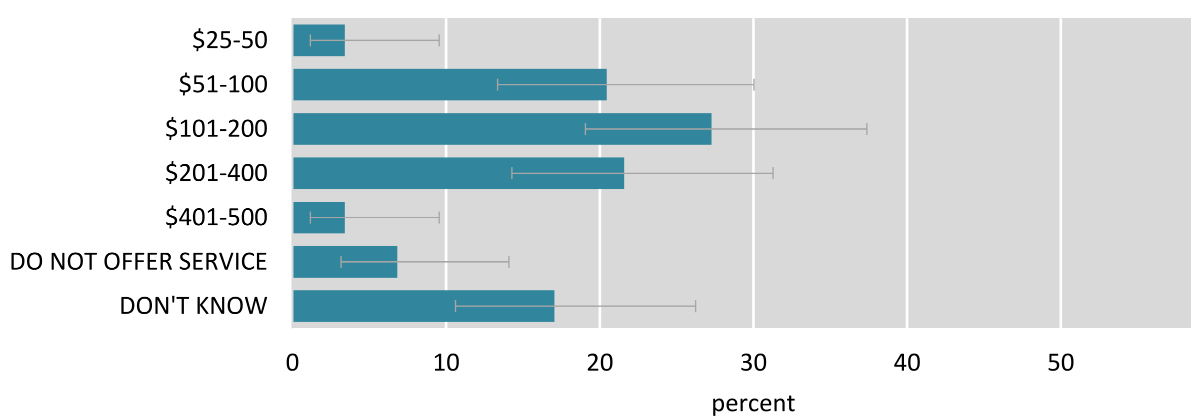
Domain for questions about indirect TPMS component pricing: Facilities that service indirect TPMS (n=89)

INTERVIEWER: In the following questions I'll ask about the average price you charge customers to repair specific components in an indirect TPMS system. Please provide your best estimate of the total price you charge for this work, including both parts and labor.

What is the average price you charge for replacing each of the following, independent of tire replacement? Your best estimate is fine.

One chassis-mounted sensor (such as a wheel speed sensor)?

[PRICEI_SENSOR]

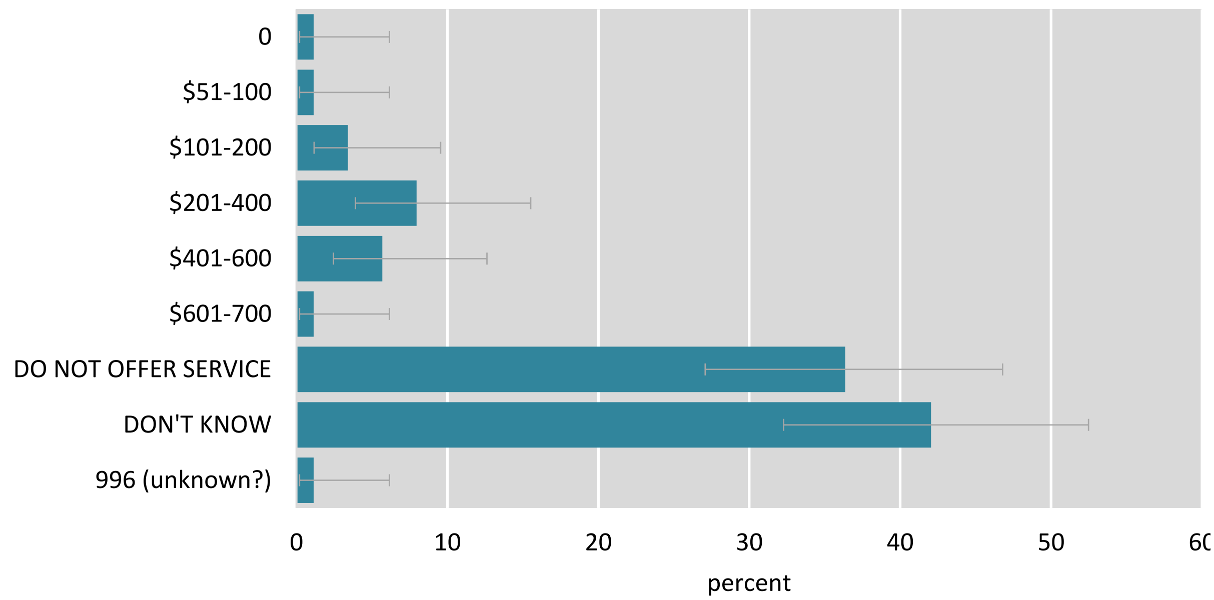


Median estimate: $145

Source: NHTSA TPMS-ORRC Repair Facilities Survey

The on-board processing unit?

[PRICEI_HWARE_A]

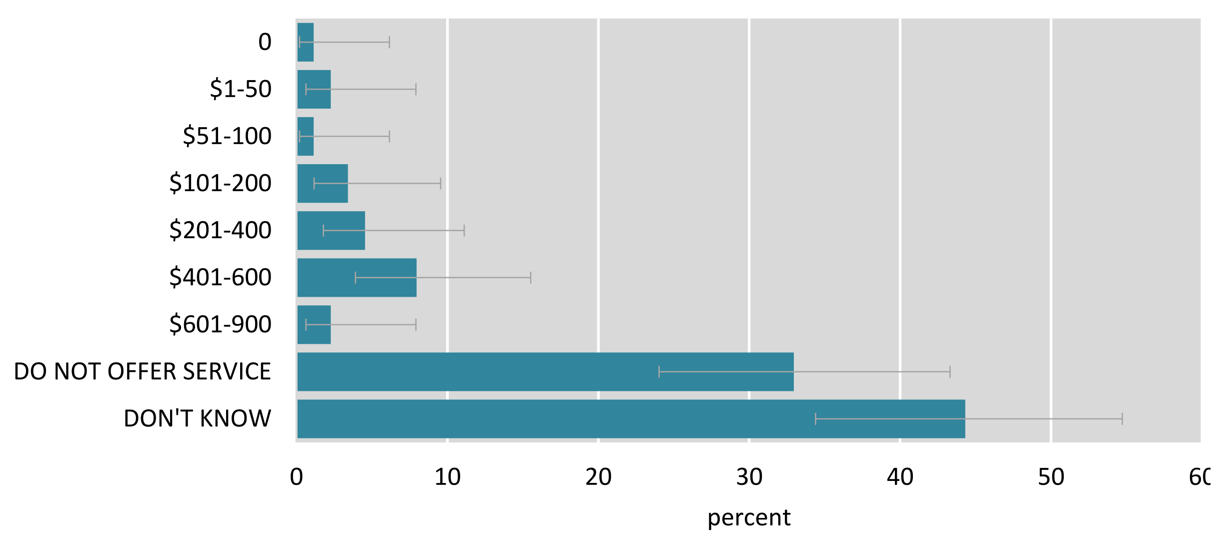


Median estimate: $280

Source: NHTSA TPMS-ORRC Repair Facilities Survey

The on-board receiver hardware?

[PRICEI_HWARE_B]

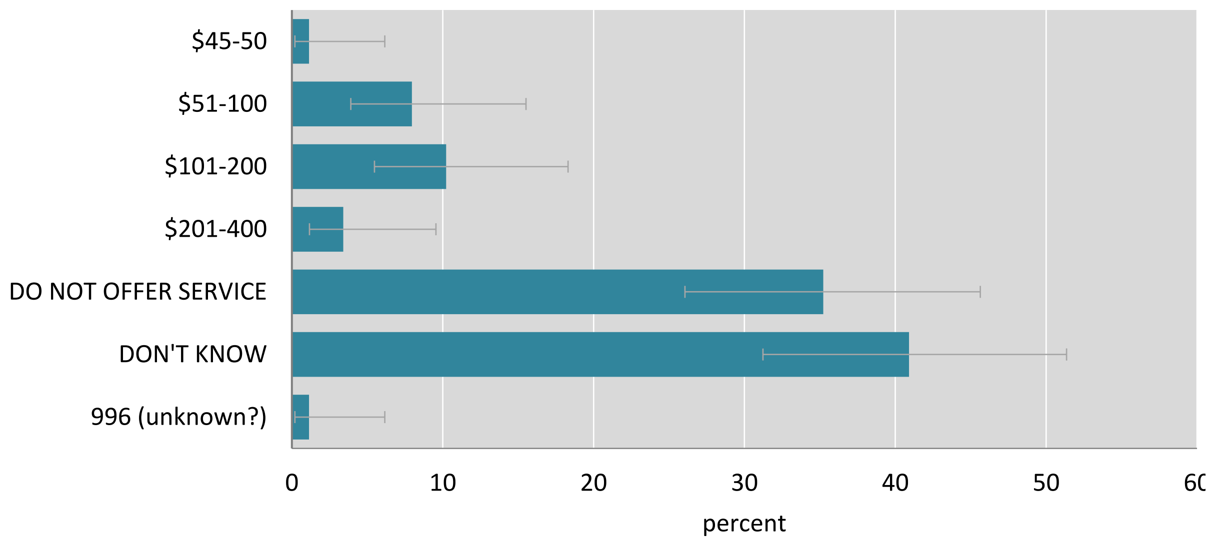


Median estimate: $250

Source: NHTSA TPMS-ORRC Repair Facilities Survey

The electrical wiring?

[PRICEI_HWARE_C]

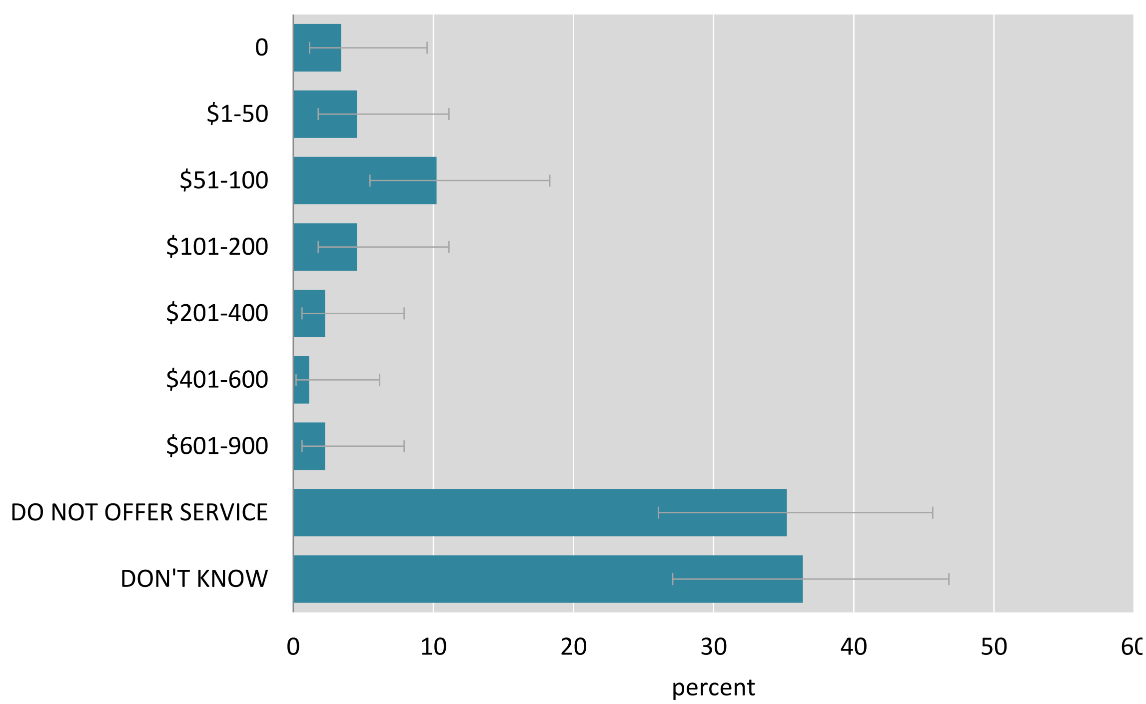


Median estimate: $125

Source: NHTSA TPMS-ORRC Repair Facilities Survey

The dash lights?

[PRICEI_HWARE_D]

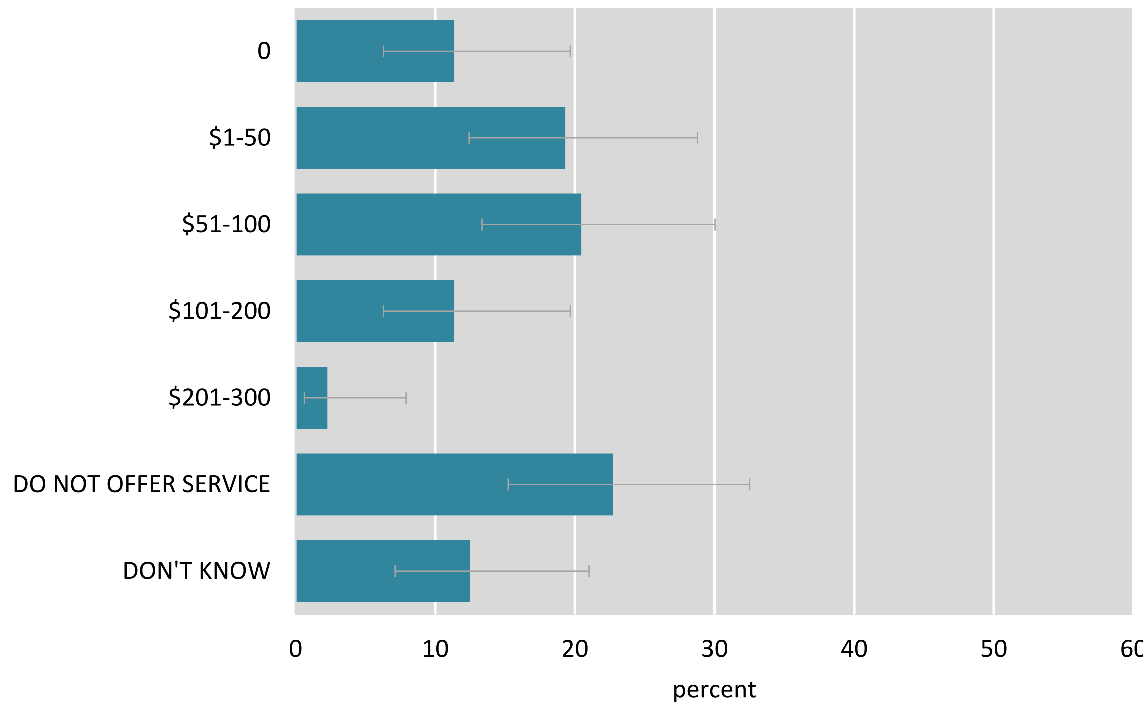


Median estimate: $83

Source: NHTSA TPMS-ORRC Repair Facilities Survey

Updating the software on an indirect system?

[PRICEI_SWARE]

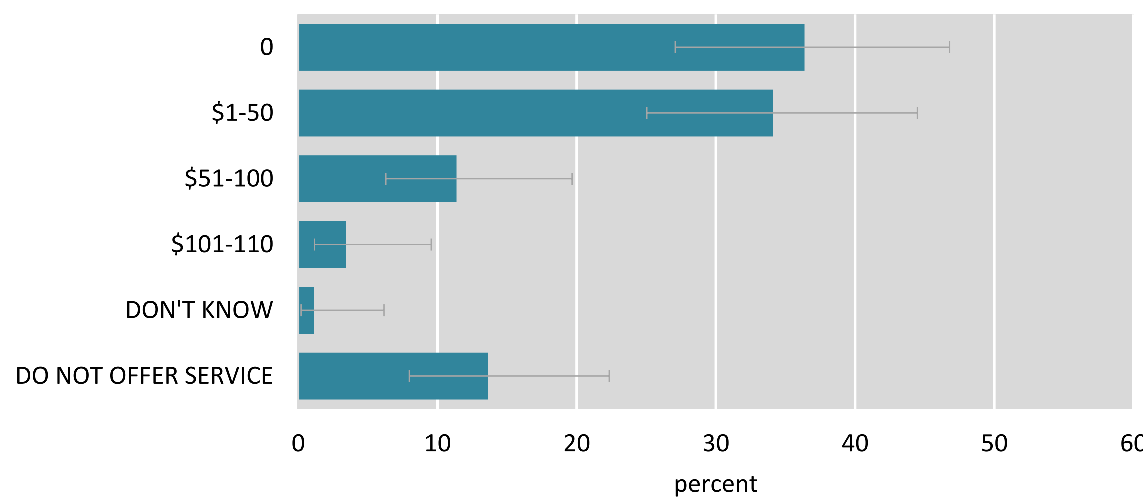


Median estimate: $57

Source: NHTSA TPMS-ORRC Repair Facilities Survey

Recalibrations of indirect TPMS systems that require pushing buttons or using the vehicle control panel to update the tire pressures, but do not require driving the vehicle?

[PRICEI_RECAL1A/B]

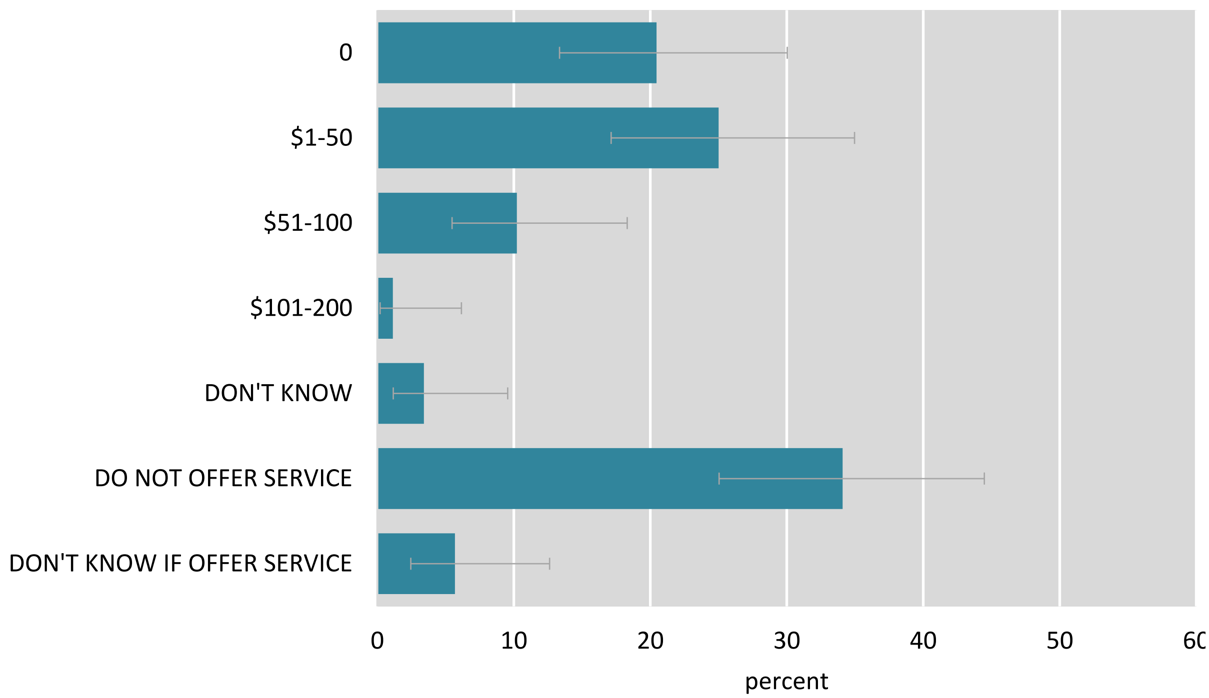


Median estimate: $17

Source: NHTSA TPMS-ORRC Repair Facilities Survey

Recalibrations of indirect TPMS systems that require the use of magnets to update the tire pressures, but do not require driving the vehicle?

[PRICEI_RECAL2A/B]

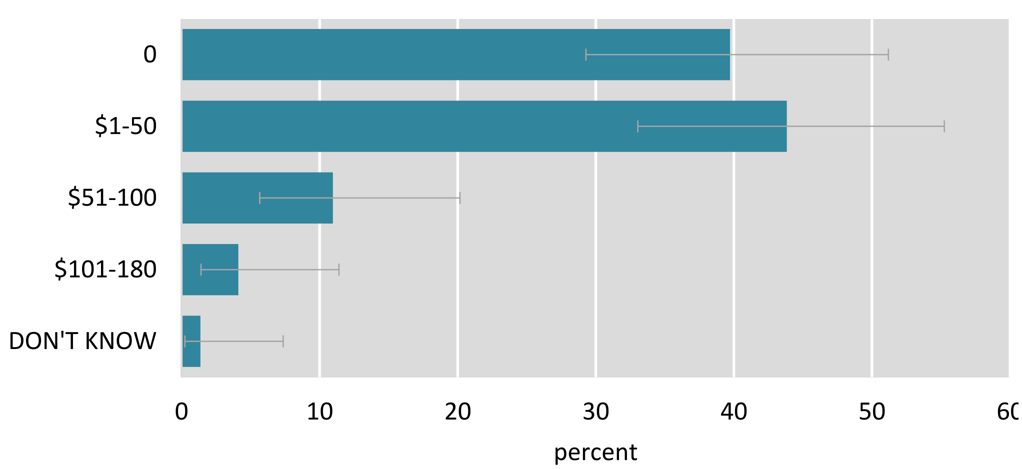


Median estimate: $18

Source: NHTSA TPMS-ORRC Repair Facilities Survey

Auto-relearn recalibrations of indirect TPMS systems, which do not require tools but do require driving the vehicle to register new sensor IDs?

[PRICEI_RECAL3A/B]



Median estimate: $18

Source: NHTSA TPMS-ORRC Repair Facilities Survey

Is there an additional charge for servicing the TPMS system on any specific makes of passenger vehicle? Please specify the makes. [PRICE_MAKE1/2]

DOMAIN: All., response was YES for 10, specified makes were:

BMW, European cars in general	1
BMW, Mercedes[-Benz]	1
GM, Chrysler	1
Mercedes[-Benz], BMW	1
VW, Hyundai, Land Rover, and some G*	1
all of them	1
European makes	1
European makes like Saab, Jags	1
Mercedes[-Benz]	1
SUVs. (larger ones)	1

*response truncated in data - unknown what rest of response was

End Repair Facilities Survey.

Appendix H. Supplier Survey

This appendix presents available results from the TPMS-ORRC Supplier Survey introduced in Section 3.3.

Respondents. The Supplier Survey universe was major passenger vehicle TPMS sensor and systems equipment suppliers. There was no sampling plan as the intent was to interview as many companies as would participate. The survey frame was developed by the survey contractor by means of industry publications, and industry organizations, advocacy groups, and boards, including Auto Alliance, Global Automakers, Tire Industry Association, and Equipment and Tool Institute.

After documenting the supplier contacts, the survey contractor attempted to contact each major system supplier directly and conduct a census of all suppliers on the frame. The initial frame included 49 suppliers[83]. After follow-up on eligibility (company involved with passenger vehicle TPMS) the frame was reduced to 36. By the final deadline, 12 suppliers returned the survey. Two of them were not involved with TPMS and one was not involved with passenger vehicles, leaving 9 eligible respondents. All respondents used the fillable pdf form.

Of the 9 eligible companies that responded, four were involved with direct TPMS only, three with indirect TPMS only, and two with both TPMS types. Thus, six companies were able to answer questions about direct TPMS and five were able to answer questions about indirect TPMS. Among the companies were at least one of each of Tier 1 suppliers[84], Tier 2 suppliers, aftermarket suppliers, and tools suppliers. Each of the following components had at least one company's involvement: direct rim-mounted sensors, direct stem-mounted sensors, direct on-board hardware (e.g., processing unit), direct software, direct electronic components, indirect chassis-mounted sensor (e.g., wheel speed sensor), indirect on-board hardware (e.g., processing unit), indirect software, diagnostic tools, and semiconductor sensor integrated circuits. Each of the following supplier roles had representation from at least one supplier: technology development, system engineering, manufacturing, and marketing/distribution.

Results. With a small set of respondents, some item non-response, and the reporting restrictions, it is only possible to report general results. The responding group was about one fourth of the population, but these results are not necessarily reflective of the full population of suppliers.

TPMS malfunctions. Suppliers were asked: in general, when TPMS malfunctions occur, how often they are associated with certain equipment (Almost Always, Often, Sometimes, Rarely, Almost Never). The ranges of the responses by TPMS type and equipment were:

<u>Direct TPMS</u>

- Tire pressure sensor battery (e.g., depleted): Often to Rarely.
- Tire pressure module (e.g., damaged, corroded): Often to Almost Never.
- On-board hardware (e.g., TPMS receiver failure): Sometimes to Almost Never.
- Software (e.g., false warning light indication): Often to Almost Never.

[83] One participating supplier was not originally included in the frame but contacted NHTSA directly and requested to participate in the study. The survey contractor and NHTSA consulted and agreed to include the additional supplier.
[84] Industry terminology referring to companies in the supply chain. The tiers indicate the commercial distance in the relationship between the manufacturer and supplier.

Other comments offered about direct malfunction factors mentioned improper relearn procedure, non-compatible sensor replaced, and sensor damaged during tire service.

<u>Indirect TPMS</u>

- Chassis sensors: Rarely to Almost Never.
- On-board hardware (e.g., false warning light indication) – Almost Always to Almost Never.
- Software (e.g., false warning light indication): Almost Always to Almost Never.

Suppliers reported that the sources of information for the preceding responses were feedback from customers (most often cited), field surveys, warranty reports, field returns involved with sensor failures, TPMS sensor module failure analysis activities, and calls on techline from vehicle service providers.

Recent design changes. Suppliers were asked about any major design changes the company has made to TPMS parts in the last five model years and the cumulative effect of the cited changes. By TPMS type, changed parts design and the cumulative effects mentioned included:

For direct TPMS,

- Rim-mounted sensor: smaller size module, increased durability, increased accuracy.
- Stem-mounted sensor:
    - Faster reporting. Better accuracy.
    - Increased pressure measure accuracy. Extended battery life. Improved reliability (fewer electronic components required to operate).
    - Less inventory investment.
- Smaller size module increased durability, increased accuracy.
- On-board hardware (e.g., processing unit): improved user interface, customized alerts, better display of information.
- Software: Increased pressure measure accuracy, improved capability to identify wheel position, operation over wider pressure range.

For indirect TPMS,

- Software: Increasing the resistance of false alarms.

Planned changes. Suppliers were also asked to briefly describe any major design changes planned to TPMS parts in the next five model years. Planned changes mentioned included:

- Improved pressure measurement accuracy.
- Extended battery life.
- Improved reliability.
- Increase software storage capacity to allow more sensor features.
- Next generation semiconductor sensor integrated circuit development.
- Direct TPMS design changes to improve the sensor to make smaller and robust.

Price information. Generally, companies did not offer information about parts pricing, presumably due to business policies or concerns. Some mentioned that software updates would not have a charge to the customer.

Appendix I. TPMS Special Study (2010/2011) Sample Makeup

Pie charts show the TPMS-SS (2010/2011) unweighted sample makeup counts.

Figure I-1 shows the sample makeup for vehicle characteristics.

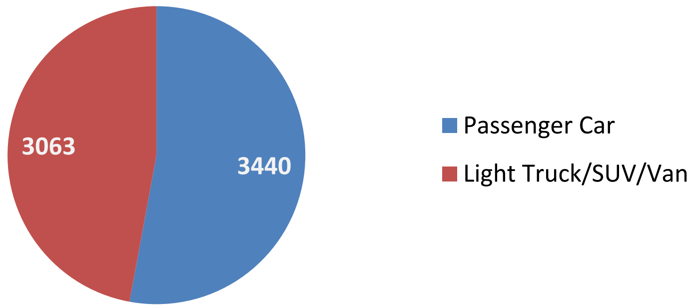
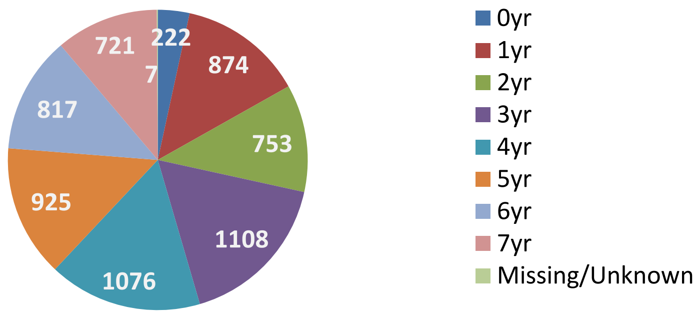
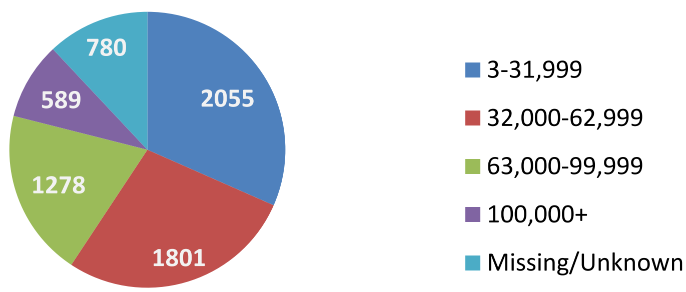
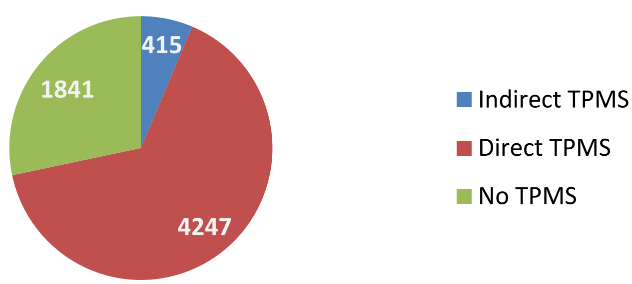
<table>
<tr><th>Characteristic</th><th>Sample Counts</th></tr>
<tr><td>Vehicle body type
As used in the original report</td><td>
</td></tr>
<tr><td>Vehicle age
In years.
The difference between 2011 and the vehicle model year:
MY 2011=0yr
MY 2010=1yr,
etc.
Vehicle model year from the VIN.</td><td>
</td></tr>
<tr><td>Vehicle mileage
Read from the odometer.</td><td>
</td></tr>
<tr><td>TPMS
Whether or not the vehicle was equipped with TPMS was assigned post data collection by model year (2008+) or dash observation variables (pre MY 2008). TPMS type assigned using NHTSA fleet info.</td><td>
</td></tr>
</table>

Figure I-1. TPMS-SS Sample Makeup, Vehicle Characteristics

Figure I-2 shows the sample makeup for driver characteristics.

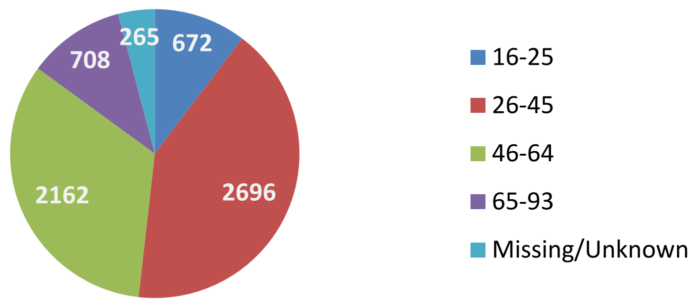
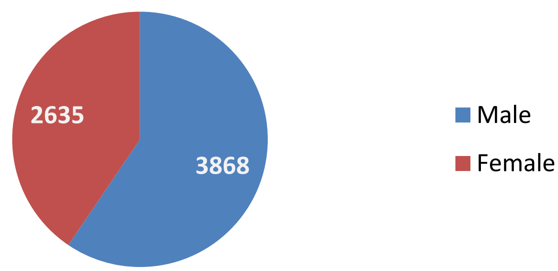
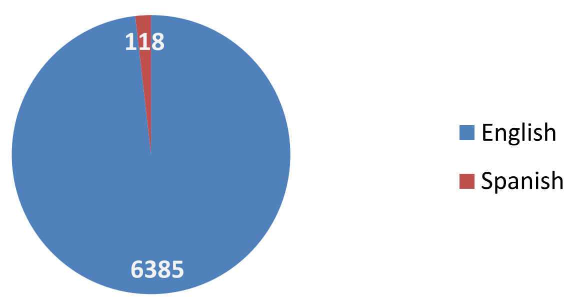
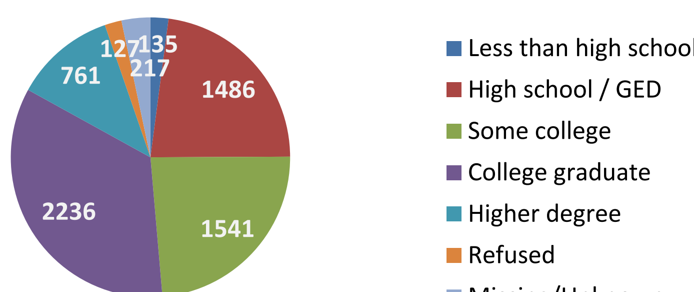
Characteristic	Sample Counts
Driver age group In years. Drivers were asked their age at the end of the interview.	
Driver sex The driver's sex as surmised by the interviewer.	
Language The language that the interview was conducted in was checked on the interview form.	
Education Drivers were asked "What is the highest grade or year of school you completed?" at the end of the interview.	

Figure I-2. TPMS-SS Sample Makeup, Driver Characteristics

Figure I-3 shows the sample makeup for weather conditions.

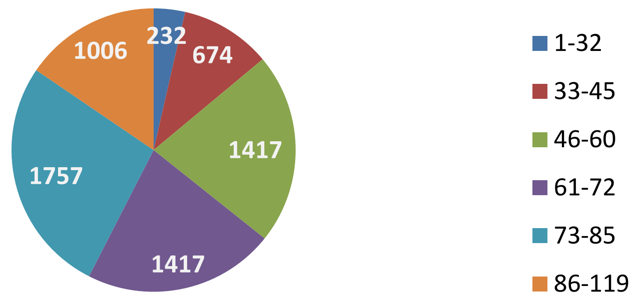
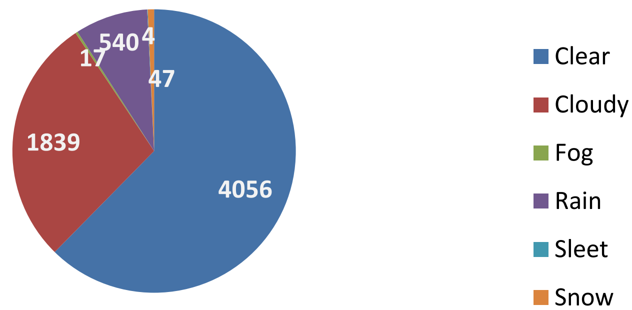
Characteristic	Sample Counts
Ambient air temperature at time of interview Degrees F. Measured at the data collection site (Data collected August 2010 - April 2011)	
Weather condition Recorded by observation at the site at the time of data collection	

Figure I-3. TPMS-SS Sample Makeup, Weather Conditions

Appendix J. TPMS Special Study (2010/2011) Response Tables

This appendix reports the percentage responses to the driver tire pressure interview in the 2010/2011 NHTSA TPMS-SS. For ease of reading, column graphs are shown with the data tables. These interview results have not been previously published.

Reading the Charts

Interviews. Data collectors alternated all respondents between the Tire Pressure interview and the Refueling interview. If time permitted, some respondents answered both interviews. After, respondents who said they had TPMS and time for more answers were given the Supplemental Interview focusing on TPMS. The Tire Pressure and the Supplemental Interview are shown here. The refueling interview did not address tire pressure or TPMS and is not covered here.

Clustered column graphs. For each question and category, the top of the column marks the point estimate for the response percentage. Error bars show 95 percent confidence intervals. Table entries below the graphs give the data point estimates and confidence intervals that generated the graphs.

Domain. The domain is the subset of respondents eligible for the question. The "*n*" specified for the domain is the number of respondents in that domain. The character string in brackets is the dataset name of the variable. The "*n*" after the variable name is the number of responses. The response "*n*" would ideally equal the domain "*n*" but may be less due to item non-response.

Other specified responses. If a question allowed for "Other, Specify" responses apart from the options given, the other specified responses are shown as recorded in the data. Sometimes, it appears that a number may have been entered that represented an available option, but they are still shown as recorded.

Missing data. Refusals are considered missing and not part of the response percentages. "Don't know" is included in the responses, since lack of knowledge may be a factor in the question.

Check one or check all that apply. Questions labeled "check all that apply" allowed the respondent to select as many of the available responses as preferred. Percentages will not necessarily add to 100 percent for those questions. Questions labeled "check on" allowed for only one response to be selected. Percentages should add to 100 percent for those questions.

Tire Pressure Interview

TPMS breakouts. Unlike the 2001 and 2018 surveys, the 2010/2011TPMS-SS data had a substantial sample of both TPMS and non-TPMS vehicles. (The 2001 fleet had TPMS only as a rare option, and the 2018 survey universe only had TPMS-equipped vehicles.) Comparing tire pressure in vehicles with and without TPMS was the motivation of the 2010/2011 survey, so for these tables interview questions are also broken out by TPMS type.

Interview flow. The Tire Pressure Interview was short with only a few skip patterns. A flow chart for the interview is shown in Figure J-1.

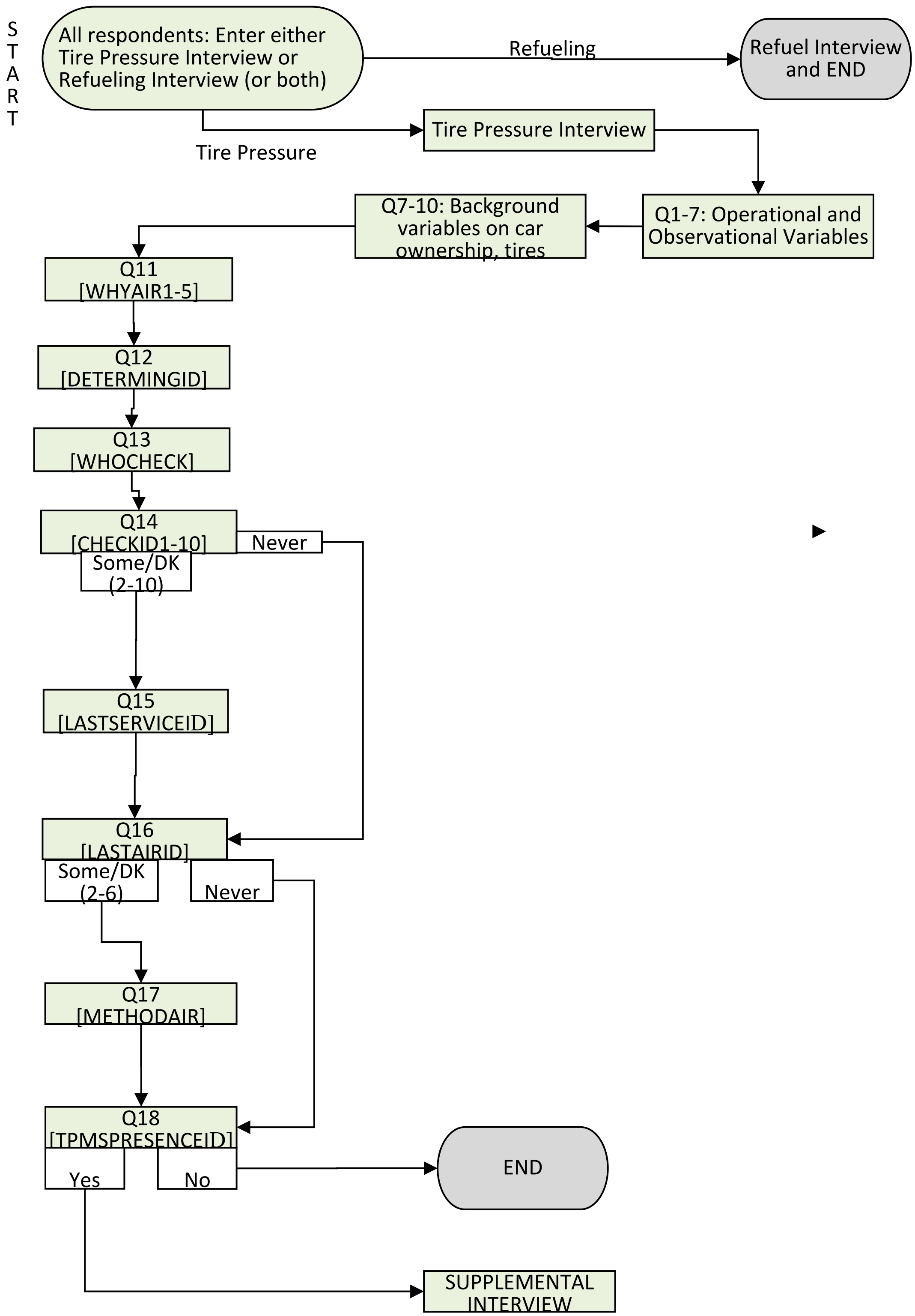
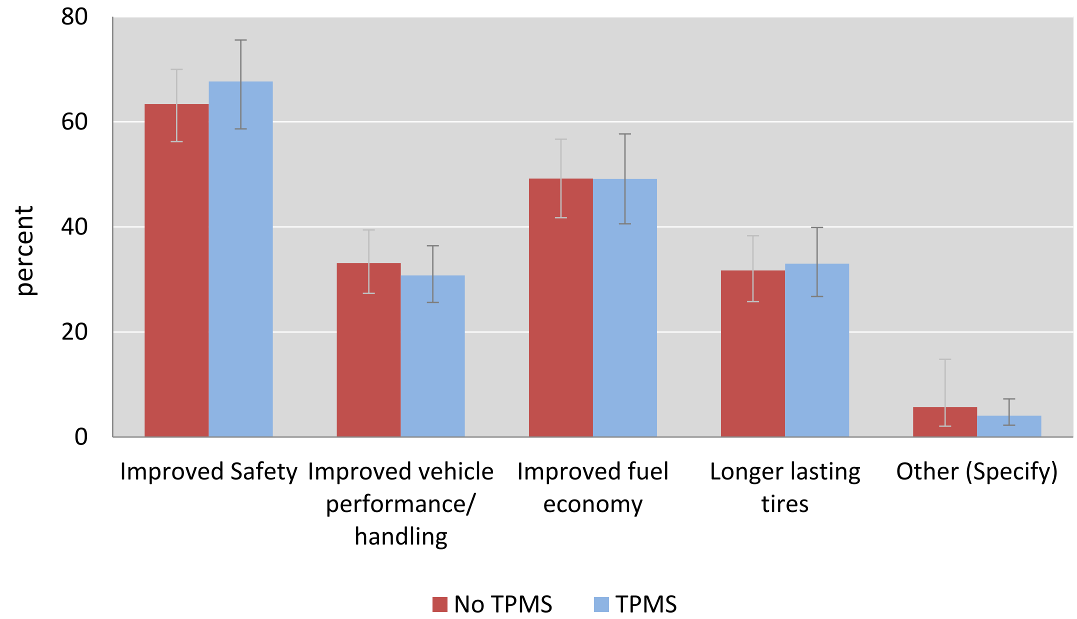


Figure J-1. Flow Chart of the 2010/2011 TPMS-SS Tire Pressure Interview

TPMS-SS Tire Pressure Interview

Q11. Drivers keep their tires at their proper pressure for different reasons. List the reasons that are important for you for keeping tires properly inflated. (Check all that apply)

DOMAIN: All in tire pressure interview (n=2,502)



[WHYAIR1] (*n*=2,452)	Percent (95% Confidence Interval)					
Response	No TPMS		TPMS		All	
Improved Safety	63.4	(56.2, 70.0)	67.7	(58.7, 75.6)	65.9	(57.8, 73.2)
Improved vehicle performance/handling	33.1	(27.3, 39.4)	30.8	(25.6, 36.4)	31.7	(26.8, 37.1)
Improved fuel economy	49.2	(41.7, 56.7)	49.1	(40.6, 57.7)	49.2	(42.0, 56.4)
Longer lasting tires	31.7	(25.8, 38.3)	33.0	(26.8, 39.9)	32.4	(26.8, 38.6)
Other (Specify)	5.7	(2.1, 14.8)	4.1	(2.2, 7.3)	4.7	(2.5, 8.8)
Source: NHTSA TPMS-SS, 2010/2011						

Other specified responses, why keep tires inflated

Why keep tires inflated, other **Drivers without TPMS**	Count
"BECAUSE I'M NOT AN IDIOT"	1
BALANCE	1
BECAUSE	1
BECAUSE DAD SAYS TO	1
BECAUSE THE TIRE SAYS TO	1
BETTER WEAR ON TIRES	1
DEPENDS ON USE	1
DO NOT CARE/KNOW	1
DO NOT CHECK	5
DOES NOT MONITOR/MAINTAIN PRESSURE	1
DOESN'T KNOW	1
DON'T CARE	1

Why keep tires inflated, other **Drivers without TPMS**	Count
DON'T CARE ONE WAY OR THE OTHER.	1
DON'T CHECK	1
DON'T KNOW	5
DON'T KNOW HUSBAND TAKES CARE OF	1
DON'T PAY ATTENTION	1
DONT CHECK THEM	1
FLAT	1
FOLLOW SERVICE DEPARTMENT RECOMMENDATION	1
HAULING	1
HUSBAND TAKES CARE OF IT	1
HYDRO-PLANE PREVENTION	1

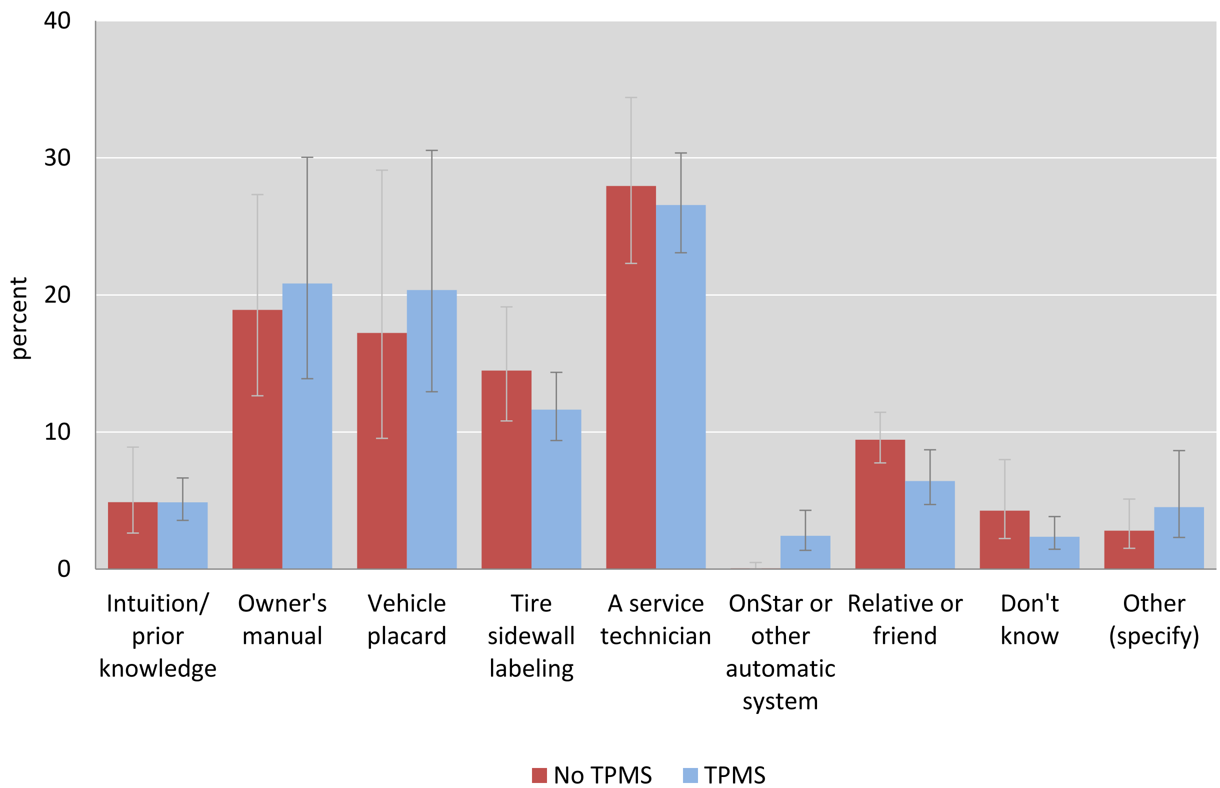
Why keep tires inflated, other **Drivers without TPMS**	Count
I DONT KNOW	1
LOAD CAPACITY	1
NO BLOWOUTS	1
NO FLATS	1
NONE	3
PAYS NO ATTENTION	1
PULL A TRAILER	1
REFUSED	1
RENTED CAR	1
REPLIED-MAINTENANCE ALWAYS KEEPS PROPER CHECK & LEVEL	1
SIDEWALLS	1
SO THEY WON'T EXPLODE, BRAKE PROPERLY	1
TO AVOID FLATS	1
TRAILERING	1
UNKNOWN	2
WEATHER	2

Why keep tires inflated, other **Drivers with TPMS**	Count
"I DO WHAT MY HUSBAND SAYS"	1
AVOIDING FLATS	1
BECAUSE IT'S A FLEET VEHICLE	1
BECAUSE MANUFACTURER SAID SO	1
BECAUSE THE MONITOR TELLS ME TO	1
BROTHER ADVISED TO KEEP UNDERINFLATED	1
COMPANY CHECKS IT MONTHLY	1
COMPANY POLICY	1
COMPANY REQUIREMENT	1
DO NOT CHECK	1
DO WHAT "THEY" SAY	1
DOES NOT MAINTAIN PRESSURE AT ALL; CO-OWNER'S RESPONSIBILITY/CONCERN	1
DOESNT THINK ABOUT IT	1
DON'T CHECK	1
DON'T KNOW	4
DON'T KNOW OF ANY	1

Why keep tires inflated, other **Drivers with TPMS**	Count
DON'T THINK ABOUT IT	1
DONT KNOW	1
FATHER DOES IT	1
FOR TOWING SAFER	1
HAULING HEAVY ITEMS	1
HE DOESN'T CARE	1
I DON'T MAINTAIN THEM. CO DOES	1
ITS WHAT YOUR SUPPOSE TO DO	1
KEEP LIGHT OFF	1
KEEP THE LIGHT OFF, THE DEALERSHIP HAS TO RESET IT.	1
LIGHT WILL COME ON	1
MAINTAINANCE	1
MAKES THE TPMS HAPPY	1
N/A; RENTAL	1
NO	1
NO TPMS	1
NONE	2
PASSIVE	1
PRECIOUS CARGO (GRANDKIDS)	1
PROPER MAINTENANCE	1
SERVICES	1
SO LIGHT DOESNT COME ON	1
SO THE TPMS WONT BEEP	1
TO KEEP THE LIGHT FROM COMING ON	1
TO KEEP THE MONITOR HAPPY	1
TO KEEP THE TMPS LIGHT OFF	1
TO KEEP THE TPMS FROM GOING ON	1
TOWING	1
TOWING TRAILER HORSES	1
TPMS	2
TPMS LIGHT	1
TRACTION	1
TRAILERING	1
UNK	1
UNKNOWN	2
WARRANTY	2
WHEN DAD SAYS TO	1
WHEN THEY TELL ME TO	1
YOU'RE SUPPOSED TO	1

Q12. Where would you, or do you, primarily turn for information on what pressure to set your tires for this vehicle? (Check one)

DOMAIN: All (n=2,502)



[DETERMINGID] (*n=2,488*) Percent (95% Confidence Interval)

Response	No TPMS		TPMS		All	
Intuition/prior knowledge	4.9	(2.6, 8.9)	4.9	(3.6, 6.6)	4.9	(3.3, 7.2)
Owner's manual	18.9	(12.6, 27.3)	20.8	(13.9, 30.0)	20.0	(13.8, 28.2)
Vehicle placard	17.2	(9.5, 29.1)	20.4	(12.9, 30.5)	19.1	(11.7, 29.5)
Tire sidewall labeling	14.5	(10.8, 19.1)	11.6	(9.4, 14.4)	12.8	(10.6, 15.4)
A service technician	28.0	(22.3, 34.4)	26.6	(23.1, 30.4)	27.1	(23.9, 30.7)
OnStar or other automatic system	0.1	(0.0, 0.5)	2.4	(1.4, 4.3)	1.4	(0.8, 2.5)
Relative or friend	9.4	(7.7, 11.4)	6.4	(4.7, 8.7)	7.7	(6.0, 9.8)
Don't know	4.3	(2.2, 8.0)	2.4	(1.4, 3.8)	3.1	(2.2, 4.4)
Other (specify)	2.8	(1.5, 5.1)	4.5	(2.3, 8.6)	3.8	(2.1, 6.7)

Source: NHTSA TPMS-SS, 2010/2011

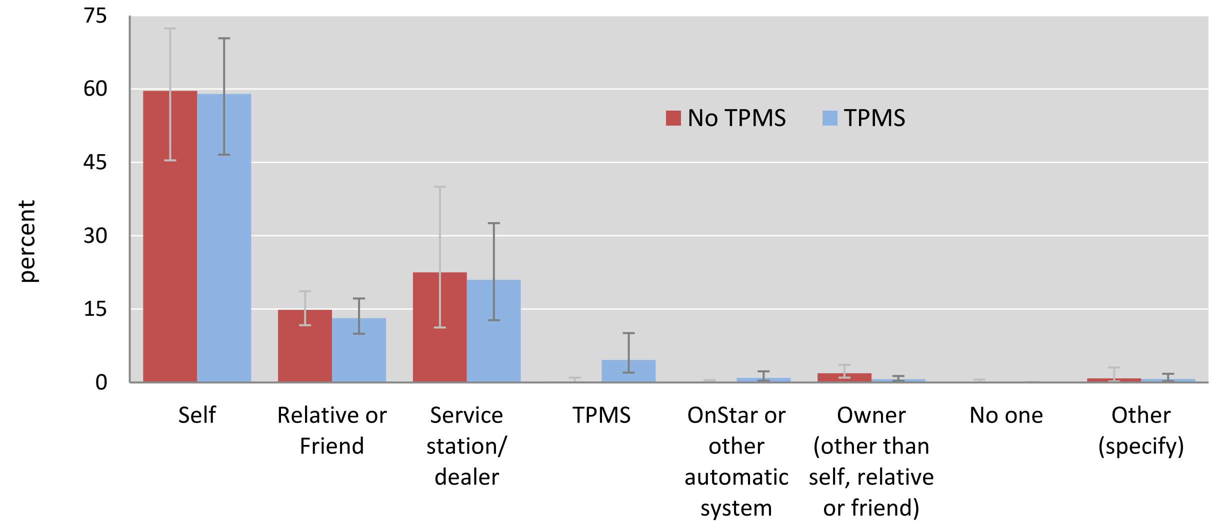
Other specified responses, where turn to find recommended pressure

Where get information on what pressure to set tires, other **Drivers without TPMS**	Count
AIR COMPRESSOR	1
APPROXIMATE IT	1
COMPANY MAINTENANCE	1
DEALER	4
FIRESTONE EMPLOYEE	1
GOOGLE	1
HARRISBURG	1
HE IS A PROFESSIONAL	1
HUSBAND	2
INTERNET	6
INTERNET OR OWNERS MANUAL	2
NONE	1
ON LINE INTERNET	1
PUTS 40LBS IN EVERY TIME	1
RENTED CAR	1
SPOUSE	2
TIRE DEALER	1

Where get information on what pressure to set tires, other **Drivers with TPMS**	Count
ACCUPRESSURE TOOL	1
CAR COMPUTER	1
CAR MAGAZINES	1
CAR ONSTAR EMAIL 1/MONTH	1
COMMON KNOWLEDGE	1
COMPANY MECHANIC	1
DEALER	5
DEALER LOANER VEHICLE	1
DID NOT KNOW- RELIED ON GUAGE ALERT	1
FATHER	1
HAVEN'T CHECKED THEM. NEW CAR	1
HUSBAND	2
I WOULD GOOGLE IT.	1
INSTRUMENT PANEL	1
INTERNET	6
LEARNED GROWING UP WORKING WITH CARS	1
MANUFACTURER'S WEBSITE	1
MICHELIN WEB SITE	1
MONITOR TELLS ME WHAT IT SHOULD BE	1
N/A	1
NONE	1
ON DASH	1
ONLINE	3
SCION BLOGS	1
TIRE MANUAL	1
TIRE STORE	1
TPMS	10
TPMS - AIR IT UP UNTIL THE LIGHT GOES OFF	1
TPMS LIGHT	1
VEHICLE INSTRUMENT PANEL	1
VEHICLE TELLS HER	1

Q13. Whose responsibility is it to check the tire pressure? (Check one)

DOMAIN: All (n=2,502)



[WHOCHECK] *n*=2494	Percent (95% Confidence Interval)					
Response	No TPMS		TPMS		All	
Self	59.6	(45.4, 72.4)	59.0	(46.6, 70.4)	59.2	(46.2, 71.0)
Relative or Friend	14.8	(11.7, 18.6)	13.2	(10.0, 17.2)	13.9	(11.4, 16.8)
Service station/dealer	22.5	(11.2, 40.0)	21.0	(12.7, 32.6)	21.7	(12.4, 35.1)
TPMS	0.1	(0.0, 1.0)	4.6	(2.0, 10.1)	2.7	(1.2, 6.0)
OnStar or other automatic system	0.1	(0.0, 0.5)	0.9	(0.4, 2.3)	0.6	(0.2, 1.3)
Owner (other than self, relative or friend)	1.9	(1.0, 3.6)	0.7	(0.3, 1.3)	1.2	(0.6, 2.1)
No one	0.1	(0.0, 0.6)	0		0.0	(0.0, 0.2)
Other (specify)	0.8	(0.2, 3.1)	0.7	(0.3, 1.8)	0.8	(0.3, 1.7)
Source: NHTSA TPMS-SS, 2010/2011						

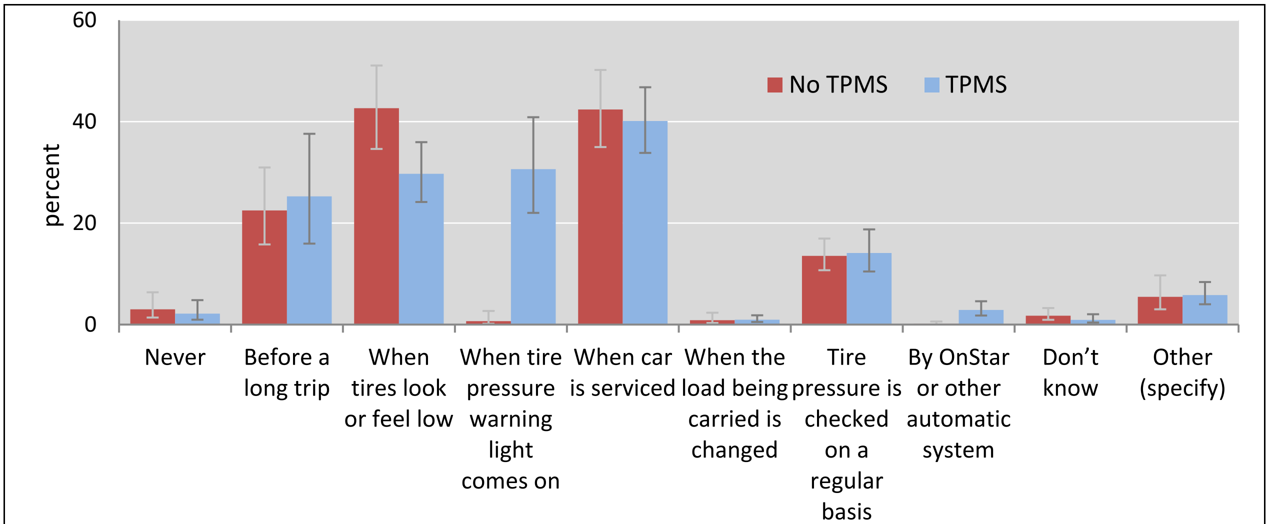
Other specified responses, check tire pressure

Whose responsibility is it to check the tire pressure? Other **Drivers without TPMS**	Count
DONT KNOW YET	1
DRIVER	1
MECHANIC	1
OIL CHANGE SERVICE	1
SELF AND OWNER EQUALLY	1
SERVICE TECHNICIAN	1
UNKNOWN	1
WHOMEVER IS DRIVING FOR THE COMPANY	1

Whose responsibility is it to check the tire pressure? Other **Drivers with TPMS**	Count
COMPANY MAINTENANCE PERSON	1
COMPANYS TRUCK SHOP	1
DRIVER	1
HUSBAND	1
IN HOUSE/COMPANY	1
JIFFY LUBE	1
OIL CHANGE	1
OIL CHANGE SERVICE TECH.	1
SERVICE TECHNICIAN	1
SPOUSE	1
THIS IS A LOANER VEHICLE	1
WEEKLY	1
WHOEVER DRIVES IT	1

Q14. Under what circumstances do you have the tire pressure on this vehicle checked, either by yourself or someone else? (Check all that apply)

DOMAIN: All in tire interview (n=2,502)



[CHECKID1-10] (*n*=2,478)	Percent (95% Confidence Interval)					
Response	No TPMS		TPMS		All	
Never	3.0	(1.4, 6.4)	2.2	(1.0, 4.8)	2.5	(1.3, 4.9)
Before a long trip	22.5	(15.8, 31.0)	25.3	(16.0, 37.6)	24.1	(16.0, 34.6)
When tires look or feel low	42.6	(34.6, 51.1)	29.7	(24.2, 36.0)	35.0	(28.6, 42.1)
When tire pressure warning light comes on	0.7	(0.2, 2.7)	30.6	(22.0, 40.9)	18.2	(13.2, 24.6)
When car is serviced	42.4	(35.0, 50.2)	40.1	(33.8, 46.8)	41.0	(34.8, 47.5)
When the load being carried is changed	0.9	(0.3, 2.3)	1.0	(0.5, 1.8)	0.9	(0.5, 1.7)
Tire pressure is checked on a regular basis	13.5	(10.7, 17.0)	14.1	(10.5, 18.8)	13.9	(10.8, 17.6)
By OnStar or other automatic system	0.1	(0.0, 0.6)	2.9	(1.8, 4.6)	1.7	(1.1, 2.7)
Don't know	1.8	(0.9, 3.3)	0.9	(0.4, 2.0)	1.3	(0.7, 2.4)
Other (specify)	5.5	(3.0, 9.7)	5.8	(4.0, 8.4)	5.8	(4.0, 8.2)
Source: NHTSA TPMS-SS, 2010/2011						

Other specified responses, when check pressure

Under what circumstances do you have the tire pressure on this vehicle checked, either by yourself or someone else? Other **Drivers without TPMS**	Count
1 WEEK	1
1 X WEEK	1
1/MONTH	1
AFTER DRIVING THE CITY ROADS	1
AFTER IT GETS COLD	1
AT CHANGE OF SEASONS	1
BEFORE WINTER OR COLD WEATHER	1
BI MONTHLY	1
BI WEEKLY	1

Under what circumstances do you have the tire pressure on this vehicle checked, either by yourself or someone else? Other **Drivers without TPMS**	Count
BOUNCY FEELING	1
CHANGE OF SEASON; TO WINTER	1
CHANGE OF SEASONS	1
CHANGE OF WEATHER	1
CHECKS 1-2 TIMES A MONTH	1
CO SAFETY CK EACH DAY	1
COLD WEATHER	1
COMPANY TAKES CARE OF MAINTAINANCE	1
EVERY 2 WEEKS	1

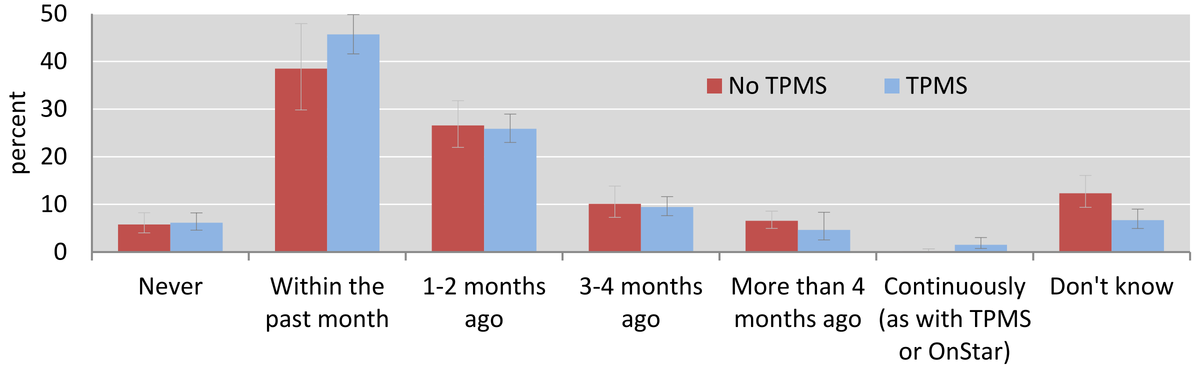
Under what circumstances do you have the tire pressure on this vehicle checked, either by yourself or someone else? Other **Drivers without TPMS**	Count
EVERY DAY	1
EVERY FEW MONTHS	1
EVERY MONTH	1
EVERY ONCE IN A WHILE	1
EVERY OTHER WEEK	1
EVERYDAY	1
LUGS	1
MILEAGE GETTING BAD	1
MONTHLY	1
MY SON	1
OIL CHANGE	1
ONCE /MONTH	1
ONCE A MONTH	4
POOR GAS MILEAGE	1
PULLS	1
REGULAR MAINTENANCE	1
REGULARLY	1
REGULARLY-WORK TRUCK	1
RENTAL COMPANY	1
ROUTINE	1
ROUTINELY	1
ROUTINELY EVERY OTHER MONTH	1
SERVICE	1
STEERING ALIGNMENT FEELS OFF	1
TEMPERATURE	1
WEATHER	2
WHEN I GET GAS	1
WHEN NO TRACTION	1
WHEN RIDE FEELS FUNNY	1
WHEN THE WEATHER CHANGES	1
WHEN TIRES ARE ROTATED	1
WHEN TOWING	1
WHEN TOWING	1

Under what circumstances do you have the tire pressure on this vehicle checked, either by yourself or someone else? Other **Drivers with TPMS**	Count
(TAXI) SERVICED EVERY WEEK	1
11 MONTHS OR SO	1
1X MONTH	1
3 MONTHS	1
AFTER A LONG TRIP, ON A COLD DAY	1
ALL THE TIME	2
ALL THE TIME- REGULARLY	1
BEFORE OFFROADING	1
BEFORE POLICE PATROL SHIFT	1

Under what circumstances do you have the tire pressure on this vehicle checked, either by yourself or someone else? Other **Drivers with TPMS**	Count
BI MONTHLY	2
CHANGE IN TEMP.	1
CHANGE IN WEATHER/SEASONAL	1
CHANGE OF SEASON	2
COMPANY GUIDELINES	1
DEALER	1
EMAIL FROM ONSTAR MONTHLY	1
EVERY 3 MONTHS	1
EVERY MONTH	1
EVERY SEASON	1
IF GAS MILEAGE CHANGES	1
IN BETWEEN OIL CHANGES BY HUSBAND	1
LIGHT FOR GAUGED COMES ON	1
MONTHLY	1
NITROGEN COMPANY SENDS A POSTCARD	1
NO ANSWER	1
NO RESPONSE GIVEN	1
OIL CHANGES	2
ON STAR	1
ONCE A MONTH	1
ONCE A WEEK	2
ONCE PER MONTH	1
PERIODICALLY	1
RANDOMLY	1
RECENT STEM PROBLEM	1
REGULARLY	1
ROUTINE	2
ROUTINE SERVICING	1
ROUTINELY	1
SEASONAL CHANGE	2
SEASONALLY	1
SYSTEM HAS AUDIBLE ALERT	1
TEMP. CHANGE	1
TPMS	12
TRAILERING	1
WEATHER	4
WEATHER CHANGE	4
WEATHER RELATED	1
WEEKLY	1
WHEN CAR HANDLES DIFFERENTLY	1
WHEN STEERING IS OFF	1
WHEN TEMPERATURE CHANGES	2
WHEN TIRES ARE ROTATED	1
WINTER	2
WORK ORDER	1

Q15. When was the last time you or someone else checked the tire pressure on this vehicle?

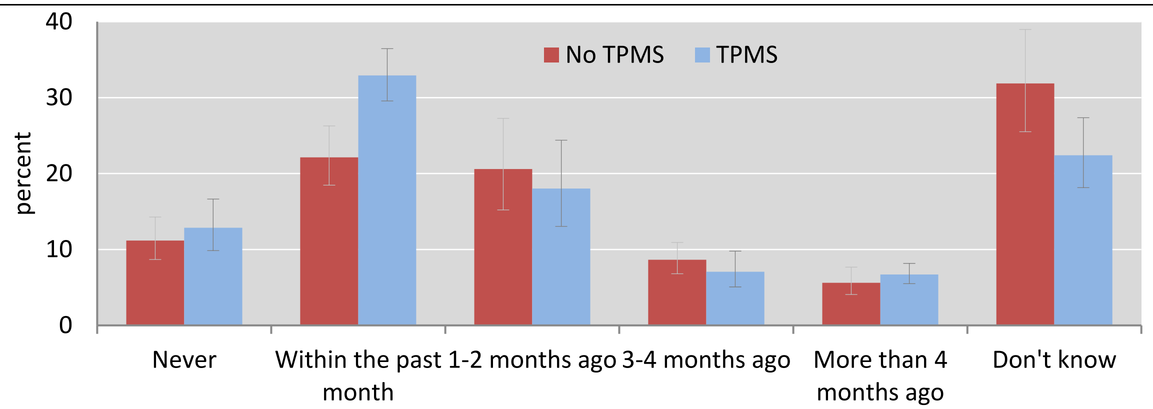
DOMAIN: Respondent or someone else checks pressure (n=2,419)



[LASTSERVICEID] (*n*=2,393)	Percent (95% Confidence Interval)					
Response	No TPMS		TPMS		All	
Never	5.8	(4.0, 8.3)	6.2	(4.6, 8.2)	6.0	(4.7, 7.7)
Within the past month	38.5	(29.8, 47.9)	45.7	(41.6, 49.8)	42.6	(37.2, 48.3)
1-2 months ago	26.6	(22.0, 31.8)	25.9	(23.0, 28.9)	26.2	(23.0, 29.6)
3-4 months ago	10.1	(7.3, 13.8)	9.4	(7.6, 11.6)	9.7	(7.8, 12.1)
More than 4 months ago	6.6	(5.0, 8.6)	4.7	(2.5, 8.3)	5.5	(3.7, 7.9)
Continuously (as with TPMS or OnStar)	0.1	(0.0, 0.7)	1.5	(0.8, 3.0)	1.0	(0.5, 1.9)
Don't know	12.3	(9.4, 16.1)	6.7	(5.0, 9.0)	9.0	(7.6, 10.7)
Source: NHTSA TPMS-SS, 2010/2011						

Q16. When was the last time you or someone else put air in the tires on this vehicle?

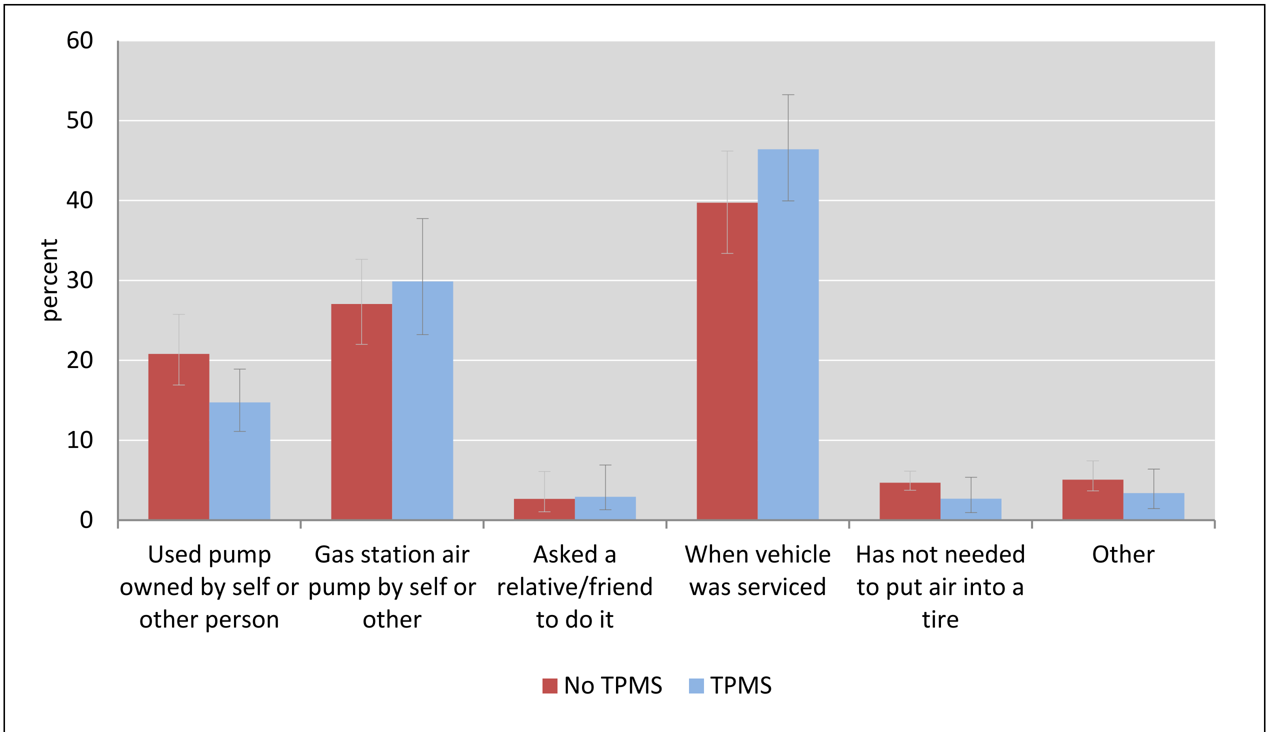
DOMAIN: All respondents in tire pressure interview (n=2502)



[LASTAIRID] (*n*=2,439)	Percent (95% Confidence Interval)					
Response	No TPMS		TPMS		All	
Never	11.2	(8.7, 14.3)	12.9	(9.9, 16.6)	12.2	(9.8, 14.9)
Within the past month	22.1	(18.5, 26.3)	32.9	(29.6, 36.5)	28.4	(26.0, 30.9)
1-2 months ago	20.6	(15.2, 27.3)	18.0	(13.0, 24.4)	19.1	(14.3, 25.0)
3-4 months ago	8.6	(6.8, 10.9)	7.1	(5.1, 9.8)	7.7	(6.2, 9.5)
More than 4 months ago	5.6	(4.1, 7.7)	6.7	(5.5, 8.2)	6.3	(5.1, 7.7)
Don't know	31.9	(25.5, 39.0)	22.4	(18.1, 27.4)	26.4	(22.1, 31.2)
Source: NHTSA TPMS-SS, 2010/2011						

Q17. The last time you or someone else put air in the tires on this vehicle – how did you do it?

DOMAIN: has put air in or had someone put air in (n=2,163)



[METHODAIR] *n*=1,970	Percent (95% Confidence Interval)					
Response	No TPMS		TPMS		All	
Used pump owned by self or other person	20.8	(17.2, 25.0)	14.7	(10.9, 19.7)	17.2	(13.4, 21.8)
Gas station air pump by self or other	27.1	(20.4, 34.9)	29.9	(24.8, 35.5)	28.7	(23.5, 34.7)
Asked a relative/friend to do it	2.7	(1.0, 6.6)	2.9	(1.3, 6.4)	2.8	(1.3, 6.2)
When vehicle was serviced	39.7	(33.3, 46.6)	46.4	(40.1, 52.9)	43.7	(38.0, 49.5)
Has not needed to put air into a tire	4.7	(3.0, 7.4)	2.7	(1.7, 4.1)	3.5	(2.3, 5.2)
Other**	5.1	(3.1, 8.1)	3.4	(2.0, 5.7)	4.1	(2.5, 6.5)
Source: NHTSA TPMS-SS, 2010/2011						

°There was not a category for “Don’t Know” on the data collection form for this question. This may be why the responding n is unusually smaller than the domain n. “Don’t know” probably was entered as .N (=no response), which is treated as missing.

**There was no “specify” option for “Other” in this question.

Q18. Screener for supplemental interview.

<u>End Tire Pressure Interview.</u>

<u>Supplemental Interview</u>

The supplemental interview was entered by drivers completing the tire pressure interview OR refueling interview who said they had a TPMS on their vehicle and were willing to answer more questions.

Interview flow. Figure J-2 shows a flow chart for the supplemental interview.

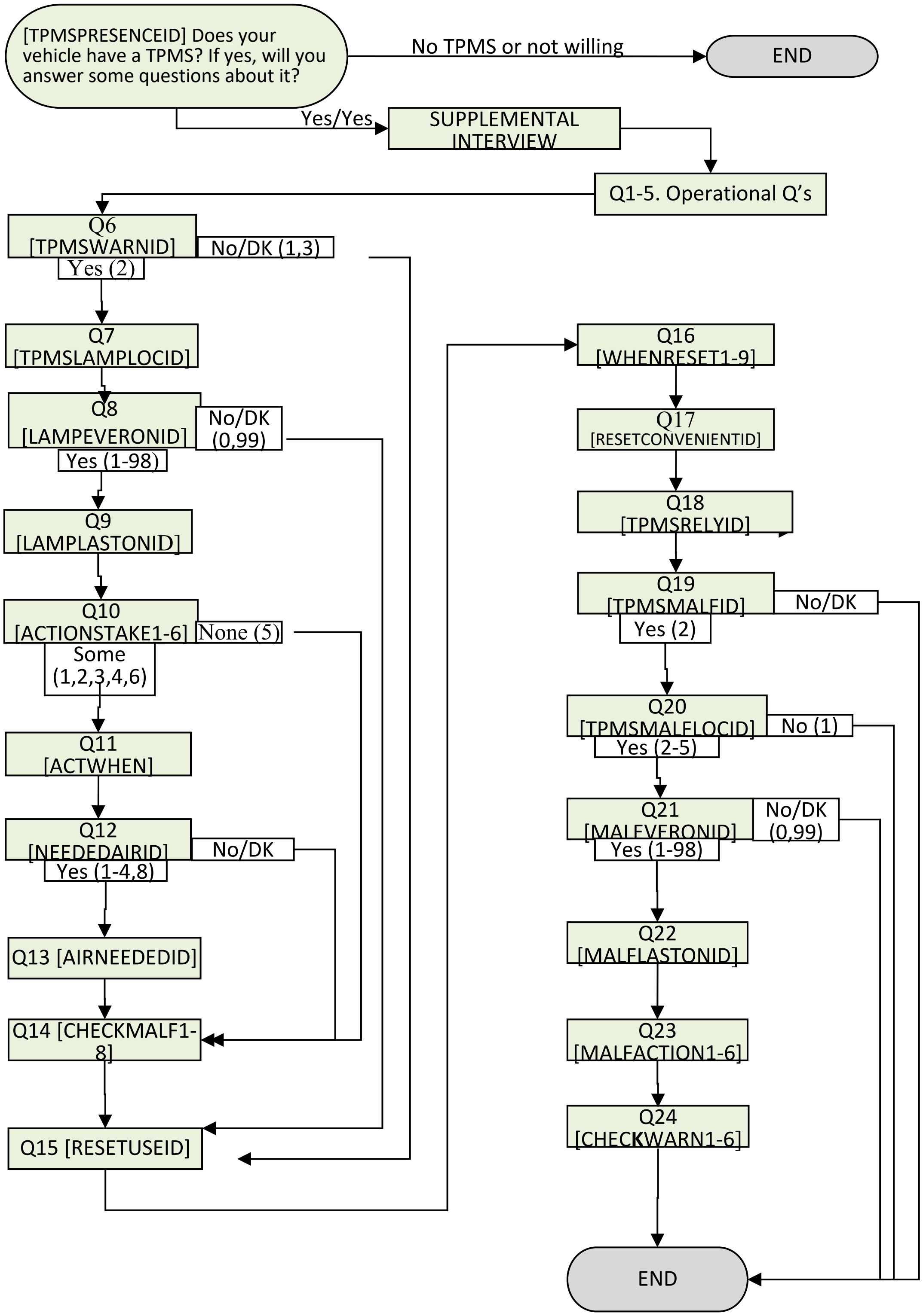
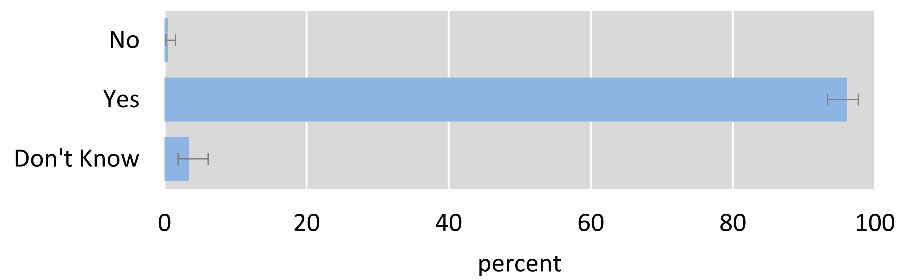


Figure J-2. Flow Chart of the TPMS-SS Supplemental Interview

Supplemental Interview

Q6. Does your TPMS have either a warning lamp or a combined warning/malfunction lamp? TPMS systems can have:
1) A warning lamp used to indicate low tire pressure.
2) A malfunction lamp used to indicate the TPMS is not working properly.
3) A combined warning/malfunction lamp used to indicate low tire pressure and/or TPMS is not working properly.

DOMAIN: All (n=1,400)



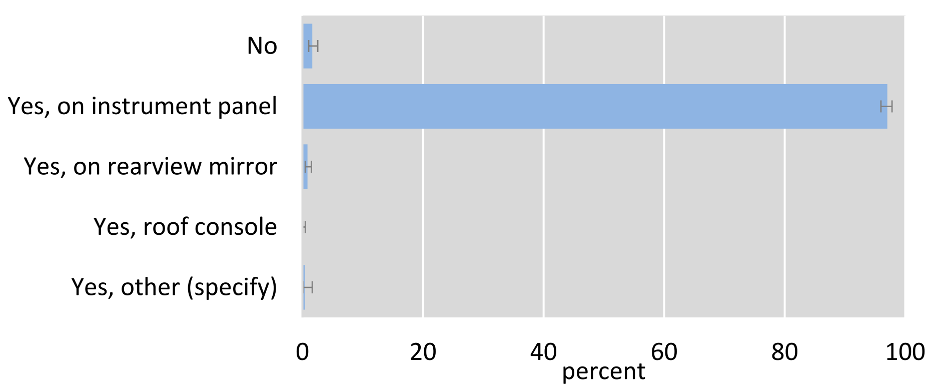
	pct	95% C.I.
No	0.5	(0.2, 1.6)
Yes	96.0	(93.3, 97.7)
Don't Know	3.4	(1.9, 6.1)

[TPMSWARNID]
n=1,400

Source: NHTSA TPMS-SS, 2010/2011

Q7. Do you know where your TPMS warning/combined lamp is located? If so, where?

DOMAIN: Said vehicle has TPMS warning or combined warning/malfunction lamp (n=1,336)



	pct	95% C.I.
No	1.6	(1.0, 2.5)
Yes, on instrument panel	97.0	(96.0, 97.8)
Yes, on rearview mirror	0.8	(0.5, 1.5)
Yes, roof console	0.1	(0.0, 0.5)
Yes, other (specify)	0.4	(0.1, 1.6)

[TPMSLAMPLOCID]
n=1,333

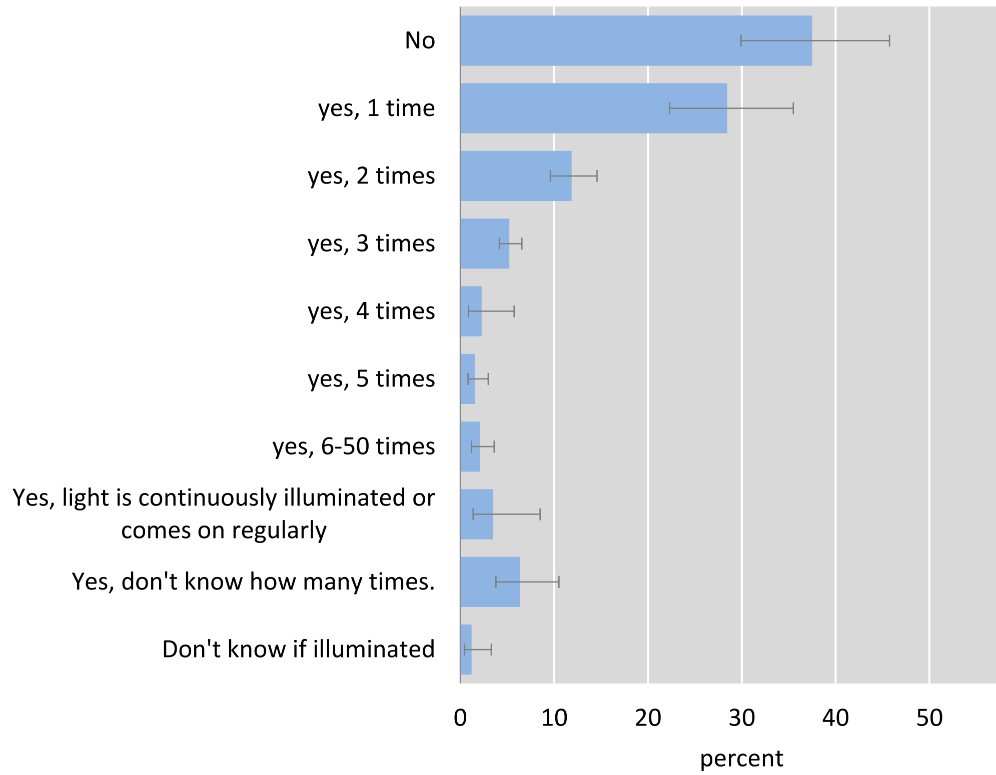
Source: NHTSA TPMS-SS, 2010/2011

Other specified responses, TPMS lamp location

Response	Count	Response	Count	Response	Count
CENTER CONSOLE	2	MENU OR NAVIGATION SCREEN	1	ON THE GPS SYSTEM	1
GEAR LEVER	1	MESSAGE CENTER	1	WITH RADIO	1
IN CENTER CONSOLE	1	NAVIGATION SYSTEM	1	WITH RADIO, ETC.	1
IN NAVIGAITON SYSTEM	1	ON RADIO DISPAY	1		

Q8. Has your TPMS warning (combined) lamp ever illuminated except during engine on/off cycles? If yes, how many times?

DOMAIN: Said vehicle has TPMS warning or combined warning/malfunction lamp (n=1,336)



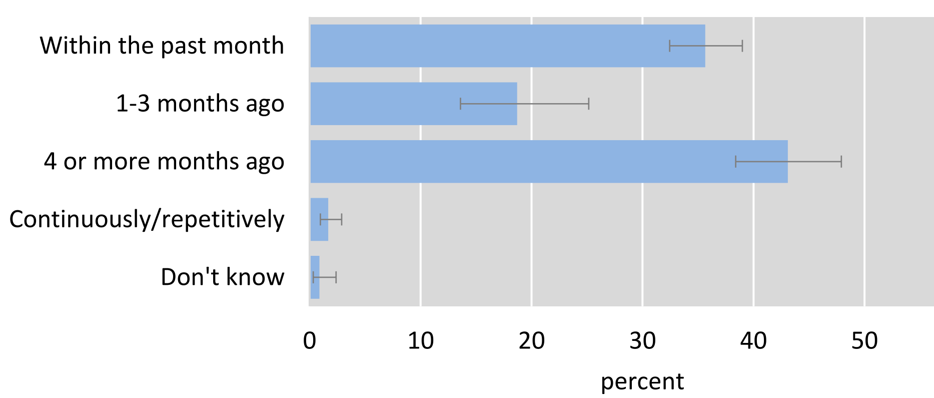
	pct	95% C.I.
No	37.5	(29.9, 45.7)
yes, 1 time	28.4	(22.3, 35.5)
yes, 2 times	11.9	(9.6, 14.6)
yes, 3 times	5.2	(4.2, 6.6)
yes, 4 times	2.3	(0.9, 5.7)
yes, 5 times	1.6	(0.8, 3.0)
yes, 6-50 times	2.1	(1.2, 3.6)
Yes, light is continuously illuminated or comes on regularly	3.5	(1.4, 8.5)
Yes, don't know how many times.	6.4	(3.8, 10.5)
Don't know if illuminated	1.2	(0.4, 3.3)

[LAMPEVERONID]
n=1,332

Source: NHTSA TPMS-SS, 2010/2011

Q9. When was the last time the warning/combined lamp illuminated on this vehicle?

DOMAIN: Lamp has illuminated (n=820)



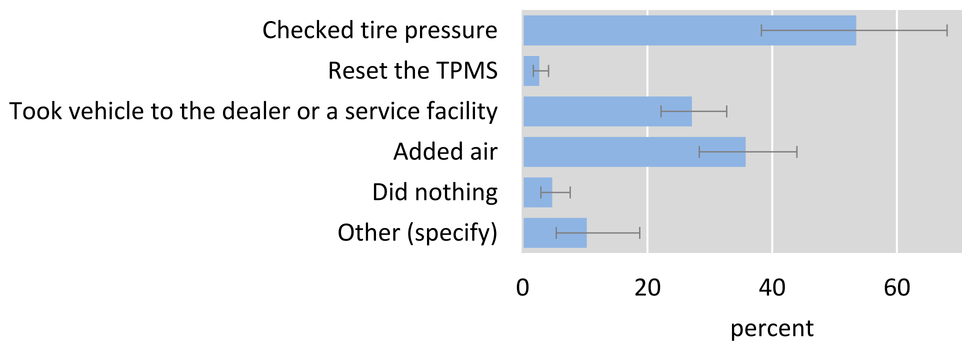
	pct	95% C.I.
Within the past month	35.7	(32.4, 39.0)
1-3 months ago	18.7	(13.6, 25.2)
4 or more months ago	43.1	(38.4, 47.9)
Continuously/repetitively	1.7	(1.0, 2.9)
Don't know	0.9	(0.3, 2.4)

[LAMPLASTONID]
n=818

Source: NHTSA TPMS-SS, 2010/2011

Q10. What actions did you take the last time the TPMS warning/combined lamp illuminated? (Check all that apply)

DOMAIN: Lamp has illuminated (n=820)



	pct	95% C.I.
Checked tire pressure	53.5	(38.3, 68.0)
Reset the TPMS	2.7	(1.7, 4.1)
Took vehicle to the dealer or a service facility	27.1	(22.2, 32.7)
Added air	35.8	(28.3, 44.0)
Did nothing	4.7	(2.9, 7.6)
Other (specify)	10.3	(5.4, 18.8)

[ACTIONSTAKE1-6]
n=817

Source: NHTSA TPMS-SS, 2010/2011

Other specified responses, actions taken when TPMS light came on

What actions did you take? other specified response	Count
"EYEBALLED" THE TIRE	1
ALL NEW TIRES	1
ASKED SPOUSE TO CHECK	1
CALLED FATHER	1
CALLED HUSBAND	1
CHANGED TIRE	1
CHANGED TIRES	1
CHANGED TO SPARE	1
CHANGED TO SPARE TIRE. TIRE WAS FLAT	1
COMPANY CAR, WONT KNOW	1
DEALER	1
DROVE AROUND TO HEAT UP TIRES	1
FLAT TIRE CHANGED	1
FOUND NAIL IN TIRE - PLUGGED IT	1
GOT 4 NEW TIRES	1
GOT NEW TIRES	1
HAD HUSBAND CHECK PRESSURE	1
HAD TIRE REPAIRED - HAD A NAIL IN TIRE	1
HAVE DIFFERENT SIZE TIRES INSTALLED	1
INFORMED TECH THAT SENSOR IS NOT PROPERLY WORKING	1
IS ON THE WAY TO ADD AIR NOW	1
LET AIR OUT TO HAUL TRAILER	1
LOOKED AT TIRES	1
LOOKED IN MANUAL	1
NAIL IN TIRE	1
NAIL IN TIRE GOT PATCHED	1
NEEDED NEW TIRE	1
NEEDS TO BE RECALCULATED	1

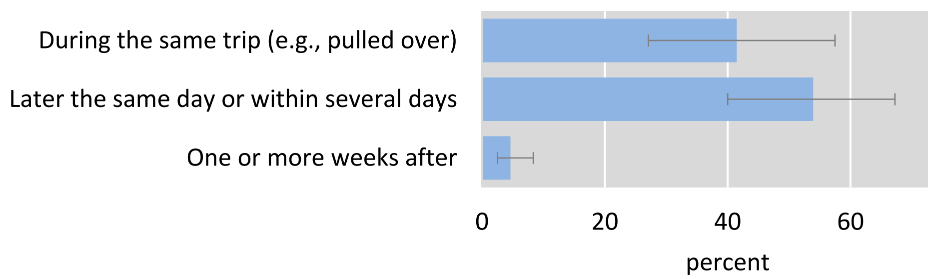
What actions did you take? other specified response	Count
NEW TIRE	1
NEW TIRES	3
NEXT DAY CHECKED THE TIRE - HAD A NAIL IN IT	1
PLUGGED TIRE	1
PULLED INTO A REST AREA-TIRE WAS GOING FLAT	1
PULLED OVER AND AAA CHANGED RR FLAT TIRE	1
PULLED OVER AND PUT ON SPARE DUE TO NAIL IN TIRE	1
PURCHASED TIRE	1
PUT AIR IN TIRE AND LIGHT ILLUMINATED	1
RAN OVER CEMENT ROCK ON ROAD AND TIRE WAS RUIN	1
READ MANUAL	1
REFILLED AIR / NAIL	1
REPAIR TIRE	2
REPAIR TIRE-NAIL	1
REPAIRED FLAT	1
REPAIRED TIRE	4
REPAIRED TIRE,HAD NAIL	1
REPLACED CRACKED RIM	1
REPLACED LEFT REAR	1
REPLACED TIRE	3
REPLACED TIRE WITH A NAIL IN IT	2
REPLACED TIRE WITH NAIL IN IT	1
REPLACED TIRE, NAIL IN TIRE	1
REPLACED TIRE. HAD NAIL.	1
REPLACED TIRES	1

What actions did you take? other specified response	Count
REPLACED-NAIL IN TIRE	1
REPLECED ALL 4 TIRES	1
RESET IT SELF	1
TALKING ABOUT IT	1
TIRE	1
TIRE PLUG	1
TIRE REPAIRED, HAD NAIL IN IT	1
TOLD DAD ABOUT IT	1
TOOK NAIL OUT OF TIRE	1

What actions did you take? other specified response	Count
TOOK TO SERVICE STATION	1
VALVE STEM CHANGE	1
VALVE STEM IS DAMAGED - SON WORKS FOR TIRE COMPANY & IS TO REPLACE/REPAIR STEM	1
WAITED UNTIL MORNING, CHECKED AGAIN AND LIGHT WAS OFF	1
WIRING SYSTEM IS BROKEN	1

Q11. How long after you first noticed the lamp illuminated did you take action?

DOMAIN: took some action (n=767)



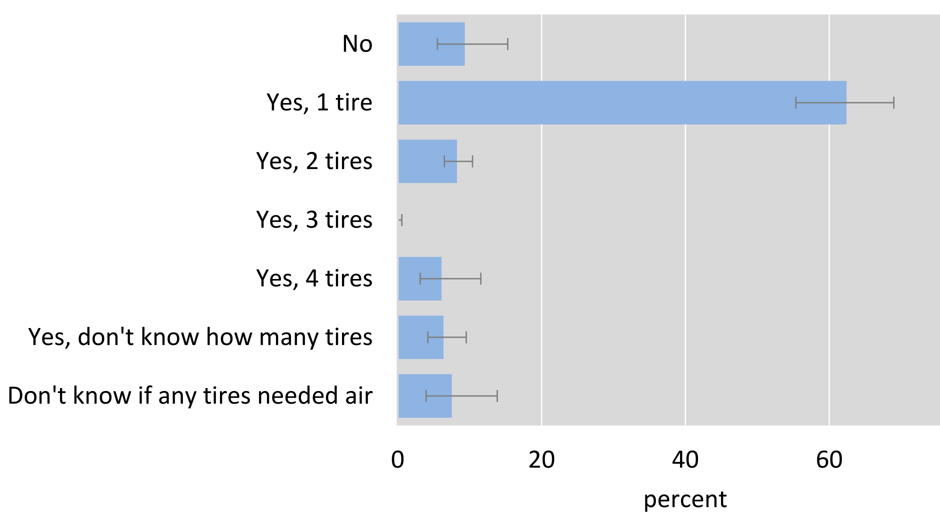
	pct	95% C.I.
During the same trip (e.g., pulled over)	41.5	(27.1, 57.5)
Later the same day or within several days	53.9	(40.0, 67.2)
One or more weeks after	4.6	(2.5, 8.3)

[ACTWHEN]
n=754

Source: NHTSA TPMS-SS, 2010/2011

Q12. Did any of the tires need air? If yes, how many?

DOMAIN: took some action (n=767)



	pct	95% C.I.
No	9.2	(5.4, 15.2)
Yes, 1 tire	62.5	(55.4, 69.1)
Yes, 2 tires	8.2	(6.5, 10.4)
Yes, 3 tires	0.04	(0.003, 0.6)
Yes, 4 tires	6.1	(3.1, 11.6)
Yes, don't know how many tires	6.4	(4.2, 9.5)
Don't know if any tires needed air	7.5	(4.0, 13.9)

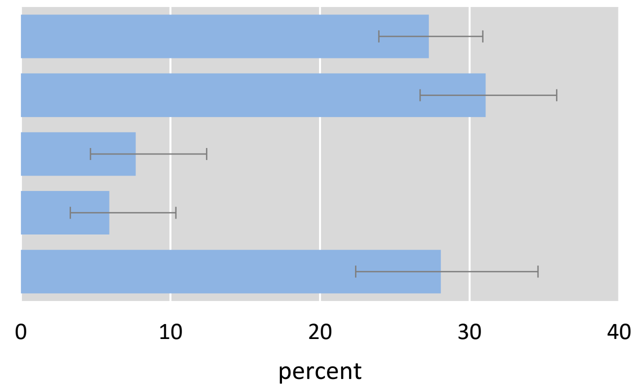
[NEEDEDAIRID]
n=754

Source: NHTSA TPMS-SS, 2010/2011

Q13. Approximately how much air was needed in each tire? (Estimate on average if multiple tires needed air)

DOMAIN: air needed (n=635)

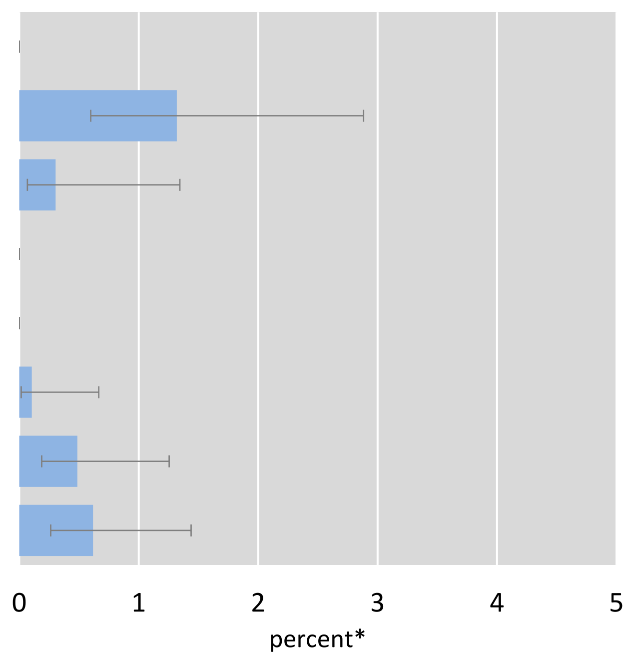
Response	Percent	95% C.I.
Less than 5 psi	27.3	(23.9, 30.9)
5 to 10 psi	31.1	(26.7, 35.8)
10 to 15 psi	7.7	(4.6, 12.4)
More than 15 psi	5.9	(3.3, 10.4)
Don't know	28.1	(22.4, 34.6)
[AIRNEEDEDID] *n*=628		
Source: NHTSA TPMS-SS, 2010/2011		



Q14. Have you or someone else checked the vehicle because the warning/combined lamp was not working correctly? If yes, what was found to be the reason?* (Check all that apply)

DOMAIN: lamp has illuminated (n=820)

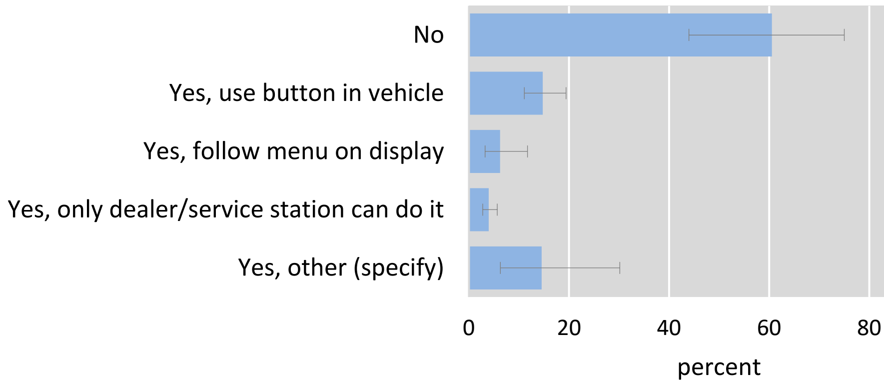
Response	percent	95% C.I.
No, did not check it	0	
Yes, needed re-set	1.3	(0.6, 2.9)
Yes, sensors or other part in the tire not	0.3	(0.1, 1.3)
Yes, batteries needed to be changed	0	
Yes, light bulb needed to be replaced	0	
Yes, general problem with TPMS System	0.1	(0.0, 0.7)
Yes, don't know	0.5	(0.2, 1.3)
Yes, other (specify)-NEW TIRES	0.6	(0.3, 1.4)
[CHECKMALF1-8] *n*=807		
Source: NHTSA TPMS-SS, 2010/2011		



*Presumably this would be "no" for everyone asked who did not select any "yes", but "no, did not check" had zero frequency in the data.

Q15. Do you know how to reset (calibrate) your TPMS?

DOMAIN: All (n=1,400)



	pct	95% C.I.
No	60.5	(44.0, 75.0)
Yes, use button in vehicle	14.8	(11.1, 19.4)
Yes, follow menu on display	6.2	(3.2, 11.7)
Yes, only dealer/service station can do it	4.0	(2.7, 5.7)
Yes, other (specify)	14.5	(6.3, 30.1)

[RESETUSEID]
n=1,352

Source: NHTSA TPMS-SS, 2010/2011

Reset method, other specify

direct TPMS	Count
ADD AIR	4
AFTER ADDING AIR	1
AIR IN TIRE	1
AIR IN TIRES	1
AUTO	21
AUTO "DRIVE"	3
AUTO DRIVE	1
AUTO MANUAL	1
AUTO RESET	3
AUTO SETS ITSELF	1
AUTOMATIC	62
AUTOMATIC RESET	2
AUTOMATIC, ADD AIR	1
AUTOMATICALLY	2
AUTOMATICALLY DOES IT	3
AUTOMATICALLY RESETS	7
AUTOMATICALLY RESETS ITSELF	3
BY ITSELF	1
COMPLICATED PROCESS OF DOING DIFFERENT THINGS TO THE VEHICLE	1
DEALER	1
DOES IT AUTOMATICALLY	1
DOES IT BY ITSELF	1
DOES IT ON ITS OWN	1
DOESN'T NEED TO BE	1
DRIVE	1
DRIVE 7 MILES TO RESET	1
DRIVE A SHORT DISTANCE	1
DRIVE IT	2
DRIVE IT AROUND	1

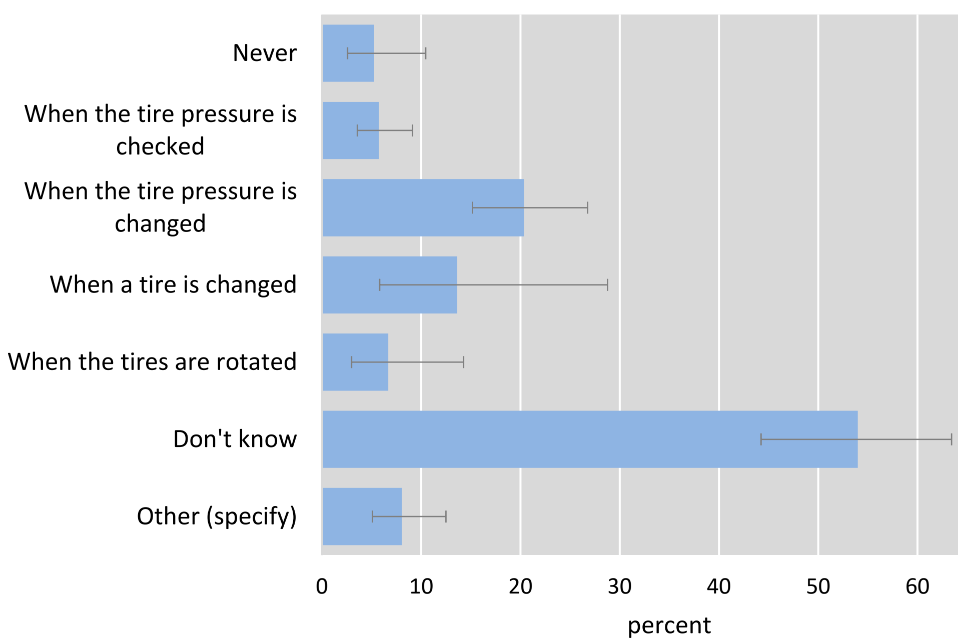
direct TPMS	Count
FILL TIRE	1
FILLED TIRE NOT ANY	1
FOLLOW INSTRUCTIONS IN BOOK	1
GOES OFF ON ITS OWN	1
HUSBAND	1
IN MANUAL	1
IT AUTOMATICALLY RESETS	1
IT DOES IT AUTOMATICALLY - ON RESTART	1
IT GOES OFF BY ITSELF	1
IT RE-SETS ITSELF AUTOMATICALLY	1
IT RESETS AUTOMATICALLY	1
IT RESETS ITSELF	4
IT RESETS ITSELF UNLESS TIRE IS REPLACED	1
KEY ON/OFF	1
LONG PROCESS OF TURNING KEY, PRESSING BRAKE, OPENING DOOR, ETC.	1
MANUAL	3
NO RESET	1
NOTHING WRITTEN	1
ON OWN	1
ON STAR	1
OWNERS MANUAL	2
PRESSURE BASED	1
PROPER AIR PRESSURE IN TIRE (S)	1
PUT AIR IN AND IT GOES OFF	1
RE-SETS ITSELF AUTOMATICALLY	1
REMOTE CONTROL	1
RESET AFTER FILL	1
RESETS AFTER ADDING AIR	1
RESETS AUTOMATICALLY	11

direct TPMS	Count
RESETS AUTOMATICALLY AFTER DRIVING 1 MILE	1
RESETS ITS SELF	1
RESETS ITSELF	11
RESETS ITSELF AUTOMATICALLY	1
RESETS ON ITS OWN	1
SELF CALIBRATES	1
SELF RESET	1
SELF RESETS WHEN TIRE IS FILLED	1
SETS ITSELF	1
SYSTEM AUTOMATICALLY RESETS	1
SYSTEM RESETS AUTOMATICALLY	1
TURN KEY ON AND OFF	1
TURN TO ACC, STEP ON BRAKE	1
UNKNOWN ANSWER	1
VEH. KNOWS W/ CORRECT TIRES	1
WHEN TIRES ARE INFLATED PROPERLY	1
WILL GO TO THE MANUAL TO FIND OUT	1
indirect TPMS	Count

direct TPMS	Count
AUTO	1
AUTO RESET	1
AUTOMATIC	1
DRIVE	1
DRIVE "AUTO RESET"	1
FOLLOWING DIRECTIONS IN BOOK	1
I CAN FIGURE IT OUT	1
INFLATE TIRES	1
LOTS OF THINGS	1
MANUAL	1
PRESS ACELERATOR, TURN KEY, ETC.	1
PROCEDURE	1
PUT AIR IN TIRE	1
RESETS AUTOMATICALLY	1
RESETS BY DRIVING	1
RESETS ITSELF	1
SELF SETTING(CHANGE PSI)	1

Q16. When should your TPMS be reset? (Check all that apply)

DOMAIN: All (n=1,400)



	pct	95% C.I.
Never	5.3	(2.6, 10.4)
When the tire pressure is checked	5.7	(3.6, 9.1)
When the tire pressure is changed	20.4	(15.2, 26.8)
When a tire is changed	13.6	(5.8, 28.8)
When the tires are rotated	6.7	(3.0, 14.3)
Don't know	54.0	(44.2, 63.4)
Other (specify)	8.0	(5.1, 12.5)

[WHENRESET1-7]
n=1,329

Source: NHTSA TPMS-SS, 2010/2011

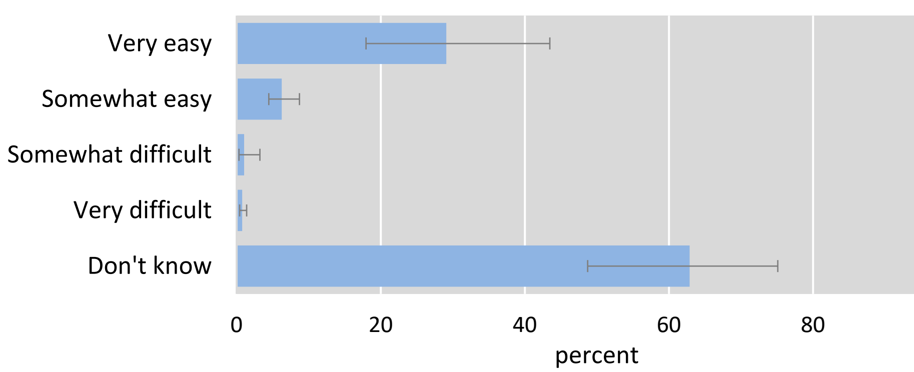
Q16. Other specify, when to reset TPMS

Other specified, when to reset TPMS	Count
AFTER IT ILLUMINATES	1
AFTER TRIP	1
ALIGNMENT	1
AT SERVICE TIME	1
AUTO	1
AUTOMATIC	6
AUTOMATIC RESET	1
AUTOMATIC WHEN AIR ADDED	1
AUTOMATICALLY RESETS	6
AUTOMATICALLY??	1
AUTOMATICLLY RESETS ITSELF	1
CHANGE SENSORS	1
CHANGE THE OIL	1
CHANGES OF SEASON'S	1
CHECK MANUAL	1
CRASH	1
DEALER	1
DIFF. SENSORS	1
DOES IT BY ITSELF	1
DOES IT ITSELF	1
IF LIGHT COMES ON	1
IT AUTOMATICALLY RE-SETS ITSELF	1
IT AUTOMATICALLY RESETS	1
IT AUTOMATICALLY RESETS ITSELF	1
IT RESETS ITSELF	1
LIGHT STAYS ON TILL SHOP DOES SOMETHING	1
NO RESET	1
NOTIFICATION BY TPMS	1
NOW, LIGHT IS ON RIGHT NOW	1

Other specified, when to reset TPMS	Count
OCCURS AUTOMATICALLY	1
RE-SETS AUTOMATICALLY	1
RESET AUTO	1
RESETS AUTOMATICALLY	8
RESETS ITSELF	6
RESETS ITSELF AUTOMATICALLY	1
SETS ITSELF	2
SYSTEM RESETS AUTOMATICALLY	1
TECHNICIAN	1
TIRE REPLACED	1
VEH. KNOWS W/ CORRECT TIRES	1
WARMER	1
WHEN IT GOES OFF	1
WHEN IT LIGHTS UP	2
WHEN IT RESETS AUTOMATICALLY	2
WHEN IT RESETS ITSELF	2
WHEN IT TELLS ME	1
WHEN LIGHT COMES ON	1
WHEN ON STAR RECOMMENDS	1
WHEN OUTSIDE TEMP CHANGES	1
WHEN SERVICED	2
WHEN SERVICED / WHEN OIL CHANGED	1
WHEN THE TPMS GOES OFF	1
WHEN THE WARNING LIGHT COMES ON	1
WHEN THERE IS A PROBLEM	1
WILL RE-SET ITSELF	1
(indirect) AUTOMATIC RESET	1
(indirect) WHEN LIGHT ILLUMINATES	1
(indirect) WHEN PROBLEM FIXED	1
(indirect) WHEN WARNING LIGHT COMES ON	1

Q17. How easy or difficult is it to reset your TPMS?

DOMAIN: All (n=n=1,400)



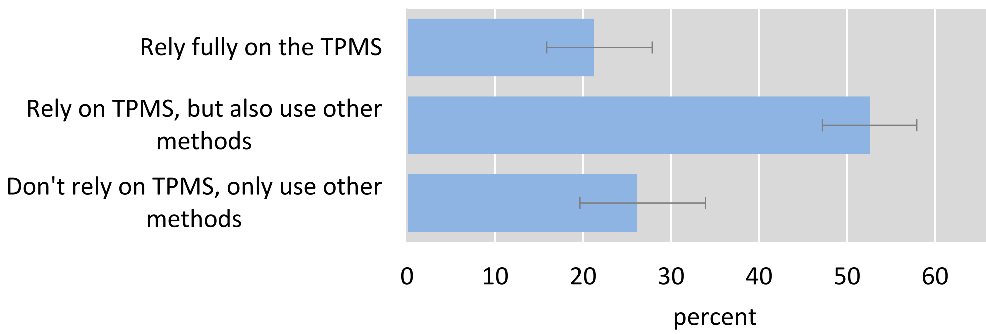
pct	95% C.I.
29.1	(18.0, 43.5)
6.3	(4.5, 8.7)
1.0	(0.3, 3.2)
0.8	(0.4, 1.4)
62.9	(48.7, 75.1)

[RESETCONVENIENT ID]*n*=1,334

Source: NHTSA TPMS-SS, 2010/2011

Q18. To what extent do you rely on your TPMS to tell you when your tires need air?

DOMAIN: All (n=1,400)



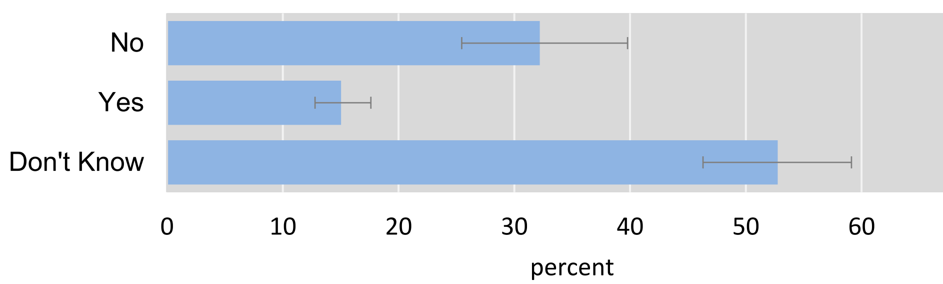
	pct	95% C.I.
Rely fully on the TPMS	21.3	(15.9, 27.9)
Rely on TPMS, but also use other methods	52.6	(47.2, 57.9)
Don't rely on TPMS, only use other methods	26.2	(19.6, 33.9)

[TPMSRELYID]
n=1,351

Source: NHTSA TPMS-SS, 2010/2011

Q19. Does your TPMS have a malfunction lamp?

DOMAIN: All (n=1,400)



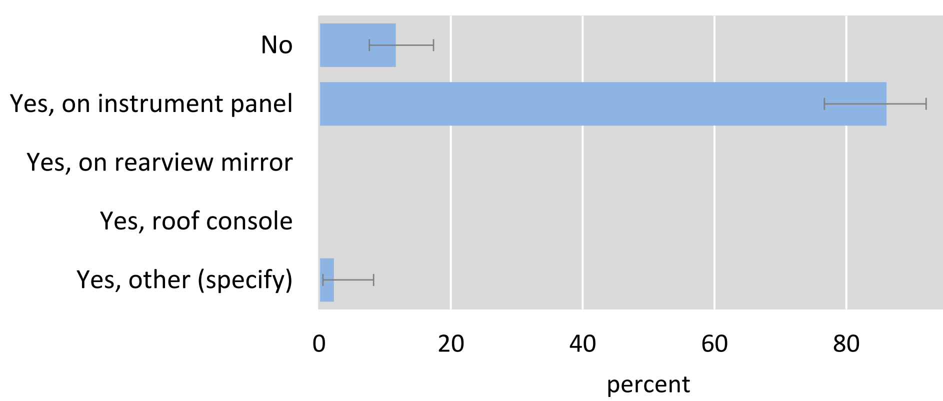
	pct	95% C.I.
No	32.2	(25.5, 39.8)
Yes	15.0	(12.8, 17.6)
Don't Know	52.8	(46.3, 59.1)

[TPMSMALFID]
n=1,337

Source: NHTSA TPMS-SS, 2010/2011

Q20. Do you know where your TPMS malfunction lamp is located? If yes, where?

DOMAIN: Said TPMS has malfunction lamp (n=222)



	pct	95% C.I.
No	11.6	(7.6, 17.4)
Yes, on instrument panel	86.1	(76.7, 92.1)
Yes, on rearview mirror	0	
Yes, roof console	0	
Yes, other (specify)	2.3	(0.6, 8.3)

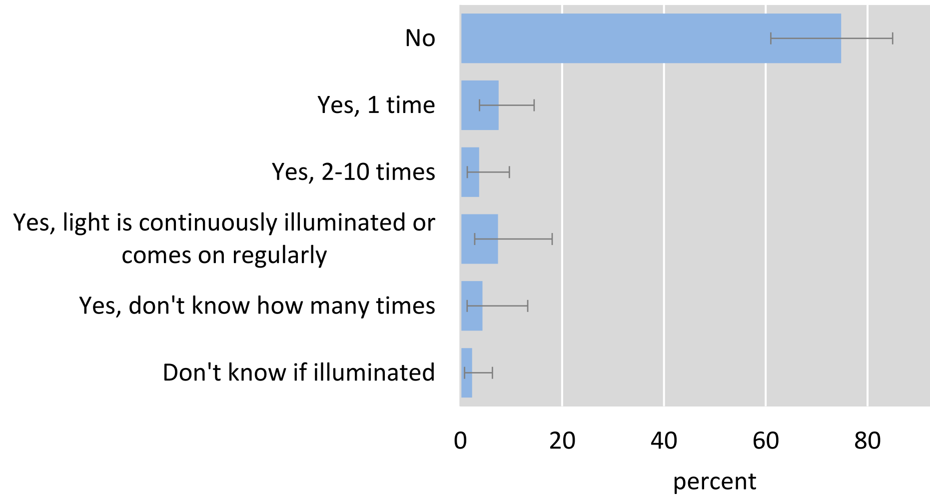
[TPMSMALFLOCID]
n=216

Source: NHTSA TPMS-SS, 2010/2011

Other specified responses, malfunction lamp location (one each): MESSAGE CENTER; MULTI-FUNCTION DISPLAY; NAVIGATION SCREEN; ON THE GPS SYSTEM; WITH RADIO, ETC.

Q21. Has your TPMS malfunction lamp ever illuminated, except during engine on/off cycles? If yes, how many times?

DOMAIN: Knows where malfunction light is located (n=188)



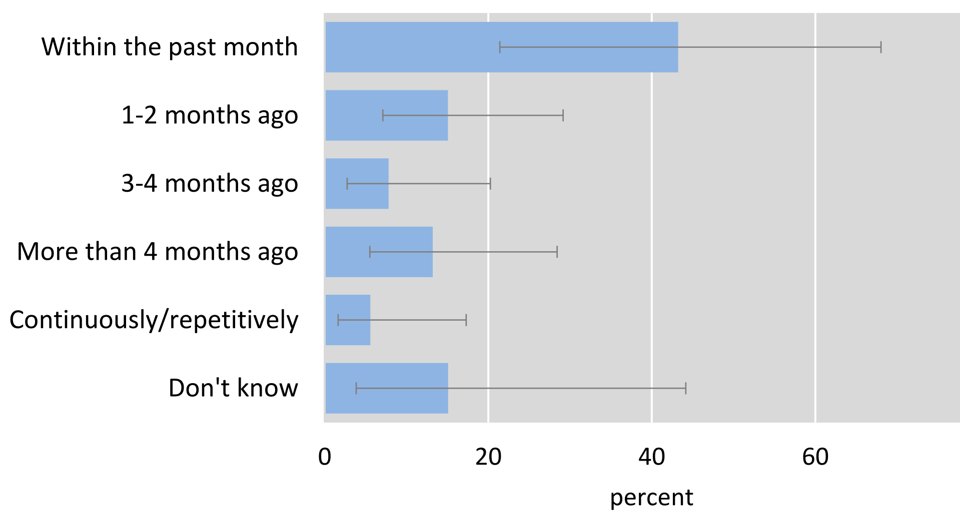
	pct	95% C.I.
No	74.8	(61.0, 84.9)
Yes, 1 time	7.5	(3.7, 14.5)
Yes, 2-10 times	3.7	(1.3, 9.6)
Yes, light is continuously illuminated or comes on regularly	7.4	(2.8, 18.0)
Yes, don't know how many times	4.3	(1.3, 13.2)
Don't know if illuminated	2.3	(0.8, 6.3)

[MALFEVERONID]
n=187

Source: NHTSA TPMS-SS, 2010/2011

Q22. When was the last time the malfunction lamp illuminated on this vehicle?

DOMAIN: Malfunction light has illuminated (n=42)



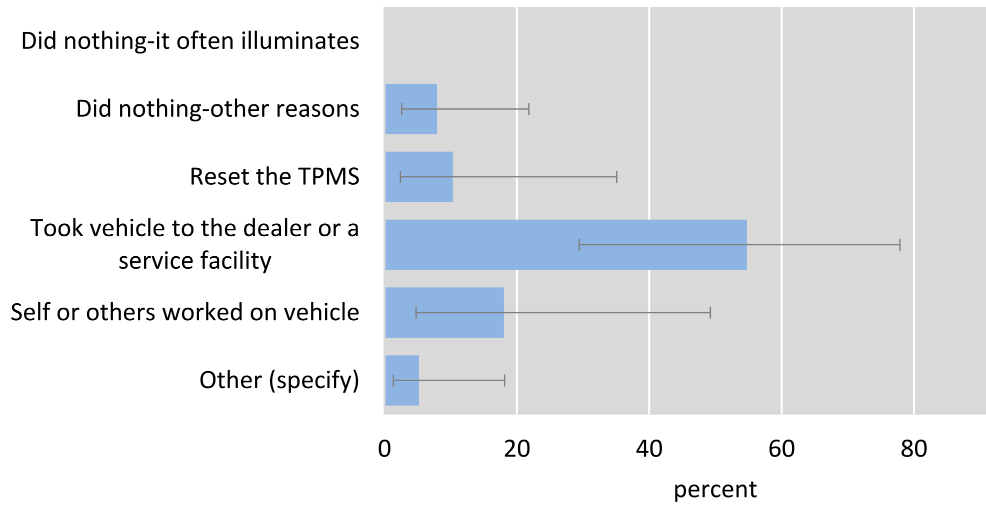
	pct	95% C.I.
Within the past month	43.2	(21.4, 68.0)
1-2 months ago	15.1	(7.1, 29.2)
3-4 months ago	7.8	(2.7, 20.3)
More than 4 months ago	13.2	(5.5, 28.4)
Continuously/repetitively	5.6	(1.6, 17.3)
Don't know	15.1	(3.8, 44.2)

[MALFLASTONID]
n=40

Source: NHTSA TPMS-SS, 2010/2011

Q23. What actions did you take the last time the TPMS malfunction lamp illuminated? (Check all that apply)

DOMAIN: Malfunction light has illuminated (n=42)



	pct	95% C.I.
Did nothing-it often illuminates	0.0	
Did nothing-other reasons	7.9	(2.6, 21.8)
Reset the TPMS	10.3	(2.4, 35.1)
Took vehicle to the dealer or a service facility	54.8	(29.4, 77.9)
Self or others worked on vehicle	18.0	(4.8, 49.2)
Other (specify)	5.2	(1.3, 18.1)

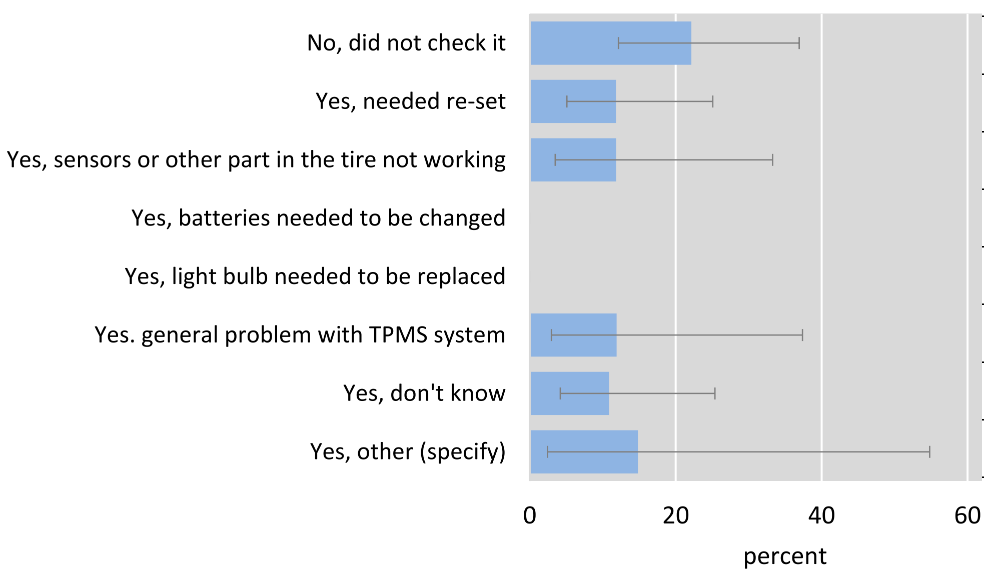
[MALFACTIONID1-6]
n=34

Source: NHTSA TPMS-SS, 2010/2011

Other specified responses (one each): ADDED AIR; BROKEN NEEDS FIXED; GOT 4 NEW TIRES

Q24. Have you or someone else checked the vehicle because the malfunction lamp was not working correctly? If yes, what was found to be the reason? (Check all that apply)

DOMAIN: Malfunction light has illuminated (n=42)



	pct	95% C.I.
No, did not check it	22.2	(12.2, 36.9)
Yes, needed re-set	11.8	(5.1, 25.1)
Yes, sensors or other part in the tire not working	11.8	(3.5, 33.3)
Yes, batteries needed to be changed	0	
Yes, light bulb needed to be replaced	0	
Yes. general problem with TPMS system	11.9	(3.0, 37.4)
Yes, don't know	10.9	(4.2, 25.4)
Yes, other (specify)	14.8	(2.4, 54.8)

[CHECKWARN1-8]
n=41

Source: NHTSA TPMS-SS, 2010/2011

Other specified responses (one each): NAIL IN TIRE; NEW TIRES; WIRING SYSTEM BROKEN

End Supplemental Interview.

Appendix K. Tire Pressure Special Study (2001) Sample Makeup

Pie charts show the Tire Pressure Special Study (2001) unweighted sample makeup counts.

Figure K-1 shows the TPSS sample makeup for vehicle characteristics.

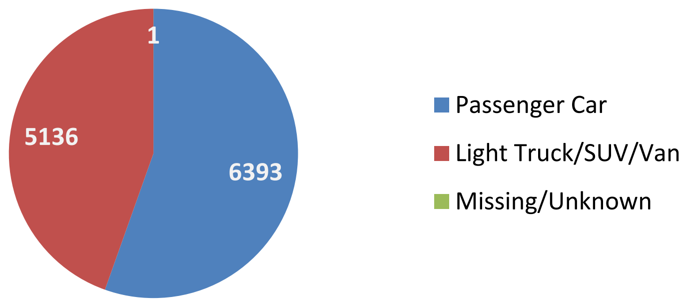
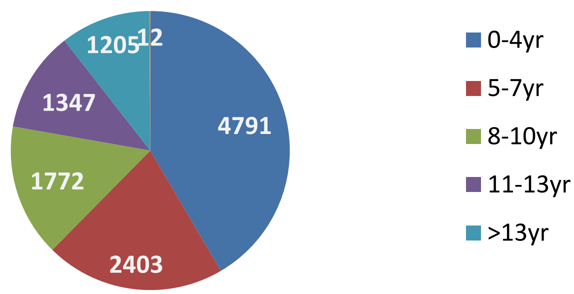
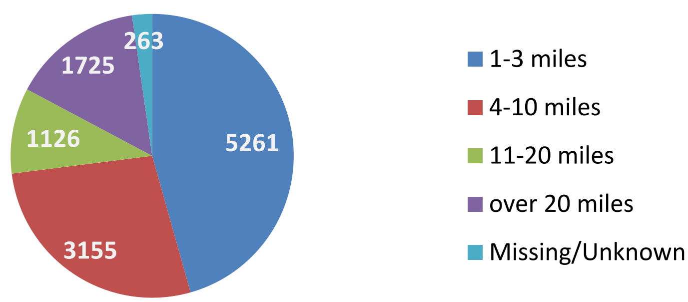
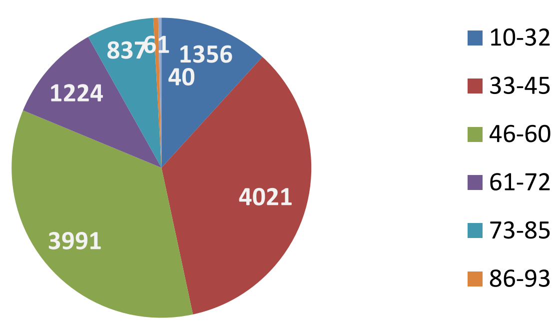
<table>
<tr><th>Characteristic</th><th>Sample Counts</th></tr>
<tr><td>Vehicle body type
As used in the original report</td><td>
</td></tr>
<tr><td>Vehicle age
Derived as 2001 – vehicle model year
MY 2001=0yr.
MY 2000=1yr
etc.
Vehicle model year read from the VIN</td><td>
</td></tr>
<tr><td>Miles driven to site
The respondent was asked, “How many miles did you drive to reach this destination?”</td><td>
</td></tr>
<tr><td>Ambient air temperature at site
Degrees F.
Measured at the data collection site with a pyrometer</td><td>
</td></tr>
</table>

Figure K-1. TPSS (2001) Sample Makeup, Vehicle Characteristics

Figure K-2 shows the TPSS sample makeup for driver characteristics.

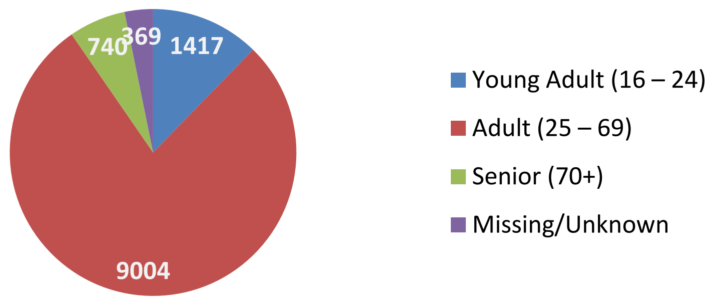
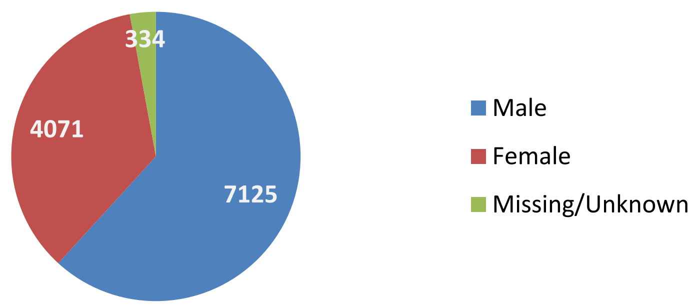
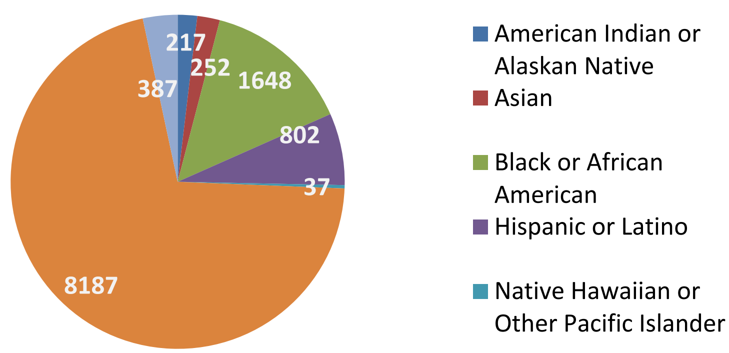
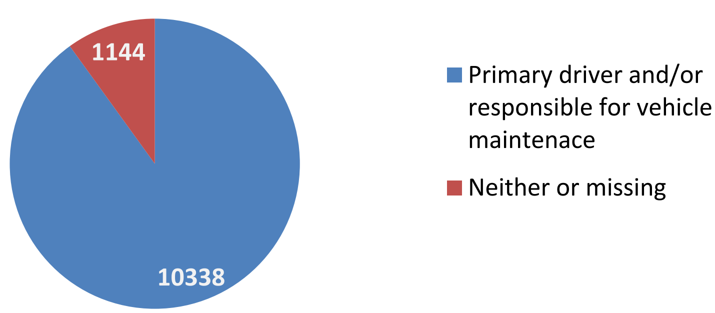
<table>
<tr><th>Characteristic</th><th>Sample Counts</th></tr>
<tr><td>Driver age group
By interviewer observation</td><td>
</td></tr>
<tr><td>Driver gender
By interviewer observation</td><td>
</td></tr>
<tr><td>Driver race
By interviewer observation</td><td>
</td></tr>
<tr><td>Driver responsibility
Drivers were asked “Are you responsible for the maintenance of this vehicle?” and “Are you the vehicle's primary driver?” Used as a screener for some interview questions</td><td>
</td></tr>
</table>

Figure K-2. TPSS (2001) Sample Makeup, Driver Characteristics

Appendix L. Tire Pressure Special Study (2001) Response Tables

This appendix shows the weighted percentage responses to driver interview questions in the 2001 NHTSA Tire Pressure Special Study. For ease of reading, bar graphs with confidence intervals are shown.

Most of the interview questions were previously covered with certain comparison factor breakouts in the NHTSA research note *Tire Pressure Special Study: Interview Data* (NCSA, 2001b). The “Other (specify)” responses have not been previously reported.

Reading the Tables

Bar charts. The end of the bar marks the point estimate for the response percentage. Error bars show 95 percent confidence intervals. Table entries below the graphs give the data point estimates and confidence intervals that generated the graphs.

Domain. The domain is the subset of respondents eligible for the question. The “*n*” specified for the domain is the number of respondents in that domain. The character string in brackets is the dataset name of the variable. The “*n*” after the variable name is the number of responses. The response “*n*” would ideally equal the domain “*n*” but may be less due to item non-response.

Other specified responses. If a question allowed for “Other, Specify” responses apart from the options given, the other specified responses are shown as recorded in the data. Sometimes, it appears that a number may have been entered that represented an available option, but they are still shown as recorded.

Missing data. Refusals are considered missing and not part of response percentages. “Don’t know” is included in responses, since lack of knowledge may be a relevant factor in the question.

Check one or check all that apply. There were no “check all that apply” questions in this interview. For each question, the respondent could pick one answer only.

Interview flow. Data collection started with tire observation, went to observations about the driver, vehicle, and survey site, and then went to the interview questions. The last four questions were only asked if the respondent was the vehicle’s primary driver or person primarily responsible for maintenance. A flow chart of the TPSS interview is shown in Figure L-1.

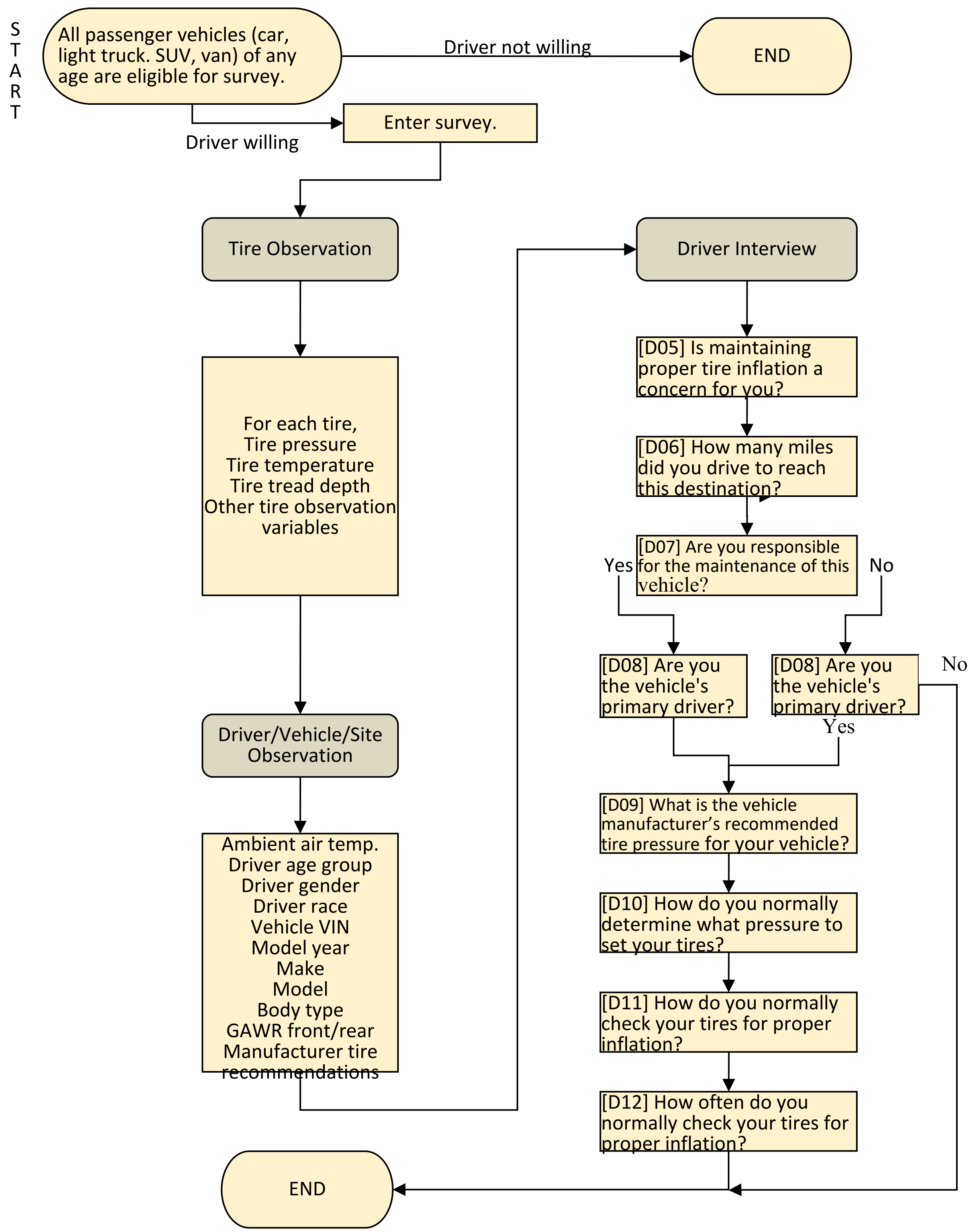
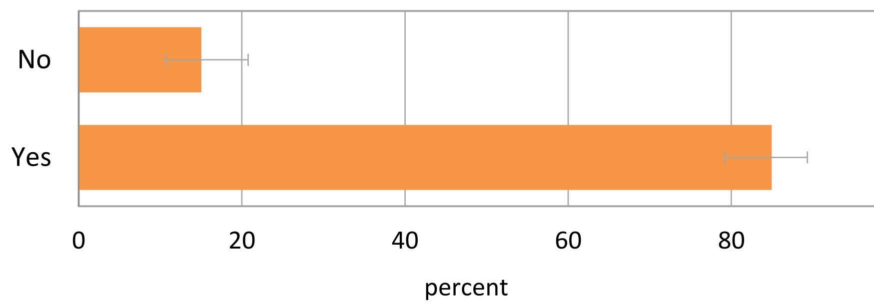


Figure L-1. Flow Chart of the 2001 NHTSA Tire Pressure Special Study

TPSS interview

D05. Is maintaining proper tire inflation a concern for you?

DOMAIN: All (n=11,530)



	pct	95% C.I.
No	15.0	(10.7, 20.8)
Yes	85.0	(79.2, 89.3)

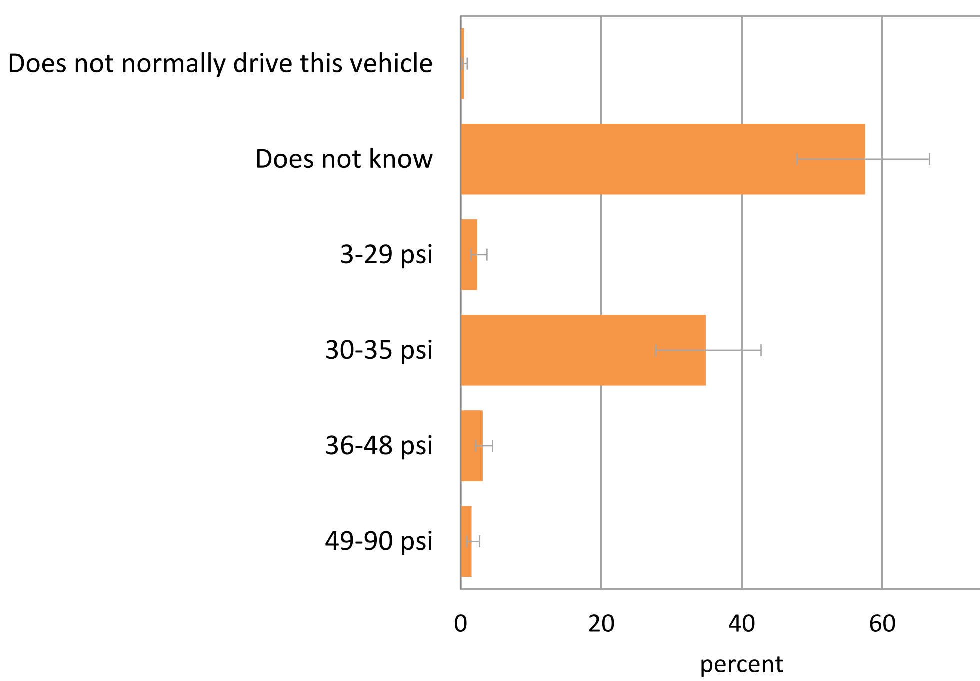
[D05]
n=11,500

Source: NHTSA TPSS, 2001

D06-Comparison variable. D07, D08-Screeners.

D09. What is the vehicle manufacturer's recommended tire pressure for your vehicle? (Per the data collector's procedures manual, if a respondent referred to a manual or other source to get this answer, the response was recorded as "don't know.")

DOMAIN: Respondent is responsible for maintenance and/or is primary driver (n=10,339)



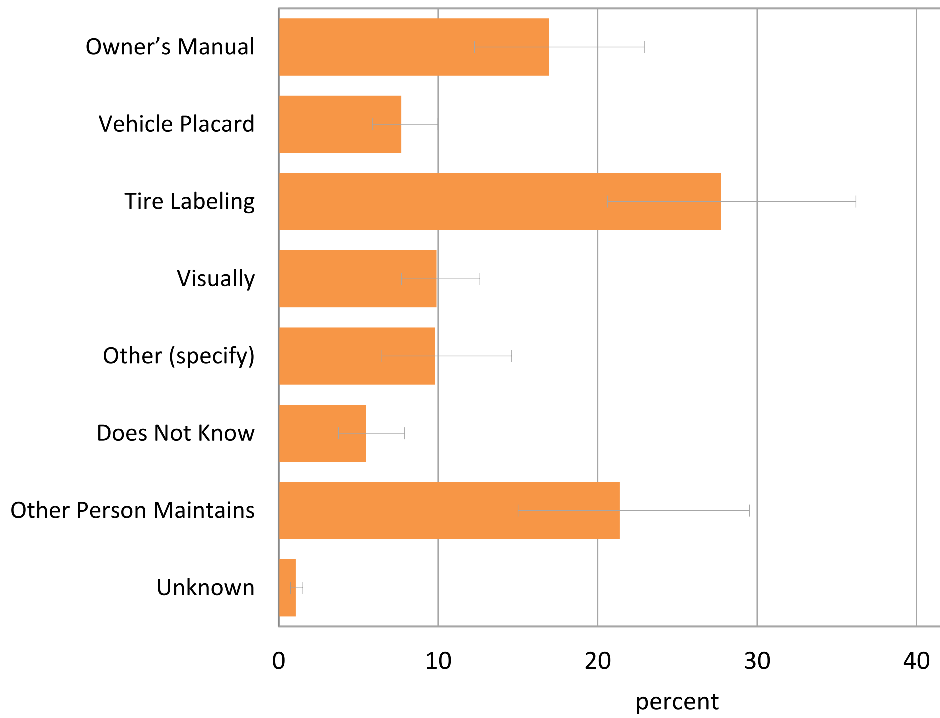
	pct	95% C.I.
Does not normally drive this vehicle	0.5	(0.2, 0.9)
Does not know	57.6	(47.9, 66.7)
3-29 psi	2.4	(1.5, 3.7)
30-35 psi	34.9	(27.8, 42.7)
36-48 psi	3.1	(2.2, 4.5)
49-90 psi	1.5	(0.9, 2.7)

[D09]
n=9,720

Source: NHTSA TPSS, 2001

D10. How do you normally determine what pressure to set your tires?

DOMAIN: Responsible for maintenance and/or primary driver (n=10,339)



	pct	95% C.I.
Owner's Manual	16.9	(12.3, 22.9)
Vehicle Placard	7.7	(5.9, 10.0)
Tire Labeling	27.7	(20.6, 36.2)
Visually	9.9	(7.7, 12.6)
Other (specify)	9.8	(6.5, 14.6)
Does Not Know	5.5	(3.8, 7.9)
Other Person Maintains	21.4	(15.0, 29.5)
Unknown	1.1	(0.8, 1.5)

[D10]
n=9,720

Source: NHTSA TPSS, 2001

D10. Other (specify)

How do you normally determine what pressure to set your tires? Other	Count
1	56
2	25
3	98
32	5
32 ALWAYS	1
32 ALWAYS USED	1
32 AS RULE OF THUMB	1
32 LBS AKWAYS	1
32 PSI	1
32-35	1
32-ALWAYS	1
32IB ALWAYS	1
4	68
5	94
5 30	1
5 30 KNOWS	1
5 ALL THE ABOVE	1
5 ASKS SOMEONE	1

How do you normally determine what pressure to set your tires? Other	Count
5 CRT 32	1
5 DEALER	2
5 DEPENDS ON WEATHER	1
5 EXPERIENCE	1
5 FAMILY NEMBER TOLD HER	1
5 FROM RECALL INTO	1
5 GENERAL INFO	1
5 HOW ITS RUNNING ON RD	1
5 KNOWS	1
5 KNOWS IT	3
5 MAINTENANCE REFERENCE	1
5 MEMORY	1
5 OIL CHANGE	1
5 PERSON EXPEERINE	1
5 PERSON WHO SOLD HIM THE	1
5 RADIO	1
5 SERVICE	2
5 SERVICE STATION	3

How do you normally determine what pressure to set your tires? Other	Count
5 SERVICING	1
5 SOMEONE TOLD HIM	1
5 STANDARD PRESSURE	1
5 STICKER ON WHEEL WELL	1
5 TIRE SHOE	1
5 TIRE TECH	1
5 WHEN OIL IS CHANGED	1
5 WHEN SERVICED	1
5, EXPERIENCE	1
5, EXPERIENCED MECHANIC	1
5, HOW TRUCK FEELS	1
5, SERVICE	2
5. OIL CHANGE	1
6	30
7	103
8	8
ACCORDING TO HOW IT DRIVE	1
ALL ARE 35	1
ALWAYS SET AT 28	1
ALWAYS SETS 32	1
ALWAYS USE 32 AS STANDARD	1
ASK	1
ASK DEALER	1
ASK GAS STATION ATTENDANT	1
ASK MECHANIC	4
ASK MY DAD	1
ASKS DAD	1
ASKS MECHANIC	1
ASKS TIRE DEALER	2
AT OIL CHANGE	1
AT SERVICE	1
AT SERVICE TIME	1
BASED ON PERFORMANCE	1
BRO IN LOW WORKS FOR TIRE	1
BROTHER	1
BROTHER CHECKS	1
BROTHER IS A MECHANIC	1
BROTHER TOLD HIM	1
BY HOW THE CAR IS DRIVING	1
BY INDIVIDUAL LOAD CARRIE	1
BY SELF KNOWLEDGE	1
BY THE LOAD	1
CALL TIRE CO	1
CAR SHOP	1
CAR TELLS HIM	1
CARGO WEIGHT	1
CHECKS WHERE PURCHASED	1
COMMEN KNOWLEDGE	1

How do you normally determine what pressure to set your tires? Other	Count
COMMON KNOWLEDGE	1
COMMON SENSE	1
CONSULT TIRE MANF. RETAIL	1
DAD	2
DAD CHECKED	1
DEALER	12
DEALER INFO	1
DEALER RECOMMENDATION	1
DEALER SERVICE SHOP	1
DEALER SHIP	1
DEALER/STORES	1
DEALERS	1
DEALERSHIP	1
DEPENDS ON CONDITIONS	1
DEPENDS ON LOAD	2
DEPENDS ON WEIGHT HAULED	1
DEPENDS UPON LOAD	1
DOES NOT CHECK	2
DOES NOT LOOK	1
DOES NOT REMEMBER	1
DOESN'T; HAS SERVICE TECH	1
DON'T CARE	1
DRIVER IS MECHANIC	1
DRIVING	1
EVERY TIRE SERVICE	1
EXPEREENCE	1
EXPERIENCE	18
EXPERIENCE AS A DRIVE	1
EXPRENCE	1
EXPRERIENCE	1
EXPRERIENCE/MANUALS	1
FATHER	2
FATHER TOLD ME	1
FATHER'S RECOMMENDATION	1
FEEL	1
FEELS DRIVING	1
FIANCEE	1
FILL TO 30	1
FIRESTONE ON PHONE	1
FIRESTONE RECORDS	1
FORD DEALER	1
FRIEND	1
FROM DEALER	1
FULL SVC	1
GARAGE	1
GAS STATION	4
GAUGE	9
GEN KNOWLEDGE FORMER MECH	1

How do you normally determine what pressure to set your tires? Other	Count
GENERAL KNOWLEDGE	1
GETS SERVICE	1
GLOVE COMPARTMEN	1
GOES WITH 30 POUNDS	1
GUAGE	2
GUASE	1
GUESS	4
HAS LIGHT	1
HAS SHOP DETERMIND	1
HE JUST KNOWS	1
HOW IT FEELS	2
HOW IT LOOKS	1
HOW VEHICLE RIDES	1
HUSBAND	11
HUSBAND CHECKS	1
HUSBAND SAID	1
I PUT 30 PSI	1
INFO FROM FAMILY	1
INFORMED BY SOMEONE	1
INTERNET WEBSITE RECOMMEN	1
JIFFY LUBE	1
JIFFY LUBE TAKES CARE OF	1
JOB	1
JUST CHECK IT	1
JUST KNOW	4
JUST KNOW IT'S 32	1
JUST KNOWS	1
JUST KNOWS FROM TIRE INST	1
KEEPS LOW IN WINTER	1
KICKING IT	1
KNOW	2
KNOW FROM PAST EXPERIENCE	1
KNOW IT'S 30	1
KNOW THAT	1
KNOW'S IT	3
KNOWLEDGE	3
KNOWLEDGE OF CAR	1
KNOWN	1
KNOWS	1
KNOWS FROM EXPERIENCE	1
KNOWS IT	10
LABEL ON GLOREBOX	1
LET OIL CHANGE PLACE DO I	1
LET SERVICE STATION CHECK	1
LET SERVICE TAKE CARE OF	1
LET SON DO IT	1
LETTER	1
LIKES 32 PSI	1

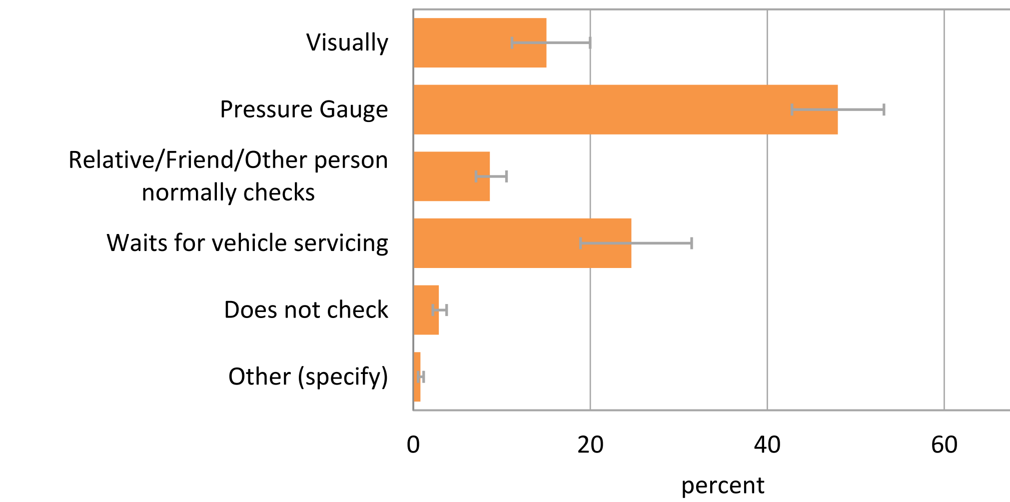
How do you normally determine what pressure to set your tires? Other	Count
LIKES 32-35	1
LIKES 35 PSI	1
LOAD	2
LOAD IN CAR	1
LT 225/75R16	1
LUBE SAID	1
MAINTENANCE FACILITY	1
MAINTENANCE FACILITY]	1
MAX ACCORDING TO TIRE	1
MECHANIC	24
MECHANIC BY TRADE	1
MECHANIC KNOWLEDGE	1
MECHANIC MAINTAINS	1
MECHANIC SPECS	1
MECHANIC TOLD HIM	1
MECHANIC. 7	1
MECHANICS	1
MECHANICS RECOMMENDATION	1
MEN	1
NEVER DOES IT	1
NEW DON'T KNOW	1
NEWSPAPER - FIRESTONES	1
NO	1
NORMAL	3
OFTEN	1
OIL CHANGE	4
OIL CHANGE PERSONNEL	1
OIL CHANGE PLACE	2
OIL CHANGE PLACE SETS	1
ON LINE	1
ON PAPER	1
ON-LINE	1
OTHER MANUALS	1
OWN EXPERIENCE	3
OWN PREFERENCE	2
OWNER FATHER	1
PAST EXPERIENCE	1
PERSONAL CHOICE	1
PERSONAL EXPERIENCE	5
PERSONAL OPINION 30-35	1
PERSONAL PREFERENCE	1
PREFERENCE	6
PREVIOUS EXPERENCE	1
PREVIOUS KNOWLEDGE	2
PREVIOUS TIRE	1
PUMP	1
PUMP TELLS ME	1
PUT IN THEN CHECK GAUGE	1

How do you normally determine what pressure to set your tires? Other	Count
PUTD 32 LBS	1
PUTS IN 30-35	1
PUTS IN MORE WHEN TOWING*	1
READ IT SOMEWHERE	1
READING IT	1
RECOMMENDED	1
REGULAR DEALER VISIT	1
REMEMBERS	1
REPAIR FACILITY	1
SELF	1
SERVICE	87
SERVICE CENTER	4
SERVICE CHECK	1
SERVICE GARAGE	1
SERVICE MAN DOES IT	1
SERVICE ON DEALER	1
SERVICE SHOP	1
SERVICE STATION	33
SERVICE STATION DOES IT	1
SERVICE STATION RECOMMEND	1
SERVICE TECH	1
SERVICE, 7	1
SERVICED	2
SERVICING	15
SERVICING EVERY 3 MONTHS	1
SET IT HOW IT RIDES	1
SETS THE SAME 34F 32R	1
SHOP	1
SHOP DOES IT	1
SHOP GAUGE	1
SHOP IN SCHOOL	1
SHOP OIL	1
SIDE WALL	1
SOMEHOW	1
SOMEONE TELLS ME	1
SOMEONE TOLD ME	1
SON	1
STANDARD	1
STANDARD PRESSURE	1
TAKES AVERAGE	1
THUMBTEST	1
TIRE	2
TIRE CHECK	1
TIRE DEALER	3
TIRE GAUGE	2
TIRE PEOPLE	1
TIRE REP.	1
TIRE SENSOR ON DASH	1

How do you normally determine what pressure to set your tires? Other	Count
TIRE SERVICE CENTER RECOM	1
TIRE SHOP	5
TIRE SHOP RECOMMENDATION	1
TIRE SPECS	1
TIRE STORE	6
TIRE STORE INFO	2
TIRE STORE RECOMMENDATION	1
TIRE WALL	1
TIRE WEAR	1
TIRES	2
TOLD BY BOSS	1
TOLD BY DEALER	1
TOLD BY SOMEONE	1
TOLD BY SOMEONE ELSE	1
TOLD HIM @ TIRE STORE	1
TOLD RIGHT PRESSURE	1
TOLD THEM	1
TREAD WEAR	1
TYPE OF LOAD	1
USED TO SELL TIRES	1
USES 32 ALL THE TIME	1
USES TIRE GAUGE	1
USUAL MONTHS	1
USUAL PRACTICE	1
USUALLY 32 PSI	1
USUALLY TIRE FILLED TO 30	1
VEHICLE SERVICE	1
WAY CAR HANDLES	1
WEA	1
WEAR ON TIRES & LOAD TYPE	1
WEATHER / WEIGHT	1
WEIGHT IN TRUCK	1
WHAT ALWAYS THOUGHT SHOUL	1
WHAT GUYS TELL ME	1
WHEN SERVICE	2
WHEN SERVICED	7
WHEN SERVICED 7	1
WHERE HE BUYS TIRES	1
WHERE I DRIVE	1
WORK AT GARAGE	1
WORKED AT STATION	1
WORLD FORD	1
WOULD NOT ANSWER	1
WOULDN'T	1
~32	1

D11. How do you normally check your tires for proper inflation?

DOMAIN: responsible for maintenance and/or primary driver (n=10,339)



pct	95% C.I.
15.0	(11.2, 20.0)
48.0	(42.8, 53.2)
8.7	(7.1, 10.5)
24.6	(18.9, 31.5)
2.9	(2.2, 3.8)
0.8	(0.6, 1.2)

[D11]
n=9,750

Source: NHTSA TPSS, 2001

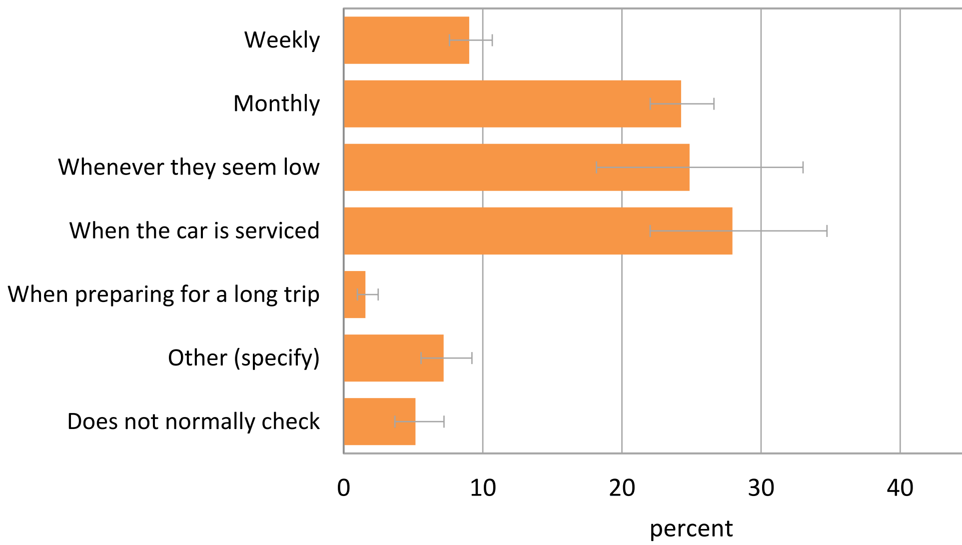
D11. Other (specify)

How do you normally check your tires for proper inflation? Other	Count
1	89
1.4	1
2	175
3	37
4	118
5	19
6	22
6 DOES NOT CARE	1
6 HUSBAND DOES IT	1
6 SLICK	1
6, AUTOMATIC	1
6,HOW TRUCK FEELS	1
DAD	1
DOES NOT CHECK	1
EVERY 3 MONTHS	1
FLEET	1
HAS LIGHT	1
HUSBAND	1
KICK	1
KICK EM	1
KICK THE TIRES	1
KICK/THUMB PUSH	1
KICKS TIRES	1

How do you normally check your tires for proper inflation? Other	Count
MECHANIC	2
NOT YET NEW CAR	1
OIL CHANGE	1
PAST EXPERIENCE	1
POUND W/ HAMMER	1
PRESS W/ FINGER	1
PUMP IT	1
ROTATION	1
SERVICE	2
SERVICE CENTER	2
SERVUCE STATION	1
SHOP	1
SIDEWALL PRESSURE	1
SOMEONE HELPS	1
SON DOES IT	1
SPOUSE	1
SQUEL NOISE WHEN TURNING	1
THEN USE S GUAGE FLOOK LO	1
TIRE SHOP	1
VIS AND PRESS	1
WORLD FORD	1
WOULD NOT ANSWER	1

D12. How often do you normally check your tires for proper inflation?

DOMAIN: Respondent is responsible for maintenance and/or is primary driver (n=10,339)



pct	95% C.I.
9.0	(7.6, 10.7)
24.3	(22.0, 26.6)
24.9	(18.2, 33.0)
27.9	(22.0, 34.7)
1.6	(1.0, 2.5)
7.2	(5.6, 9.2)
5.2	(3.7, 7.2)

[D12]
n=9,750

Source: NHTSA TPSS, 2001

D12. Other (specify)

How often do you normally check your tires for proper inflation? Other	Count
1	24
1 EVERY 2 MONTHS	1
2	85
2 WEEKS	1
2-3 MONTHS	1
2-3 WEEKS	1
2.3	1
3	152
3 MONTHS	2
3-4 MONTHS	1
3.4	1
3000 MILES	2
3000 MILES OR FELL LOW	1
3000 MILES SERVICE	1
3000 MILES WHEN BEING SER	1
304 MONTHS	1
4	118
5	7
6	89
6 3 MONTHS	1
6 2MONTHS	1
6 COUPLE X A YR	1
6 1 EVERY 6 MONTHS	1
6 1 YR	1

How often do you normally check your tires for proper inflation? Other	Count
6 2-3 TIMES YEAR	1
6 2/3 MONTHLY	1
6 2WEEKS	1
6 2X EVERY 3000 MLLES	1
6 2X YEAR	1
6 2X YEARLY	1
6 2X YR	1
6 2XYR	1
6 3000 MILES	1
6 3X A YEAR	1
6 3XYR	1
6 4-5 TIMES YR	1
6 4X A YR	1
6 4XYR.	1
6 ALL THE ABOVE	1
6 BI-MONTHLY	2
6 BIMONTHLY	1
6 BIWEEKLY	1
6 DAILY	3
6 EVERY 2 MONTHS	2
6 EVERY 3-4 MONTHS	1
6 EVERY 3000 MILES W/OIL	1
6 EVERY 3MONTHS	1
6 EVERY 6 MONTHS	1

How often do you normally check your tires for proper inflation? Other	Count
6 EVERY 8 MTHS	1
6 IF I GET A FLAT TIRE	1
6 MAINTAINCE LIGHT	1
6 MONTHS	9
6 ONCE 2 TEAR	1
6 ONCE TWICE YR	1
6 PER	1
6 TWICE YR	1
6 UNKNOWN	1
6 WEEKS	1
6 WHEN BUYING A TIRE	1
6 WHENEVER FILL UP W/GAS	1
6 YEARLY	2
6, 3000 MILES	1
6, AUTOMATIC	1
6, BIWEEKLY	1
6-8 WEEKS	1
6000 MILES	1
7	23
ALMOST NEVER	1
ANNUALLY	1
ASK OUR OPINION	1
AT 3000 MILES	1
AT GAS UP	1
BASED ON PERFORMANCE	1
BI - MONTHLY	1
BI - MONTHY	1
BI ANNUAL	4
BI MONTHLY	8
BI WEEKLY	15
BI-MONTHLY	6
BI-WEEKLY	9
BI-WWEKLY	1
BI/WEEKLY	1
BIMONTHLY	7
BIWEEKLY	5
BUILT IN MONITORING SYSTE	1
CHANGE OF SEASON	4
COUPLE MONTHS	2
COUPLE OF MONTHS	1
COUPLE OF TIMES A YEAR	2
COUPLE OF WEEKS	1
COUPLE TIMES A YEAR	1
COUPLE WEEKS	1
DAD DEPOSIT	1
DAILY	30
DAILY / VISUALLY	1
DEPENDING ON HOW OTHER US	1

How often do you normally check your tires for proper inflation? Other	Count
DEPENDS ON LOAD	1
DEPENDS ON WEATHER	2
DOES NOT KNOW	2
EVERY	1
EVERY OTHER MONTH	1
EVERY 1000 MILES	1
EVERY 1000 MILES SERVICE	1
EVERY 2	1
EVERY 2 DAYS	1
EVERY 2 HOURS	1
EVERY 2 MONTHS	34
EVERY 2 MOS	1
EVERY 2 OR 3 MONTHS	1
EVERY 2 WEEKS	22
EVERY 2-3 MONTHS	2
EVERY 2-3 MOS	1
EVERY 2-3 WEEKS	2
EVERY 2000 MI	1
EVERY 3 MONTH	2
EVERY 3 MONTHS	30
EVERY 3 OR 4 MOS.	1
EVERY 3 WEEKS	4
EVERY 3,000 MILES	1
EVERY 3-4 MONTHS	4
EVERY 3-5 MONTHS	1
EVERY 3.000	1
EVERY 3/4 MONTHS	1
EVERY 3000	3
EVERY 3000 MILES	8
EVERY 4 MONTHS	5
EVERY 4 TANKS OF GAS	1
EVERY 4-5 MONTHS	1
EVERY 5 OR 6 MOS.	1
EVERY 5500 MILES	1
EVERY 6 MONTHS	8
EVERY 6 WEEKS	3
EVERY 6 WEEKS + 4	1
EVERY 6000 MILES	1
EVERY 90 DAYS	1
EVERY COUPLE HUNDRED MILE	1
EVERY COUPLE MONTHS	5
EVERY COUPLE OF MONTHS	3
EVERY COUPLE OF WEEKS	2
EVERY COUPLE WEEKS	1
EVERY DAY	7
EVERY DAY ONE TIRE IS LEA	1
EVERY DAY WHEN I GET IN	1
EVERY FEW MONTHS	2

How often do you normally check your tires for proper inflation? Other	Count
EVERY FEWMONTHS	1
EVERY MORNING	1
EVERY OIL CHANGE	1
EVERY ONCEIN A WHILE	1
EVERY OTHER GAS UP	1
EVERY OTHER MONTH	7
EVERY OTHER WEEK	3
EVERY THREE MONTHS	1
EVERY TIME FILL UP	1
EVERY TWO MONTHS	1
EVERY TWO WEEKS	3
EVERYDAY	2
FEW MONTHLY	1
GETTING GAS	1
GWKS OR SO	1
HANDLING	2
HUSBAND	1
HUSBAND DOES	1
HUSBAND DOES IT	1
IT DEPENDS	1
JUST GOT CAR	1
MORE THAN 2 MONTHS	1
NOT ENOUGH	1
NOT OFTEN	3
NOT OFTEN ENOUGH	1
NOT SURE	2
NOT TOO OFTEN	1
NOT VERY OFTEN	1
OCCASIONALLY	2
OFF AND ON	1
OIL CHANGE	4
ONCE A YEAR	2
ONCE EVERY 2 MONTHS	1
ONCE EVERY 3 MONTHS	2
ONCE EVERY SIX MONTHS	1
ONCE IN A BLUE MOON	1
ONE A YEAR	1
ONE EVERY 3 WEEKS	1
OTHER PEOPLE DO IT	1
OTHER PERSON	1
OTHER PERSON CHECKS	1
PERIODICALLY	1
QUARTELY	1
QUARTERLY	6
RELATIVE OR FRIEND CHECKS	1

How often do you normally check your tires for proper inflation? Other	Count
ROTATE 6000 MILES	1
ROTATION	1
SEASONAL	1
SEATOWAL	1
SEMI ANNUAL	1
SEMI-MONTHLY	1
SHOP	1
SOMEONE ELSE SAYS	1
SON CHECKS	2
TEICE A YEAR	1
THREE MONTHS	2
TWICE A MONTH	3
TWICE A WEEK	4
TWICE A YEAR	7
TWICE MONTHLY	1
TWICE YEAR	1
UN KNOWN	1
UNK	1
UNKNOW	1
UNKNOWN	2
UNKNOWN HOW OFTEN	1
WEATHER CHANGE	1
WHEN ASKED	1
WHEN CAR IS SERVICED	1
WHEN DUMMY LIGHT GOES ON	1
WHEN EVER IT WOBBLES	1
WHEN HAULING HEAVY LOAD	1
WHEN I FEEL SOMETHING WRO	1
WHEN I THINK ABOUT IT	2
WHEN I YELL AT HIM ENOUGH	1
WHEN IT FEELS FUNY	1
WHEN IT SQUELS	1
WHEN RATATED	1
WHEN USED	1
WHEN WEIGHT IS ADDED	1
WHENEVER GASSING UP	1
WHERE STATION W/ WORKING	1
WHEREVER I STOP	1
WITH GASSING	1
WITH OIL CHANGE	1
WORLD FORD	1
WOULD NOT ANSWER	1
WRITE VEH RUNNING ROUGH	1
YEARLY	3
YEARLY (2)	1

End TPSS interview.

Appendix M. Survey Methods Comparison

The three tire surveys of 2001, 2010/2011, and 2018 were developed independently, with different goals, protocol, and variables. Understanding the key method points can help in comparing results and planning future surveys. compares key method and protocol items for the three surveys. Table M-1 compares key method and protocol items for the three surveys.

Table M-1. Comparison of NHTSA Tire-Related Vehicle Surveys, 2001-2018

Survey	Tire Pressure Special Study	TPMS Special Study	TPMS-ORRC Field Survey
When conducted	February 2001	Aug. 2010-April 2011	June-Nov. 2018
Primary focus/ reason for survey	Tire pressure, TREAD act, support NHTSA Rulemaking	Effectiveness of TPMS on tire pressure, evaluation of FMVSS No. 138	TPMS malfunction and miscalibration, follow-up to evaluation of FMVSS 138, FAST ACT, support NHTSA Rulemaking
Probability sample, weighted data	Yes	Yes	Yes
Sampling geographic areas used	The 24 nationwide sampling areas of the NASS CDS.	The 24 nationwide sampling areas of the NASS CDS.	The 24-PSU version of nationwide sampling areas of the CISS (successor to NASS CDS).
Data collection sites	Fuel stations	Fuel stations	Fuel stations
How data collectors worked	All NASS researchers worked only on TPSS in their PSU for same two week period	NASS researchers did cases in their PSU along with regular work over a 9-month period	Teams dedicated to survey traveled from PSU to PSU over a five month period
Achieved Sample Size	11,530 (10,881 with complete tire pressure)	6,503 (6,103 with complete tire pressure)	4,477 (after dropping three ineligible trucks)
Vehicle types	Light passenger vehicles	Light passenger vehicles	Light passenger vehicles
Model years admitted/ vehicle ages at time of survey	All model years admissible. The survey has tire pressure measurements from MY 1967 to 2001 (the newest at the time of the survey), ages 0-34 at the time of the survey.	MY 2004 to 2011 (the newest at time of survey), ages 0-7 at the time of the survey, to get a mix of similar vehicles with and without TPMS for the evaluation.	Vehicles compliant to FMVSS 138 (started MY 2006), so MY 2006 to 2019 (the newest at time of survey) were admissible, ages 0-13 at time of survey.

Survey	Tire Pressure Special Study	TPMS Special Study	TPMS-ORRC Field Survey
TPMS or non-TPMS admitted	No restriction on TPMS or not, but TPMS a rare option in the fleet at the survey time	TPMS and non-TPMS admitted, both types needed for comparative evaluation; FMVSS-compliant not a criterion	Only vehicles certified to FMVSS No. 138 admitted, determined via VIN scan and lookup tables in tablet.
Tire pressure taken	All vehicles	All vehicles	Indirect TPMS vehicles
TPMS indicator warnings recorded	No (TPMS was a rare option at the time)	No	Yes
Vehicle Identification Number (VIN)	Recorded, truncated to remove serial number	Recorded, truncated to remove serial number	Recorded, truncated to remove serial number
Drivers admitted	Any, but surveyed drivers were asked if they were primary driver or not, and responsible for maintenance or not; used in routing interview questions.	Any, and no distinction was made during interview.	Only primary driver or person responsible for maintenance was admitted, via driver screen-in questions.
How vehicles approached	Dedicated area at station with sign inviting drivers to get tire pressure taken.	Data collector discretion to approach vehicles any place in the station.	Approach all vehicles at a selected focal island, with a hierarchy if focal island empty. Approach, anywhere at station, all models known to have indirect TPMS.
Mileage collected	Not collected	Odometer reading	Odometer reading

Survey	Tire Pressure Special Study	TPMS Special Study	TPMS-ORRC Field Survey
TPMS presence and type identified in data/TPMS role in survey	No	TPMS presence and type were added during analysis via model year and fleet information. For interview routing, the driver was asked if vehicle had TPMS. If response was yes, they were asked to take the supplemental interview.	Only TPMS vehicles compliant to FMVSS No. 138 were surveyed. Compliance status and TPMS type were assigned during screening via the VIN scan and lookup tables in the tablet. Some survey routing depended on TPMS type.
Driver age collected	Age group assessed by data collector observation, 16-24,25-69,70+	Asked in interview, individual age recorded	Asked in interview, option to give age or age group, but recorded only as groups: under 18,18-25,26-35, 36-45,46-55,56-65,65+. Group also assessed by data collector observation during initial approach: under 25, 25-69, 70+
Ambient temperature	Recorded	Recorded	Recorded
General weather	Not recorded	Recorded, 6 categories	Recorded, 10 categories
Other tire variables collected	Tread depth, manufacturer, several others	Tread depth, manufacturer, model, size	Valve stems and caps material and condition, if direct TPMS
Other demographic and interview variables	All three surveys had driver interview components and some demographic elements recorded from observation or interview questions. The elements vary by survey.		

Appendix N. Knowledge Index

The steps shown below were used to derive the knowledge index used in Section 6.

1. [TPMSEQ], asked of all drivers: To your knowledge, is this vehicle equipped with a tire pressure monitoring system, known as TPMS,—whether or not it is currently working? Knowledge index score: Yes, 1 point; no or don't know, 0 points; missing, score missing.
2. [TPMSTYPE], asked of drivers who answered "yes" to [TPMSEQ], above: To your knowledge, is the TPMS system in this vehicle "direct," using sensors in the wheels, or "indirect," using sensors in the antilock braking system? Response matches known true TPMS type from [IND_TPMS], 1 point; response states incorrect type or don't know, 0 points; [TPMSEQ] was no or don't know, 0 points; [TPMSEQ] missing, score missing.
3. [TPMSDASH], asked of all drivers: Looking at these pictures – and allowing for minor variations in style – please point to those items that you have seen on your vehicle's dash at any time in the past, either when starting the engine or later when the vehicle was running. Select all that apply. [TPMSON], recorded in all cases: Inspector select all TPMS-related indicator lights or readouts visibly illuminated on the dash ON (II) position. Select all that apply. Driver and inspector matched a light, 1 point (includes driver selection of text light matches any of inspector's three versions of text light). No match, driver didn't refuse, and inspector saw a light, 0 points. Driver refused or inspector did not see any lights, score is missing. (Inspector-noted tape on dashboard is not a factor because in each case where tape was seen, TPMS light was also seen.)
4. [TPMSDASHA], asked of all drivers: (referring to [TPMSDASH]), what does this light/these lights mean to you? Related to tire pressure/TPMS, 1 point; other or don't know, 0 points; refused, score missing. (This is back-coded from respondent's verbal answer – options are not read to respondent, so shouldn't be biased; however, from earlier questions, drivers may surmise the answer to this.)
5. [AIR1], asked of all drivers in extended interviews: Where would you look to find the pressure required for correct inflation of the tires on this vehicle? Vehicle placard, 2 points; owner's manual, 1 point; any other response, 0 points; refused or missing, score missing. Note that the tire sidewall does not give recommended pressure, it gives maximum pressure (NHTSA, n.d.-a; Ashley, 2015), so does not get a point. Vehicle placard is considered higher than owner's manual because the vehicle placard is required, but the manual may or may not give the recommended pressure or may refer the owner to the placard.
6. [AIR2], asked of all drivers in extended interviews: Do you know how to inflate your tires to the correct pressure? Yes, 1 point; no or don't know, 0 points; missing, score missing.
7. [RESET1], asked of all drivers in extended interviews: Who would be able to reset the TPMS system in your vehicle when needed, such as after work has been done to the tires or wheels? Select all that apply. Select owner/driver or repair shop/dealer, 1 point. Not select those but select other or don't know, 0 points. Refused or missing, score missing.
8. [RESET2], asked of all drivers in extended interviews: What action is required to reset the TPMS system? Press a button, select option via vehicle's electronic menu, special tools are used by a repair shop/dealer, 1 point (assumes knowledge but true answer can vary by model). Not select any of those but select other or don't know, 0 points. Refused/missing, score missing.

The knowledge index is the sum of points scored in steps 1 to 8. If a component is missing, a score was not calculated.

Appendix O. Field Survey Tire Pressure Procedure

Tire pressure and temperature were taken for surveyed vehicles with functioning indirect TPMS if the driver gave permission. The teams were equipped with high-quality pressure gauges and pyrometers for use in tire pressure measurement. The procedure was as follows:

<u>Inspector:</u>

1. Enter tire size and pressure recommended by manufacturer; see driver-side door jamb/driver-side door post. if only one size is listed on the placard, then enter that size and pressure; if more than one tire size is listed on the placard, then enter all listed tire sizes and pressures on the placard (up to three allowed).
2. Enter actual tire size that most closely matches placard recommendation.
3. Using supplied tire pressure gauge, manually read the tire pressure from the identified tire.
4. Using the supplied pyrometer, manually capture the tire temperature from the identified tire.

<u>Tablet:</u>

1. Set the temperature adjustment to observed tire pressure as: adjusted pressure = observed pressure - [(observed temperature - 65) ∗ .1]
2. Set the lowest tire adjusted pressure value as the recorded value to represent the vehicle.
3. Set the internal calculation of TP_LOW (pressure is low) as:

   if ((recommended-recorded)/(recommended)>=.25 then set TP_LOW=01, else set TP_LOW=02.

The tablet calculations mean that a vehicle was recorded as having low pressure (severe underinflation) if at least one tire was underinflated by at least 25 percent (after adjusting for temperature), consistent with the TPMS threshold.

Appendix P. TPMS-ORRC Field Survey Specifications

The specifications for the computer-assisted personal interview (CAPI) surveys (inspection and interview) programmed for the TPMS-ORRC Field Survey are reproduced in this appendix.

United States Department of Transportation
National Highway Traffic Safety Administration

VEHICLE INSPECTION (CAPI)

Form Approved O.M.B. No. 2127-0626
Expiration Date: 02/16/2021

Tire Pressure Monitoring System – Outage Rates and Repair Costs

Paperwork Reduction Act Burden Statement

A federal agency may not conduct or sponsor, and a person is not required to respond to, nor shall a person be subject to a penalty for failure to comply with a collection of information subject to the requirements of the Paperwork Reduction Act unless that collection of information displays a current valid OMB Control Number. The OMB Control Number for this information collection is 2127-0626 (Expiration date: 02/16/2021). Public reporting for this collection of information is estimated to be approximately 10 minutes per response, including the time for reviewing instructions, completing and reviewing the collection of information. All responses to this collection of information are voluntary. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to: Information Collection Clearance Officer, National Highway Traffic Safety Administration, 1200 New Jersey Ave, S.E., Washington, DC, 20590. NHTSA Form 1273.

Formatting conventions:

Questionnaire item
///PROGRAMMING LOGIC///
Explanatory notes

Programmer Notes:

- *All variables are assumed to be numeric*
- *For SELECT ALL THAT APPLY items, create a series of variables with **_1**, **_2**, etc. appended to original variable name to indicate selection status of each response option*
- *For OTHER: SPECIFY items, create a new variable (length $ 256) with **_OTHER** appended to original variable name to hold open-end text*

Disposition Definitions:

- *61 = Completed inspection*
- *Create GPS variable to tag location of interview*

///PROGRAMMER: wirelessly transfer masterid to INTERVIEWER tablet via sync. DISPLAY sync button//

DAILY POP-UP PROMPT FOR INTERVIEWERS TO ENTER THE FOLLOWING INTO TABLET:
USERID
TEAM ID
PARTNER ID
PARTNER DEVICE ID
SITE ID
STATION ID

MODULE 1: ALL VEHICLES APPROACHED

///Set MASTERID to contain crew ID and timestamp to enable linking with Driver Interview///

DATE **[INTERNAL]**
TIME **[INTERNAL]**

SITEID **[1-24]**
TEAMID **[1-4]**
STATIONID

BODY_OBS **Body type of vehicle**
01. AUTO (INCLUDES SEDAN/WAGON/HATCHBACK)
02. SPORT UTILITY VEHICLE (SUV)
03. VAN (INCLUDES TRADITIONAL AND MINIVANS)
04. LIGHT TRUCK

MAKE_OBS **Make of vehicle**
01. AUDI
02. BMW
03. BUICK
04. CADILLAC
05. CHEVROLET
06. CHRYSLER
07. DODGE
08. FORD
09. GMC
10. HONDA
11. HYUNDAI
12. JEEP
13. KIA
14. LEXUS
15. MAZDA
16. MERCEDES
17. NISSAN

18. RAM
19. SUBARU
20. TOYOTA
21. VOLKSWAGEN
22. VOLVO
23. OTHER: SPECIFY
98. DON'T KNOW

LANG_OBS **Language spoken**
01. ENGLISH
02. SPANISH
03. OTHER
98. DON'T KNOW

AGE_OBS **Age of driver**
01. YOUNG ADULT (Up to 25)
02. ADULT (25-69)
03. SENIOR (70 and over)
98. DON'T KNOW

SEX_OBS **Sex of driver**
01. MALE
02. FEMALE
98. DON'T KNOW

OCCUPAD **Number of ADULT occupants (if ages are unclear, count all as adult)**
/RANGE 1-10/
98. DON'T KNOW

OCCUPCH **Number of CHILD occupants (if ages are unclear, count all as adult)**
/RANGE 1-10/
98. DON'T KNOW

DAMG_OBS **Is there damage to the vehicle?**
01. NONE VISIBLE (ALLOWING FOR PAINT SCRAPES, WINDOW ISSUES, WIPER ISSUES)
02. MINOR (E.G., DENTED FENDERS/BODY PANELS)
03. MAJOR (E.G., MAJOR DAMAGE TO HOOD, FRONT END, REAR END, DOORS THAT WOULD MAKE PARTS OF VEHICLE UNUSABLE)
98. DON'T KNOW

HITCH **Is the vehicle equipped with a rear hitch?**
01. YES
02. NO
98. DON'T KNOW

ELEC_OBS **Is the car a hybrid or electric?**
01. YES
02. NO

98. DON'T KNOW

END MODULE 1

SET DISPOSITION 61= "COMPLETE" IF MAKE_OBS – BODY_OBS IS ANSWERED IN MODULE 1 AND TPMSTAPE - EMAG IS ANSWERED IN MODULE 2

MODULE 2: IF DRIVER IS PARTICIPATING AND 2006<=MODELYEAR<=2016

///ASK ALL///
VINSCAN **CAPTURE MAKE, MODEL, YEAR INFORMATION**

Are you ready to read the image?
01 Yes
02 No

///ASK IF VINSCAN=01///
MY_BPILLAR1 **INSPECTOR: READ THE IMAGE WITH READER**
PROGRAMMER: ALLOW 17 alpha/numeric character
PROGRAMMER: DISPLAY BUTTON "I WANT TO USE CAMERA"
PROGRAMMER: RECORD ELAPSED TIME TO CAPTURE VIN; IF TIME<5 SECONDS THEN SET BARCODESCAN=1, ELSE SET BARCODESCAN=0; IF TIME>=5 SECONDS THEN SET MANVIN=1; ELSE SET MANVIN=0

///ASK IF INSPECTOR PRESSES "I WANT TO USE CAMERA" IN MY_BPILLAR1///
CAMERA **PROGRAMMER: ACTIVATE CAMERA TO READ VIN**
INSPECTOR: READ THE IMAGE

PROGRAMMER: SET MODELYEAR

- **IF INTERNET CONNECTION=YES**
  - **THEN SET MODELYEAR=vPicModelYear**
- **IF INTERNET CONNECTION=NO**
  - **THEN SET MODELYEAR = MODELYEAR EXTRACTED FROM 10^{TH} VIN CHARACTER IN MY_BPILLAR1;**
  - **IF MY_BPILLAR1 IS MISSING, THEN SET MODELYEAR = MODEL YEAR EXTRACTED FROM 10^{TH} VIN CHARACTER IN CAMERA;**
  - **IF MODELYEAR=06 OR 07, THEN SCREENOUT VEHICLE AS INELIGIBLE**

IND_TPMS **PROGRAMMER: SET IND_TPMS=01 (INDIRECT TPMS VEHICLE) IF VPIC MATCHES NHTSA look-up Table 3/Table 4, ELSE SET IND_TPMS=02**

//IF MODELYEAR < 2006 OR MODELYEAR > 2016//
INELIG **INSPECTOR INFORM INTERVIEWER: Vehicle is INELIGIBLE for an interview.**

01 CONTINUE

//IF 2006<=MODELYEAR<=2016 AND FMVSS 138 COMPLIANT//
ELIG **INSPECTOR INFORM INTERVIEWER: Vehicle is ELIGIBLE for an interview.**
AWAIT KEYS TO PERFORM DASH INSPECTION.

01 CONTINUE

//ASK IF ELIG=01//

TPMSTAPE **Has an attempt been made to cover up any indicator lights on the dash (e.g., with tape)?**
01. YES
02. NO

///IF ELIG=01, TURN KEY FROM LOCK (0) TO ON (II) POSITION AND PAUSE 5 SECONDS///

TPMSON **Select all TPMS-related indicator lights or readouts visibly illuminated on the dash (allowing for minor stylistic variations or differences in wording):**
[SELECT ALL THAT APPLY FROM GRAPHICAL GRID]

///VALIDATE: SELECTION OF "NONE VISIBLE" MEANS NO OTHER OPTIONS ARE SELECTED///

01. IMAGE: CROSS SECTION OF TIRE WITH EXCLAMATION POINT	**02. IMAGE: ICON SAYING "TPMS"**
03. IMAGE: OVERHEAD VIEW OF VEHICLE WITH NO TIRE PRESSURES	**04. IMAGE: OVERHEAD VIEW OF VEHICLE WITH TIRE PRESSURES**
05. WORDS ON DIGITAL READOUT: "CHECK {LEFT FRONT} TIRE PRESSURE"	**06. WORDS ON DIGITAL READOUT: "TIRE PRESSURE TOO LOW"**
07. WORDS ON DIGITAL READOUT: "TPMS SYSTEM MALFUNCTION"	
08. DASH OBSTRUCTED (e.g., tape, paper)	**09. CLEAR VIEW OF DASH, NO TPMS LIGHTS VISIBLE**

//ASK ALL IF ELIG=01//

WARN1 **Are ANY indicator lights (other than TPMS indicators) illuminated in ON (II) position?**
01. YES
02. NO
98. DON'T KNOW

///ASK ALL IF ELIG=01///

TPMSSTART **TURN KEY FROM ON (II) TO START (III) POSITION AND PAUSE 5 SECONDS**
Select all TPMS-related indicator lights or readouts visibly illuminated on the dash (allowing for minor stylistic variations or differences in wording):
[SELECT ALL THAT APPLY FROM GRAPHICAL GRID]

///VALIDATE: SELECTION OF "NONE VISIBLE" MEANS NO OTHER OPTIONS ARE SELECTED; SELECTION OF 01, 06, 07, 08 MEANS 02, 03, 04, 09 CANNOT BE SELECTED AND VICE VERSA///

01. Cross section of tire with exclamation point SOLID	**02. Cross section of tire with exclamation point FLASHING**
03. Icon saying "TPMS" SOLID	**04. Icon saying "TPMS" FLASHING**

05. Overhead view of vehicle with no tire pressures	**06. Overhead view of vehicle with tire pressures**
07. WORDS ON DIGITAL READOUT: "CHECK {LEFT FRONT} TIRE PRESSURE"	**08. WORDS ON DIGITAL READOUT: "TIRE PRESSURE TOO LOW"**
09. WORDS ON DIGITAL READOUT: "TPMS SYSTEM MALFUNCTION"	
10. DASH OBSTRUCTED (e.g., tape, paper)	**11. CLEAR VIEW OF DASH, NO TPMS LIGHTS VISIBLE**

//ASK ALL IF ELIG=01//

WARN2 **Are any other indicator lights (other than TPMS indicators) illuminated in START (III) position?**

01. YES
02. NO
98. DON'T KNOW

//ASK ALL IF ELIG=01; PROGRAMMER PUT THIS QUESTION ON THE SAME SCREEN AS WARN2//

ODOMETER **Odometer reading**

/RANGE 1-1,000,000/

- **IF TPMSON NE 9 AND TPMSSTART IN 2,3,4,9 THEN TPMSMALF=1; indicator(s) working @ ON, system malfunction @ START**
- **ELSE IF TPMSON NE 9 AND TPMSSTART IN 1,6,7,8 THEN TPMSMALF=2; indicator(s) working @ ON, low pressure only @ START**
- **ELSE IF TPMSON=9 AND TPMSSTART=11 THEN TPMSMALF=3; no TPMS indicator(s) @ ON, no TPMS indicator(s) @ START**
- **ELSE IF TPMSON NE 9 AND TPMSSTART=5,11 THEN TPMSMALF=4; indicator(s) @ ON, OK @ START**
- **ELSE TPMSMALF=5; status unclear**

PROGRAMMER: TRANSFER DATA TO INTERVIEWER TABLET ALONG WITH MODELYEAR AND IND_TPMS

INSPECTOR: If transfer does not work then communicate result to interviewer verbally or via pre-determined hand signal. DISPLAY DASH INSPECTION RESULT.

//ASK ALL IF ELIG=01//

EMAG **Does the vehicle contain visible equipment that could cause electromagnetic interference (e.g., radar detector)? [Toll collection tags do NOT count as electromagnetic interference equipment]**

01. YES
02. NO

///IF IND_TPMS=01 AND MALFCODE=02,04///

MANU_TSPR **VEHICLE INSPECTOR: ENTER TIRE SIZE AND PRESSURE RECOMMENDED BY MANUFACTURER; SEE DRIVER-SIDE DOOR JAMB/DRIVER-SIDE DOOR POST. IF ONLY ONE SIZE IS LISTED ON THE PLACARD, THEN ENTER THAT SIZE AND PRESSURE; IF MORE THAN ONE TIRE SIZE IS LISTED ON THE PLACARD, THEN ENTER ALL LISTED TIRE SIZES AND PRESSURES ON THE PLACARD.**

PROGRAMMER: ALLOW 2 NUMERIC CHARACTERS AND UP TO 3 TIRE SIZE AND PRESSURE ENTRIES

TSR_X //range 13-22//
TPR_X //range 30-40//

///IF IND_TPMS=01 AND MALFCODE=02,04///

ACT_TS_X **VEHICLE INSPECTOR: ENTER ACTUAL TIRE SIZE THAT MOST CLOSELY MATCHES PLACARD RECOMMENDATION.**

PROGRAMMER: ALLOW 2 numeric characters //range 13-22//

PROGRAMMER SET REC_TP_X (RECOMMENDED MANUFACTURER TIRE PRESSURE) BASED ON TIRE SIZE RECORDED IN ACT_TS_X AND TSR_X

PROGRAMMER PRESENT AERIAL GRAPHIC OF CAR AND TIRES AND HIGHLIGHT SELECTED TIRE INSPECTOR SELECT TIRE VIA LABEL

///IF IND_TPMS=02, LOOP: X = {LF, LR, RR, RF}///

STEMCON_X **Enter condition of valve stem on <u>X</u> tire.**

01. GOOD
02. POOR
03. NOT VISIBLE

///ASK IF STEMCON_X = 1,2, Not missing valve stem on X tire///

STEMMAT_X **Enter material of valve stem on <u>X</u> tire.**

01. RUBBER/PLASTIC
02. METAL
03. OTHER

///ASK IF STEMCON_X = 1,2, Not missing valve stem on X tire///

CAPCON_X **Enter condition of valve cap on X tire.**
01. GOOD
02. POOR
03. NONE VISIBLE

///ASK IF CAPCON_X = 1,2, Not missing valve cap on X tire///
CAPMAT_X **Enter material of valve cap on X tire.**
01. RUBBER/PLASTIC
02. METAL
03. OTHER

///ASK IF IND_TPMS=01 AND MALFCODE=02, 04 AND REC_TP_X<>MISSING///
TP_1-4
TP_x **INSPECTOR: (USING SUPPLIED TIRE PRESSURE GAUGE) MANUALLY READ THE TIRE PRESSURE FROM THE IDENTIFIED TIRE.**

PROGRAMMER: ALLOW 2 numeric characters //range 15-45//
----
99 NOT ENTERED

///ASK IF IND_TPMS=01 AND MALFCODE=02, 04 AND REC_TP_X<>MISSING///
TEMP_1-4
TEMP_x **INSPECTOR: (USING THE SUPPLIED PYROMETER) MANUALLY CAPTURE THE TIRE TEMPERATURE FROM THE IDENTIFIED TIRE.**

PROGRAMMER: ALLOW 3 numeric characters //range 020-150//
----
999 NOT ENTERED

///ASK IF TP_X<>MISSING AND TEMP_X<>MISSING///
TP_ADJ_X **PROGRAMMER: Temperature Adjustment to Observed Tire Pressure**
Adjusted pressure = TP_X - [(TEMP_X - 65) ∗ .1]

///ASK IF TP_ADJ_X<>MISSING///
TP_SET **PROGRAMMER: SET TIRE PRESSURE OF LOWEST TP_ADJ_X VALUE TO REPRESENT VEHICLE**

///ASK IF IND_TPMS=01 AND TP_SET <>MISSING///
TP_LOW **INTERNAL CALCULATION TO COMPARE REC_TP_X AND TP_SET.**
IF ((REC_TP_X-TP_SET)/(REC_TP_X)>=.25 THEN SET TP_LOW=01, ELSE SET TP_LOW=02

///END LOOP///

//ASK ALL IF ELIG=01//
SPARE **Does the vehicle appear to have one or more spare tires (mini- or full-size) or non-matching wheels installed?**
01. YES

02. NO

END MODULE 2

MODULE 3

/// ASK ALL///

CHK_RECALL1 Would you like the details of any open recalls on your vehicle?

01 YES

02 NO

///ASK IF CHK_RECALL1=01//

CHK_RECALL2. PROGRAMMER: DISPLAY RECALL RESULTS FROM NHTSA.GOV/RECALLS INSPECTOR: REPORT AND/OR DISPLAY RECALL RESULTS TO RESPONDENT; IF DISPLAY DOESN'T WORK THEN HAND DRIVER THE WALLET CARD WITH INFO ON ACCESSING RECALL DETAILS

//ASK IF IND_TPMS=01 AND TP_LOW=01 (AIR PRESSURE MEASURED 25+% BELOW PLACARD PRESSURE VEHICLE INSPECTION)//

AIR_LOW When we checked the tire pressure in your tires, they were under-inflated according to the manufacturer recommendations for this vehicle.

01 continue

END MODULE 3

DRIVERS INTERVIEW (CAPI)

Form Approved O.M.B. No. 2127-0626
Expiration Date: 02/16/2021

United States Department of Transportation
National Highway Traffic Safety Administration

Tire Pressure Monitoring System
Outage Rates and Repair Costs

Paperwork Reduction Act Burden Statement

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Formatting conventions:

Questionnaire item
///PROGRAMMING LOGIC///
Explanatory notes

Programmer Notes:

All variables are assumed to be numeric
For SELECT ALL THAT APPLY items, create a series of variables with _1, _2, etc. appended to original variable name to indicate selection status of each response option
Create variable "CURRYEAR" to equal the 4-digit year when survey is administered
Create variable "VAGE" to represent age of vehicle where VAGE=CURRYEAR – MODELYEAR; IF VAGE <0, SET VAGE=0
Create GPS variable to tag location of interview

Disposition Definitions:

22 = Refusal at MY_RECALL1
23 = Refusal at MY_RECALL2
24 = Refusal at Primary Driver/Upkeep
25 = Driver already participated in this survey
26 = Refusal at INTRO1A
27 = Screen Out: Rental/Zipcar
28 = Refusal at Rental
29 = Screen Out: Model year/not FMVSS 138 compliant
30 = Refused dash inspection
31 = Screen Out: Primary driver/upkeep not with respondent
32 = Screen Out: Could not speak to primary driver/upkeep
33 = Refusal after transfer
34 = Screen Out: Unable to locate primary driver/upkeep after transfer
35 = Refused or unable to collect VIN

38 = End Survey (app button), terminated early
61 = Complete: Phase-in vehicle, TPMS reported to be disabled
63 = Complete: Post-phase-in vehicle, TPMS reported to be disabled
64 = Complete: Post-phase-in vehicle, no lights, not reported as disabled

66 = Complete: TPMS system malfunction
67 = Complete: TPMS low pressure
68 = Complete: TPMS functioning properly
71 = At Quota: Phase-in vehicle, TPMS reported to be disabled
73 = At Quota: Post-phase-in vehicle, TPMS reported to be disabled
74 = At Quota: Post-phase-in vehicle, no lights, not reported as disabled
76 = At Quota: TPMS system malfunction
77 = At Quota: TPMS low pressure
78 = At Quota: TPMS functioning properly

PROGRAMMER: DISPLAY END SURVEY BUTTON ON SCREENS. IF SELECTED, DISPLAY:

"I won't have any further questions for you today. Thanks for your time."

DAILY POP-UP PROMPT FOR INTERVIEWERS TO ENTER THE FOLLOWING INTO TABLET:
USERID
TEAM ID
PARTNER ID
PARTNER DEVICE ID
SITE ID
STATION ID

MODULE INTRO

///Scan or enter MASTERID generated by INSPECTOR to sync this interview with Vehicle Observation data///

SITE ID [1-24]
TEAM ID [1-4]
STATIONID

INTRO1A **Hello. I'm _____ and we are doing a survey related to vehicle safety for the US Department of Transportation. Would you spend a few minutes answering some questions about your dashboard displays and letting us check the make, model, and model year? It will only take a few minutes. To thank you for participating, we are offering to check whether your vehicle has any open manufacturer recalls.**
[INTERVIEWER: CONTINUING WITH INTERVIEW?]
01. YES
02. NO
03. DRIVER ALREADY PARTICIPATED IN THIS SURVEY

///IF INTRO1A=2 SKIP TO SCREEN7: THEN SET DISPO=26, Refusal at INTRO1A///
///IF INTRO1A=3 SKIP TO END: SET DISPO=25, Driver already participated in this survey

///IF INTRO1A=01///
MY_RECALL1 **First, what is the model year of this vehicle?**
[IF NECESSARY: The year the vehicle was made.]
[IF NECESSARY: Your best guess about the year.]
DISPLAY BUTTONS FOR YEARS
01 BEFORE 2006
06 – 18 /SEPARATE BUTTONS FOR EACH YEAR /2006 – 2018/
9998 DON'T KNOW
9999 REFUSED

///IF MY_RECALL1=9999, SKIP TO SCREEN7; THEN SET DISPO=22, Refusal at MY_RECALL1///

///ASK IF MY_RECALL1=9998, Don't know exact model year///
MY_RECALL2 **Is the model year of this vehicle 2006 or later?**
01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///IF MY_RECALL2=99, SKIP TO SCREEN7; THEN SET DISPO=23, Refusal at MY_RECALL2///

///IF ((MY_RECALL1=01 OR 2017 OR 2018) OR (MY_RECALL2=02)), SET DISPO=29, Screen Out: Model year/not FMVSS 138 compliant

SCREEN9 **It appears your vehicle is not eligible for our survey. I won't have any further questions for you today. Thanks for your time.**

IF ASKED: We're only surveying model year 2006-2016 vehicles that meet Federal Motor Vehicle Safety Standard 138.

INTERVIEWER: Communicate to INSPECTOR that case screened out///

///ASK IF MY_RECALL1=2006-2016,9998 OR MY_RECALL2=01,98///

RENTAL **Is this vehicle a short-term rental or part of a car sharing service, such as a Zipcar? [INTERVIEWER: SHORT-TERM=1 MONTH OR LESS; CAR-SHARE=SHORT_TERM HOURLY RENTAL]**

01. YES
02. NO
99. REFUSED

///IF RENTAL=99, SKIP TO SCREEN7; THEN SET DISPO=28, Refusal at Rental/Zip car///

///ASK IF RENTAL=1, Vehicle is rental/Zipcar, SET DISPO==27, Screened out: Rental/Zip car///

SCREEN1 **I won't have any further questions for you today, since we're only surveying vehicles that are owned or leased. Thanks for your time.**

01. CONTINUE

///ASK IF MY_RECALL1>01 OR MY_RECALL2=01///

PRIM1A **Are you the main driver of this vehicle?**
[IF NECESSARY: Are you the person who drives this vehicle most frequently?]

01. YES
02. NO
99. REFUSED

///ASK IF MY_RECALL1>01 OR MY_RECALL2=01///

PRIM1B **Are you mainly responsible for having this vehicle repaired or serviced, other than just refueling?**

01. YES
02. NO
99. REFUSED

///ASK IF PRIM1A=2 AND PRIM1B=2, Respondent is not primary driver and not primary for upkeep///

PRIM1C **Is the main driver of this vehicle, or the person responsible for its upkeep, here with you?**

01. YES
02. NO
99. REFUSED

///ASK IF PRIM1C=1///

PRIM1D **May I speak with that person?**
[IF NECESSARY: I need to talk in-person.]

01. YES
02. NO
99. REFUSED

///IF PRIM1A=99 OR PRIM1B=99 OR PRIM1C=99 OR PRIM1D=99, SKIP TO INTRO2; THEN SET DISPO=24, Refused Primary Driver/Upkeep///

///ASK IF PRIM1D=1///

INTRO1B **Hello. I'm _____ and we are doing a survey related to vehicle safety for the US Department of Transportation. Would you spend a few minutes answering some questions about your dashboard displays and letting us check the make, model, and model year? It will only take a few minutes. To thank you for participating, we are offering to check whether your vehicle has any open manufacturer recalls.**
[INTERVIEWER: CONTINUING WITH INTERVIEW?]

01. YES
02. NO

///ASK IF INTRO1B=1///

PRIM2A **Are you the main driver of this vehicle?**
[IF NECESSARY: Are you the person who drives this vehicle most frequently?]

01. YES
02. NO
99. REFUSED

///ASK IF INTRO1B=1///

PRIM2B **Are you mainly responsible for having this vehicle repaired or serviced, other than just refueling?**

01. YES
02. NO
99. REFUSED

///IF INTRO1B=2 OR PRIM2A=99 OR PRIM2B=99, SKIP TO SCREEN7: THEN SET DISPO=33, Refusal after transfer///

SET VARIABLE PRIM=01 IF PRIM1A=01 OR PRIM1B=01 OR PRIM2A=01 OR PRIM2B=01, ELSE SET PRIM=02

///IF PRIM=01, Located PRIMARY respondent ///

MY_VIN1 **Ok, to start my partner will get some basic information from the door jamb. If your vehicle is eligible for our survey we will then check your vehicle's dash to see what lights are coming on.**

[INTERVIEWER: INSTRUCT INSPECTOR TO OBTAIN MAKE, MODEL, YEAR AS AUTHORIZED BY THE DRIVER. EXPLAIN IF NECESSARY: we're checking the make, model, and year information. No private information will be stored in my system.]

[Training note: *Pause to provide educational materials and allow respondent to begin refueling vehicle as soon as ignition test is complete*.]

01. Continue
99. Refused

***********INSPECTOR PROCEEDS TO CAPTURE VIN************

///IF PRIM=01///

ELIG **INTERVIEWER: ENTER ELIGIBILITY STATUS FROM INSPECTOR SCAN**

01 ELIGIBLE

02 INELIGIBLE

///IF ELIG=02///

SCREEN2 **It appears your vehicle is ineligible. I won't have any further questions for you today. Thanks for your time.**

IF ASKED: We're only surveying model year 2006-2016 vehicles that meet Federal Motor Vehicle Safety Standard 138.

01. CONTINUE

///IF ELIG=02//

SKIP TO END: SET DISPO=29, SCREENED OUT: Model year/NOT FMVSS 138 COMPLIANT

///ASK IF ELIG=01, Eligible Vehicle///

DASHINT1 **Your vehicle is eligible for our survey. Let's quickly check your vehicle's dash TOGETHER to see what lights are coming on. To do that we need the car key. Afterward, you can fuel your car while we finish the survey.**
[Training note: *Pause to provide educational materials and allow respondent to begin refueling vehicle as soon as ignition test is complete*.]

01 CONTINUE

99 REFUSED

///IF DASHINT1=99 SKIP TO SCREEN7: THEN SET DISPO=30, Refused dash inspection///

///IF DASHINT1=01///

DASHTRANS. **INTERVIEWER PLEASE WAIT FOR WIRELESS TRANSFER OF DASH INSPECTION; PRESS "MANUAL ENTRY" IF WIRELESS TRANSFER DOES NOT WORK**

///ASK IF DASHINT1=01///

MYINDMAL_SCAN **PROGRAMMER: DISPLAY CODE AND RESULT TRANSFERRED FROM INSPECTOR TABLET [CONTAINS MODEL YEAR, INDIRECT TPMS CODE, AND DASH INSPECTION CODE]**

MY_SCAN //STORE 2-digit MODEL YEAR//

IND_SCAN //STORE 2-digit IND_TPMS VALUE WHERE 01=INDIRECT AND 02=DIRECT//

MALFCODE_SCAN //STORE 2-digit MALFCODE VALUE WHERE

01. INDICATOR(S) @ ON, SYSTEM MALF @ START
02. INDICATOR(S) @ ON, LOW PRESSURE ONLY @ START
03. NO INDICATOR(S) @ ON, NO INDICATOR(S) @ START
04. INDICATOR(S) @ ON, NO INDICATOR(S) @ START
05. STATUS UNCLEAR

PROGRAMMER: SET SCANSTAT=1 IF SUCCESSFUL SCAN, ELSE SET SCANSTAT=2

//IF SCANSTAT=02, FAILED TO TRANSFER CODE FROM INSPECTOR TABLET//
MYINDMAL_MAN INTERVIEWER: ENTER MODEL YEAR, INDIRECT TPMS CODE, AND DASH INSPECTION CODE REPORTED BY INSPECTOR

MY_MAN //ENTER 2-digit MODEL YEAR//
IND_MAN //ENTER 2-digit IND_TPMS VALUE WHERE 01=INDIRECT AND 02=DIRECT
MALFCODE_MAN //ENTER 2-digit MALFCODE VALUE WHERE

01. INDICATOR(S) @ ON, SYSTEM MALF @ START
02. INDICATOR(S) @ ON, LOW PRESSURE ONLY @ START
03. NO INDICATOR(S) @ ON, NO INDICATOR(S) @ START
04. INDICATOR(S) @ ON, NO INDICATOR(S) @ START
05. STATUS UNCLEAR

//IF MY_MAN, IND_MAN, MALFCODE_MAN<>MISSING//
MYINDMAL_CFRM PROGRAMMER: DISPLAY MY_MAN, IND_MAN, MALFCODE_MAN ENTERED BY INTERVIEWER

INTERVIEWER: REPORT CODES TO INSPECTOR FOR MATCH CONFIRMATION

Do your codes match the vehicle inspector code?
01 YES
02 NO [GO BACK TO MYINDMAL_MAN]

///IF MODELYEAR NOT SET SKIP TO SCREEN7: THEN SET DISPO=35, REFUSED OR UNABLE TO COLLECT VIN///

///MODELYEAR TARGET TO BE MONITORED AND ADJUSTED BASED ON FIELD EXPERIENCE///

MINIMA SAMPLE SIZES [REQUIRED SAMPLE FLOOR]

Model Year	Car	LTV
2006-2008	300	300
2009-2011	300	300
2012-2014	300	300
2015-2016	300	300

///PROGRAMMER CREATE VARIABLE MALFCODE///

01. INDICATOR(S) @ ON, SYSTEM MALF @ START
   a. **IF MALFCODE_SCAN=01 OR MALFCODE_MAN=01, SET MALFCODE=01**
02. INDICATOR(S) @ ON, LOW PRESSURE ONLY @ START
   a. **IF MALFCODE_SCAN=02 OR MALFCODE_MAN=02, SET MALFCODE=02**
03. NO INDICATOR(S) @ ON, NO INDICATOR(S) @ START
   a. **IF MALFCODE_SCAN=03 OR MALFCODE_MAN=03, SET MALFCODE=03**
04. INDICATOR(S) @ ON, NO INDICATOR(S) @ START
   a. **IF MALFCODE_SCAN=04 OR MALFCODE_MAN=04, SET MALFCODE=04**
05. STATUS UNCLEAR
   a. **IF MALFCODE_SCAN=05 OR MALFCODE_MAN=05///**

At this point, the primary driver or upkeeper has been located (if not original respondent) and agreed to participate (confirmed within-range model year and agreed to dash inspection); all others have screened out.

///ASK IF ELIG=01, Eligible Vehicle///

TPMSEQ **To your knowledge, is this vehicle equipped with a tire pressure monitoring system, known as TPMS,—whether or not it is currently working?**

01. YES
02. NO
98. DON'T KNOW
99. **REFUSED**

///ASK IF TPMSEQ=1, Respondent reports vehicle is equipped with TPMS///

TPMSTYPE **To your knowledge, is the TPMS system in this vehicle "direct", using sensors in the wheels, or "indirect", using sensors in the anti-lock braking system?**

01. DIRECT
02. INDIRECT
98. DON'T KNOW
99. **REFUSED**

///ASK IF DASHINT=01, Continuing with interview, Located eligible respondent ///

TPMSDASH **Looking at these pictures – and allowing for minor variations in style – please point to those items that you have seen on your vehicle's dash at any time in the past, either when starting the engine or later when the vehicle was running.**
[INTERVIEWER: SHOW RESPONDENT IMAGES OF TPMS SYMBOLS]

01. IMAGE: CROSS SECTION OF TIRE WITH EXCLAMATION POINT	**02. IMAGE: ICON SAYING "TPMS"**
03. IMAGE: OVERHEAD VIEW OF VEHICLE WITH NO TIRE PRESSURES	**04. IMAGE: OVERHEAD VIEW OF VEHICLE WITH TIRE PRESSURES**
05. WORDS ON DIGITAL READOUT: "CHECK {LEFT FRONT} TIRE PRESSURE"	**06. NONE**

///ASK IF DASHINT=01, Located eligible respondent **///**

TPMSDASHA **What does this light/these lights mean to you? [INTERVIEWER: BACKCODE RESPONSE; IF NECESSARY, ASK WHAT LIGHT(S) MEANS WITH REGARD TO SPECIFIC VEHICLE SYSTEMS]**

01. RELATED TO TIRE PRESSURE/TPMS
02. OTHER
98. DON'T KNOW
99. REFUSED

///ASK IF DASHINT=01, Located eligible respondent///

NEXTVEH **How important is it to you that your next personal vehicle be equipped with a TPMS system? Would you…**

01. Strongly prefer the vehicle be equipped with TPMS?
02. Somewhat prefer the vehicle be equipped with TPMS?
03. Have no preference whether the vehicle is equipped with TPMS?
04. Somewhat prefer the vehicle NOT be equipped with TPMS?
05. Strongly prefer the vehicle NOT be equipped with TPMS?
98. DON'T KNOW
99. REFUSED

///ASK IF ELIG=01 AND TPMSEQ=1,2,98,99 AND (MALFCODE IN 3, 5), Eligible vehicle but no indicator lights @ ON///

DISABLE2 **Based on the model year of your vehicle, it should have been manufactured with a TPMS system, but during our vehicle inspection we were not able to confirm that your vehicle has a functioning TPMS system. Has the TPMS system in this vehicle been disabled?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF
(MALFCODE =02,04 AND IND_TPMS=02 AND NUMBER OF COMPLETES WITH (DISPO 67, 68) >= 350)
///

SCREEN6 **I won't have any further questions for you today. Thanks for your time.**

01. CONTINUE

///IF MALFCODE=02 OR 04 AND IND_TPMS=02 AND (MODELYEAR>=2006) THEN SELECT EVERY VEHICLE FOR EXTENDED INTERVIEW, ELSE IF MALFCODE=02 OR 04 AND IND_TPMS=02 AND (MODELYEAR>=2006) AND (DISPO 67+DISPO 68=350) THEN SKIP TO INTRO2 AND SET SUBGROUP2STOP=1///

SET 2 DAYPARTS: 8 A.M. – 12P.M.; 12:01 P.M.-5 P.M.

SUBGROUP 1: DIRECT TPMS (MALFUNCTION/DISABLED)
SUBGROUP 2: DIRECT TPMS (LOW PRESSURE, OK)
SUBGROUP 3: INDIRECT TPMS (LOW PRESSURE, OK]
SUBGROUP 4: INDIRECT TPMS (MALFUNCTION/DISABLED)

SET SUBGROUP1STOP=0, ELSE SET SUBGROUP1STOP=1, WHERE 0=NO AND 1=YES
SET SUBGROUP2STOP=0, ELSE SET SUBGROUP2STOP=1, WHERE 0=NO AND 1=YES
SET SUBGROUP3STOP=0, ELSE SET SUBGROUP3STOP=1, WHERE 0=NO AND 1=YES
SET SUBGROUP4STOP=0, ELSE SET SUBGROUP4STOP=1, WHERE 0=NO AND 1=YES
SET DP1STOP=0, ELSE SET DP1STOP=1, WHERE 0=NO AND 1=YES
SET DP2STOP=0, ELSE SET DP2STOP=1, WHERE 0=NO AND 1=YES

EXTENDED INTERVIEWS DIVIDED AS FOLLOWS

1. **TPMS MALFUNCTIONS/DISABLED [SUBGROUP 1 OR SUBGROUP 4]**
    a. **MALFCODE=1 =MALFUNCTION**
    b. **MALFCODE=(3 OR 5) AND (DISABLE2=1) =DISABLED**
    c. **MALFCODE=3 AND DISABLE2 IN (02,98,99) =MALFUNCTION**
    d. **SELECT 100% OF THESE RECORDS FOR EXTENDED INTERVIEW**
        i. **PROGRAM "HOOKS" TO ALTER 100% SELECTION IF FIELD EXPERIENCE PROJECTS TOO MANY CASES**
2. **DIRECT TPMS OK [SUBGROUP 2]**
    A. **MALFCODE=2 OR 4 AND IND_TPMS=02**
    B. **COLLECT 350 INTERVIEWS SPLIT AMONG 24 PSUS**
    DIVIDE INTERVIEWS BETWEEN TEAM 1 AND TEAM 2 AT EACH PSU
    350/24 = 15 PER PSU
    15/2 = 7.5 PER CREW PER PSU…..CALL IT 7 TO 8

		DAY OF WEEK			
		WED	THURS	FRI	SAT
DAYPARTS	A.M.	1	NOTE 1	1	1
	P.M.	1	1	1	1
NOTE 1 = ONE CREW HAS 1, THE OTHER ZERO, AT ½ THE PSUS. AT THE OTHER HALF, DO THIS 0-1 IN THE PM					

3. **INDIRECT TPMS OK [SUBGROUP 3]**
    a. **MALFCODE=2 OR 4 AND IND_TPMS=01**
    b. **SELECT 100% OF THESE RECORDS FOR EXTENDED INTERVIEW**
        i. **PROGRAM "HOOKS" TO ALTER 100% SELECTION IF FIELD EXPERIENCE PROJECTS TOO MANY SUBGROUP 3 CASES**

Respondents continuing past this point will be given an extended interview.

///ASK IF MALFCODE=1,2,4, Indicator lights on @ ON///
INTRO1C **The remaining questions will focus on the results on our dash inspection.**
01. CONTINUE

///IF DISABLE2=1 SKIP TO MODULE DISABLED///

///IF DISABLE2=2,98,99 SKIP TO MODULE MALFUNCTION #3///

///IF MALFCODE=1 SKIP TO MODULE MALFUNCTION #1///

///IF MALFCODE=2 AND IND_TPMS=02 SKIP TO MODULE MALFUNCTION #2///

///IF MALFCODE=4 AND IND_TPMS=02 SKIP TO MODULE PAST MALFUNCTION #1///

END MODULE INTRO

MODULE INDIRECT: IF IND_TPMS=01 AND MALFCODE=2 OR 4

This module is entered by any respondents who are driving a vehicle with an indirect TPMS system that is FMVSS-compliant and is not malfunctioning or disabled.

///ASK IF IND_TPMS=01 AND MALFCODE=2 OR 4///

IND_CHK **When was the last time you used a pressure gauge to check the tire pressure in the tires on this vehicle?**

01. TODAY
02. IN THE PAST WEEK
03. IN THE PAST MONTH
04. MORE THAN A MONTH AGO
05. NEVER
98. DON'T KNOW
99. REFUSED

IND_TPMS=01///

IND_RECB **Did you know that the Tire Pressure Monitoring System on this vehicle needs to be recalibrated on occasion?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF IND_RECB=01///

IND_AWARE **Are you aware that you can recalibrate the Tire Pressure Monitoring System yourself?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF IND_AWARE=01///

IND_KNOW **Do you know how to recalibrate your Tire Pressure Monitoring System?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///IF IND_KNOW=01, 98, 99, ASK//

IND_MRECB **Have you ever recalibrated your Tire Pressure Monitoring System on this vehicle in the past?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///IF IND_MRECB=1///

IND_RCBY **Which of the following were reasons that you recalibrated this vehicle's Tire Pressure Monitoring System?**

INTERVIEWER: READ EACH ITEM AND PAUSE TO SELECT EACH ITEM THAT APPLIES BEFORE READING NEXT ITEM

IND_RCBY_1	**After tire replacement or rotation**
IND_RCBY_2	**After changing between winter / summer tires**
IND_RCBY_3	**If the TPMS warning light stayed on after start**
IND_RCBY_4	**After checking tire pressure and/or adding air to tires**
IND_RCBY_5	**After vehicle service performed by dealership, gas station, or repair facility**
IND_RCBY_6	**After you serviced your vehicle**

///ASK ALL///

IND_SVC **If you have had this vehicle serviced or have had the tires changed, did the facility or dealership recalibrate your Tire Pressure Monitoring System?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

//SKIP TO MODULE PAST MALFUNCTION #1//

MODULE DISABLED: IF DISABLE2=1

This module is entered by any respondents who report that the TPMS system in their vehicle was disabled.

///ASK IF DISABLE2=1///

DIS_OTH2 **Who disabled the TPMS system in this vehicle?**

01. RESPONDENT
02. MECHANIC/REPAIR FACILITY
03. FRIEND
04. RELATIVE
05. OTHER
98. DON'T KNOW
99. REFUSED

///ASK IF DISABLE2=1///

DIS_HOW **What was done to disable the TPMS system in this vehicle? [SELECT ALL THAT APPLY]**

01. REMOVED TIRE PRESSURE SENSORS
02. MODIFIED BRAKE SYSTEM/WHEELSPEED SENSORS
03. DISABLED ON-BOARD COMPONENTS
04. PULLED BULB OR FUSE
05. COVERED UP DASH LIGHT
06. OTHER
07. NOTHING
98. DON'T KNOW
99. REFUSED

///ASK IF DISABLE2=1///

DIS_COST **How much did it cost to disable the TPMS system? [INTERVIEWER: PROBE FOR NEAREST WHOLE NUMBER VALUE]**

01. $0.00
02. $1 - $49
03. $50 - $99
04. $100 - $299
05. $300 - $499
06. $500 - $999
07. $1,000 OR MORE
98. DON'T KNOW
99. REFUSED

///ASK IF DISABLE2=1///

DIS_WHY **What was the primary reason you decided to disable the TPMS system in this vehicle?**

[INTERVIEWER: BACKCODE]

01. TO GET THE DASH WARNING LIGHTS TO TURN OFF
02. TPMS IS NOT NECESSARY FOR VEHICLE OPERATION
03. TPMS WAS FAULTY/INACCURATE
04. TPMS WAS DISTRACTING/IRRITATING
05. TPMS IS TOO EXPENSIVE TO MAINTAIN/REPAIR
06. OTHER
98. DON’T KNOW
99. REFUSED

/// SKIP TO MODULE PAST MALFUNCTION #1 ///

END MODULE DISABLED: IF DISABLE2=1

MODULE MALFUNCTION #1: IF MALFCODE =1

This module is entered by respondents experiencing TPMS Malfunction #1: TPMS System Malfunction indicator is currently illuminated.

///ASK IF MALFCODE =1///

MALF1AW1 Are you aware that a TPMS dash light is currently on in your vehicle?

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF MALF1AW1=1///

MALF1AW1A What does this light mean to you? [INTERVIEWER: BACKCODE RESPONSE; IF NECESSARY, ASK WHAT LIGHT MEANS WITH REGARD TO SPECIFIC VEHICLE SYSTEMS]

01. LOW TIRE PRESSURE
02. TPMS MALFUNCTION
03. OTHER
98. DON'T KNOW
99. REFUSED

///ASK IF MALF1AW1=1, Aware that TPMS Malfunction light is on///

MALF1AW2 How long has this malfunction light been on? If the light has been turning on and off intermittently, please think back to the first time you noticed that the light was on.

01. LESS THAN 1 WEEK
02. 1 – 2 WEEKS
03. 3 – 4 WEEKS
04. 1 – 6 MONTHS
05. 7 – 12 MONTHS
06. MORE THAN 1 YEAR
98. DON'T KNOW
99. REFUSED

///ASK IF MALF1AW1=1, Aware that TPMS Malfunction light is on///

MALF1AF1A Did any of the following events occur shortly before the TPMS system malfunction light came on? [INTERVIEWER: PAUSE AFTER EACH ITEM TO COLLECT "YES" OR "NO" RESPONSE]
[SELECT ALL THAT APPLY]

01. The tires were rotated
02. Specialty (e.g., seasonal or off-road) tires were switched out
03. One or more new tires or wheels were installed or replaced
04. One or more tire stems were installed or replaced
05. One or more tire pressure sensors were installed or replaced
06. Work was performed on the braking system
07. Work was performed to on the on-board computer system
08. The vehicle was involved in an accident
09. The vehicle experienced an extended period of flooding / snow
10. Anything else?
11. NONE OF THE ABOVE
98. DON'T KNOW

99. REFUSED

///ASK IF MALF1AW1=2,98,99, Not aware that TPMS Malfunction light is on///

MALF1AF1B **Did any of the following events occur recently? [INTERVIEWER: PAUSE AFTER EACH ITEM TO COLLECT "YES" OR "NO" RESPONSE]**
[SELECT ALL THAT APPLY]

01. The tires were rotated
02. Specialty (e.g., seasonal or off-road) tires were switched out
03. One or more new tires or wheels were installed or replaced
04. One or more tire stems were installed or replaced
05. One or more tire pressure sensors were installed or replaced
06. Work was performed on the braking system
07. Work was performed to on-board computer system
08. The vehicle was involved in an accident
09. The vehicle experienced an extended period of flooding / snow
10. Anything else?
11. NONE OF THE ABOVE
98. DON'T KNOW
99. REFUSED

///ASK IF MALF1AF1A=4,5 OR MALF1AF1B=4,5, Tire stems/sensors replaced///

MALF1AF2 **Did you install or replace the tire stems or tire pressure sensors yourself?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF MALF1AF1A=4,5 OR MALF1AF1B=4,5, Tire stems/sensors replaced///

MALF1AF3 **How much did this work cost? [INTERVIEWER: PROBE FOR NEAREST WHOLE NUMBER VALUE]**

01. $0.00
02. $1 - $49
03. $50 - $99
04. $100 - $299
05. $300 - $499
06. $500 - $999
07. $1,000 OR MORE
98. DON'T KNOW
99. REFUSED

///ASK IF MALF1AW1=1, Aware that TPMS Malfunction light is on///

MALFIX1 **Has anyone explained to you what needs to be done to make the malfunction light turn off?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF MALFIX=1, Someone explained how to correct malfunction///

MALFIX2 **Who explained this to you?**
[INTERVIEWER: SELECT ALL THAT APPLY]

01. RELATIVE/FRIEND/COLLEAGUE
02. DEALERSHIP/AUTO REPAIR SHOP/MECHANIC
03. OWNER'S MANUAL
04. OTHER BOOK, MAGAZINE, OR ARTICLE
05. TV OR RADIO
06. INTERNET
07. SOCIAL MEDIA (E.G., FACEBOOK, TWITTER, YOUTUBE)
08. OTHER
98. DON'T KNOW
99. REFUSED

///ASK IF MALFIX=1, Someone explained how to correct malfunction///

MALFIX3 **What were you told needed to be done to correct the malfunction? [INTERVIEWER: IF THE DRIVER PROVIDES MORE THAN ONE ACTION, ASK THE DRIVER TO STATE THE MOST IMPORTANT ACTION THEY WERE TOLD TO TAKE]**

01. RECALIBRATION
02. REPAIR/REPLACE TIRE PRESSURE MONITORING SENSORS
03. REPAIR/REPLACE ON-BOARD COMPONENTS (HARDWARE OR SOFTWARE)
04. OTHER: SPECIFY
98. DON'T KNOW
99. REFUSED

///ASK IF MALF1AW1=1, Aware that TPMS Malfunction light is on///

MALCOST1A **Have you priced the work required to correct the TPMS system malfunction (whether or not you had the work done)?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF MACLOST1A=1, Had the work priced///

MALCOST1B **What was the price for this work? [INTERVIEWER: PROBE FOR NEAREST WHOLE NUMBER VALUE]**

01. $0.00
02. $1 - $49
03. $50 - $99
04. $100 - $299
05. $300 - $499
06. $500 - $999
07. $1,000 OR MORE
98. DON'T KNOW
99. REFUSED

///ASK IF MALCOST1A=2,98,99, Haven't had repair priced/DK/REF ///

MALCOST2A **Do you have a general idea of what the price to repair the system would be?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF MALCOST2A=1, Has an idea of cost of work///

MALCOST2B **What is your estimate of the price to perform this repair? [INTERVIEWER: PROBE FOR NEAREST WHOLE NUMBER VALUE]**

01. $0.00
02. $1 - $49
03. $50 - $99
04. $100 - $299
05. $300 - $499
06. $500 - $999
07. $1,000 OR MORE
98. DON'T KNOW
99. REFUSED

///ASK IF MALF1AW1=1, Aware that TPMS Malfunction light is on///

MALFIX4 **Do you plan to correct the current malfunction in the system?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF MALFIX4=1, Plan to correct malfunction///

MALFIX5 **How do you plan to correct the current malfunction?**

01. TAKE MY VEHICLE INTO THE DEALERSHIP OR REPAIR FACILITY
02. HIRE SOMEONE ELSE TO REPAIR IT
03. ORDER THE PARTS AND REPAIR IT MYSELF
04. REPAIR IT MYSELF WITH THE HELP OF OTHERS
05. OTHER
98. DON'T KNOW
99. REFUSED

///ASK IF MALFIX4=2, No plan to correct malfunction///

MALFIX6 **What is the primary reason you are not planning to repair the current malfunction in the system?**
[INTERVIEWER: BACKCODE]

01. CURRENTLY USING SEASONAL TIRES AND WILL SWITCH TIRES OUT WHEN THE WEATHER PERMITS, WHICH SHOULD FIX THE PROBLEM
02. CANNOT AFFORD THE COST TO REPAIR
03. TPMS SYSTEM IS A LUXURY AND NOT NECESSARY FOR THE OPERATION OF THE VEHICLE
04. IT IS NOT MANDATED BY THE STATE THAT I REPAIR THE SYSTEM
05. WILL BE SELLING / GETTING RID OF THIS CAR SHORTLY
06. NOT SURE THE TPMS MALFUNCTION INDICATOR IS ACCURATE
07. TOO INCONVENIENT/IT'S JUST A NUISANCE
08. OTHER
98. DON'T KNOW
99. REFUSED

///IF MALFIX6=6, Not sure if TPMS indicator is accurate///

MALCONF **Why do you think the TPMS system malfunction indicator is inaccurate?**
[IF NECESSARY: What is the primary reason?]
[INTERVIEWER: BACKCODE]

01. THE TPMS MALFUNCTION LIGHT HAS COME ON BEFORE AND TURNED OFF BY ITSELF, WITHOUT ANY REPAIRS
02. HEARD FROM OTHER SOURCES THAT IT MAY BE INACCURATE
03. OTHER
04. NO SPECIFIC REASON
98. DON'T KNOW
99. REFUSED

///ASK IF MALCONF NE 1 OR MALF1AW1=2,98,99, Driver does not say TPMS malfunction light is flashing intermittently OR Not aware that TPMS Malfunction light is on ///

MALPREV1 **A previous malfunction would be an episode in which the TPMS system malfunction light turned on and then turned off and remained off for at least one week, either by itself or due to servicing the vehicle. Aside from the current malfunction, have there been any previous malfunctions of the TPMS system?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF MALCONF=1 OR MALPREV=1, Previous malfunction episode reported///

MALPREV2 **Other than the current malfunction, how many times has the TPMS system malfunctioned?**

01. 1 OTHER TIME
02. 2 – 4 OTHER TIMES
03. 5 OR MORE OTHER TIMES
98. DON'T KNOW
99. REFUSED

///SKIP TO MODULE CLOSE///

END MODULE MALFUNCTION #1: IF MALFCODE =1

MODULE MALFUNCTION #2: IF MALFCODE =2

This module is entered by respondents experiencing TPMS Malfunction #2: TPMS Low Tire Pressure indicator is currently illuminated.

///ASK IF MALFCODE =2///
MALF2AW1 Are you aware that a TPMS dash light is currently on in your vehicle?
01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF MALF2AW1=01///
MALF2AW1A What does this light mean to you? [INTERVIEWER: BACKCODE RESPONSE; IF NECESSARY, ASK WHAT LIGHT MEANS WITH REGARD TO SPECIFIC VEHICLE SYSTEMS]
01. LOW TIRE PRESSURE
02. TPMS MALFUNCTION
03. OTHER
98. DON'T KNOW
99. REFUSED

///IF MALF2AW1=2,98,99 SKIP TO MODULE PAST MALFUNCTION #1///

///ASK IF MALF2AW1=1, Aware that low tire pressure light is on///
MALF2FIX1 Since this light came on, have you checked the pressure in any of your tires?
01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF MALF2FIX1=1, Checked tire pressure///
MALF2FIX2 Were all of the checked tires properly inflated?
01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF MALF2AW1=1, Aware that low tire pressure light is on///
MALF2AW2 How long has the low tire pressure light been on? If the light has been turning on and off intermittently, please think back to the first time you noticed that the light was on.
01. LESS THAN 1 WEEK
02. 1 – 2 WEEKS
03. 3 – 4 WEEKS
04. 1 – 6 MONTHS
05. 7 – 12 MONTHS
06. MORE THAN 1 YEAR
98. DON'T KNOW
99. REFUSED

///IF MALF2FIX1=2,98,99 OR MALF2FIX2=2,98,99, SKIP TO MODULE PAST MALFUNCTION #1///
///ASK IF MALF2FIX2=1, Verified all tires properly inflated///

MALF2AF1 **Your TPMS system may be malfunctioning. Did any of the following events occur shortly before the low pressure light came on? [INTERVIEWER: PAUSE AFTER EACH ITEM TO COLLECT "YES" OR "NO" RESPONSE]**
[SELECT ALL THAT APPLY]

01. The tires were rotated
02. Specialty (e.g., seasonal or off-road) tires were switched out
03. One or more new tires or wheels were installed or replaced
04. One or more tire stems were installed or replaced
05. One or more tire pressure sensors were installed or replaced
06. Work was performed on the braking system
07. Work was performed to on-board computer system
08. The vehicle was involved in an accident
09. The vehicle experienced an extended period of flooding / snow
10. Anything else?
11. NONE OF THE ABOVE
98. DON'T KNOW
99. REFUSED

///ASK IF MALF2AF1=4,5, Tire stems/sensors replaced///

MALF2AF2 **Did you install or replace the tire stems or tire pressure sensors yourself?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF MALF2AF1=4,5, Tire stems/sensors replaced///

MALF2AF3 **How much did this work cost? [INTERVIEWER: PROBE FOR NEAREST WHOLE NUMBER VALUE]**

01. $0.00
02. $1 - $49
03. $50 - $99
04. $100 - $299
05. $300 - $499
06. $500 - $999
07. $1,000 or more

///ASK IF MALF2AF1=6, Work done to brake system///

MALF2AF4 **Did you perform the work on the braking system yourself?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF MALF2AF1=6, Work done to brake system///

MALF2AF5 **How much did this work cost? [INTERVIEWER: PROBE FOR NEAREST WHOLE NUMBER VALUE]**

01. $0.00
02. $1 - $49
03. $50 - $99
04. $100 - $299
05. $300 - $499
06. $500 - $999
07. $1,000 or more

///SKIP TO MODULE PAST MALFUNCTION #1///

END MODULE MALFUNCTION #2: IF MALFCODE =2

MODULE MALFUNCTION #3: IF MALFCODE (IN 3) AND DISABLE2=2,98,99 OR MALFCODE (IN 5) AND DISABLE2=2,98,99 AND ELIG=1

This module is entered by respondents experiencing TPMS Malfunction #3: Vehicle is known to be equipped with TPMS and respondent denied disabling system, but no TPMS lights are illuminated at ON position.

///ASK IF MALFCODE IN (3) AND DISABLE2=2,98,99///

MALF3RE **At any time since you've had this vehicle, have you seen any TPMS dash lights on?**
[IF NECESSARY: SHOW RESPONDENT IMAGES OF TPMS INDICATOR LIGHTS]

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF MALF3RE=1, Has seen TPMS indicator light previously///

MALF1AW2A **When was the last time you noticed a TPMS dash light turned on?**

01. LESS THAN 1 WEEK AGO
02. 1 – 2 WEEKS AGO
03. 3 – 4 WEEKS AGO
04. 1 – 6 MONTHS AGO
05. 7 – 12 MONTHS AGO
06. MORE THAN 1 YEAR AGO
98. DON'T KNOW
99. REFUSED

///ASK IF MALFCODE IN (3) AND DISABLE2=2,98,99///

MALF3AF **Since you've had this vehicle, have any of the following events occurred?**
[INTERVIEWER: PAUSE AFTER EACH ITEM TO COLLECT "YES" OR "NO" RESPONSE]
[SELECT ALL THAT APPLY]

01. The vehicle was involved in an accident
02. Service was performed that did or may have involved the vehicle's electrical wiring
03. The vehicle experienced an extended period of flooding / snow
04. Anything else?
05. NONE OF THE ABOVE
98. DON'T KNOW
99. REFUSED

///SKIP TO MODULE PAST MALFUNCTION #1///

END MODULE MALFUNCTION #3: IF MALFCODE IN (3) AND DISABLE2=2,98,99

MODULE PAST MALFUNCTION #1: IF MALFCODE =2,3,4,5

This module is entered by all respondents except those currently experiencing TPMS Malfunction #1 (TPMS System Malfunction indicator is illuminated). Purpose is to gather data about this kind of malfunction if it happened in the past (when not currently indicated).

///ASK IF TPMSEQ IN 2,98,99 AND MALFCODE IN (3,5)///

REMIND1 **Earlier you indicated that your vehicle may not be equipped with a TPMS system, but based on the model year the vehicle should be equipped with TPMS.**

01. CONTINUE

///ASK IF MALFCODE =2,3,4,5///

MALEVER **Has the TPMS system malfunction dash light ever been on and stayed on while you were driving this vehicle?**

[IF NECESSARY: SHOW RESPONDENT IMAGES OF MALFUNCTION INDICATOR LIGHT]

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF MALEVER=1, System malfunction light has been illuminated previously///

LASTMAL **When was the last time the TPMS system malfunction light was on?**

01. LESS THAN A MONTH AGO
02. 1 – 6 MONTHS AGO
03. 7 – 12 MONTHS AGO
04. 1 – 2 YEARS AGO
05. 3 OR MORE YEARS AGO
98. DON'T KNOW
99. REFUSED

///ASK IF MALEVER=1, System malfunction light has been illuminated previously///

LASTACT1 **Did you take any action in response to the indicator light?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF LASTACT1=1, Took some action in response to malfunction light///

LASTACT2 **What needed to be done to correct the malfunction?**

01. RECALIBRATION
02. REPAIR/REPLACE TIRE PRESSURE MONITORING SENSORS
03. REPAIR/REPLACE ON-BOARD COMPONENTS (HARDWARE OR SOFTWARE)
04. REPAIRS, OTHER THAN ABOVE
05. OTHER REPAIRS, SPECIFICS UNKNOWN
06. OTHER
98. DON'T KNOW
99. REFUSED

///ASK IF LASTACT1=1, Took some action in response to malfunction light///

LASTACT3 **What actions did you take in response? [SELECT ALL THAT APPLY] [MUL=7] [08,98,99 ARE MUTUALLY EXCLUSIVE]**

01. REPAIRED THE SYSTEM MYSELF
02. DISABLED THE SYSTEM
03. HAD THE DEALER / REPAIR FACILITY REPAIR THE SYSTEM AT A COST
04. HAD THE DEALER / REPAIR FACILITY REPAIR UNDER WARRANTY
05. HAD THE DEALER / REPAIR FACILITY DISABLE THE SYSTEM
06. PURCHASED NEW TIRES
07. PURCHASED NEW TIRE PRESSURE MONITORING SENSORS
08. NONE, BECAUSE THE MALFUNCTION INDICATOR TURNED OFF ON ITS OWN
09. OTHER
98. DON'T KNOW
99. REFUSED

///ASK IF MALEVER=1, System malfunction light has been illuminated previously///

LASTAF **Did any of the following events occur shortly before the TPMS system malfunction light came on? [INTERVIEWER: PAUSE AFTER EACH ITEM TO COLLECT "YES" OR "NO" RESPONSE]**

[SELECT ALL THAT APPLY]

01. The tires were rotated
02. Specialty (e.g., seasonal or off-road) tires were switched out
03. One or more new tires or wheels were installed or replaced
04. One or more tire stems were installed or replaced
05. One or more tire pressure sensors were installed or replaced
06. Work was performed on the braking system
07. Work was performed to on-board computer system
08. The vehicle was involved in an accident
09. The vehicle experienced an extended period of flooding / snow
10. The TPMS system was intentionally disabled
11. Anything else?
12. NONE OF THE ABOVE
98. DON'T KNOW
99. REFUSED

///ASK IF LASTAF=4,5, Tire stems/sensors replaced///

LASTFIX1 **Did you install or replace the tire stems or tire pressure sensors yourself?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF LASTAF=4,5, Tire stems/sensors replaced///

LASTFIX2 **How much did this work cost? [INTERVIEWER: PROBE FOR NEAREST WHOLE NUMBER VALUE]**

01. $0.00
02. $1 - $49
03. $50 - $99
04. $100 - $299
05. $300 - $499
06. $500 - $999
07. $1,000 OR MORE
98. DON'T KNOW
99. REFUSED

///ASK IF LASTAF=6, Work done to brake system///

MALF2AF4_2 **Did you perform the work on the braking system yourself?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF LASTAF=6, Work done to brake system///

MALF2AF5_2 **How much did this work cost? [INTERVIEWER: PROBE FOR NEAREST WHOLE NUMBER VALUE]**

01. $0.00
02. $1 - $49
03. $50 - $99
04. $100 - $299
05. $300 - $499
06. $500 - $999
07. $1,000 or more

///IF LASTAF=10 AND (MALFCODE NE (3,5), SKIP TO MODULE DISABLED, THEN RETURN///

///SKIP TO MODULE CLOSE///

END MODULE PAST MALFUNCTION #1

MODULE CLOSE

All respondents enter this module.

///ASK ALL EXTENDED INTERVIEWS///

TDRIVE **How long have you had this vehicle?**

01. LESS THAN 1 YEAR
02. 1 YEAR
03. 2 YEARS
04. 3 YEARS
05. 4 YEARS
06. 5 YEARS
07. 6 YEARS
08. 7 YEARS
09. 8 YEARS
10. 9 YEARS
11. 10 YEARS
12. MORE THAN 10 YEARS
98. DON'T KNOW
99. REFUSED

//IF TDRIVE IN (01,02,03,04,05,06,07,08,09,10,11,12) – 1 > VAGE THEN DISPLAY PROMPT: I need to confirm your answer. Based on the model year of this vehicle, [INSERT MODELYEAR], it is [INSERT VAGE] old.

///ASK ALL EXTENDED INTERVIEWS///

MAINT2A **Does this vehicle currently have a manufacturer warranty or other vehicle protection/extended maintenance plan?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF MAINT2A=1///

MAINT2B **Is this the original manufacturer warranty?**

01. Yes
02. NO
98. DON'T KNOW
99. REFUSED

///ASK ALL EXTENDED INTERVIEWS ///

AIR1 **Where would you look to find the pressure required for correct inflation of the tires on this vehicle?**
[INTERVIEWER: BACKCODE RESPONSE]

01. ON THE TIRE WALL
02. DOOR PLACARD
03. OWNER'S MANUAL
04. RELATIVE/FRIEND/COLLEAGUE
05. DEALERSHIP/AUTO REPAIR SHOP/MECHANIC
06. OTHER BOOK, MAGAZINE, OR ARTICLE
07. TV OR RADIO
08. INTERNET
09. SOCIAL MEDIA (E.G., FACEBOOK, TWITTER, YOUTUBE)
10. OTHER
98. DON'T KNOW
99. REFUSED

///ASK ALL EXTENDED INTERVIEWS ///

AIR2 **Do you know how to inflate your tires to the correct pressure?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK ALL EXTENDED INTERVIEWS ///

TRYFIX1 **Before today, has the TPMS low tire pressure light in your dash ever come on and remained on after driving your vehicle?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF TRYFIX1=1, Had low pressure light come on///

TRYFIX2 **Did you or someone else add air to one of more tires after this light came on?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF TRYFIX2=1, Had low pressure light come on and then added air to tires///

TRYFIX3 **Did the TPMS low tire pressure light continue to stay on even after adding air to the tires and driving?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF MALEVER=2, Has never experienced a TPMS system malfunction///

HYPMAL2 **If the TPMS malfunction light turned on, indicating a problem with the system itself, what action would you most likely take in response?**
[IF NECESSARY: What would be your primary action?]
[INTERVIEWER: BACKCODE]

01. TAKE NO ACTION
02. HAVE THE DEALER / REPAIR FACILITY REPAIR THE SYSTEM
03. ORDER THE PARTS AND REPAIR THE SYSTEM MYSELF
04. HAVE THE DEALER / REPAIR FACILITY DISABLE THE SYSTEM
05. DISABLE THE SYSTEM MYSELF
06. OTHER
98. DON'T KNOW
99. REFUSED

///ASK IF HYPMAL2=02-06, would take action to fix a TPMS malfunction///

HYPMAL3 **How quickly would you try to get the problem fixed?**

01. I WOULD FIX IT AS SOON AS I COULD GET THE VEHICLE TO THE SHOP
02. I WOULD HAVE IT FIXED, BUT TIMING WOULD DEPEND UPON THE COST OF REPAIR
03. I WOULD HAVE IT FIXED AT MY NEXT SCHEDULED MAINTENANCE APPOINTMENT (INCLUDING OIL CHANGE, TIRE ROTATION, ETC.)
04. I WOULD NOT FIX IT UNTIL I WAS GOING TO GET RID OF THE CAR
98. DON'T KNOW
99. REFUSED

///
IF MALFIX5=1,2,3 OR (LASTACT3_3, LASTACT3_4, OR LASTACT3_5=TRUE) OR MALF1AF1A=4,5 OR MALF1AF1B=4,5 OR MALF2AF1=4,5 OR LASTAF=4,5 OR HYPMAL2=1,2,3 THEN AUTOPUNCH PAYFIX1=1, Has already indicated spending money to repair TPMS
ELSE, ASK ALL
///

PAYFIX2 **What is the most you would be willing to spend to repair a malfunctioning TPMS system?**

01. $0.00
02. $1 - $49
03. $50 - $99
04. $100 - $299
05. $300 - $499
06. $500 - $999
07. $1,000 OR MORE
98. DON'T KNOW
99. REFUSED

///ASK ALL EXTENDED INTERVIEWS ///

RESET1 **Who would be able to reset the TPMS system in your vehicle when needed, such as after adding air to the tires or doing work on the tires or wheels?**
[INTERVIEWER: SELECT ALL THAT APPLY]

01. THE OWNER/DRIVER

02. THE REPAIR SHOP OR DEALER
03. OTHER
98. DON'T KNOW
99. REFUSED

///ASK ALL EXTENDED INTERVIEWS ///

RESET2 **What action is required to reset the TPMS system? [INTERVIEWER: PROBE FOR THE PRIMARY ACTION]**

01. PRESS A BUTTON
02. SELECT OPTION VIA VEHICLE'S ELECTRONIC MENU CONTROL
03. SPECIAL TOOLS ARE USED BY A REPAIR SHOP/DEALER
04. OTHER
98. DON'T KNOW
99. REFUSED

///ASK ALL EXTENDED INTERVIEWS ///

TPMSREQ **To your knowledge, is the TPMS system in your vehicle legally required to be functioning properly?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK ALL///

INTRO2 **Now I just need to ask you some basic demographic information.**

01. CONTINUE

///ASK IF INTRO2=1///

AGE **What is your age? [INTERVIEWER: IF RESPONDENT HESITATES TO REPORT SINGLE AGE READ THE LIST OF CATEGORIES AND ASK THEM TO INDICATE THE CATEGORY THAT BEST MATCHES THEIR AGE]**

01. UNDER 18
02. 18 – 25
03. 26 – 35
04. 36 – 45
05. 46 – 55
06. 56 – 65
07. 65 OR OLDER
98. DON'T KNOW
99. REFUSED

///ASK IF INTRO2=1///

EDUC **What is the highest level of education you have completed?**

01. SOME ELEMENTARY/MIDDLE/HIGH SCHOOL
02. HIGH SCHOOL GRADUATE (OR DIPLOMA) OR GED
03. ASSOCIATE'S DEGREE / SOME COLLEGE
04. BACHELOR'S DEGREE
05. GRADUATE/PROFESSIONAL DEGREE

98. DON'T KNOW
99. REFUSED

///ASK IF INTRO2=1///
ZIP. What is your home ZIP code?

ENTER RESPONSE //ALLOW 5 DIGIT NUMERIC CODE//
99998 RESPONDENT LIVES OUTSIDE U.S.
99999 REFUSED

///IF SCREEN6 NE 1 THEN SET DISPO = 61, Complete: Phase-in vehicle, TPMS reported to be disabled – DISABLED COMPLETE///

///IF SCREEN6 = 1 THEN SET DISPO = 71, At Quota: Phase-in vehicle, TPMS reported to be disabled ///

///IF DISABLE2=1 AND SCREEN6 NE 1 THEN SET DISPO = 63, Complete: Post-phase-in vehicle, TPMS reported to be disabled – DISABLED COMPLETE///

///IF DISABLE2=1 AND SCREEN6 = 1 THEN SET DISPO = 73, At Quota: Post-phase-in vehicle, TPMS reported to be disabled ///

///IF DISABLE2=2,98,99 AND MALFCODE =3 AND SCREEN6 NE 1 THEN SET DISPO = 64, Complete: Post-phase-in vehicle, no lights, not reported as disabled – MALFUNCTION COMPLETE///

///IF DISABLE2=2,98,99 AND MALFCODE =3 AND SCREEN6=1 THEN SET DISPO = 74, At Quota: Post-phase-in vehicle, no lights, not reported as disabled ///

///IF MALFCODE =1 AND SCREEN6 NE 1 THEN SET DISPO = 66, Complete: TPMS system malfunction COMPLETE///

///IF MALFCODE =1 AND SCREEN6=1 THEN SET DISPO = 76, At Quota: TPMS system malfunction ///

///IF MALFCODE =2 AND SCREEN6 NE 1 THEN SET DISPO = 67, Complete: TPMS low pressure ///

///IF MALFCODE =2 AND SCREEN6=1 THEN SET DISPO = 77, At Quota: TPMS low pressure ///

///IF MALFCODE =4 AND SCREEN6 NE 1 THEN SET DISPO = 68, Complete: TPMS functioning properly ///

///IF MALFCODE =4 AND SCREEN6=1 THEN SET DISPO = 78, At Quota: TPMS functioning properly ///

///SET COUNTER FOR MODELYEAR AND INCREMENT COUNT FOR DISPOSITIONS 61, 63, 64, 66, 67, 68. TARGET TO BE MONITORED AND ADJUSTED BASED ON FIELD EXPERIENCE///

MINIMA SAMPLE SIZES [REQUIRED SAMPLE FLOOR]

Model Year	Car	LTV
2006-2008	300	300

2009-2011	**300**	**300**
2012-2014	**300**	**300**
2015-2016	**300**	**300**

///SKIP TO MODULE END///

END MODULE CLOSE

MODULE END

///ASK IF PRIM1C=2, Primary driver/upkeep not with respondent///

SCREEN3 **I won't have any further questions for you today, since we're only surveying drivers who are primarily responsible for the upkeep of their car. Thanks for your time.**
01. CONTINUE

///IF PRIM1C=2 SET DISPO=31, SCREENED OUT: Primary driver/upkeep not with respondent///

///ASK IF PRIM1D=2, Could not speak to primary driver/upkeep///

SCREEN4 **I won't have any further questions for you today, since we're only surveying drivers who are primarily responsible for the upkeep of their car. Thanks for your time.**
01. CONTINUE

///IF PRIM1D=2 SET DISPO=32, SCREENED OUT: Could not speak to primary driver/upkeep///

///ASK IF PRIM2A=2 AND PRIM2B=2, Unable to locate primary driver/upkeep ///

SCREEN5 **I won't have any further questions for you today, since we're only surveying drivers who are primarily responsible for the upkeep of their car. Thanks for your time.**
01. CONTINUE

///IF INTRO1A=2, MY_RECALL1=9999, RENTAL=99, PRIM1A=99, PRIM1B=99, PRIM1C, PRIM1D, INTRO1B=2, PRIM2A=99, PRIM2B=99, DASHINT1=99///

SCREEN7 **I won't have any further questions for you today. Thanks for your time.**
01. CONTINUE

///IF PRIM2A=2 AND PRIM2B=2 SET DISPO=34, SCREENED OUT, Unable to locate primary driver/upkeep///

///ASK ALL IF DISPOSITION >60///

THANK **[INTERVIEWER: REJOIN WITH INSPECTOR TO GIVE DRIVER RECALL INFO]**

Thank you for your participation in this survey.
01. CONTINUE

//ADD BUTTONS FOR INTERVIEWER TO INDICATE WHETHER TO UPLOAD RECORD

SUBMIT INTERVIEWER: SUBMIT TO ONLINE DATABASE?
01 YES
02 MARK QUESTIONNABLE ///SAVE AND UPLOAD BUT DON'T INCREMENT TALLY///
03 NO, UPLOAD LATER

///IF SUBMIT=01 or 02///

SUBMITV INTERVIEWER: Are you sure you want to submit data to online database?

01 Yes
02 No

END MODULE END

Appendix Q. TPMS-ORRC Repair Facilities Survey Specifications

The specifications for the computer-assisted telephone interview (CATI) programmed for the TPMS-ORRC Repair Facilities Survey are reproduced in this appendix.

REPAIR FACILITIES SURVEY (CATI)

Form Approved O.M.B. No. 2127-0626
Expiration Date: 8/31/2018

United States Department of Transportation
National Highway Traffic Safety Administration

Tire Pressure Monitoring System
Outage Rates and Repair Costs

Received:

Paperwork Reduction Act Burden Statement

A federal agency may not conduct or sponsor, and a person is not required to respond to, nor shall a person be subject to a penalty for failure to comply with a collection of information subject to the requirements of the Paperwork Reduction Act unless that collection of information displays a current valid OMB Control Number. The OMB Control Number for this information collection is 2127-0626 (Expiration date: 08/31/2018). Public reporting for this collection of information is estimated to be approximately 20 minutes per response, including the time for reviewing instructions, completing and reviewing the collection of information. All responses to this collection of information are voluntary. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to: Information Collection Clearance Officer, National Highway Traffic Safety Administration, 1200 New Jersey Ave, S.E., Washington, DC, 20590. NHTSA Form 1276.

Formatting conventions:

Questionnaire item
///PROGRAMMING LOGIC///
Explanatory notes

Programmer Notes:

- *All variables are assumed to be numeric*
- *For SELECT ALL THAT APPLY items, create a series of variables with **_1**, **_2**, etc. appended to original variable name to indicate selection status of each response option*
- *For all "Other: Specify" items, create a new variable (length $ 256) with **_OTHER** appended to original variable name to hold open-end text*

Disposition Definitions:

- *25 = Screened out, Not a repair facility*
- *26 = Screened out, Facility does not service passenger vehicles*
- *27 = Screened out, Facility does not service TPMS*
- *61 = Complete*

SCREENING

///ON FIRST ATTEMPT FOR EACH RECORD, CREATE FLAG VARIABLE MGRONLY = 1 TO INDICATE THAT WE ARE INITIALLY SCREENING SPECIFICALLY FOR SERVICE MANAGER. ALSO CREATE COUNTER VARIABLE ATTEMPTS = 0 TO TRACK HOW MANY ATTEMPTS HAVE BEEN MADE///

///ASK ALL///

INTRORF1 **Hi, I'm [NAME] calling on behalf of the United States Department of Transportation. Can I please speak with the service manager or equivalent <///IF MGRONLY=0, INSERT: or, if this person is unavailable, any employee who is knowledgeable about TPMS or tire service in general///>?**

[INTERVIEWER: READ IF NECESSARY: We're conducting a survey of outage rates and repair costs for tire pressure monitoring systems, or TPMS, and your business was selected at random.]

01. YES – SPEAKING
02. TRANSFER INITIATED
03. NO – REQUESTED PERSON(S) UNAVAILABLE
04. NO – NOT A REPAIR FACILITY
99. REFUSED

///IF INTRORF1=3 THEN DO
ATTEMPTS = ATTEMPTS + 1
IF ATTEMPTS >= 6 THEN MGRONLY = 0
IF NOT AT PROTOCOL THEN SCHEDULE CALLBACK
END///

///IF INTRORF1=04, SKIP TO END: SET DISPO=25, Screened out: Not a repair facility///

///ASK IF INTRORF1=01 or 02 ///

INTRORF2 **//IF INTRORF1=02 THEN INSERT <Hi, I'm [NAME] calling on behalf of United States Department of Transportation.> //**
We're conducting a survey of outage rates and repair costs for tire pressure monitoring systems, or TPMS. You may have recently received a letter from the National Highway Safety Administration (NHTSA) inviting you to participate in this survey.

01. CONTINUE
99. REFUSED

///ASK IF INTRORF2=01, Screening successful///

INTRORF2B **This survey is voluntary. It has been approved by OMB under control number 2127-0626. Your answers will be kept private, used only for statistical purposes, and protected to the full extent of the law.**
You do not have to answer any question you do not want to, and you can end the interview at any time. If you don't know the answer to any question, you can say that you don't know.

This call may be monitored or recorded for quality assurance purposes.

01. CONTINUE

///ASK IF INTRORF2B=01, Screening successful///

RFNAME **Is the name of your facility [POPULATED]?**

01. YES
02. NO
99. REFUSED

///ASK IF INTRORF2B=01, Screening successful///

RFTYPE **Please indicate the category that BEST describes your auto repair facility. Is it…**

01. Franchised (not attached to a dealership)
02. Connected to a dealership
03. Independently owned
04. OTHER: SPECIFY
98. DON'T KNOW
99. REFUSED

///ASK IF RFTYPE=04, OTHER SPECIFY///

RFTYPE_OTHER Please specify Other response

///ASK IF INTRORF2B=01, Screening successful///

RFPSSGR **Does this facility service passenger vehicles—that is, passenger cars or light trucks, including pickups, vans, and SUVs?**

01. YES
02. NO
99. REFUSED

///IF RFPSSGR=2 SKIP TO END: SET DISPO=26, Facility does not service passenger vehicles///

///ASK IF RFPSSGR=01, Facility services passenger vehicles///

RFTPMS1 **Does this facility service Tire Pressure Monitoring Systems, known as TPMS, in passenger vehicles?**

01. YES
02. NO
99. REFUSED

///IF RFTPMS1=2 SKIP TO END: SET DISPO=27, Facility does not service TPMS in passenger vehicles///

///ASK IF RFTPMS1=1, Facility services TPMS in passenger vehicles///

RFTPMS2 **Does this facility service both direct and indirect TPMS systems in passenger vehicles? [INTERVIEWER: IF NECESSARY, PROMPT TO CLARIFY THE TYPE SERVICED: Do you service only direct TPMS, or only indirect TPMS?]**

01. DIRECT AND INDIRECT
02. DIRECT ONLY
03. INDIRECT ONLY
99. REFUSED

FACILITY INFO

///ASK IF RFTPMS1=1, Facility services TPMS in passenger vehicles///

RFOPEN1 **How many years has this facility been in business?**
[IF NECESSARY: Include all locations, if the facility has moved]

/RECORD NUMBER: RANGE = 1-100/
996. LESS THAN ONE YEAR
997. MORE THAN 100 YEARS
998. DON'T KNOW
999. REFUSED

///ASK IF RFOPEN1=996, Open less than one year///

RFOPEN2 **How many months has this facility been in business?**

/RECORD NUMBER: RANGE = 1-11/
98. DON'T KNOW
99. REFUSED

///ASK IF RFTPMS1=1, Facility services TPMS in passenger vehicles ///

RFBRAND1 **Does this facility only service specific makes of passenger vehicles?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF RFBRAND1=1, Services only specific makes of passenger vehicles///

RFBRAND2 **Which makes of passenger vehicles are serviced at this facility?**

/OPEN-END: ENTER RESPONSE/

///ASK IF RFTPMS1=1, Facility services TPMS in passenger vehicles ///

RFVEHIC **In the past 90 days, how many passenger vehicles has this facility serviced?**

/RECORD NUMBER: RANGE = 0-9997/
9998. DON'T KNOW
9999. REFUSED

///ASK IF RFTPMS1=1, Facility services TPMS in passenger vehicles ///

INTRORF3 **In the remaining questions, I'll be asking specifically about Tire Pressure Monitoring Systems, or "TPMS," on passenger vehicles.**
01. CONTINUE

///ASK IF INTRORF3=1, Continuing with interview///

SRVTOT **In the past 90 days, what percent of the passenger vehicles serviced in this facility were equipped with a TPMS system (whether or not it was functional)? Your best estimate is fine.**
/RECORD NUMBER: RANGE = 0-100/
998. DON'T KNOW
999. REFUSED

///ASK IF RFTPMS2=1, Facility services direct and indirect TPMS///

SRVDIR **Of these vehicles equipped with a TPMS system, what percent were direct TPMS systems? Your best estimate is fine.**
/RECORD NUMBER: RANGE = 0-100/
998. DON'T KNOW
999. REFUSED

///IF RFTPMS2=1 AND SRVDIR IN 0:100, AUTOPUNCH: SRVINDIR = 100-SRVDIR, percent of vehicles equipped with a TPMS system that were indirect systems///

///IF RFTPMS2=2, AUTOPUNCH: SRVDIR=100, SRVINDIR=0///

///IF RFTPMS2=3, AUTOPUNCH: SRVDIR=0, SRVINDIR=100///

///ASK IF INTRORF3=1, Continuing with interview///

TPMSVOL **Is the volume of TPMS service in this facility in the last 90 days higher or lower compared to other times of year? Would you say…**
01. Much higher
02. Somewhat higher
03. About the same
04. Somewhat lower
05. Much lower
98. DON'T KNOW
99. REFUSED

///ASK IF INTRORF3=1, Continuing with interview///

CHKMALF1 **As a standard practice, does your facility perform a TPMS system inspection on all TPMS-equipped vehicles that come in?**
01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF CHKMALF1 IN (2,98,99), Do not check that TPMS is working for all vehicles///

CHKMALF2 **As a standard practice, does your facility check that the TPMS system is working properly each time a TPMS-equipped vehicle…**

a. …Has wheel or tire service performed?
b. …Has been involved in an accident?
c. …Is brought in for recommended maintenance (such as a 50,000 mile checkup) that does not include work on wheels or tires?
d. Is brought in for any other type of work?

01 YES
02 NO
98. DON'T KNOW
99. REFUSED

COMPONENT LIFESPAN

>> AVERAGE LIFESPAN

///ASK IF INTRORF3=1, Continuing with interview///

INTRORF4 **In the next set of questions, I'll be asking about the average functional lifespan of TPMS components. Please base your answers on your knowledge about servicing TPMS systems, not on any marketing or other information provided by the suppliers of these products.**

01. CONTINUE

///ASK IF RFTPMS2=1,2, Facility services direct TPMS in passenger vehicles ///

LSD_RSENSOR **In a direct TPMS system, what is the average functional lifespan of a rim-mounted sensor?**

[NOTE: IF LESS THAN 1 YEAR, ENTER 1]
[NOTE: IF MORE THAN 10 YEARS, ENTER 11]
/RECORD NUMBER: RANGE = 1-11/
98. DON'T KNOW
99. REFUSED

///ASK IF RFTPMS2=1,2, Facility services direct TPMS in passenger vehicles ///

LSD_SSENSOR **In a direct TPMS system, what is the average functional lifespan of a stem-mounted sensor?**

[NOTE: IF LESS THAN 1 YEAR, ENTER 1]
[NOTE: IF MORE THAN 10 YEARS, ENTER 11]
/RECORD NUMBER: RANGE = 1-11/
98. DON'T KNOW
99. REFUSED

///ASK IF RFTPMS2=1,2, Facility services direct TPMS in passenger vehicles ///

LSD_OVERALL **What is the average functional lifespan of a <u>direct</u> TPMS system as a whole – that is, before it requires some kind of service?**
[NOTE: IF LESS THAN 1 YEAR, ENTER 1]
[NOTE: IF MORE THAN 10 YEARS, ENTER 11]
/RECORD NUMBER: RANGE = 1-11/
98. DON'T KNOW
99. REFUSED

///ASK IF RFTPMS2=1,3, Facility services indirect TPMS in passenger vehicles ///

LSI_SENSOR **In an indirect TPMS system, what is the average functional lifespan of a <u>chassis-mounted sensor</u> (such as a wheel speed sensor)?**
[NOTE: IF LESS THAN 1 YEAR, ENTER 1]
[NOTE: IF MORE THAN 10 YEARS, ENTER 11]
/RECORD NUMBER: RANGE = 1-11/
98. DON'T KNOW
99. REFUSED

///ASK IF RFTPMS2=1,3, Facility services indirect TPMS in passenger vehicles ///

LSI_OVERALL **What is the average functional lifespan of an <u>indirect</u> TPMS system as a whole – that is, before it requires some kind of service?**
[NOTE: IF LESS THAN 1 YEAR, ENTER 1]
[NOTE: IF MORE THAN 10 YEARS, ENTER 11]
/RECORD NUMBER: RANGE = 1-11/
98. DON'T KNOW
99. REFUSED

TPMS MALFUNCTIONS

///ASK IF INTRORF4=1, Continuing with interview///

INTRORF5 **Now I'd like you to think about TPMS malfunctions in passenger vehicles. For this survey, a TPMS malfunction is defined as any time a TPMS system is not working correctly – including problems with the sensors or the on-board components.**
01. CONTINUE

>> DIRECT TPMS

///ASK IF RFTPMS2=1,2, Facility services dTPMS///

INTRORF5D **The following questions will be specifically about the vehicles with <u>direct</u> TPMS systems that were seen in the last 90 days.**
01. CONTINUE

///ASK IF INTRORF5D=1, Continuing with interview///

MALFREQD **Over the past 90 days, how often did vehicles with direct TPMS come in with a TPMS malfunction whether or not a repair was later done? Please use a 1 to 5 scale where 1 means Never and 5 means Almost Always. [Would you say…]**

01. 1- NEVER
02.
03.
04.
05. 5 - ALMOST ALWAYS
98. DON'T KNOW
99. REFUSED

///ASK IF MALFREQD=1, No dTPMS malfunctions seen in past 90 days///

MALFREQD2 **When was the last time a TPMS malfunction was seen in a vehicle with direct TPMS?**

01. Within the past 6 months
02. Within the past 12 months
03. More than 12 months ago
04. Never
98. DON'T KNOW
99. REFUSED

///IF MALFREQD=1 THEN SKIP TO DISABLED///

///ASK IF MALFREQD=2,3,4,5, Some dTPMS malfunctions seen in past 90 days///

MALIDENTD **How frequently were these malfunctions originally identified by the owner when the vehicle was first brought in for service?**
[Please use a 1 to 5 scale where 1 means Never and 5 means Almost Always.]
[INTERVIEWER NOTE: IN PAST 90 DAYS]

01. 1 - NEVER
02.
03.
04.
05. 5 – ALMOST ALWAYS
98. DON'T KNOW
99. REFUSED

///ASK IF MALFREQD=2,3,4,5, Some dTPMS malfunctions seen in past 90 days///

MALSRCD **Which of the following was most frequently the source of the TPMS malfunction in these vehicles?**

01. Sensors
02. On-board hardware
03. On-board software
98. DON'T KNOW
99. REFUSED

///ASK IF MALFREQD=2,3,4,5, Some dTPMS malfunctions seen in past 90 days///

MALSRVCD **What was the most common service your facility performed to fix the malfunctions in these vehicles?**

01. Recalibrate the TPMS system
02. Install new rim-mounted sensors
03. Install new stem-mounted sensors
04. Repair or replace on-board hardware
05. Repair or replace on-board software
06. Perform another type of service
07. Perform no service
98. DON'T KNOW
99. REFUSED

///ASK IF MALFREQD=2,3,4,5, Some dTPMS malfunctions seen in past 90 days///

ASKDISABD1 **How frequently did the owners of these vehicles ask you to disable the direct TPMS system or to leave it unrepaired? Please use the same 1 to 5 scale where 1 means Never and 5 means Almost Always. [Would you say…]**

01. 1 - NEVER
02.
03.
04.
05. 5 – ALMOST ALWAYS
98. DON'T KNOW
99. REFUSED

///ASK IF ASKDISABD1=2,3,4,5, Some customers ask about disabling the dTPMS system or leaving it unrepaired ///

ASKDISABD2 **What is the most common reason these owners gave for wanting the direct TPMS system in their vehicle disabled or for not wanting it fixed?**

01. It's not accurate or reliable
02. It costs too much
03. It isn't necessary for the operation of the vehicle
04. It isn't legally required to be working
05. OTHER: SPECIFY
98. DON'T KNOW
99. REFUSED

///ASK IF INTRORF5D=1, Continuing with interview///

DISABLED **Over the past 90 days, how frequently were disabled TPMS systems seen in vehicles with direct TPMS? Please use the same 1 to 5 scale where 1 means Never and 5 means Almost Always. [Would you say…]**

01. 1 - NEVER
02.
03.
04.
05. 5 – ALMOST ALWAYS
98. DON'T KNOW

99. REFUSED

///ASK IF INTRORF5D=1 AND (MALFREQD=2,3,4,5 OR MALFREQD2=1,2,3), Continuing with interview and has seen dTPMS malfunctions///

MALEVENTD **Based on your overall experience, what most commonly causes malfunctions in direct TPMS systems? Please include up to three causes.**
[CATI: MUL=3, CAPTURE RESPONSES IN ORDER IN MALEVENTD_01-MALEVENTD_03]
[MAIL: OPEN-ENDED, 3 LINES]

01. VEHICLE ACCIDENT
02. VEHICLE AGE
03. VEHICLE MILEAGE
04. ROTATION OF TIRES
05. REPLACEMENT OF TIRES
06. WEATHER/CLIMATE (INCLUDING FLOODING OR SNOW)
07. ELECTRICAL INTERFERENCE
08. WORN OUT BATTERIES
09. OTHER: SPECIFY
98. DON'T KNOW
99. REFUSED

>> INDIRECT TPMS

///ASK IF RFTPMS2=1,3, Facility services iTPMS///

INTRORF5I **The following questions will be specifically about the vehicles with indirect systems seen in the last 90 days.**

01. CONTINUE

///ASK IF INTRORF5I=1, Continuing with interview///

MALFREQI **Over the past 90 days, how often did vehicles with indirect TPMS come in with a TPMS malfunction whether or not a repair was later done? Please use a 1 to 5 scale where 1 means Never and 5 means Almost Always. [Would you say…]**

01. 1 - NEVER
02.
03.
04.
05. 5 – ALMOST ALWAYS
98. DON'T KNOW
99. REFUSED

///ASK IF MALFREQI=1, No iTPMS malfunctions seen in past 90 days///

MALFREQI2 **When was the last time a TPMS malfunction was seen in a vehicle with indirect TPMS?**

01. Within the past 6 months
02. Within the past 12 months
03. More than 12 months ago
04. Never
98. DON'T KNOW
99. REFUSED

///IF MALFREQI=1 THEN SKIP TO DISABLEI///

///ASK IF MALFREQI=2,3,4,5, Some iTPMS malfunctions seen in past 90 days///

MALIDENTI **How frequently were these malfunctions <u>originally identified by the owner</u> when the vehicle was first brought in for service?**
[Please use a 1 to 5 scale where 1 means Never and 5 means Almost Always.]
[INTERVIEWER NOTE: IN PAST 90 DAYS]

01. 1 - NEVER
02.
03.
04.
05. 5 – ALMOST ALWAYS
98. DON'T KNOW
99. REFUSED

///ASK IF MALFREQI=2,3,4,5, Some iTPMS malfunctions seen in past 90 days///

MALSRCI **Which of the following was most frequently the source of the TPMS malfunction in these vehicles?**

01. Chassis-mounted sensor (such as a wheel speed sensors)
02. On-board hardware
03. On-board software
98. DON'T KNOW
99. REFUSED

///ASK IF MALFREQI=2,3,4,5, Some iTPMS malfunctions seen in past 90 days///

MALSRVCI **What was the <u>most common</u> service your facility performed to fix the malfunctions in these vehicles?**

01. Recalibrate the TPMS system
02. Install new chassis-mounted sensors (such as wheel speed sensors)
03. Repair or replace on-board hardware
04. Repair or replace on-board software
05. Perform another type of service
06. Perform no service
98. DON'T KNOW
99. REFUSED

///ASK IF MALFREQI=2,3,4,5, Some iTPMS malfunctions seen in past 90 days///

ASKDISABI1 **How frequently did the owners of these vehicles ask you to <u>disable the TPMS system or to leave it unrepaired</u>? Please use the same 1 to 5 scale where 1 means Never and 5 means Almost Always. [Would you say…]**

01. 1 - NEVER
02.
03.
04.
05. 5 – ALMOST ALWAYS
98. DON'T KNOW
99. REFUSED

///ASK IF ASKDISABI1=2,3,4,5, Some customers ask about disabling the iTPMS system or leaving it unrepaired ///

ASKDISABI2 **What is the most common reason these owners gave for wanting the indirect TPMS system in their vehicle disabled or for not wanting it fixed?**

01. It's not accurate or reliable
02. It costs too much
03. It isn't necessary for the operation of the vehicle
04. It isn't legally required to be working
05. OTHER: SPECIFY
98. DON'T KNOW
99. REFUSED

///ASK IF INTRORF5I=1, Continuing with interview///

DISABLEI **Over the past 90 days, how frequently were disabled TPMS systems seen in vehicles with indirect TPMS? Please use the same 1 to 5 scale where 1 means Never and 5 means Almost Always. [Would you say…]**

01. 1 - NEVER
02.
03.
04.
05. 5 – ALMOST ALWAYS
98. DON'T KNOW
99. REFUSED

///ASK IF INTRORF5I=1 AND (MALFREQI=2,3,4,5 OR MALFREQI2=1,2,3), Continuing with interview and has seen iTPMS malfunctions ///

MALEVENTI **Based on your overall experience, what most commonly causes malfunctions in indirect TPMS systems? Please include up to three causes.**
[CATI: MUL=3, CAPTURE RESPONSES IN ORDER IN MALEVENTI_01-MALEVENTI_03]
[MAIL: OPEN-ENDED, 3 LINES]

01. VEHICLE ACCIDENT
02. VEHICLE AGE
03. VEHICLE MILEAGE
04. ROTATION OF TIRES
05. REPLACEMENT OF TIRES
06. WEATHER/CLIMATE (INCLUDING FLOODING OR SNOW)
07. ELECTRICAL INTERFERENCE
08. OTHER: SPECIFY
98. DON'T KNOW
99. REFUSED

REPAIR COSTS

>> DIRECT TPMS

///ASK IF RFTPMS2=1,2, Facility services dTPMS///

PRICED_INTRO **In the following questions I'll ask about the average price you charge customers to repair specific components in a <u>direct</u> TPMS system. Please provide your best estimate of the total price you charge for this work, including both parts and labor.**

01. CONTINUE

///ASK IF RFTPMS2=1,2, Facility services dTPMS///

What is the average price you charge for replacing each of the following, independent of tire replacement? Your best estimate is fine.

PRICED_RSENSOR **One <u>rim-mounted sensor</u>?.**
PRICED_SSENSOR **One <u>stem-mounted sensor</u>?**
PRICED_HWARE_A **The on-board processing unit?**
PRICED_HWARE_B **The on-board receiver hardware?**
PRICED_HWARE_C **The on-board electrical wiring?**
PRICED_HWARE_D **The onboard dash lights?**

/RECORD NUMBER: RANGE = 0-996/
997. DO NOT OFFER SERVICE
998. DON'T KNOW
999. REFUSED

///ASK IF RFTPMS2=1,2, Facility services dTPMS///

PRICED_SWARE **What is the average price you charge for <u>updating the software</u> on a <u>direct</u> system? Your best estimate is fine.**

/RECORD NUMBER: RANGE = 0-996/
997. DO NOT OFFER SERVICE
998. DON'T KNOW
999. REFUSED

///ASK IF RFTPMS2=1,2, Facility services dTPMS///

PRICED_RECAL1A **Does this facility perform recalibrations of <u>direct</u> TPMS systems that require an activation tool with the vehicle in relearn mode to register new sensor IDs, but do not require driving the vehicle?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF PRICED_RECAL1A = 01, Performs stationary-scan dTPMS recalibration///

PRICED_RECAL1B What is the average price you charge for this work? Your best estimate is fine.

/RECORD NUMBER: RANGE = 0-997/

///ASK IF RFTPMS2=1,2, Facility services dTPMS///

PRICED_RECAL2A Does this facility perform recalibrations of <u>direct</u> TPMS systems that require an activation tool in conjunction with a scan tool to register new sensor IDs, but do not require driving the vehicle?

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF PRICED_RECAL2A = 01, Performs OBD dTPMS recalibration///

PRICED_RECAL2B What is the average price you charge for this work? Your best estimate is fine.

/RECORD NUMBER: RANGE = 0-997/

///ASK IF RFTPMS2=1,2, Facility services dTPMS///

PRICED_RECAL3A Does this facility perform auto-relearn recalibrations of <u>direct</u> TPMS systems, which do not require tools but do require driving the vehicle to register new sensor IDs?

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF PRICED_RECAL3A = 01, Performs auto-relearn dTPMS recalibration///

PRICED_RECAL3B What is the average price you charge for this work? Your best estimate is fine.

/RECORD NUMBER: RANGE = 0-997/

///ASK IF RFTPMS2=1,2, Facility services dTPMS///

PRICED_RECAL4A Does this facility perform stationary recalibrations of <u>direct</u> TPMS systems, which do not require tools but do require a series of steps – such as button presses, pumping the brake pedal, and cycling the ignition – before deflating each tire to register the new sensor IDs?

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF PRICED_RECAL4A = 01, Performs stationary-no scan dTPMS recalibration///

PRICED_RECAL4B What is the average price you charge for this work? Your best estimate is fine.

/RECORD NUMBER: RANGE = 0-997/

>> INDIRECT TPMS

///ASK IF RFTPMS2=1,3, Facility services iTPMS///

PRICEI_INTRO **In the following questions I'll ask about the average price you charge customers to repair specific components in an indirect TPMS system. Please provide your best estimate of the total price you charge for this work, including both parts and labor.**

01. CONTINUE

///ASK IF RFTPMS2=1,3, Facility services iTPMS///

What is the average price you charge for replacing each of the following, independent of tire replacement? Your best estimate is fine.

PRICEI_SENSOR **One chassis-mounted sensor (such as a wheel speed sensor)?**
PRICEI_HWARE_A **The on-board processing unit?**
PRICEI_HWARE_B **The on-board receiver hardware?**
PRICEI_HWARE_C **The electrical wiring?**
PRICEI_HWARE_D **The dash lights?**

/RECORD NUMBER: RANGE = 0-996/
997. DO NOT OFFER SERVICE
998. DON'T KNOW
999. REFUSED

///ASK IF RFTPMS2=1,3, Facility services iTPMS///

PRICEI_SWARE **What is the average price you charge for updating the software on an indirect system? Your best estimate is fine.**

/RECORD NUMBER: RANGE = 0-996/
997. DO NOT OFFER SERVICE
998. DON'T KNOW
999. REFUSED

///ASK IF RFTPMS2=1,3, Facility services iTPMS///

PRICEI_RECAL1A **Does this facility perform recalibrations of indirect TPMS systems that require pushing buttons or using the vehicle control panel to update the tire pressures, but do not require driving the vehicle?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF PRICEI_RECAL1A = 01, Performs stationary-scan iTPMS recalibration///

PRICEI_RECAL1B **What is the average price you charge for this work? Your best estimate is fine.**

/RECORD NUMBER: RANGE = 0-997/

///ASK IF RFTPMS2=1,3, Facility services iTPMS///

PRICEI_RECAL2A **Does this facility perform recalibrations of <u>indirect</u> TPMS systems that require the use of magnets to update the tire pressures, but do not require driving the vehicle?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF PRICEI_RECAL2A = 01, Performs OBD iTPMS recalibration///

PRICEI_RECAL2B **What is the average price you charge for this work? Your best estimate is fine.**

/RECORD NUMBER: RANGE = 0-997/

///ASK IF RFTPMS2=1,3, Facility services iTPMS///

PRICEI_RECAL3A **Does this facility perform auto-relearn recalibrations of <u>indirect</u> TPMS systems, which do not require tools but do require driving the vehicle to register new sensor IDs?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF PRICEI_RECAL3A = 01, Performs auto-relearn iTPMS recalibration///

PRICEI_RECAL3B **What is the average price you charge for this work? Your best estimate is fine.**

/RECORD NUMBER: RANGE = 0-997/

>> ADDITIONAL CHARGES

///ASK IF INTRORF5D=1 OR INTRORF5I=1, Continuing with interview///

PRICE_MAKE1 **Is there an additional charge for servicing the TPMS system on any specific <u>makes</u> of passenger vehicle?**

01. YES
02. NO
98. DON'T KNOW
99. REFUSED

///ASK IF PRICE_MAKE1=1///

PRICE_MAKE2 **Which specific makes of passenger vehicle receive this additional charge?**

/OPEN-END: RECORD LIST OF VEHICLE MAKES/

///SET DISPO=61, COMPLETE///

///LABEL: END///

THANK **Those are all the questions I have. Thank you for your participation. The information you have provided will be valuable for improving knowledge about TPMS. Thank you and goodbye.**

01. CONTINUE

MODE INTERVIEWER: PLEASE SELECT MODE OF COMPLETE

01. CATI survey
02. MAIL data entry

Appendix R. Suppliers Survey Form

The pdf form for TPMS-ORRC Suppliers Survey is reproduced in this appendix.

NHTSA Tire Pressure Monitoring System—Outage Rates and Repair Costs

Suppliers Survey

United States Department of Transportation
National Highway Traffic Safety Administration

Thank you in advance for your time in completing the NHTSA Tire Pressure Monitoring System—Outage Rates and Repair Costs (TPMS-ORRC) Survey. You are being asked to complete this survey because your company has been identified as a possible supplier of TPMS components or systems. While your participation is important to NHTSA, it is entirely voluntary. This survey is not part of any agency investigation. Your response is voluntary. Subject to applicable Federal law, NHTSA will maintain the anonymity of the answers you provide. The survey results will be reported only in aggregate and published results will not include any information that specifically identifies a respondent. You may submit a request for confidential treatment for any business information that you provide.

CONFIDENTIAL TREATMENT OF BUSINESS INFORMATION

1. To submit a claim that all or some of the information provided to NHTSA in response to this questionnaire constitutes confidential business information, you must follow NHTSA's rules governing confidential business information, located at 49 C.F.R. Part 512. In general, these rules require you to submit two confidential copies of your submission with the information you request be kept confidential appropriately marked and a redacted copy of your submission with the confidential information removed. You must submit your request for confidential treatment to:

   Chief Counsel
   National Highway Traffic Safety Administration
   1200 New Jersey Avenue, SE
   West Building, 41-227
   Washington, DC 20590
   Attn: NCSA-TPMS

   A failure to comply with the requirements of 49 C.F.R. Part 512 may result in a denial of your request for confidential treatment.

2. Exclude the information your company claims to be confidential before submitting your completed PDF survey to ICF International at:

   SupplierSurvey@icfsurveysupport.com

INSTRUCTIONS FOR MARKING YOUR ANSWERS

When filling out the PDF, please:

1. Select the oval or box that corresponds with your answer(s).
2. Type any written explanations in the space provided; otherwise, leave text fields blank if you do not have a response for that question.
3. Please do not edit the alphanumeric code located in the bottom right corner of the page.

If you choose to print and mail the survey form, please:

1. Fill in the ovals completely.
2. For numbers, print ***legibly*** within the boxes. Example: **|0|5|.**
3. For written explanations, print ***legibly*** on or within the lines.
4. Please do not make any stray marks.

If you have any questions or concerns, please contact ICF at SupplierSurvey@icfsurveysupport.com, or (844) 356-4605.

SECTION 1. INTRODUCTION

When completing this survey, please consider the sources of TPMS malfunction of which you and your company are aware, the number of replacement components or systems that are distributed by your company, and the price of those components. For this survey, a TPMS malfunction is defined as any time a TPMS system is not working correctly—including problems with the sensors or the on-board components.

SECTION 2. TPMS MALFUNCTION SOURCES

1. **Is your company involved in the design, manufacture or other aspects of the TPMS supply industry?** *Please choose one response.*

- ○ Yes, direct systems only
- ○ Yes, indirect systems only
- ○ Yes, both direct and indirect systems
- ○ No → *GO TO SECTION 5*

IF YES TO Q1:

1a. For each category of direct and indirect TPMS components listed below, please indicate the role(s) your company serves in the TPMS supply chain. If your company is not involved with a specific component, leave the entire row for that component blank.

	Component	Company Role (SELECT ALL THAT APPLY)				
						Other: Specify
DIRECT	a. Rim-mounted sensor	☐	☐	☐	☐	
DIRECT	b. Stem-mounted sensor	☐	☐	☐	☐	
DIRECT	c. On-board hardware (e.g., processing unit)	☐	☐	☐	☐	
DIRECT	d. Software	☐	☐	☐	☐	
INDIRECT	e. Chassis-mounted sensor (e.g., wheel speed sensor)	☐	☐	☐	☐	
INDIRECT	f. On-board hardware (e.g., processing unit)	☐	☐	☐	☐	
INDIRECT	g. Software	☐	☐	☐	☐	

☞ ***IF YOU INDICATED INDIRECT SYSTEMS ONLY IN Q1, GO TO Q3***

SECTION 2. TPMS MALFUNCTION SOURCES (continued)

2. In general, when <u>direct</u> TPMS malfunctions occur, how often are they associated with the following equipment?

	Almost Always	Often	Sometimes	Rarely	Almost Never
a. Tire pressure sensor battery (e.g., depleted)	○	○	○	○	○
b. Tire pressure module (e.g., damaged, corroded)	○	○	○	○	○
c. On-board hardware (e.g., TPMS receiver failure)	○	○	○	○	○
d. Software (e.g., false warning light indication)	○	○	○	○	○
e. Other *Specify*:	○	○	○	○	○

☞ ***IF YOU INDICATED <u>DIRECT SYSTEMS ONLY</u> IN Q1, GO TO Q4***

3. In general, when <u>indirect</u> TPMS malfunctions occur, how often are they associated with the following equipment?

	Almost Always	Often	Sometimes	Rarely	Almost Never
a. Chassis sensors (e.g., damaged)	○	○	○	○	○
b. On-board hardware (e.g., wheel speed sensor failure)	○	○	○	○	○
c. Software (e.g., false warning light indication)	○	○	○	○	○
d. Other *Specify*:	○	○	○	○	○

4. What sources of information informed your ratings to the preceding question(s) about TPMS component replacement? *Please select all that apply.*

- ☐ Feedback from customers
- ☐ Field surveys
- ☐ Warranty reports
- ☐ Other: Specify ____

5. **Please think about any major design changes your company has made to TPMS parts *in the last 5 model years*. For each TPMS part in the table below, please indicate the following:**
   1) **The number of major design changes your company has made,**
   2) **How many of these changed designs were still interchangeable with parts in older vehicles,**
   3) **Which model years were affected by these changes, and**
   4) **The cumulative effect of all of these design changes for this part (e.g., increased durability, increased accuracy)**

   If your company has not made any major changes to a component in the last 5 model years, leave that entire row blank.

	Component	MAJOR CHANGES IN THE LAST 5 MODEL YEARS			
		Number of Major Changes	Number Interchangeable	Model Years Affected	Cumulative Result
DIRECT	a. Rim-mounted sensor				
DIRECT	b. Stem-mounted sensor				
DIRECT	c. On-board hardware (e.g., processing unit)				
DIRECT	d. Software				
INDIRECT	e. Chassis-mounted sensor (e.g., wheel speed sensor)				
INDIRECT	f. On-board hardware (e.g., processing unit)				
INDIRECT	g. Software				

6. **If your company is planning any major design changes to TPMS parts in the next five model years, please briefly describe them below:**

SECTION 4. TPMS REPAIR PRICE

7. **What is your average price of a TPMS system (sensor, module, etc.) for the types of customers listed in the table below? Please indicate the price point in the supply chain (e.g., as sold to vehicle manufacturer or end-retail customer). Please also include your volume range for the price. If your company does not supply a particular type of customer, leave that entire row blank.**

	DIRECT Systems		INDIRECT Systems	
Customer Type	**Price**	**Volume Range**	**Price**	**Volume Range**
a. Vehicle manufacturer	$		$	
b. Aftermarket parts wholesaler	$		$	
c. Service facility	$		$	
d. End-retail customer	$		$	

☞ ***IF YOU INDICATED <u>INDIRECT SYSTEMS ONLY</u> IN Q1, GO TO Q9***

8. **What is your average price for the following commonly replaced <u>direct</u> TPMS parts? Please indicate the price point in the supply chain (e.g., as sold to TPMS system integrator, vehicle manufacturer).**

Customers of Direct TPMS Systems	Direct sensor module (in-wheel, both stem and rim)	On-board Hardware (e.g., Processing Unit)	Software
a. TPMS system integrator	$	$	$
b. Vehicle manufacturer	$	$	$
c. Aftermarket wholesaler	$	$	$
d. Service facility	$	$	$
e. End-retail customer	$	$	$

☞ ***IF YOU INDICATED <u>DIRECT SYSTEMS ONLY</u> IN Q1, GO TO SECTION 5***

9. **What is your average price for the following commonly replaced <u>indirect</u> TPMS parts? Please indicate the price point in the supply chain (e.g., as sold to TPMS system integrator, vehicle manufacturer).**

Customers of Indirect TPMS Systems	Indirect sensing components	On-board Hardware (e.g., Processing Unit)	Software
a. TPMS system integrator	$	$	$
b. Vehicle manufacturer	$	$	$
c. Aftermarket wholesaler	$	$	$
d. Service facility	$	$	$
e. End-retail customer	$	$	$

SECTION 5. END

Thank you! You have completed the survey.

The information you have provided will be valuable for improving knowledge about TPMS.

<u>Please click the submit button below to deliver your final answers. A new email message will open up with your completed survey as an attachment. Please send the email to complete the submittal process.</u>

Submit

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U.S. Department
of Transportation

National Highway
Traffic Safety
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