Selected Issues in Passenger Vehicle Tire Safety

Special Investigation Report

NTSB/SIR-15/02
PB2016-100009

National
Transportation
Safety Board

NTSB/SIR-15/02
PB2016-100009
Notation 8727
Adopted October 27, 2015

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National Transportation Safety Board

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National Transportation Safety Board. 2015. *Selected Issues in Passenger Vehicle Tire Safety*. Special Investigation Report NTSB/SIR-15/02. Washington, DC.

Abstract: Each year, about 33,000 tire-related passenger vehicle crashes occur, resulting in about 19,000 injuries. In 2013, a total of 539 people died in tire-related passenger vehicle crashes. This special investigation report summarizes the National Transportation Safety Board (NTSB) investigations into four such crashes and discusses the safety issues uncovered. This report also considers statements made by experts during the December 9 and 10, 2014, Passenger Vehicle Tire Safety Symposium held by the NTSB in Washington, DC. Among the issues this report addresses are problems with the tire registration and safety recall system, failure to establish the current level of crash risk posed by tire aging and the lack of consumer guidance on this issue, poor tire maintenance practices by consumers, and barriers to technological innovation that could prevent or mitigate tire-related crashes. Safety recommendations to the National Highway Traffic Safety Administration, AAA, the Rubber Manufacturers Association, and the major tire manufacturers are included.

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Abbreviations

ASTM	ASTM International
CFR	*Code of Federal Regulations*
DOT	US Department of Transportation
ESC	electronic stability control
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FMVSSs	*Federal Motor Vehicle Safety Standards*
Ford	Ford Motor Company
Goodyear	The Goodyear Tire & Rubber Company
I-10	Interstate 10
I-75	Interstate 75
Kumho	Kumho Tire USA Inc.
Michelin	Michelin North America
MTD	*Modern Tire Dealer*
NADA	National Automobile Dealers Association
NASS/CDS	National Automotive Sampling System/Crashworthiness Data System
NASS/GES	National Automotive Sampling System/General Estimates System
NHTSA	National Highway Traffic Safety Administration
NMVCCS	*National Motor Vehicle Crash Causation Survey*
NTSB	National Transportation Safety Board
RFID	radio-frequency identification
RMA	Rubber Manufacturers Association

SUV	sport utility vehicle
TIA	Tire Industry Association
TIN	tire identification number
tires	radial tires
TPMS	tire pressure monitoring system
TREAD Act	Transportation Recall Enhancement, Accountability, and Documentation Act
US-90	US Highway 90
UV	ultraviolet radiation
VIN	vehicle identification number
VMT	vehicle miles traveled

Executive Summary

In 2013, a total of 539 people died in tire-related crashes in passenger vehicles. Each year, about 33,000 passenger vehicle tire-related crashes occur, resulting in about 19,000 injuries. Most tire-related crashes are preventable and, although actions that could reduce tire-failure-related injuries and deaths are known, they continue to be debated rather than implemented.

In February 2014, the National Transportation Safety Board (NTSB) investigated two fatal tire-related motor vehicle crashes in which the initiating event was tire tread separation. The first crash occurred in Centerville, Louisiana, and it involved a sport utility vehicle (SUV) and a school bus. The SUV was traveling westbound on US Highway 90 when its left rear tire experienced a tread separation and sudden air loss. The second crash occurred in Lake City, Florida, and it involved a 15-passenger van occupied by three adults and seven children. The van was traveling northbound on Interstate 75 when its left rear tire sustained a complete tread separation. The NTSB also conducted limited investigations in 2014 of two additional fatal crashes caused by tire failure—one involving a pickup truck that experienced a tread separation on its left front tire in Eloy, Arizona, and the other involving an SUV that experienced a tread separation on its right rear tire in Patterson, California. Overall, as a result of these crashes, 12 people died and 42 people were injured.

On December 9 and 10, 2014, the NTSB hosted a Passenger Vehicle Tire Safety Symposium to learn more about the tire-related issues uncovered during its crash investigations and to gather additional information and expert opinion on the factors that lead to tire failure. Based on its investigative findings and the information gathered during the symposium, the NTSB identified the following general areas of safety concern:

- problems with the tire registration and safety recall system,
- failure to establish the current level of crash risk posed by tire aging and lack of consumer guidance on this issue,
- poor tire maintenance practices by consumers, and
- barriers to technological innovation that could prevent or mitigate tire-related crashes.

This special investigation report summarizes the NTSB's investigative efforts on tire-related passenger vehicle crashes, discusses the safety issues uncovered during these investigations and the December 2014 symposium, and makes recommendations to prevent or mitigate the severity of tire-related crashes. The report includes safety recommendations to the National Highway Traffic Safety Administration, AAA, the Rubber Manufacturers Association, and the major tire manufacturers.

1 Introduction

1.1 Background

Tires are among the most important yet often neglected components on a vehicle. They are the only part of a vehicle that contacts the roadway, and they are expected to be robust enough to bear the weight of the vehicle and its cargo through many thousands of miles of travel, while staying pliant enough to ensure passenger comfort. They are also expected to be durable and versatile enough to maintain friction through thousands of acceleration, braking, and turning events under varying weather conditions, such as snow and rain. The tires made today are better than those produced even a decade ago. Nevertheless, tire-related crashes still occur regularly. In 2013, a total of 539 people died in passenger vehicle tire-related crashes.[1] Each year, about 33,000 tire-related crashes occur, resulting in about 19,000 injuries.[2] This report addresses several general issue areas associated with tire safety. First, the process used to identify and inform purchasers of a tire recall and to recover the defective tires has proven ineffective. Second, although the National Highway Traffic Safety Administration (NHTSA) and others have spent over a decade researching the effects of "tire aging," as time-related degradation is often termed, NHTSA has not established the crash risk posed by tire aging, and little guidance has been made available to consumers to help them understand what they should do to avoid tire failures due to aging. Third, a tire's durability and performance depend on a number of factors, the most important of which is periodic maintenance; yet surveys indicate that many consumers are unaware of how essential tire maintenance is and how often it should be done. Finally, although tire manufacturers continue to produce more robust tires that require less maintenance, some have voiced concerns that regulatory hurdles and impasses stifle technological innovation.

In February 2014, the National Transportation Safety Board (NTSB) investigated two fatal tire-related motor vehicle crashes in which the initiating event was tire tread separation. The first crash occurred in Centerville, Louisiana, and it involved a sport utility vehicle (SUV) and a school bus. The SUV was traveling westbound on US Highway 90 (US-90) when its left rear tire experienced a complete tread separation and sudden air loss. The SUV departed the roadway onto an earthen median, entered the eastbound lanes, and collided with a school bus traveling eastbound on US-90. The SUV driver and three passengers died, and the remaining SUV passenger was seriously injured; in addition, the school bus driver and 30 passengers were injured. The tire that failed was over 10 years old and poorly maintained (NTSB 2015a). The second crash occurred in Lake City, Florida; it involved a 15-passenger van occupied by three adults and seven children. The van was traveling northbound on Interstate 75 (I-75) when its left rear tire sustained a complete tread separation but remained inflated. The van rotated clockwise, departed the right side of the roadway, and rolled over on an earthen embankment. Two adults in the van died, and the remaining van occupants were injured. The failed tire was subject to a safety recall that cited the potential for tread loss and/or rapid air loss resulting from tread belt

[1] This total is based on an analysis of data from the Fatality Analysis Reporting System (FARS). See appendix B for additional information on the analyses. "Tire-related crashes" are those accidents in which tire failure may have caused or contributed to the crash.

[2] These totals are derived from an analysis of data from the National Automotive Sampling System/General Estimates System (NASS/GES).

separation (NTSB 2015b). The NTSB also conducted limited investigations in 2014 of two additional fatal crashes caused by tire failure—one involving a pickup truck that experienced a tread separation on its left front tire in Eloy, Arizona, and the other involving an SUV that experienced a tread separation on its right rear tire in Patterson, California. Overall, as a result of these crashes, 12 people died and 42 people were injured.

On December 9 and 10, 2014, the NTSB hosted a Passenger Vehicle Tire Safety Symposium to gather information and expert opinion on the factors that lead to tire failure. The symposium focused primarily on passenger vehicle and light truck tires, although some topics applied to all pneumatic tires.[3] The symposium included participants from the industry, consumer organizations, and the federal government. It covered the following topics: (1) causes of tire failure and vehicle dynamics, (2) available data on tire-related crashes, (3) factors that contribute to tire aging, (4) tire safety recalls, (5) current technological initiatives, and (6) consumer awareness of tire maintenance procedures. The information gathered at the symposium is referenced throughout this report and is available through the NTSB symposium website and docket.[4]

1.2 Tire Structure Overview

This section provides background on tire structure to help the reader understand the factors that can lead to tire failure (Gent and Walter 2006). It focuses on radial tires, which account for virtually all the passenger vehicle tires sold in the United States.[5]

As illustrated in figure 1, the innermost part of a tire consists of a liner that allows the tire to retain air. Tire body plies comprise the next layer and consist of two or more layers of rubber-coated fabric (usually polyester, nylon, or aromatic polyamide) that run perpendicular (radially) to the tread. These plies support the internal pressure of the inflated tire and increase the impact resistance of the sidewall. Two or three belts of steel, plated in bronze to facilitate adhesion to rubber, are coated in rubber (skim) to bond the belts to the rest of the tire and are placed longitudinally around the tire. The steel belts restrict expansion of the body ply, stabilize the tread area, and provide impact resistance. Various wedges, cushions, and strips reduce inter-ply shear stresses at the edges of the belts and protect the body plies from the belt edges. A nylon overlay is often wrapped around the belts to further restrict expansion from centrifugal forces during high-speed operation. A thin layer of rubber, called an undertread, is added between the treads and the plies below to boost adhesion between the surfaces and to cover the ends of the steel belts. The treads and sidewall comprise the external layer of the tire; the treads are designed for traction, durability, noise abatement, and handling. The sidewall provides structural integrity and protects the body plies from abrasion, impact, and flex fatigue. Brass- or bronze-coated steel wires (beads), wrapped or reinforced with body plies, anchor the tire to the rim.

[3] Pneumatic tires contain air or gas under pressure.

[4] For more information, see www.ntsb.gov/tiresafety, accessed October 1, 2015. Information from the symposium can also be found in the NTSB docket system under NTSB accident ID number DCA14SS010, which can be accessed at www.ntsb.gov.

[5] Radial tires are pneumatic tires in which the ply cords that extend to the beads are laid at 90 degrees to the centerline of the tread.

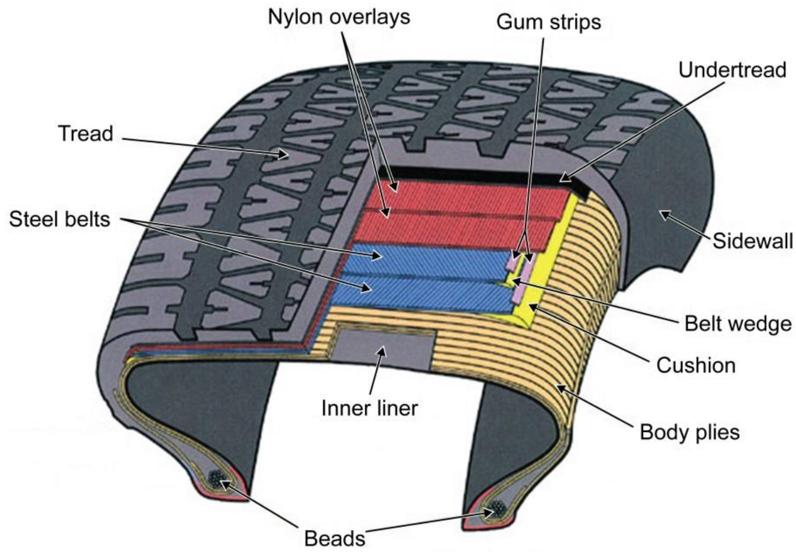

Figure 1. Cross-section of a passenger vehicle tire, indicating the locations of structural components.

The polymer compounds, ply materials, and tread designs on tires are adjusted in accordance with the purpose and performance of a particular type of vehicle, as well as customer expectations. For example, tires for high-performance sports cars are generally designed with stiffer, low-profile sidewalls and softer treads for better handling and traction on dry surfaces; in contrast, tires for family sedans generally have taller and more pliant sidewalls for increased ride comfort, with treads that are more wear-resistant and generate less noise during use.

According to data published in the *Modern Tire Dealer* (*MTD*), in 2013, the tire industry shipped 278.3 million new tires for passenger vehicles and light trucks (*MTD* 2014).[6] That total included 44 million original equipment tires for new passenger vehicles and 201.6 million replacement tires for passenger vehicles. Another 4.4 million original equipment tires and 28.3 million replacement tires were shipped for light trucks. Consumers purchased about 61 percent of replacement tires from smaller independent tire dealers, but they also purchased them from large tire retail chains (14 percent), warehouse clubs (9 percent), manufacturer-controlled outlets (8 percent), and automotive dealerships (8 percent). According to data from the Rubber Manufacturers Association (RMA), the trade association representing tire manufacturers with plants in the United States, about 232,000 establishments sell or service tires in the United States (Norberg 2014).

[6] *MTD* is a periodical publication (available in digital and hard copy formats) intended to serve the independent tire dealer industry. See www.moderntiredealer.com/default.aspx, accessed July 13, 2015.

2 NTSB Investigations of Tire-Related Crashes

In February 2014, the NTSB launched investigations of two separate multi-fatality crashes. In each instance, the crash was initiated by tread separation on the left rear tire that caused the driver to lose control of the vehicle. In the Centerville, Louisiana, crash, the subject tire was over a decade old and in poor condition; in the Lake City, Florida, crash, the subject tire had been recalled by the manufacturer a year and a half before the accident. NTSB reports that provide more details about these crashes are available as separate publications (NTSB 2015a and NTSB 2015b). (The NTSB also reviewed police evidence for tire-related crashes occurring in 2014 in Eloy, Arizona, and Patterson, California. Appendix C provides summaries of these two crashes, and further information on them is available in the NTSB's docket system.)[7]

2.1 Centerville, Louisiana

About 11:30 a.m. central standard time, on Saturday, February 15, 2014, a 2005 IC Bus 66-passenger school bus, occupied by a 40-year-old driver and 34 members of the Lafayette High School baseball team, was traveling eastbound on US-90 near Centerville, Louisiana. Approaching from the opposite direction, a 2004 Kia Sorento SUV, occupied by a 37-year-old driver and four passengers, was traveling westbound on US-90 in the right lane at a witness-estimated speed of 70 mph (the posted speed was 70 mph). The SUV's left rear tire experienced a complete tread separation and rapid air loss. The SUV veered into the left westbound lane, rotating in a counterclockwise direction, and departed the roadway into a 64-foot-wide depressed grassy median area. After passing through the median, the SUV crossed the left lane of eastbound traffic and collided with the school bus, which was traveling in the right eastbound traffic lane.

The left front of the SUV contacted the right front of the school bus, resulting in the rapid rotation of the SUV and secondary impacts along the right side of the school bus. The SUV came to a rest in the grass right-of-way separating US-90 from a frontage road on the south side of the highway. The school bus continued in a southeasterly direction, departing the roadway to the right, where it crossed the earthen median, the frontage road, and a drainage ditch, before coming to a rest in a sugar cane field. Figure 2 shows the two vehicles in their positions of final rest. As a result of the collision, the belted SUV driver and three unbelted rear passengers were ejected and died. The fourth SUV passenger, who had been seated in the front passenger seat and was wearing a seat belt, was seriously injured. Of the 35 school bus occupants, 30 received injuries ranging from minor to serious. The bus driver sustained minor injuries (NTSB 2015a).

[7] See Eloy, Arizona, NTSB docket number HWY14IH008; Patterson, California, NTSB docket number HWY14IH011.

Figure 2. Centerville school bus and SUV at final rest. (Source: Louisiana State Police)

Based on the evidence, the NTSB established that the probable cause of the Centerville, Louisiana, crash was the Kia SUV driver's loss of control due to the tread separation and rapid air loss of the left rear tire, which altered vehicle-handling characteristics. Contributing to the crash was the deteriorated condition of the tire due to inadequate maintenance.

The subject tire was a Michelin North America (Michelin) Cross Terrain manufactured in the 44th week of 2003, making the tire 10 years old when the crash occurred.[8] The tread depth for most of the tire was 2/32 inch or more, meeting the minimum requirement in Louisiana; however, the tire also had a bald spot located toward the inboard shoulder, where the tread depth was zero.[9] (See figure 3.)

[8] The tire identification number was DOT 0CBU JDWX 4403. The last four digits indicate the week (44th week) and the year (2003) the tire was manufactured.

[9] The original tread depth for the subject tire, according to manufacturer literature, was 11/32 inch.

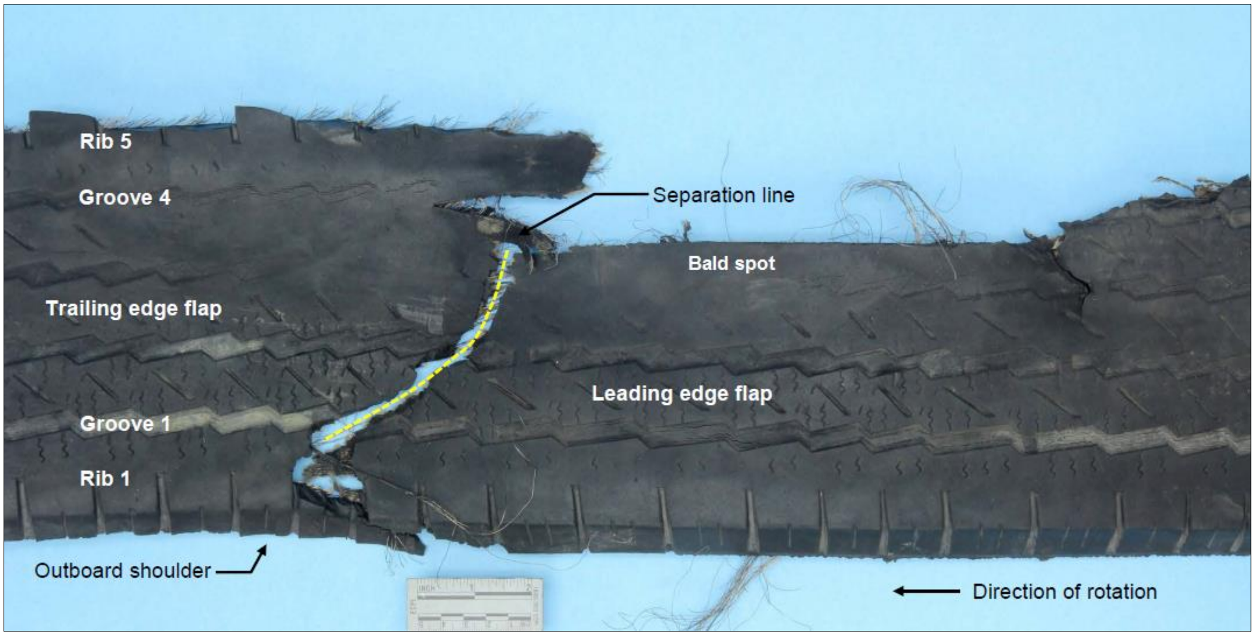

Figure 3. Delaminated tread from the left rear tire of the Centerville SUV. The two flaps created by the tear are in their approximate pre-separation positions. A narrow section of tread is missing near the location of a bald spot in the tire.

The tread separated from the tire carcass near the bald spot. The tread separation started as a delamination between the inner and outer steel belts on the inboard side of the tire.[10] Over time, the delamination formed a thumbnail-shaped pocket between the belts, which extended along the shoulder of the tire. The difference in treadwear between the delaminated region and the remainder of the tread indicates that the pocket was probably present for at least hundreds, if not thousands, of miles. Additional delamination formed along the outboard shoulder and progressed toward the inboard shoulder. The tread separated from the tire when the delaminations merged. The tire carcass subsequently split in the radial direction (from the outboard to the inboard shoulder), and the tire lost pressure. (See figure 4.)

[10] "Delamination" is a term used to describe the separation of composite layers of material.

Figure 4. Detreaded tire carcass from the Centerville SUV.

Other physical damage to the subject tire included three foreign objects that penetrated the tread and the outer steel ply. One object, found approximately 46 inches clockwise from the tip of the leading edge flap, is shown in figure 5.[11] The steel wires in the outer ply were deformed where the objects had penetrated the tread.

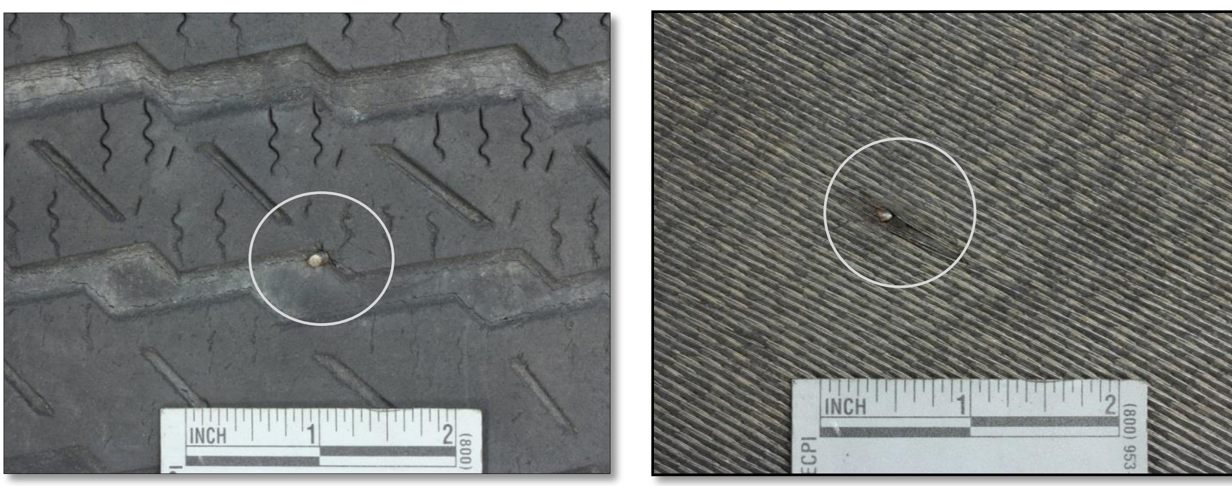

Figure 5. Tread image (left) and separation side image (right) of a foreign object that penetrated the Centerville SUV tire’s tread approximately 46 inches from the separation. (Area of object penetration is circled on both images.)

[11] The “leading edge flap” is the side of the tread that forms a triangular wedge of tread pointing toward the direction of rotation, as indicated in figure 3.

Additionally, there were compression set marks on the outboard sidewall and cracking along the sidewall and shoulder area (see figure 6, left image). Cracking can occur due to overdeflection, the presence of foreign materials, ozone deterioration, loss of rubber elasticity over time, and high operating temperatures.[12] A wheel weight clip, which is a device used to balance the tire, left multiple impression marks near the bead on the inboard side of the tire (see figure 6, right image); this suggests that the tire had been operated in an underinflated condition during its lifetime, thereby allowing the weight to shift.

Figure 6. Centerville SUV tire; at left is the inboard sidewall exhibiting cracking on the sidewall, buttress, and shoulder; at right are the impressions left by the wheel weight clip near the bead on the inboard side of the tire.

2.2 Lake City, Florida

About 8:15 a.m. eastern standard time on Friday, February 21, 2014, a 2002 Ford Motor Company (Ford) 350 XLT 15-passenger van, occupied by three adults and seven children, ranging in age from 12 to 16 years old, was traveling northbound on I-75 near Lake City, in Columbia County, Florida. The van was owned and operated by the First Baptist Church in New Port Richey, Florida, and was en route to a church camp in Covington, Georgia. According to one of the passengers, during the trip, the driver of the van perceived a vibration that he believed was originating from one of the vehicle’s tires. The driver pulled the van off the highway into a rest area to investigate. Finding nothing visibly wrong, the driver continued with the trip. After traveling an additional 13 miles from the rest area, the van experienced a tread separation of the left rear tire (which remained inflated). The driver lost control of the van, and it rotated clockwise as it veered to the right. The van left the roadway, moved onto a grassy embankment, and rolled over. (See figure 7.) During the rollover event, the driver, another adult, and two juvenile occupants were ejected. According to local law enforcement, none of the ejected occupants were wearing seat belts. As a result of the crash, the two ejected adults died. The remaining van occupants received various injuries and were transported to area hospitals for treatment (NTSB 2015b).

[12] “Overdeflection” is a change in the tire’s radius that is beyond the tire’s intended operating limits. Overdeflection typically occurs when a tire is underinflated or overloaded. “Ozone deterioration,” also referred to as “weather checking,” is characterized by the formation of small superficial cracks along the sidewall. See section 4 of this report for more information.

Figure 7. Lake City vehicle and tire; at left is a postcrash view of the 2002 Ford 15-passenger van at final rest on its left side, and, at right is the delaminated tire tread. (Source: Florida Highway Patrol)

Based on the evidence, the NTSB established that the probable cause of the Lake City, Florida, crash was the failure of the left rear tire due to a tread separation, which led to the loss of vehicle control. Contributing to the crash were the failure of the tire merchant to adhere to its training material and provide the purchaser with a tire registration form as required, and record-keeping discrepancies that inadvertently allowed an outdated address to be used in the recall notification process. Contributing to the severity of the injuries was the nonuse of available seat belts.

The subject tire was a BFGoodrich Commercial T/A all-season tire manufactured in the 47th week of 2011, making it about 2 years old at the time of the crash. (See figure 8.) The tire was among those recalled by Michelin, the parent company of BFGoodrich, on July 25, 2012. An examination of the tire showed that the tread separation initiated at a spot along its outer shoulder and developed into a thumbnail-shaped pocket between the inner and outer steel belts. As the initial separation grew in size, a second separation formed along the inner shoulder and expanded until it joined the initial separation. The tread separated from the tire shortly thereafter. The tire was examined for features consistent with overdeflection/underinflation, impact damage, or abuse prior to the separation, but none were found.

Figure 8. Carcass of left rear tire from the Lake City vehicle (left) and its delaminated tread (right).

The driver's perception of a vibration coming from one of the vehicle's tires shortly before the tire failure is consistent with the tread being pulled away from the tire and then being compressed between the tire and the road with each wheel revolution. Because the pocket was within the tire, the driver would not have seen any indication of it when he pulled over to inspect the tires. A postcrash inspection of the van revealed no damage within the left rear wheel well or to the surrounding fender panel that would have been consistent with repeated impacts by the separating tire tread.

3 Tire Registration and Safety Recalls

From 2009 to 2013, a total of 55 tire safety recalls took place, involving more than 3.2 million tires. However, only about 44 percent of the recalled tires (about 1.4 million tires) were accounted for by the recalls (Chern 2014), which suggests that a majority of the recalled tires may have stayed in service. One such tire failed 19 months after its recall was announced and resulted in the deaths of two people in Lake City, Florida.

This section reviews the NTSB's investigative findings from the Lake City crash and examines the regulatory issues and industry practices that keep manufacturers from recovering many defective and noncompliant tires. Issues of particular concern are (1) the poor tire registration rates among customers purchasing tires from independent dealers, (2) the inaccessibility of the tire identification number (TIN) and its underutilization in locating recalled tires, and (3) the insufficiency of consumer awareness and available information during a tire recall.

3.1 Recalled Tire Involved in the Lake City Crash

The left rear tire that failed on the 15-passenger van had been subject to a recall announced 19 months prior to the Lake City crash. Records indicated that it had been purchased on February 10, 2012, from Sam's Club in New Port Richey, Florida. On July 25, 2012, a safety recall was announced for select BFGoodrich Commercial T/A all-season radial tires, which included the left rear tire on the van. The recall was initiated by the tire manufacturer, Michelin, because of tread/belt endurance issues discovered during quality reviews. Safety recall notices sent to tire owners in July 2012 stated, "It is possible that any one of the tires being recalled may experience tread loss and rapid air loss resulting from tread belt separation. This condition may increase the risk of vehicle crash."

Michelin identified a total population of 799,900 tires subject to the recall that had entered the US market as replacement tires. The manufacturing dates for the population ranged from the 13th week of 2010 (beginning March 29, 2010) to the 29th week of 2012 (beginning July 16, 2012). As required by Title 49 *Code of Federal Regulations* (*CFR*) Part 577, in late July 2012, Michelin sent recall notification letters to known tire purchasers, dealers, and distributors that had received the subject tires from the manufacturer.[13] The notifications were sent to purchasers via first class mail. On its own initiative, Michelin mailed a second set of notification letters in November 2012. In addition, Michelin requested sales information from tire dealers, including Sam's Club, in an attempt to locate tire purchasers who might not have registered their tires.

Sam's Club complied with Michelin's request by providing addresses for purchasers of the recalled tire. However, the address that Sam's Club gave to Michelin for the purchaser of the tire—the First Baptist Church in New Port Richey—was out of date. According to church staff,

[13] For the purposes of this report, the term "dealer" refers to any person or entity that sells or distributes tires to consumers.

the church had moved to its current address in 2008. NTSB investigators reviewed the records of the church's recent Sam's Club transactions and found that, although the billing statements listed the church's current address, the repair orders listed the church's pre-2008 address. According to church administrators, the First Baptist Church in New Port Richey did not receive any notification letters informing it of the tire recall. In an interview with NTSB investigators, the church staff member who purchased the tire stated that, at the time of purchase, he was not asked to provide information for tire registration. The service receipt for the left rear tire included a statement in small print indicating that the buyer should see the cashier to obtain a tire registration form. This provision of this statement does not satisfy federal regulations (49 *CFR* 574.8), which require the seller to provide a registration form to the purchaser that includes the name of the dealer and the TINs of the tires purchased.

At the NTSB's request, Michelin gave the NTSB the results of a 2010–2013 survey of independent dealers, which indicated that less than 2 percent of tires purchased were being registered.[14] Michelin allows its tires to be registered through its website, and the manufacturer experienced a steady increase in the registration of its tires after the 2009 rule change that allowed for electronic registration.[15] Although each year has shown an increase in the total number of tires registered via the Internet, the annual rate of the increase has slowed.

As required by regulation (49 *CFR* Part 573), Michelin filed six quarterly reports with NHTSA on the progress of the July 25, 2012, recall; the final report covered the third quarter of 2013. In this final report, the manufacturer estimated that about 86 percent of the recalled tires were no longer in service either as a result of being physically recovered or through attrition. Data provided in the quarterly submissions indicated that about 19 percent of the subject tires were recovered while a fraction of a percent of the tires had been returned to the manufacturer before sale. About 66 percent of the recalled tires were determined to be no longer in service as a result of the manufacturer's calculation that the service life of the tires had expired.

3.2 Registration of New Tires

The success of the tire recall process depends substantially on the effectiveness of the tire registration process. Federal regulations (49 *CFR* Part 574) require that each tire manufacturer compile a list of the individuals or entities that have purchased its tires, so they can be contacted in the event of a recall.[16] The basis for compiling this list is the tire registration process.[17] In most instances, without the registration information, a tire manufacturer has no means to identify and subsequently notify a tire purchaser in the event of a safety recall.

[14] Data underlying the survey were not provided, although Michelin stated that historically the rate of tire registration has been in the single digits among independent dealers.

[15] See NHTSA docket NHTSA-2008-0187, "Tire Registration and Recordkeeping," 73 *Federal Register* (November 28, 2008): 72358.

[16] These include tire distributors, dealers, and first purchasers.

[17] Manufacturers may be able to supplement their purchaser list through other data sources, though this is not required and may generally only occur during the implementation of a safety recall campaign.

3.2.1 Methods of Registration

Federal regulations describe the information to be collected when a tire is registered and the methods that may be used to convey this information to the manufacturer. The primary method of collecting and transmitting this information is the paper registration form. In general, the form includes fields for the name and address of the tire purchaser, the dealer that sold the tires, and the TIN of each tire purchased. Each tire manufacturer is required to provide a sufficient number of registration forms to every distributor and dealer offering that manufacturer's tires for sale. Each manufacturer must also record and maintain the information received on the registration forms for not less than 5 years.

Changes to Part 574 implemented in 2009 allowed manufacturers to accept the registration of tires via the Internet, telephone, or other electronic means. The NTSB reviewed the Internet homepages of 18 tire manufacturers to ascertain how many were taking advantage of this regulatory change and found that 11 provided web links for online registration.[18] Three of the 18 manufacturers clearly identified the purpose of the link as tire registration and positioned the link at the top or middle of the main web page.[19] Eight of the 18 manufacturers provided a clearly identified link for registration in small print at the bottom of their main web page. Two of the 18 manufacturers had a clearly identified link located on a website subpage related to customer service. NTSB investigators could only locate the link for tire registration provided by one of the manufacturers by entering the term "registration" into the site search feature. No information on tire registration could be found on the remaining four manufacturers' homepages. In addition to manufacturer websites, NTSB investigators visited the RMA homepage and found a "tire registration" link prominently displayed, which took the viewer to the registration pages of the association's members (tire manufacturers).

3.2.2 Current Registration Process

The roles and responsibilities of tire dealers and distributors in the registration process differ depending on whether they are independent or controlled by a manufacturer.[20] Dealers and distributors controlled by a manufacturer are required to register newly purchased tires for the consumer and to forward the registration information to the tire manufacturer. Independent dealers and distributors are required to provide the registration form to the purchaser, after recording on the form their business identity and the TINs of the tires purchased.[21] An independent dealer or distributor may elect to complete and mail the registration form to the manufacturer on behalf of the purchaser or to use an electronic means (for example, by Internet) to transmit the registration information within 30 days. NHTSA regulations stipulate that an

[18] The 18 tire manufacturers included those with active recalls and the top manufacturers for 2013, as reported by the *MTD*.

[19] Links were identified as "Tire Registration" or "Register Your Tires."

[20] A 1982 revision to section 30117 of the Motor Vehicle Safety Act limited the responsibility of independent dealers and distributors solely to providing registration forms to purchasers. In addition, the revision did not authorize NHTSA to establish regulations that would require independent dealers and distributors to maintain any records on purchasers. Tire manufacturers are also required to cover all costs associated with the registration process.

[21] Dealers and distributors may also use registration forms acquired from sources other than the manufacturer, as long as those forms meet the requirements for size, layout, and content specified in 49 *CFR* Part 574.

independent dealer or distributor that registers a new tire via the Internet need not provide a paper registration form to the purchaser but must provide the purchaser a printed invoice containing all information required for registration (including the TIN, as well as dealer and manufacturer identification).

The registration requirements for independent dealers have changed over the years. In 1970, Congress gave NHTSA the authority to require that tire manufacturers maintain the names and addresses of tire purchasers.[22] Beginning that year, NHTSA required all tire dealers to record the names and addresses of all tire purchasers and forward that information with the dealer's name and address to the tire manufacturer. In 1982, after the House Committee on Energy and Commerce found that only about 20 percent of tires sold by independent tire dealers were being registered (as opposed to 86 percent for manufacturer-controlled dealers), Congress shifted the responsibility of registration to the tire purchaser, requiring only that independent distributors and dealers (comprising 92 percent of all retailers) provide the purchaser with a registration form that includes the name of the dealer and the TINs of the tires purchased. It became the purchaser's responsibility to fill out the rest of the form and mail it to the manufacturer. Dealers controlled by a tire manufacturer were still required to register tires and maintain purchaser information. By statute, NHTSA could not require independent dealers to register tires at the point of sale.[23]

In 1988, NHTSA assessed the effect of the 1982 regulatory change on the rate of tire registration.[24] The agency found that the registration rates for tires purchased from independent dealers declined by half, to about 9 percent, whereas the registration rates for tires purchased from manufacturer-controlled dealers remained unchanged at 86 percent. Also, although NHTSA determined that manufacturers were distributing a sufficient number of blank registration forms to dealers and distributors, completed registration forms making their way back to the manufacturer were originating from less than 30 percent of independent tire dealers. From these findings, NHTSA concluded that over 70 percent of independent tire dealers were not routinely providing registration forms to their customers; however, the agency determined that it would not be the best use of its enforcement resources to bring compliance actions against those dealers that ignore the regulations.

At the 2014 NTSB Passenger Vehicle Tire Safety Symposium, the Tire Industry Association (TIA), which represents 7,000 members in the retail and commercial tire and tire retread industry, acknowledged that only a small percentage of tires sold by independent dealers are ever registered. However, the TIA maintained that because dealers often do not receive registration forms from manufacturers (despite the regulatory requirement that the forms be provided), some dealers have resorted to purchasing universal registration forms from third-party vendors. The TIA stated that most of its members acquire the tires they sell through wholesalers and not directly from the manufacturer, which may mean that the wholesalers are not passing along the registration forms to the independent dealers. When queried whether all tires should be registered at the point of sale, the TIA stated that doing so would take time, money, and

[22] See 35 *Federal Register* (November 10, 1970): 17257.

[23] See 49 *United States Code*, section 30117.

[24] See 53 *Federal Register* (November 4, 1988): 44632–44633.

resources from its members, most of which are small businesses. The TIA expressed interest in future technological advancements that could facilitate electronic registration, as long as its members incur no costs.

The RMA also commented on the registration process. The RMA estimated that the rate of tire registration by dealers controlled by manufacturers is nearly 100 percent. In contrast, the RMA estimated the collective registration rate from independent dealers as 10 percent or less. The RMA reported that most independent dealers relied on the customer to complete the registration form. The RMA stated that it believes all tires should be registered at the point of sale, thereby returning the responsibility to the selling dealer.

3.2.3 Improving the Registration Process

The need to improve the efficiency of tire safety recalls was highlighted on March 30, 2015, when the Secretary of Transportation proposed revisions to the pending transportation funding bill, titled the Generating Renewal, Opportunity, and Work with Accelerated Mobility, Efficiency, and Rebuilding of Infrastructure and Communities Throughout America Act, or Grow America Act.[25] Sections 4112 and 4113 of the proposed legislation focused on tire safety. Section 4112, titled "Tire Registration by Independent Sellers," would give the Secretary the authority to require independent tire dealers and distributors to record and maintain the names and addresses of tire purchasers, information identifying the tire that was purchased, and any additional information the Secretary deems appropriate. Any associated rulemaking would require independent tire dealers and distributors to electronically transmit such records to the tire manufacturer by secure means, at no cost to tire purchasers or lessors. The bill supports the potential use of scanners and other electronic means to facilitate electronic registration. Section 4112 would essentially reverse the changes instituted by Congress in 1982 and harmonize the tire registration regulations for all tire dealers and distributors (whether independent or manufacturer-controlled). The changes would also allow NHTSA to require tire dealers and distributors to register tires electronically.

In summary, manufacturers rely almost exclusively on the information available from the tire registration process to identify and alert those consumers whose tires are subject to recall. Tire registration is crucial to the success of any recall, yet only those tire dealers controlled by the manufacturers, comprising about 8 percent of all dealers, are required to register tires at the point of sale. Independent tire dealers are only required to provide the purchaser with a tire registration form that contains dealer information and the TINs of the tires purchased. Independent dealers rarely volunteer to register tires at the point of sale and, according to NHTSA and as illustrated by the Lake City accident, they often fail to provide the purchaser with the registration form. The NTSB concludes that the current tire registration process has proven to be ineffective in enabling tire manufacturers to compile complete and accurate customer contact information, which is vital to ensuring the success of a tire recall.

[25] The latest version of the Grow America Act, H.R. 3064, was introduced on July 15, 2015, and it continues to include these improvements to tire safety.

The NTSB understands that, in many cases, tires are not transferred directly from the manufacturer to dealers but are routed through wholesalers and importers; as a result, registration forms can be mishandled and fail to reach the dealer. Additionally, the NTSB is aware of the commitment of time needed to complete each registration form by hand, especially for dealers that sell large volumes of tires on a daily basis. The regulatory change allowing manufacturers to accept the registration of tires via the Internet or other electronic means provides a technological solution that is slowly gaining popularity among dealers and tire customers, but these methods still require dealers to enter information, which can take time and introduce transcription errors.

Scanning technologies that allow dealers to electronically read barcodes or radio-frequency identification (RFID) tags permanently affixed on a tire offer an alternative that could expedite the registration process. Using this technology, a tire's TIN could be quickly scanned, recorded, and electronically uploaded to a computerized registration system. Such a system would reduce the time needed for a dealer to register a tire, thereby increasing the probability that tire registration would take place. Use of scanning technologies could also reduce transcription errors. Although resources would be required to create an industry standard for software that takes full advantage of this technology, such an innovation would also simplify the tracking, storage, and distribution of tires, resulting in significant cost savings for both manufacturers and dealers. In fact, the tire manufacturer Kumho Tire USA Inc. (Kumho) is already tagging all its passenger vehicle tires with RFID to aid in inventory management (*Tire Review* 2013). The NTSB concludes that a computerized system for capturing, storing, and uploading tire registration information would expedite the tire registration process, reduce transcription errors, and encourage more dealers to register tires at the point of sale.

Changes in regulations are needed to ensure that manufacturers obtain the correct TIN and contact information for all tire purchasers for use in the event of a tire recall. The NTSB recommends that NHTSA seek authority to require all tire dealers to register tires at the point of sale, and then require them to do so. The NTSB believes that a return to the requirement that all dealers register tires at the point of sale will lead to a substantial increase in the registration of tires sold by independent dealers. Regulatory changes that allow for online means of registration provide options that reduce the burden to tire dealers. However, to encourage tire dealers to register tires and to further expedite the process, the NTSB also recommends that NHTSA develop voluntary standards, in consultation with tire industry leaders, for a computerized method of capturing, storing, and uploading tire registration information at the point of sale.

Even when a tire is properly registered, tire manufacturers may still face challenges when attempting to locate and notify the current owner of a recalled tire. Making additional information available, beyond the original purchaser's street address, that might help locate and identify purchasers of a recalled tire could reduce these challenges. For example, revising the tire registration form to include fields for the purchaser's e-mail address and telephone number would provide additional means by which tire manufacturers could reach those who have relocated to different addresses. More importantly, collecting the vehicle identification number (VIN) of the vehicle on which the tires were installed would allow tire manufacturers to perform vehicle title and registration searches to identify current tire owners, just as vehicle manufacturers do for vehicle recalls. The linkage between the TIN and the VIN would not only help tire manufacturers locate tire owners who have moved to a different address but also help them identify those who have recently purchased a previously owned vehicle equipped with tires involved in a recall. Adding entry fields to the tire registration form would require changes to 49 *CFR* Part 574; however, there is already industry support for this change (Norberg 2014), which should facilitate the rulemaking process. The NTSB concludes that modifying the tire registration form to include fields for the purchaser's e-mail address, telephone number, and VIN would provide additional means by which tire manufacturers could notify tire owners of recalls and recover more recalled tires that would otherwise continue in use. The NTSB recommends that NHTSA include fields on the tire registration form for the purchaser's e-mail address, telephone number, and VIN to assist manufacturers in locating and notifying owners of recalled tires.

3.3 Tire Identification Number

Tire labels in the United States are required to meet the requirements in 49 *CFR* Parts 571 and 574. NHTSA's website for vehicle-related consumer safety information (www.safercar.gov) includes a graphic that describes the labels commonly found on the sidewall of a tire.[26]

With respect to this report, the label of most importance is the TIN. The US Department of Transportation (DOT) requires that all tires be labeled with a TIN that begins with the letters "DOT" and is followed by a string of alphanumeric characters. The last four characters of the TIN are the date code, and they identify the week and year the tire was manufactured. The TIN does not uniquely identify a tire; instead, it identifies the tire as part of a batch manufactured during a certain week. If a defect is identified and a recall is initiated, the TIN is used to determine the batch or batches to include in the recall. Manufacturers identify the affected population of tires by make, model, size, and TIN. Although the make, model, and size are important pieces of information, it is the date code on the complete TIN that ultimately confirms whether a tire is in the recall population.

According to federal regulations, the complete TIN must appear on the intended outboard side of a tire. A partial TIN, without the four-digit date code, must appear on the intended inboard side. In April 2015, NHTSA published a final rule standardizing the length of the TIN so that it must provide 13 characters for new tires and 7 characters for retreaded tires.[27] Figure 9 shows the standard TIN layout, per the final rule, for new tires and the information that each set of TIN characters represents. Manufacturers have until 2025 to comply with this new rule. Until 2025, a complete TIN for a new tire could range in length between 6 and 12 characters and a partial TIN between 2 and 8 characters.

DOT	P P P	M M M M M M	W W	Y Y
DOT Symbol	Plant code 3 characters	Manufacturer tire code 6 characters	Week of production	Year of production

Figure 9. Arrangement of the 13-character standardized TIN for a new tire, as required by 49 *CFR* Part 574. (Manufacturers have until 2025 to comply with this TIN arrangement.)

[26] See www.safercar.gov/tires/pages/tires_labeling.html, accessed June 30, 2015.

[27] See 80 *Federal Register* (April 13, 2015): 19553–19564.

It may not always be apparent to tire technicians and consumers which side of a tire is the intended outboard side, and in some cases, the purchaser may request that the intended outboard side face inward.[28] In 2001, NHTSA estimated that about 65 percent of all tires in service are mounted so that the complete TIN faces inward, making it difficult to locate the complete TIN in a majority of cases.[29]

NHTSA has on several occasions explored requiring tire manufacturers to provide the complete TIN on both sidewalls, but because of manufacturers' objections, it has concluded that such a requirement would cause substantial safety and economic hardships, given current tire production methods.[30] According to tire manufacturers, although most of the TIN code remains consistent during the manufacturing of a particular tire model and size, the date code has to be changed weekly; changing the date code requires a worker to partially enter the typical clamshell-type tire press and physically change the plates bearing the date code. Manufacturers have noted that additional costs and safety considerations, such as allowing molds to cool, elevating workers into the upper portion of the press, and even redesigning some tire presses, would have to be addressed if a second TIN is to be provided on a tire. In addition, manufacturers have argued that even when a tire is mounted so that the complete TIN is facing inward, it can be readily identified by service technicians when the vehicle is raised on a vehicle lift.

In 2002, NHTSA published a final rule on placement of the TIN on tires manufactured after September 2006.[31] First, each tire labeled as required by 49 *CFR* Part 574 must have the complete TIN molded onto the intended outboard sidewall of the tire. The "intended outboard sidewall" is defined as a tire sidewall that contains a whitewall, white lettering, or manufacturer or model name molding, which is higher or deeper than lettering on the other side of the tire. (If a tire does not have an intended outboard sidewall, the manufacturer may mark the complete TIN on either tire sidewall.) Second, except for retreaded tires, either the complete TIN or a partial TIN must appear on the opposite tire sidewall (a partial TIN does not include the four-digit date code at the end of the alphanumeric TIN sequence). In 2004, NHTSA revised its 2002 final rule to allow tire manufacturers the option of laser etching the date code into the tire sidewall.[32]

Despite NHTSA's decision not to require the complete TIN on both sides of the tire, in its November 2002 final rule, the agency noted that when tires are mounted so that the TIN appears on the inward-facing sidewall, motorists have three inconvenient options for finding and recording the TIN: the motorist may (1) slide under the vehicle with a flashlight, search the inside sidewalls for the TIN, and record it; (2) remove each tire, find and record the TIN, and then replace the tire; or (3) enlist the aid of a garage or service station that can perform option 1 or place the vehicle on a vehicle lift so that the TIN can be found and recorded. NHTSA has

[28] For example, the white side of a whitewall tire would be the intended outboard side; however, some purchasers request that such tires be installed with the white side facing inward.

[29] See 66 *Federal Register* (December 19, 2001): 65536–65567.

[30] NHTSA originally proposed on July 23, 1970 (35 *Federal Register:* 11800–11805), that the TIN be marked on both sidewalls.

[31] See 67 *Federal Register* (November 18, 2002): 69600–69632.

[32] See 69 *Federal Register* (June 3, 2004): 31306–31321; and 69 *Federal Register* (August 19, 2004): 51399–51400 (correcting amendments).

acknowledged that, because of the difficulty and inconvenience of checking for the TIN, the percentage of people who respond to a tire recall campaign is reduced, so more motorists continue to unknowingly drive vehicles with potentially unsafe tires.

The NTSB agrees with NHTSA’s assessment that not providing the complete TIN—which includes the date code needed to identify a recalled tire—on both sides of the tire hampers the recall process and endangers motorists. Tire lines can have a lengthy production history, and only the date code can conclusively identify whether a tire is part of the production for the period being recalled. Moreover, the date code is a vital piece of information for tire maintenance. Vehicle and tire manufacturers publish technical bulletins and manuals with recommendations that tires be inspected, and even replaced, based on the production date; therefore, it is essential to effective maintenance that vehicle owners have easy access to the date code on the complete TIN. Finally, on the occasions when vehicle owners need to locate and decode their TINs, they must be able to distinguish between complete and partial TINs, making an already difficult task even more challenging. Therefore, eliminating partial TINs and requiring a complete TIN on both sides of a tire would reduce the potential for confusion and misidentification. The NTSB concludes that having a complete TIN on both sides of a tire would help consumers to accurately identify a recalled tire and to conduct maintenance as necessary and appropriate to the tire.

The NTSB acknowledges that some tire manufacturers would need to change their manufacturing processes to include the TIN on both sides of a tire. A number of manufacturers have already implemented safe procedures to accomplish this task and currently produce tires that provide the complete TIN on both sides of their tires. In addition, current regulations allow alternative, and possibly less burdensome, methods of adding the date code to tires, such as laser etching it onto the tire sidewall. Manufacturers should be free to select the method of providing complete TINs on both sides of the tire that integrates best with their production processes. The NTSB recommends that NHTSA require tire manufacturers to include the complete TIN on both the inboard and outboard sidewalls of a tire.

3.4 Tire Safety Recalls

NHTSA estimates that from 2009 to 2013, tire recall completion rates averaged about 44 percent. The completion rates reflect not only the tires physically recovered by the manufacturer but also the tires that the manufacturer estimates have ended their service life and are no longer on the road. Typically, a tire manufacturer physically recovers only about 20 percent of recalled tires.[33] By contrast, in most vehicle recalls, about 78 percent of affected vehicles are eventually serviced, according to NHTSA. Therefore, the NTSB concludes that, while vehicle recalls ultimately succeed in causing more than three-quarters of recalled vehicles to be serviced, tire recall recovery rates can be as low as 20 percent.

[33] See www.tirereview.com/clemson-university-tire-industry-selleck/, accessed June 16, 2015.

3.4.1 Tire Recall Requirements

The National Traffic and Motor Vehicle Safety Act (49 *United States Code* chapter 301) mandates that a manufacturer of motor vehicles and motor vehicle equipment, including tires, must initiate a safety recall when there is noncompliance with the *Federal Motor Vehicle Safety Standards* (FMVSSs) or when a safety defect is present.[34] NHTSA generally considers a safety defect to be a problem that poses an unreasonable risk to motor vehicle safety and may exist in a group of vehicles of the same design or manufacture or in equipment of the same type and manufacture.

When a tire recall is initiated, manufacturers are required to notify NHTSA, as well as dealers and purchasers of the tires. Purchasers must be notified by first class or certified mail, with the initial notifications to be provided no later than 60 days after the manufacturer determines that a safety defect or noncompliance with an FMVSS exists. The notification must provide the following information:

- a clear description of the defect or noncompliance;
- an evaluation of the risk to motor vehicle safety reasonably related to the defect or noncompliance;
- the measures to be taken to obtain a remedy of the defect or noncompliance;
- a statement that the manufacturer will remedy the defect or noncompliance without charge;
- the earliest date on which the defect or noncompliance will be remedied without charge, and for tires, the period during which the defect or noncompliance will be remedied without charge;
- the procedure the recipient of a notice is to follow to inform the Secretary of Transportation when a manufacturer, distributor, or dealer does not remedy the defect or noncompliance without charge; and
- other information the Secretary of Transportation prescribes by regulation.

Recall remedies must be provided free of charge, with certain limitations. A remedy free of charge is required only for tires bought within the 5 years prior to the notification to NHTSA. Manufacturers are only required to provide a remedy for 60 days after the purchaser receives notification of the recall or notification from the manufacturer that a replacement is available. However, the RMA stated during the December 2014 NTSB Passenger Vehicle Tire Safety Symposium that tire manufacturers are generally willing to provide a remedy beyond the required 60-day period.

[34] The FMVSSs are promulgated under 49 *CFR* Part 571, subpart B.

Selling a tire that is subject to a recall is prohibited. Manufacturers are required to inform NHTSA of how best to prevent the recalled tires from being resold for installation on a motor vehicle and must inform outlets and distributors authorized to replace the recalled tires about the ban on reuse or resale. After a recall has been initiated, the manufacturer administering the recall is required to submit reports to NHTSA on the progress of the campaign on a quarterly basis for six consecutive quarters, beginning with the quarter in which the recall campaign was initiated.

3.4.2 Vehicle Recall Requirements

In 2012, the Moving Ahead for Progress in the 21st Century Act directed the DOT to initiate rulemaking to make motor vehicle safety recall information available to the public on the Internet in a searchable format by make, model, and VIN.[35] In August 2013, NHTSA published a final rule requiring certain vehicle manufacturers to provide a searchable public database via the Internet for all safety recall campaigns they conduct. The regulation under 49 *CFR* 573.15, "Public Availability of Motor Vehicle Recall Information," requires manufacturers that have produced for sale, sold, offered for sale, introduced or delivered for introduction in interstate commerce, or imported into the United States 25,000 or more light vehicles or 5,000 or more motorcycles to make motor vehicle safety recall information available to the public on the Internet.[36] The vehicle recall search application must be available from the manufacturer's main US website, but data may be managed by the manufacturer or a third party designated by the manufacturer. The recall information must be searchable by vehicle make, model, and VIN. The search response must include information on any uncompleted safety recalls conducted during the preceding 15 years. Other requirements include the following:

- provide an Internet link to the search feature conspicuously placed on the manufacturer's main United States web page;
- allow users to search a vehicle's recall remedy status;
- ensure safety recalls subject to the requirements of this section are conspicuously placed first;
- state, for vehicles that have been identified as covered by a safety recall but for which the recall remedy is not yet available, that the vehicle is covered by the safety recall and that the remedy is not yet available;
- provide the date of the last information update;
- provide the recall campaign number, state the date the defect or noncompliance was reported, provide a brief description of the safety defect or noncompliance, describe the risk to safety, and describe the remedy program;

[35] See Public Law 112–141, sections 31301–31303, July 6, 2012.

[36] See 78 *Federal Register* (August 20, 2013): 51382–51462; 79 *Federal Register* (July 28, 2014): 43670–43678 (responses to petition for reconsideration, technical corrections); and 79 *Federal Register* (August 14, 2014): 47591 (delay of effective date, correction).

- instruct the user to contact the manufacturer if the user has questions or wishes to question the accuracy of any information, and provide a link or other contact information for doing so; and
- provide NHTSA the ability to link its VIN lookup tool to the manufacturer's public recall data (NHTSA's tool works as a portal to the manufacturer's data).

3.4.3 Tire Recall Search Tools

Although motor vehicle recall information is searchable by vehicle make, model, and VIN, as required by 49 *CFR* 573.15, there are currently no manufacturer- or government-supported searchable databases for tire recalls based on the TIN.[37] NHTSA does maintain a search tool for recalled tires on its website that is based on the tire's brand name (manufacturer) and line.[38] However, the NHTSA search tool is not as user-friendly as it could be.

For instance, a basic search by brand may return multiple results, depending on how the tire name appears in the NHTSA database. Although searches conducted through the NHTSA website provide access to all recalls, the consumer would need to recognize the tire description as provided in the defect information report, including the brand name, tire line, tire size, or other information that may have been used by the reporting manufacturer to describe the product. Although in most cases it is relatively simple to identify a tire brand on the NHTSA website, some manufacturers are listed multiple times due to variations in the spelling and styling of their names. Links from the differently provided names often return different search results (see figures 10 and 11), which reduces the effectiveness of the search tool. The NTSB concludes that the tool for conducting tire recall searches on the NHTSA website is confusing and could cause consumers to erroneously determine that their tires are not among those being recalled.

[37] The RMA has indicated that it is developing a searchable TIN database for tires manufactured by its members. Additionally, the Tire Safety Group, which is operated by Safety Group LLC, maintains a website with a TIN lookup feature for tire safety recalls. See www.tiresafetygroup.com/, accessed July 15, 2015.

[38] See www-odi.nhtsa.dot.gov/owners/SearchSafetyIssues, accessed July 15, 2015.

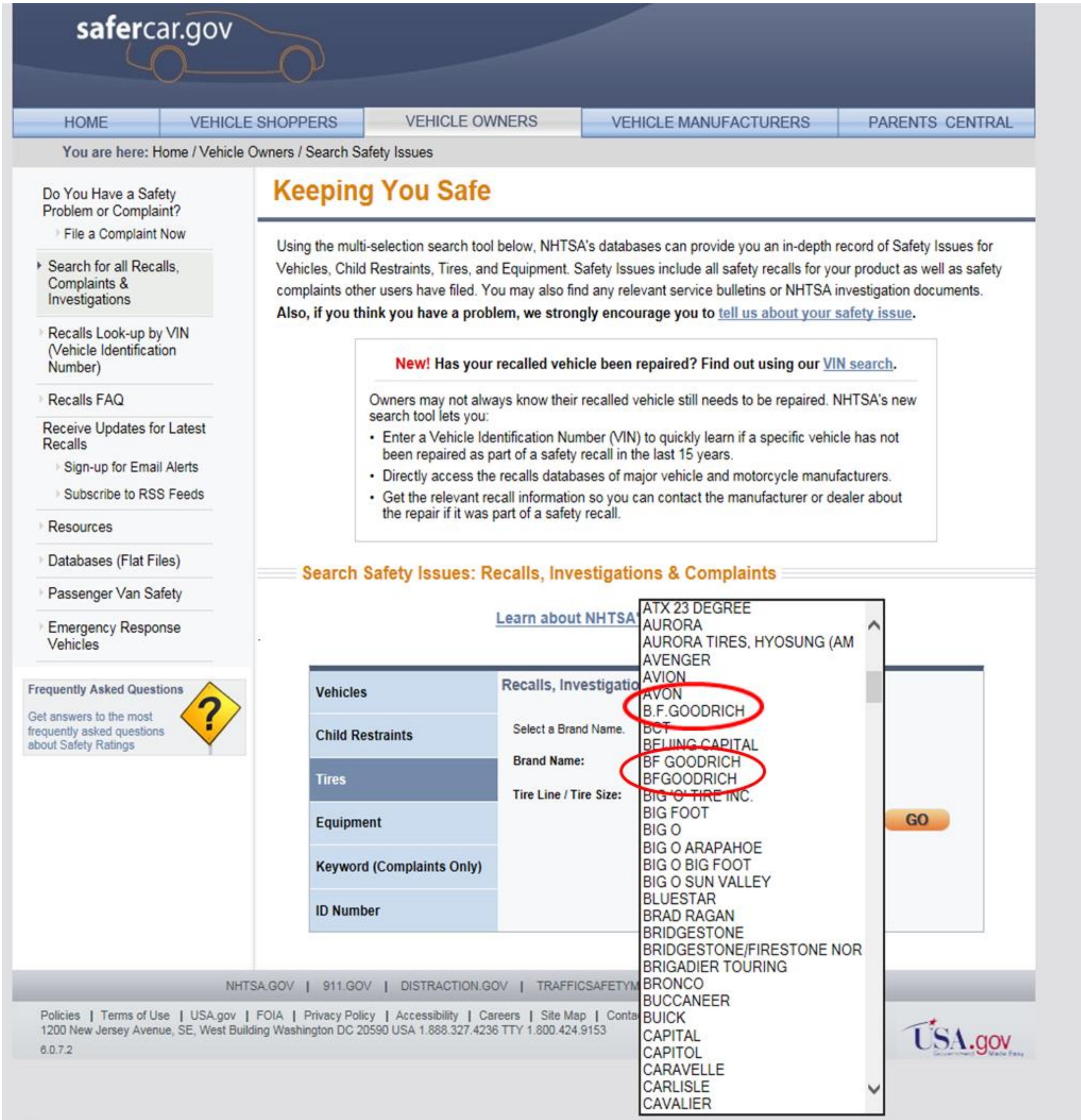

Figure 10. Tire manufacturer or brand name pull-down menu on the NHTSA recall search page, depicting multiple name stylings/spellings for one tire manufacturer.

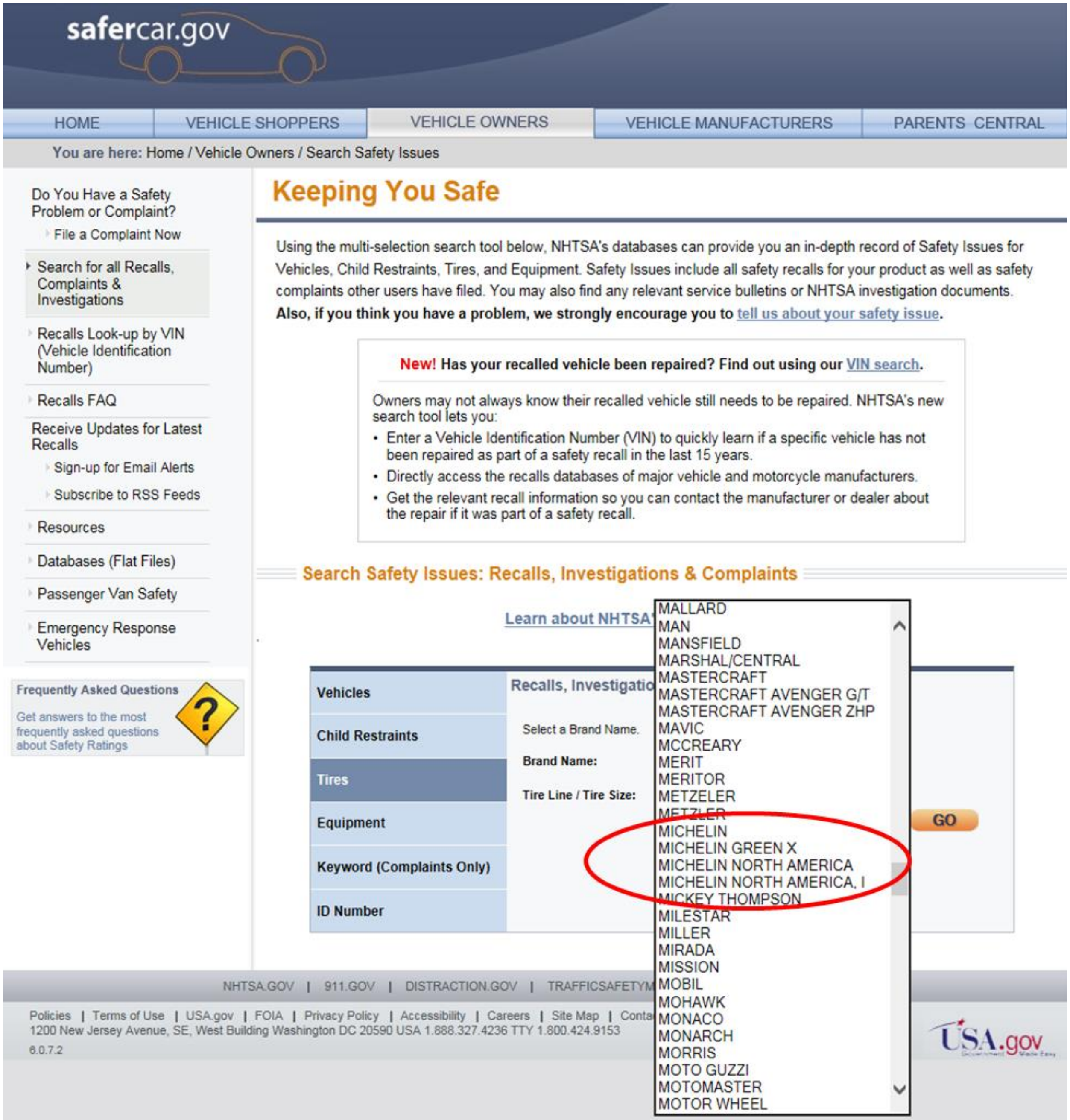

Figure 11. Tire manufacturer or brand name pull-down menu on NHTSA recall search page, depicting multiple entries for one manufacturer due to variations in name listed.

When visiting the websites of 18 tire manufacturers, NTSB staff had difficulty in determining from the homepages which manufacturers were engaged in active recalls. Of the 18 manufacturers, at least 14 had conducted a safety recall. Half (7 of 14) of those had announced recalls during 2014 or 2015. Of these seven manufacturers, only two provided information easily located on the web page. One manufacturer placed a link prominently at the top-center of the main web page, while the other had a link at the bottom of the main web page. The NTSB concludes that by not displaying tire recall information on their websites consistently and prominently, tire manufacturers have made it more difficult for consumers to respond appropriately to a tire recall.

The NTSB believes that regulations similar to 49 *CFR* 573.15, requiring tire manufacturers to make safety recall information available to the public on the Internet, would establish consistency among manufacturer websites and help tire owners trying to determine whether their tires are subject to a safety recall. Like the recall requirements for vehicle manufacturers, the tire recall information should be searchable by TIN as well as by brand and model. Having a TIN lookup tool on each tire manufacturer's homepage would enable more people to locate and use the tool as needed. Therefore, the NTSB recommends that the tire manufacturers (and their subsidiaries) Bridgestone Americas Inc., Continental Tire the Americas LLC, Cooper Tire & Rubber Company, The Goodyear Tire & Rubber Company, Hankook Tire America Corporation, Kumho Tire USA Inc., Michelin North America Inc., Pirelli Tire North America Inc., Toyo Tire Holdings of Americas Inc., and Yokohama Tire Corporation put the safety recall information for their tires on their websites in a format that is searchable by TIN as well as by brand and model.[39] To ensure that such action is carried out by existing and future tire manufacturers, the NTSB further recommends that NHTSA require tire manufacturers to put the safety recall information for their tires on their websites in a format that is searchable by TIN as well as by brand and model; if necessary, NHTSA should seek legislative authority to implement this recommendation. NHTSA's tire recall website would also benefit from a TIN lookup tool, because a tool based on the TIN would be less ambiguous and potentially less confusing for customers to use than one based solely on brand names or tire models. Therefore, the NTSB recommends that NHTSA modify the tire recall search feature on its website to allow users to search for recalls by TIN as well as by brand and model.

[39] Industry statistics indicate that these companies (and their subsidiaries) account for more than 95 percent of the new tires shipped in the United States.

4 Tire Aging

4.1 Aspects of Tire Aging

NHTSA defines tire aging as "the reduction or loss in a tire's material properties, which over time leads to a reduction of its performance capabilities" (NHTSA 2007). According to NHTSA, tire aging occurs due to a combination of mechanical and chemical processes. The mechanical processes include the stresses and strains incurred by a tire while in service, and the chemical processes include the effects of temperature and oxygen on tire components, which occur regardless of tire use. The agency has further stated, based on published research (Kataoka, Zetterlund, and Yamada 2003), that "Deleterious changes occur in tire properties after storage at ambient temperatures for five years or after use on cars for similar periods" (Gent and Walter 2006). On this basis, spare tires are subject to the deteriorative effects of aging even though they do not undergo road use. NHTSA's definition is consistent with ASTM International's (ASTM) definition of thermo-oxidative aging, which is "The process whereby chemical and physical material properties of a tire change with exposure to heat and oxygen (ASTM 2010)."[40]

Among the factors that can cause tire rubber to degrade with time are weather checking and oxidation. Weather checking is characterized by the formation of small, superficial cracks along the sidewall and is generally due to exposure to ozone and ultraviolet radiation (UV). Over time, these cracks can deepen and allow further ozone and UV penetration into the sidewall, weakening the structure. The effects of oxidation are more insidious and pose a higher risk to tire integrity than weather checking. Oxygen can penetrate into the rubber more deeply than ozone can. Oxygen penetration can occur via the ambient air but does so primarily through the tire's inner liner. The sections of a tire most prone to the effects of oxidation are the rubber between and around the steel belts, known as the "skim" and the "wedge," respectively.[41] When the skim and wedge rubber oxidize, they lose elasticity and adhesion. With time and use, cracks begin to form along the belt edges inside the tire. These cracks can eventually widen and spread between the belts, potentially causing tread separation (Baldwin and Bauer 2008). Research conducted by NHTSA found that underinflation and ambient heat further contribute to tread separation failures (NHTSA 2001). Both situations generate high temperatures within the tire, which accelerate the aging of rubber and can eventually reduce the tire's structural integrity, leading to failure.

4.2 Tire Failures Due to Aging

The NTSB has been concerned about the effects of tire aging since 2001, when it investigated two tire-related 15-passenger van crashes that occurred in Henrietta, Texas, and Randleman, North Carolina (NTSB 2003). The tires that failed in these crashes were more than 8 years old and exhibited severe surface cracks due to weather checking along the sidewalls and

[40] ASTM F2838-10 provides several definitions of tire aging, depending on the circumstances being described. For example, "in-service aging" is defined as "material property changes within tires due to consumer usage"; and "accelerated laboratory aging" is defined as "increased rate of tire material property changes under specified conditions, including temperature, inflation pressure, oxygen concentration in the filling gas, and time."

[41] The belt skim rubber bonds the steel belts together. It also bonds the steel belts to the rest of the tire. Wedges reduce inter-ply shear stresses at the edges of the belts and protect the body plies from the belt edges.

tread grooves. The tires also showed evidence of having been operated while underinflated. More recently, in 2014, the NTSB investigated two other crashes that involved aging tires. The 12-year-old tire that failed in the 2014 Patterson, California, rollover crash exhibited weather checking along the shoulder and in the grooves of the tread, as well as belt edge separation, suggesting that aging contributed to its failure. (See appendix C.) The 10-year-old tire that failed in the 2014 Centerville, Louisiana, crash also exhibited signs of aging; however, NTSB investigators had difficulty assessing its effects due to the tire's poor level of maintenance.

It can be difficult to determine the prevalence of crashes related to tire aging because the TIN is generally not recorded at a crash scene. In an attempt to determine the scope of the issue, NHTSA examined data from a special study conducted for the period 2005–2007 called the *National Motor Vehicle Crash Causation Survey* (NMVCCS), in which the TINs from crash-involved vehicle tires were documented (NHTSA 2012).[42] NHTSA analyzed cases of tire tread separation and sidewall separation and weighted the results to arrive at a national estimate; it determined that about 23 percent of tow-away or police-reported crashes related to tires involved tire aging.

4.3 Federal Actions to Address Tire Aging

4.3.1 The TREAD Act

In 2000, a surge in tread separation failures involving Ford SUVs equipped with Firestone tires prompted Congress to enact the Transportation Recall Enhancement, Accountability, and Documentation Act (TREAD) Act.[43] This act directed the Secretary of Transportation to initiate rulemaking to, among other things, require a warning system in new motor vehicles to indicate to the operator when a tire is significantly underinflated, and improve the resistance and endurance standards for tires. Members of Congress also requested that NHTSA consider the feasibility of including an aging test in the standards to evaluate the risk of tire failure at a period later in the life of a tire than provided in the current regulation, which only evaluates new tires.

NHTSA responded by publishing a final rule requiring all vehicles manufactured after September 2007 to be equipped with a tire pressure monitoring system (TPMS), which would warn drivers when one or more of their tires is 25 percent or more underinflated.[44] According to NHTSA, TPMS would reduce crash risks associated with underinflated tires, such as skidding or loss of control; hydroplaning and extended braking distances; flat tires and blowouts; and overloading. In addition, NHTSA published a final rule for a new tire performance standard,

[42] The NMVCCS included investigations of 6,950 crashes during the 3-year period from January 2005 to December 2007. Of these, data from 5,471 crashes were collected in such a way as to be considered a nationally representative sample. A unique aspect of this survey was that researchers were able to arrive at the scene of the crash and collect data before it was cleared by law enforcement agents, which allowed them to obtain detailed data on the vehicles, roadway, ambient conditions, and people involved.

[43] See Public Law 106–414, November 1, 2000.

[44] See 70 *Federal Register* (April 8, 2005): 18136–18191. The TPMS regulation is codified at 49 *CFR* 571.138, which is commonly referred to as FMVSS No. 138.

codified in FMVSS No. 139.[45] The new rule established more stringent tire speed and endurance tests for new tires and added a new low-inflation test.[46] NHTSA had intended to include a procedure to test tires for aging; however, after discovering that the tire industry did not have a uniform approach to accelerated aging, the agency decided that it needed to conduct further research and develop a procedure of its own.

4.3.2 NHTSA Tire-Aging Research and Associated Developments

Tire-Aging Research. According to NHTSA, its research goal was to "develop an accelerated tire-aging test protocol that would simulate several years of service in regions of the US with high average ambient temperatures, thus providing a test that could predict how a new tire will perform after several years in service" (NHTSA 2007). For this research effort, NHTSA enumerated five objectives, which included (1) gaining a better understanding of the tire degradation process; (2) assessing the validity of existing accelerated tire-aging methods; (3) developing an accelerated, laboratory-based tire-aging method suitable for regulatory purposes that simulates real-world tire aging in states with high average ambient temperatures and evaluates the tire's safety performance; (4) evaluating various regulatory options, taking into account minimum performance based on tire age; and (5) reporting the agency's findings to support future activities related to tire aging. To meet these objectives, the agency embarked on five phases of research that ultimately produced an accelerated-aging protocol that replicated the visual characteristics of tires in service for about 4 years in Phoenix, Arizona.

2014 NHTSA Decision on Tire-Aging Standard. In 2014, NHTSA published a summary of its research findings and explained in this document that it had decided not to pursue rulemaking to include an accelerated-aging protocol as part of the performance standards for new tires because such a protocol is not needed (NHTSA 2014). NHTSA stated that its decision was based on the following three factors: (1) NHTSA considers that TPMS has reduced the prevalence of severely underinflated tires; (2) findings that FMVSS No. 139-compliant tires performed better than noncompliant tires when subjected to NHTSA's accelerated-aging process; and (3) crash data analysis showing that injuries and fatalities decreased after 2007, when both FMVSS No. 138 (TPMS regulation) and FMVSS No. 139 took effect. The NTSB appreciates NHTSA's efforts toward creating a tire-aging protocol; however, NHTSA's reasons for not pursuing tire-aging regulation lack support, and further evaluation is needed to establish that tire-aging-related crashes have decreased due to FMVSS Nos. 138 and 139.

First, NHTSA considers that the TPMS requirement has the potential to dramatically reduce the prevalence of severely underinflated tires, a primary contributor to tire failure. A survey conducted by NHTSA in 2011 showed that TPMS was effective in reducing underinflated tires among vehicles equipped with the system (Sivinski 2012). Of the vehicles surveyed, NHTSA found that 23 percent of those without TPMS had at least one tire that was underinflated by 25 percent or more, but only 12 percent of the vehicles equipped with TPMS had such an underinflated tire. Based on these results, NHTSA estimated that equipping vehicles with TPMS

[45] See 68 *Federal Register* (June 26, 2003): 38116–38152. FMVSS No. 139 is codified in 49 *CFR* 571.139, and went into effect in June 2007.

[46] The original motor vehicle safety standards were issued in 1967, and they established an endurance test, a high-speed test, a strength test, and a resistance-to-bead unseating test for passenger vehicle tires.

resulted in a 56 percent reduction in the likelihood of having a severely underinflated tire on the vehicle.

The NTSB, however, believes that issues have not yet been fully addressed that may reduce the effectiveness of TPMS. For example, in its 2003 report on the Henrietta and Randleman crashes (NTSB 2003), the NTSB expressed concern that the proposed 25 percent underinflation threshold for TPMS may not be stringent enough to prevent premature tire failure. In addition, during the 2014 NTSB Passenger Vehicle Tire Safety Symposium, AAA expressed a similar concern (although the AAA representative also stated that TPMS has been beneficial in reducing the incidence of tire failure and low-inflation tire wear). Moreover, feedback from regional AAA offices indicates that consumers may be wrongly relying on TPMS to address tire pressure issues rather than conducting their own regular tire pressure maintenance. In addition, AAA expressed some doubt that consumers would maintain their TPMS after the sensor battery necessary to the device expires.

Second, according to NHTSA’s tire-aging summary report, tires compliant with FMVSS No. 139 exhibited better performance during the testing associated with developing an accelerated tire-aging test protocol compared to tires manufactured before the implementation of FMVSS No. 139 (NHTSA 2014). Of the 60 FMVSS No. 139-compliant tires that were aged and then subjected to an endurance and low-pressure performance test, 33 tires (55 percent) completed testing without visible damage, and 27 tires (45 percent) were damaged during testing. Seven of the 27 tires exhibited serious damage, such as separation of the tread or sidewall, while the other 20 tires exhibited less serious damage, such as cracking along the shoulder and sidewall, sidewall bubbles, and tread chunking (Terril, Connolly, and Popio 2012).

By contrast, of the 40 pre-FMVSS No. 139 tires subjected to the same testing protocol, 23 tires (57.5 percent) completed testing with no visible damage, and 17 tires (42.5 percent) were damaged during testing. Of the 17 damaged tires, 14 exhibited serious damage, including separation of the tread, sidewall, and inner liner (MacIsaac and Evans 2013). (See table 1.)

Table 1. Comparison of performance test results between pre- and post-FMVSS No. 139 tires.

	Number of tires tested	No visible damage (%)	Serious damage (%)	Less serious damage (%)
Pre-FMVSS No. 139 tires	40	23 (57.5)	14 (35)	3 (7.5)
Post-FMVSS No. 139 tires	60	33 (55)	7 (11.7)	20 (33.3)

Based on NHTSA’s work, the NTSB acknowledges that FMVSS No. 139 has probably resulted in more robust tires that are more likely to reach the end of their tread life before failing due to the effects of aging. However, in the 8 years that FMVSS No. 139 has been in effect, field data have not been collected and analyzed to validate that NHTSA’s accelerated tire-aging protocol simulates real-world conditions and that the risk of tire-aging-related crashes has actually decreased. In light of NHTSA’s research showing that 45 percent of protocol-aged FMVSS No. 139-compliant tires still exhibited damage after completing performance testing, it is imperative that NHTSA conduct further research to validate the accelerated-aging protocol and to confirm that FMVSS No. 139 has resulted in a substantial reduction in the risk of tire-aging-related crashes, especially in the Sun Belt states. Only after such research is conducted can a conclusion be made about whether an accelerated-aging protocol is still needed to reduce the incidence of tire failure and associated crashes.

Finally, NHTSA's analyses of tire-related crash data indicated that injuries and fatalities decreased after 2007, which was when both FMVSS No. 138 (requiring TPMS) and FMVSS No. 139 took effect (NHTSA 2014). NHTSA estimated that in the period 2007–2010, about 11,000 tire-related crashes occurred annually, resulting in about 6,400 injuries and 200 fatalities. When compared to yearly estimates for 1995–2006, there appeared to be a 35 percent reduction in tire-related crashes, a 42 percent reduction in injuries, and a 50 percent reduction in fatalities.

The NTSB is concerned that NHTSA has yet to publish the statistical methodology it employed to arrive at its estimates. The 2014 summary report on tire aging (NHTSA 2014) did not discuss how the agency controlled for the potential effects of confounding variables (such as the economic recession) in its analyses, nor did it provide estimates of market penetration for those tires meeting the new regulations during the 2007–2010 period. As a result, it is difficult to attribute any reduction in tire-related traffic injuries and fatalities to the changes in federal regulations. Also, as is further described in appendix B, the NTSB considers it likely that the data NHTSA used to conduct its analysis might have led to an underestimation in the number of injuries and fatalities caused by tire-related crashes, and these results might have further influenced the agency's decision to forego further rulemaking.

Given these concerns, the NTSB concludes that further research is needed to confirm that the implementation of FMVSS Nos. 138 and 139 has substantially reduced the risk of tire-aging-related crashes, injuries, and fatalities.

According to NHTSA, it generally evaluates the safety impact of significant rulemakings, and it may yet plan an evaluation for FMVSS Nos. 138 and 139. NHTSA also has stated that further research or rulemaking on tire aging will depend on the safety impact of these standards. The NTSB considers that NHTSA should determine not only whether these standards have reduced the risk of tire-related crashes and fatalities but also whether and how these standards should affect NHTSA's decisions regarding the application of the tire-aging test protocol in future guidance or standards.

Therefore, the NTSB recommends that NHTSA determine the level of crash risk associated with tire aging since the implementation of FMVSS Nos. 138 and 139; if, based on this determination, it appears that the aging-related risk should be mitigated, NHTSA should develop and implement a plan to promote the tire-aging test protocol to reduce the risk.

4.4 Guidance to Consumers on Tire Aging and Service Life

As has been noted, a tire will deteriorate with time regardless of use; however, many factors influence its rate of deterioration, including the construction of the tire, environmental temperature, road conditions, driving habits, miles driven, exposure to direct sunlight, and quality of maintenance, as well as the load to which it is subjected. Federal standards that result in more robust tires and a reduced probability of severe underinflation may address some of the major factors that accelerate tire aging, but other hazards remain.

During the 2014 NTSB Passenger Vehicle Tire Safety Symposium, Safety Research & Strategies, a safety advocacy organization, acknowledged that new tire performance standards have resulted in the production of more robust tires but expressed concern that government and industry leaders may be satisfied with "push(ing) the problem down the road" and are not providing meaningful information to consumers (Kane 2014).

The NTSB reviewed guidance material on tire aging and service life published by the automotive industry, tire industry, and NHTSA to determine the consistency of the information being disseminated.[47] The NTSB found that while several vehicle and tire manufacturers publish similar guidance on tire aging and service life, not all do so, and the guidance provided is not always consistent with the information provided by other industry members or by NHTSA.

4.4.1 Automotive Industry Guidance

Most, but not all, vehicle manufacturers recommend that tires be replaced after 6 years of use, regardless of treadwear.[48] Ford, which has conducted extensive tire-aging research, includes the following advisory message about tire degradation and aging in its vehicle owner's manuals:

> Warning: Tires degrade over time depending on many factors such as weather, storage conditions, and conditions of use (such as load, speed, inflation pressure) the tires experience throughout their lives. In general, tires should be replaced after six years regardless of treadwear. However, heat caused by hot climates or frequent high loading conditions can accelerate the aging process and may require tires to be replaced more frequently. You should replace your spare tire when you replace the road tires or after six years due to aging even if it has not been used. (Ford 2014)

Some other vehicle manufacturers include similar warnings in their owner's manuals but do not include an additional warning for those owners living in warmer climates. For example, Chrysler addresses tire replacement and tire safety as follows:

> Tires and spare tires should be replaced after six years, regardless of the remaining tread. Failure to follow this warning can result in sudden tire failure. You could lose control and have a collision resulting in serious injury or death (Chrysler Group LLC 2013).

[47] "Service life" is the time period that an in-service tire can be expected to last. Historically, the primary determinant of service life has been a tire's tread life. The average service life of a tire in 2004 was 3.6 years, based on the average passenger miles traveled and the average tread life of a tire (NHTSA 2007). For tires that are not in use as often, environmental conditions, quality of maintenance, roadway conditions, and tire aging may factor more significantly in service life.

[48] The NTSB was able to confirm that the following vehicle manufacturers include such guidance in their vehicle user's manuals: Toyota, BMW, Mercedes, Ford, Chrysler, Fiat, General Motors, and Volkswagen.

Finally, other vehicle manufacturers do not recommend replacement of tires after 6 years but instruct the owner to have the tires checked by a qualified technician, as Nissan advises below: [49]

> Tires degrade with age and use. Have tires, including the spare, over 6 years old checked by a qualified technician because some tire damage may not be obvious. Replace the tires as necessary to prevent tire failure and possible personal injury.

4.4.2 Tire Industry Guidance

Most, but not all, tire manufacturers have published tire-aging-related guidance for consumers. They generally recommend that a tire be inspected at least once a year by a qualified service technician after 5 years of use, although some recommend that periodic inspections begin 6 years from the date of manufacture.[50] Almost all guidelines state that all tires more than 10 years old be replaced as a precaution. The following guidance from Bridgestone/Firestone is typical of most major tire manufacturers:[51]

> In addition to regular tire inspections, customers should have their tires inspected by a qualified tire service person after five (5) years of use to determine if the tires can continue in service. It is recommended that spare tires be inspected at the same time. Further, even when tires appear to be usable from their external appearance or the tread depth may have not reached the minimum wear out depth, it is recommended that all tires (including spare tires) that were manufactured more than ten (10) years previous be replaced with new tires. (Bridgestone/Firestone 2005)

Other manufacturers, such as The Goodyear Tire & Rubber Company (Goodyear) and Pirelli Tire North America, have issued product service bulletins that emphasize the consumer's role in tire care and maintenance. They have recommended that consumers inspect their tires, including spare tires, regularly. These service bulletins stress that, due to the variety of factors that may influence the integrity of a tire, it is not possible to predict a tire's service life accurately.

4.4.3 NHTSA Guidance

NHTSA's primary outlet for tire safety information is the agency's TireWise website, which was launched in May 2014.[52] The website is housed within the NHTSA *safercar.gov* homepage and includes information on a variety of topic areas, including tire purchase, maintenance, labeling, aging, and fuel efficiency. The section on tire aging defines the term; identifies those consumers whose tires are most at risk of aging-related failure (for example,

[49] See owners.nissanusa.com/nowners/navigation/manualsGuide, accessed October 14, 2015.

[50] Service or technical bulletins with similar information have been published by tire manufacturers Michelin, BFGoodrich, Kumho, Hankook Tire America, Yokohama Tire, and Bridgestone.

[51] Bridgestone is the parent corporation of Firestone.

[52] See www.safercar.gov/tires/index.html, accessed June 17, 2015.

those consumers who live in the Sun Belt states, those who drive recreational vehicles or 15-passenger vans, and those who seldom drive their vehicles); and provides guidance on determining the chronological age of a tire by decoding its TIN.[53] The website also states that "Most vehicle owners can easily overlook tire aging, increasing their risk of a crash." It further states that "You cannot detect tire aging simply by looking at your tires." TireWise does not provide specific guidance to consumers regarding the service life of a tire, but it does provide the following information: "As tires age, they are more prone to failure. Some vehicle and tire manufacturers recommend replacing tires that are six to 10 years old, regardless of treadwear."

4.4.4 Assessment of Guidance to Consumers on Tire Aging

A variety of factors can influence the rate of tire deterioration, which can complicate the process of creating guidelines on tire aging. It can be difficult to predict where, when, and how consumers will use their tires. In addition, tire quality and durability can differ considerably among manufacturers and between the tire models of each brand. Moreover, the new regulatory requirements may mean that most tires are more resistant to the effects of aging. Although many variables are involved, all tires degrade over time and must eventually be replaced, regardless of treadwear.

Each manufacturer's tread life warranty is based on accumulated knowledge, data analyses, and assumptions of typical driver behavior; although creating tire-aging and service life guidelines based on quantifiable evidence and expert knowledge is challenging, the task is not impossible. Providing consumers with guidance on tire aging is especially vital because, unlike the clear visual cue of a worn tire tread, the harmful effects of tire aging are not always evident when looking at a tire.

The NTSB considers that, although the guidance provided by most vehicle and tire manufacturers is helpful, the information offered may differ from provider to provider. Such variations may reduce the usefulness of the information to consumers or even cause them to doubt its veracity. Moreover, the perception that tire manufacturers have a financial interest in encouraging consumers to purchase replacement tires could reduce consumer trust in tire-aging guidance provided solely by tire industry sources. The NTSB concludes that the guidance provided by the tire and automotive industries regarding tire service life and the risks associated with tire aging can be inconsistent and confusing, which may lead consumers to make inappropriate tire replacement decisions.

In addition, the guidance published by NHTSA and the tire industry rarely includes information targeted to tire owners whose tires are at greater risk of failure because of where and how they are used regarding actions they can take to inhibit the effects of tire aging.[54] For example, consumers and tire dealers living in the Sun Belt states could be educated on the tire characteristics or design features that offer better resistance to the effects of aging, enabling them

[53] The Sun Belt states are considered to be (southern) California, Arizona, New Mexico, Texas, Louisiana, Mississippi, Alabama, Georgia, and Florida.

[54] One notable exception is the targeted information that NHTSA published on 15-passenger van safety, which is available through www.safercar.gov. (See www.safercar.gov/Vehicle+Shoppers/Passenger+Van+Safety), accessed September 12, 2015.)

to make more informed purchasing decisions. In addition, Sun Belt residents could be provided with tips on maintenance and driving practices that could inhibit the effects of aging, such as parking indoors or in the shade when possible; avoiding overly high speeds; and minimizing impacts to, and overloading of, the tires. For those who own recreational vehicles, 15-passenger vans, and vehicles that are driven infrequently, targeted guidance might include the importance of proper vehicle storage, of not exceeding the vehicle load capacity, and of driving the vehicle a few miles on a periodic basis.[55] The NTSB concludes that NHTSA and industry stakeholders have not provided enough guidance to those consumers whose tires are most at risk of experiencing an aging-related failure. By sharing information on the issue of tire aging, industry, federal, and safety advocacy stakeholders could address the impact of newer regulatory developments on existing tire-aging guidance, as well as recent trends in consumer driving habits, the creation of targeted guidance for consumers whose tires are most at risk of aging-related failure, and the feasibility of providing tire ratings that account for the ability of classes of tires to resist the effects of aging.

Providing clear and consistent guidance to consumers is vital to improving highway safety and reducing fatal tire-related crashes. Because there continue to be discrepancies between the safety guidelines communicated by the automotive industry, tire industry, and safety advocacy community regarding tire aging and service life, NHTSA should take a leadership role in developing consistent guidance for the public. Therefore, the NTSB recommends that NHTSA develop a consensus document with input from the automotive industry, the tire industry, and safety advocacy groups that addresses tire aging and service life and that also includes best practices for those consumers whose tires are most at risk of experiencing an aging-related failure. The consensus document could eventually be used as a source document by vehicle and tire manufacturers when preparing vehicle users manuals and other publications directed toward tire service technicians and consumers to ensure consistency in the tire-aging information being provided to users.

[55] Driving flexes the tire and facilitates the migration of anti-degradants to its surface (Ignatz-Hoover and others 2003).

5 Efforts to Raise Consumer Awareness of Tire Safety Issues

Consumers play a vital role in ensuring tire safety. Purchasing replacement tires can be a substantial expenditure, and basic tire maintenance is vital not only to prolonging tire service life and avoiding failures but also to maximizing gas mileage, performance**,** and ride comfort. To help ensure tire safety, consumers should regularly check the inflation pressure of their tires and keep them inflated to the pressure indicated in the vehicle owner's manual or on the "Tire and Loading Information" label located on the driver's side door edge (or post) of the vehicle.[56] Consumers should not wait until the TPMS warning light on their dashboard activates to check the inflation of their tires because, by that time, at least one tire is severely underinflated. When checking the inflation pressure, the consumer should also inspect tires for tread wear and the presence of embedded objects. With respect to tread wear, consumers should consider replacing any tire that has a tread depth of less than 4/32 inch and should not drive on any tire with a tread depth of 2/32 inch or less, to avoid losing vehicle control during inclement weather. If an object is found embedded in a tire, the tire should be taken immediately for repair to prevent air leakage and further deterioration at the area of the puncture; some punctured tires may require replacement, depending on the size and location of the puncture.[57] Periodic tire rotation can prevent irregular wear and help maximize tire service life. Consumers should refer to their vehicle owner's manual to determine how often their tires should be rotated. Tires should also be balanced and aligned to minimize vibration and help ensure that the vehicle does not pull to the right or left.

Performing basic tire maintenance should take only a few minutes each month; however, according to AAA, about 63 percent of drivers neglect to rotate their tires or check their tread depths, and 56 percent of drivers do not check their tire pressure (Nielsen 2014). Additionally, of 45,000 vehicles that AAA physically inspected, 14 percent had at least one tire with a tread depth below 2/32 inch, the minimum allowed in most states, and 21 percent had at least one tire underinflated 20 percent or more below specifications. Data reported by the RMA showed similar results (Zielinski 2014).

The 2014 Centerville, Louisiana, crash was initiated by the failure of a poorly maintained tire that showed signs of being operated in an underinflated condition. During the 2014 NTSB Passenger Vehicle Tire Safety Symposium, presenters acknowledged how difficult it is to convince consumers to take the actions necessary to reduce the risks of tire failure, such as registering their tires, periodically checking their tires for abnormalities, and maintaining the recommended tire pressures.

[56] It should be noted that the tire pressure information imprinted on the tire itself identifies the maximum cold inflation pressure that the tire is rated to hold. This maximum pressure is not necessarily the recommended inflation pressure for the tire.

[57] In general, a tire with a puncture that is larger than 1/4 inch or that is located on the tire's sidewall or shoulder cannot be repaired and should be replaced.

The most common failure mode for tires is overdeflection, which can occur when a tire is underinflated or overloaded (Giapponi 2014). Overdeflection causes heat buildup as well as stresses and strains along the shoulder and belt edges of a tire, which can lead to tread separations (Paige 2012; Gent and Walter 2006). Other modes of failure include repeated or severe tire impacts (for example, from potholes), punctures or damage that allows air between the plies, and exposure to harsh environments. Symposium participant TRGtech Tire Consulting indicated that consumers can avoid many of these failure modes through more careful driving and tire maintenance, including monthly tire pressure checks (Giapponi 2014).

5.1 Consumer Awareness Campaigns

Several mature programs and relatively new campaigns are attempting to heighten consumer awareness of tire safety and the importance of periodic maintenance. NHTSA's TireWise website provides information on a variety of topic areas, including purchasing the correct tire, conducting proper maintenance, deciphering tire labels, and being aware of tire aging. The section on buying tires includes a tire rating lookup tool that allows consumers to compare tires based on treadwear, traction performance, and temperature resistance. The tire maintenance section features tips on staying safe and saving money, such as by maintaining the proper tire pressure, checking tires for treadwear, and balancing and rotating tires on a regular basis. It also provides information on TPMS, tire recalls, and how to keep control of a vehicle after a tire failure. TireWise also offers educational materials designed for use by customers that tire dealers can display, post on a website, or hand out. According to NHTSA, the TireWise website is part of its larger tire safety campaign to reach consumers, which includes social media outreach and community and industry partnerships (McMeen 2014).[58]

With respect to tire industry outreach to consumers, the TIA maintains a web page on tire safety that can be reached from its homepage.[59] This web page contains information on tire maintenance, manufacturing, labeling, and service life, as well as TPMS. It provides several videos on such topics as tire registration, selection, and inspection. In addition, TIA produces training materials for its members and has trained more than 90,000 technicians since 1997. A primary focus of TIA efforts has been to educate its members on safe tire operation, including federal and industry guidelines, so that they can educate their customers (Rohlwing 2014).

The RMA has a tire safety link on its homepage, which provides information on tire registration and repair. The web page also has displays and brochures for the RMA's "Be Tire Smart" program, which began in 2000 and focuses on educating consumers about tire inflation and treadwear, as well as the need for periodic tire balancing and rotation. The RMA also hosts Tire Safety Week, which generally takes place in late May each year, and has formed partnerships with various stakeholders to reach more consumers.[60] Individual tire manufacturers

[58] Partners include the online automotive industry (for example, Edmunds.com, KBB.com, and Cars.com); the automotive service industry (for example, the Automotive Service Association and the Automotive Maintenance and Repair Association); car dealer organizations (such as the National Automobile Dealers Association [NADA] and NADA Guides); and vehicle safety organizations (for example, the Consumer Auto Safety Association and Advocates for Highway and Auto Safety).

[59] See www.tireindustry.org/consumer-safety, accessed June 17, 2015.

[60] Partners include AAA, the Governors Highway Safety Association, TIA, the NADA, and state tire dealer associations.

are also engaged in public service initiatives to educate consumers. For example, Michelin sponsors "Beyond the Driving Test," a campaign to increase tire safety awareness among novice drivers, which aims to have each state include tire safety in its driver education curricula by 2020.[61]

Information on tires is also available through consumer groups, such as AAA and Consumers Union, which publishes *Consumer Reports* magazine. *Consumer Reports* independently rates up to 80 tire models each year on safety, performance, and comfort elements, making the ratings available to its subscribers.[62] *Consumer Reports* also reaches consumers through its Internet site and social media outlets, such as blogs and its YouTube channel. In a survey it conducted, *Consumer Reports* found that the most popular sources of information on tires were mechanics (46 percent) and the Internet (44 percent) (Petersen 2014). The magazine has reported that "tires" is typically one of the top five search items for its website subscribers, perhaps because consumers do not have abundant sources of independent information on tire performance.

Based on the presentations given during the 2014 NTSB Passenger Vehicle Tire Safety Symposium and the NTSB's own research, it appears that for those consumers seeking information, there are sufficient resources available to guide them in their tire purchase and maintenance decisions. However, despite the availability of brochures, online information, and consumer awareness campaigns, surveys indicate that many consumers continue to be unaware of basic tire safety information. For example, in 1999, a survey funded by AAA found that the most common consumer strategy for determining the correct tire pressure was to look at the pressure information printed on the sidewall of the tire (Roper Starch Worldwide Inc. 1999). Sixteen years later, an RMA survey indicated little change in consumer behavior, with 50 percent of drivers still wrongly believing that the correct inflation pressure is provided on the tire sidewall rather than on the "Tire Loading Information" label on the driver's side door edge (or post) or in the vehicle owner's manual.[63] Consequently, it may be beneficial for advocates of tire safety to evaluate current outreach strategies and identify those approaches that have the most promise of reaching and motivating consumers to maintain their tires properly. The NTSB concludes that stakeholder efforts to educate consumers on basic tire maintenance have yielded little change in consumer behavior. Therefore, the NTSB recommends that AAA and the RMA work together to evaluate the effectiveness of current tire safety efforts in influencing consumer tire purchase and maintenance behaviors, and publish the results of the evaluation.

[61] See www.beyondthedrivingtest.com, accessed June 17, 2015. According to the website, this campaign was implemented in response to data showing that automobile crashes are the leading killer of teens in in the United States, causing 5,000 deaths each year. The data also show that 2.2 million crashes occur per year among inexperienced drivers, and an estimated 12 percent of these crashes can be attributed to tire-related issues, such as insufficient tread or pressure.

[62] These elements include dry handling, wet handling, snow traction, ice braking, ride and noise, dry cornering, wet cornering, treadwear, rolling resistance, dry braking, wet braking, and hydroplaning.

[63] See www.rma.org/2015-fact-sheets/, accessed September 12, 2015.

5.2 NTSB Outreach Activities

The NTSB has worked to share what it has learned about tire safety with the public and will continue to do so through social media channels and outreach activities. In May 2015, as part of Tire Safety Week, the NTSB published a safety alert informing consumers about the importance of registering and maintaining their tires (see appendix D), and the NTSB continues to conduct tire safety outreach activities through social media.[64] The NTSB will also develop an article summarizing the main issues of this report and will distribute it to stakeholders in industry and safety advocacy to provide more information to tire buyers and the motoring public.

[64] The NTSB updated the tire safety alert in October 2015. This and other NTSB safety alerts can be accessed through www.ntsb.gov/safety/safety-alerts.

6 Technologies to Prevent or Mitigate Tire-Related Crashes

Discussions during the 2014 NTSB Passenger Vehicle Tire Safety Symposium suggested that alternative solutions that rely less on consumers to address tire safety issues are needed. Vehicle-based technology systems that can compensate for the changes in vehicle dynamics and for typical driver responses following a tire failure could help prevent crashes or mitigate their severity. Tire-based innovations that decrease the consumer's role in tire maintenance and keep consumers informed about the condition of their tires could significantly reduce tire-related traffic injuries.

6.1 Vehicle-Based Technologies

Vehicle-based technologies hold promise for making a tire failure situation more controllable. Among these are advanced versions of electronic stability control (ESC) systems and advanced steering systems. Before describing these systems, it is important to understand the ways in which tire failures can change the stability and control of a vehicle.

Drag forces are generated at the affected tire when a tread separation occurs in a rear tire. These drag forces pull the vehicle toward the side of the affected tire (Dickerson, Arndt, and Arndt 1999). During test scenarios, noise and vibration emanated from the failed tire before the vehicle began pulling to the side of the affected tire. In most cases, experienced test drivers were able to keep the vehicle in the travel path with small steering corrections (Fay and others 1999). In other cases, the drag forces were significant and resulted in large deviations of the vehicle from the travel path (Tandy and others 1999). Other tests have reported that higher vehicle speed and an extended duration of the tread separation event are associated with greater lateral deviation from the travel path (Arndt and Arndt 2001). Higher travel speeds reduce the damping forces that resist vehicle rotation and help stabilize the vehicle, which means that a vehicle traveling at 70 mph is inherently less stable following a rear tire failure than the same vehicle traveling at 50 mph (Milliken and Milliken 1995). Tests have found that drag forces end once the tread fully separates from the tire. By contrast, for a partial tread separation, drag forces continue until the vehicle comes to rest. If the affected tire loses air, drag forces also continue until the vehicle comes to rest (Beauchamp, Koch, and Thornton 2013). Changes in vehicle response and maneuverability characteristics and forces generated as a result of the failure can make it difficult for a driver to predict how to steer safely following a tread separation in a rear tire. In addition, drag forces or driver panic caused by the failure could lead a driver to respond in a manner that further destabilizes the vehicle, resulting in a loss of control.[65]

According to the surviving SUV passenger in the Centerville crash, after the tire failure, the vehicle drifted to the left, and the driver responded by braking and steering. A truck driver

[65] Loss of control can occur for a variety of reasons. For the purposes of this report, "loss of control" refers to a change in a vehicle's response characteristics that is beyond what a driver can adapt to and keep steering the vehicle along the intended path.

traveling behind the SUV stated that when the tire "popped," the vehicle lost control, went to the right, and then was overcorrected back to the left, crossing the median. The NTSB conducted simulations of the Centerville crash sequence to learn more about the dynamics of the loss of control and the effects of transient forces. The simulations showed significant differences in steering response before and after the tire failure. These differences would have made it difficult for the SUV driver to predict how to steer the vehicle safely following the tire failure. The simulations also indicated that the tire failure would have been followed by greater lateral and rotational motion for a given steering input than the responses the driver would have been used to, based on everyday driving experience. As a result, any aggressive steering input in response to the tire failure, or in an attempt to control the vehicle, could significantly increase the risk of loss of control. To control the vehicle during a rear tire failure, the driver must quickly adjust to the change in steering response by minimizing steering input while counteracting the transient forces generated by the tire failure. Although tests have shown that professional drivers are generally able to control their vehicles following a rear tire failure, this may be a more difficult task for nonprofessional drivers who are traveling at high speeds and are not expecting a tire failure.[66]

The simulation scenarios that most closely matched the physical evidence in the Centerville crash were those in which the driver did not brake until the SUV entered the center median. This suggested that if braking occurred, the driver modulated it so that it did not affect vehicle control; alternatively, the driver may have braked as the vehicle was leaving the roadway or when it was already in the center median. The simulations also indicated that the driver might have been able to keep the SUV on the roadway had she reduced her steering input and reacted to transient forces in a timely manner; however, the driver could have still lost control had the changes in the vehicle's response characteristics exceeded her capacity to adapt to these changes.

The Centerville SUV was not equipped with an ESC system. An ESC system is an active safety technology that uses a vehicle's antilock braking system to help a driver maintain control of a vehicle in situations where it begins to lose directional stability. Typically, an ESC system intervenes by using onboard computers to control individual wheel brakes, helping to keep the vehicle headed in the intended direction as indicated by the steering wheel angle, lateral acceleration, and rate of rotation. Since 2011, passenger vehicles have been required to be equipped with ESC systems. There is no specific requirement that these systems be designed to help a driver maintain control following a tire failure, and in tire failure simulations, the NTSB has found that an ESC system can increase the vehicle's responsiveness but might not prevent the loss of control.

However, an ESC system could be used as a foundation for more advanced braking and steering systems that use remote sensors located around the vehicle (for example, cameras or radar) to help drivers to keep control of their vehicle and maintain their position on the roadway

[66] Although the circumstances of the Centerville and Lake City crashes led the NTSB to focus on rear tire failure, all tire failures can negatively impact a driver's ability to control the vehicle. Generally, a rear tire failure causes normal steering inputs to result in large and unexpected changes in the direction of vehicle travel. By contrast, front tire failures generally require larger steering inputs to change a vehicle's travel path.

after a tire failure.[67] Ideally, such systems would identify a tire failure and, by determining the intended path of the vehicle prior to the failure, eliminate incorrect steering responses and help prevent loss of control. The NTSB is not aware of any group or organization focused on technologies that could prevent the loss of control following a tire failure. Given the evidence that the transitory forces generated during a tire failure are not always controllable, even by professional drivers, tire failure situations present an instance in which advanced vehicle technologies could be particularly beneficial to the driver.

6.2 Tire-Based Innovations

During the 2014 NTSB Passenger Vehicle Tire Safety Symposium, several tire manufacturers described product innovations that may produce significant safety improvements if widely implemented.

Goodyear representatives provided presentations on three technologies that address tire air maintenance, tire treadwear, and vehicle control (Euchner 2014). Regarding air maintenance, Goodyear is conducting research on a tire that would automatically maintain its own air pressure as it is driven. This would improve the tire life by reducing overdeflection and heat buildup. It would also improve fuel economy and vehicle handling. According to Goodyear, the technology is being tested on commercial vehicles, where it would make the greatest economic impact, because tire maintenance is the single largest component of maintenance costs for commercial carriers.[68] Regarding treadwear, Goodyear presented a concept to embed self-powered sensors in the tire that could alert drivers when the tire should be replaced. Finally, Goodyear is developing an "intelligent tire," which would relay information directly to a vehicle's onboard computer regarding tire pressure, temperature, tread depth, and other information. Using this data, the onboard computer could refine its vehicle control algorithms in real time to improve vehicle handling and braking performance.

During its symposium presentation, Michelin discussed how tire technology can mitigate rear-end crashes, which represent 31 percent of all traffic crashes. Michelin has developed advanced materials and compounds that allow tires to have low rolling resistance while still being able to grip the road (Shepherd 2014). In addition, advances in tread design have led to tires that channel water effectively throughout their service life. Michelin has also been continuing its research into nonpneumatic tires.

At the symposium, Bridgestone provided a presentation on the importance of modernizing federal tire regulations so that they do not unintentionally inhibit innovation (Johnson 2014). For example, Bridgestone cited regulations that restrict the use of non-pneumatic tires for any purpose other than as spares or other temporary-use tires. Bridgestone suggested that technological innovations build upon each other and depend on associated regulatory support, such as how the TPMS requirement allowed Bridgestone to introduce DriveGuard, a run-flat tire line that can be used on a variety of passenger vehicles. Bridgestone

[67] Such systems continuously modulate the steering ratio in response to vehicle speed, which improves directional stability and optimizes the steering response.

[68] See www.energy.gov/eere/articles/eere-energy-impacts-self-inflating-tires-could-save-you-money-gas-improve-driving, accessed June 17, 2015.

expressed support for technologies such as RFID that could improve tire registration and recall success rates, as well as allow consumers and technicians to obtain information on their tires through personal electronic devices.

The NTSB concludes that vehicle- and tire-based technologies exist or are in development that could help prevent or mitigate tire-related crashes and injuries. The NTSB recommends that NHTSA develop, in consultation with automotive and tire industry representatives, a tire safety action plan to reduce or mitigate tire-related crashes by promoting technological innovation and adapting regulations as necessary.

7 Conclusions

7.1 Findings

1. The current tire registration process has proven to be ineffective in enabling tire manufacturers to compile complete and accurate customer contact information, which is vital to ensuring the success of a tire recall.

2. A computerized system for capturing, storing, and uploading tire registration information would expedite the tire registration process, reduce transcription errors, and encourage more dealers to register tires at the point of sale.

3. Modifying the tire registration form to include fields for the purchaser's e-mail address, telephone number, and vehicle identification number would provide additional means by which tire manufacturers could notify tire owners of recalls and recover more recalled tires that would otherwise continue in use.

4. Having a complete tire identification number on both sides of a tire would help consumers to accurately identify a recalled tire and to conduct maintenance as necessary and appropriate to the tire.

5. While vehicle recalls ultimately succeed in causing more than three-quarters of recalled vehicles to be serviced, tire recall recovery rates can be as low as 20 percent.

6. The tool for conducting tire recall searches on the National Highway Traffic Safety Administration website is confusing and could cause consumers to erroneously determine that their tires are not among those being recalled.

7. By not displaying tire recall information on their websites consistently and prominently, tire manufacturers have made it more difficult for consumers to respond appropriately to a tire recall.

8. Further research is needed to confirm that the implementation of Federal Motor Vehicle Safety Standard Nos. 138 and 139 has substantially reduced the risk of tire-aging-related crashes, injuries, and fatalities.

9. The guidance provided by the tire and automotive industries regarding tire service life and the risks associated with tire aging can be inconsistent and confusing, which may lead consumers to make inappropriate tire replacement decisions.

10. The National Highway Traffic Safety Administration and industry stakeholders have not provided enough guidance to those consumers whose tires are most at risk of experiencing an aging-related failure.

11. Stakeholder efforts to educate consumers on basic tire maintenance have yielded little change in consumer behavior.

12. Vehicle- and tire-based technologies exist or are in development that could help prevent or mitigate tire-related crashes and injuries.

8 Recommendations

As a result of its investigation, the National Transportation Safety Board makes the following recommendations:

To the National Highway Traffic Safety Administration:

Seek authority to require all tire dealers to register tires at the point of sale, and then require them to do so. (H-15-27)

Develop voluntary standards, in consultation with tire industry leaders, for a computerized method of capturing, storing, and uploading tire registration information at the point of sale. (H-15-28)

Include fields on the tire registration form for the purchaser's e-mail address, telephone number, and vehicle identification number to assist manufacturers in locating and notifying owners of recalled tires. (H-15-29)

Require tire manufacturers to include the complete tire identification number on both the inboard and outboard sidewalls of a tire. (H-15-30)

Require tire manufacturers to put the safety recall information for their tires on their websites in a format that is searchable by tire identification number as well as by brand and model; if necessary, seek legislative authority to implement this recommendation. (H-15-31)

Modify the tire recall search feature on your website to allow users to search for recalls by tire identification number as well as by brand and model. (H-15-32)

Determine the level of crash risk associated with tire aging since the implementation of Federal Motor Vehicle Safety Standard Nos. 138 and 139; if, based on this determination, it appears that the aging-related risk should be mitigated, develop and implement a plan to promote the tire-aging test protocol to reduce the risk. (H-15-33)

Develop a consensus document with input from the automotive industry, the tire industry, and safety advocacy groups that addresses tire aging and service life and that also includes best practices for those consumers whose tires are most at risk of experiencing an aging-related failure. (H-15-34)

Develop, in consultation with automotive and tire industry representatives, a tire safety action plan to reduce or mitigate tire-related crashes by promoting technological innovation and adapting regulations as necessary. (H-15-35)

To AAA and the Rubber Manufacturers Association:

> Work together to evaluate the effectiveness of current tire safety efforts in influencing consumer tire purchase and maintenance behaviors, and publish the results of the evaluation. (H-15-36)

To the tire manufacturers (and their subsidiaries) Bridgestone Americas Inc., Continental Tire the Americas LLC, Cooper Tire & Rubber Company, The Goodyear Tire & Rubber Company, Hankook Tire America Corporation, Kumho Tire USA Inc., Michelin North America Inc., Pirelli Tire North America Inc., Toyo Tire Holdings of Americas Inc., and Yokohama Tire Corporation:

> Put the safety recall information for your tires on your websites in a format that is searchable by tire identification number as well as by brand and model. (H-15-37)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

CHRISTOPHER A. HART Chairman	**ROBERT L. SUMWALT** Member
T. BELLA DINH-ZARR Vice Chairman	**EARL F. WEENER** Member

Adopted: October 27, 2015

Appendix A: Investigations

The NTSB received notification of the Centerville, Louisiana, collision on February 15, 2014. The NTSB launched investigators from the Office of Highway Safety to address survival factors, human factors, vehicle, and highway issues. Parties to the investigation included the Louisiana State Police and the Louisiana Department of Transportation and Development.

The NTSB received notification of the Lake City, Florida, collision on February 21, 2014. One investigator from the Office of Highway Safety was launched to the scene. Parties to the investigation were the Florida Highway Patrol and the First Baptist Church of New Port Richey.

The NTSB received notification of the Eloy, Arizona, multiple-vehicle collision on March 30, 2014. It received notification of the single-vehicle rollover crash in Patterson, California, on May 22, 2014. No investigators were launched to either scene.

The NTSB held a public symposium on passenger vehicle tire safety on December 9–10, 2014, in connection with these crashes.

Appendix B: Tire-Related Crash Data Analyses

B.1 Trends in Tire-Related Fatal Crashes Compared to All Fatal Crashes

The NTSB analyzed data contained in the Fatality Analysis Reporting System (FARS) to examine yearly trends in the number of tire-related fatal crashes.[1] The FARS database is maintained by NHTSA; it is a census of all police-reported fatal motor vehicle crashes occurring on public roadways in the United States. Using 2007 as the dividing point, data gathered for the period 2000–2006 were compared to data gathered for 2007–2013.[2] (See table B-1.) A total of 268,700 fatal crashes occurred in the United States in the period 2000–2006, resulting in 299,084 fatalities. These numbers dropped to 223,695 fatal crashes and 244,544 fatalities for the period 2007–2013. These figures represent a 16.7 percent and an 18.2 percent decline in fatal crashes and fatalities, respectively, between the two periods. Focusing on tire-related fatal crashes involving passenger vehicles, the declines in both fatal crashes and fatalities were considerably less.[3] Fatal crashes involving one passenger vehicle decreased from 3,637 to 3,410 crashes (a 6.2 percent decline), while fatalities decreased from 4,446 to 4,045 fatalities (a 9 percent decline) between the two periods. Therefore, tire-related fatal crashes involving passenger vehicles did not decline at the same pace as all fatal crashes in the United States between 2000–2006 and 2007–2013.

[1] Tire-related crashes are those in which the investigating officer considers tire failure, such as a tire blowout or flat tire, a contributing or related factor to a crash.

[2] The year 2007 was the dividing point used by NHTSA in its 2014 summary report on tire aging to show that tire-related traffic fatalities had decreased since the introduction of FMVSS Nos. 138 and 139 in 2007.

[3] Table B-1 includes fatal crashes in which only one passenger vehicle experienced a tire-related issue. There are fatal crashes coded in FARS where multiple vehicles were reported as experiencing a tire failure; however, these crashes were omitted to provide a more conservative estimate.

Table B-1. Tire-related fatal crashes and fatalities by year and road user type, 2000–2013. (Data source: FARS)

Year	Tire-related fatal crashes				All fatal crashes	
	Passenger vehicles		All vehicles			
	Numbers		Numbers		Numbers	
	Crashes	Fatalities	Crashes	Fatalities	Crashes	Fatalities
2000	570	691	646	784	37,526	41,945
2001	500	645	593	748	37,862	42,196
2002	468	569	559	671	38,491	43,005
2003	539	671	636	777	38,477	42,884
2004	523	631	621	739	38,444	42,836
2005	510	604	604	705	39,252	43,510
2006	527	635	605	723	38,648	42,708
2007	499	596	603	707	37,435	41,259
2008	428	492	524	616	34,172	37,423
2009	434	539	527	647	30,862	33,883
2010	527	627	651	768	30,296	32,999
2011	503	587	606	697	29,867	32,479
2012	553	665	675	801	31,006	33,782
2013	466	539	602	692	30,057	32,719
Total 2000–2013	**7,047**	**8,491**	**8,452**	**10,075**	**492,395**	**543,628**
Total 2000–2006	**3,637**	**4,446**	**4,264**	**5,147**	**268,700**	**299,084**
Total 2007–2013	**3,410**	**4,045**	**4,188**	**4,928**	**223,695**	**244,544**
% Change between 2007–2013 and 2000–2006	**-6.2**	**-9.0**	**-1.8**	**-4.3**	**-16.7**	**-18.2**

As shown by the blue line in figure B-1, all fatal crashes in the United States gradually declined throughout the period 2000–2013. The decline was most pronounced between 2007 and 2009, which coincided with a recession in the United States.[4] The red line in figure B-1 represents the rate of tire-related fatalities during the same period. It shows that the rate of tire-related fatalities began to rise in 2007 and continued to do so until 2013.[5] Thus, the overall rate of decline in US highway fatalities was not mirrored by a similar rate of decline in tire-related fatalities involving passenger vehicles, especially during the 2007–2013 period.

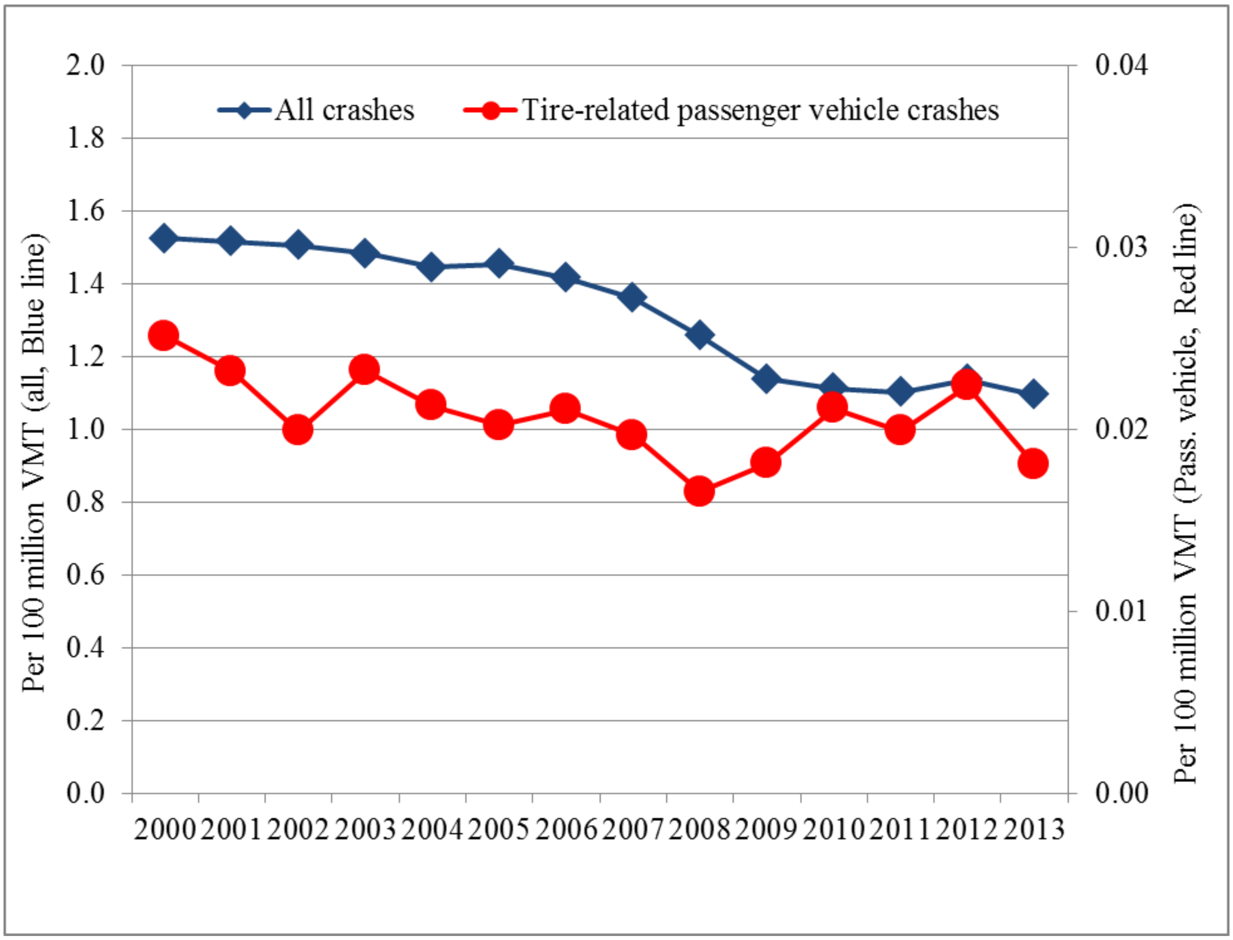

Figure B-1. Comparison of fatality rates for all highway vehicle crashes with tire-related passenger vehicle crashes, based on FARS data and Federal Highway Administration (FHWA) VMT data for 2000–2013.

4 Overall, the US vehicle miles traveled (VMT) were extracted from Insurance Institute for Highway Safety fatality facts–general statistics. (Source: www.iihs.org/iihs/topics/t/general-statistics/fatalityfacts/overview-of-fatality-facts, accessed October 1, 2015.)

5 Fatality rates were computed using the same denominator, that is, 100 million VMT. There was no available VMT data specifically for passenger vehicles for the period 2000–2013. Because the rates for tire-related passenger vehicle crashes are considerably lower than the rates for all crashes, figure B-1 uses two axes (all crashes on the left and tire-related passenger vehicle crashes on the right). The purpose of figure B-1 is to compare the general trends over time for the two groups.

B.2 Tire Aging

The FARS database does not contain information about the age of crash vehicle tires. Therefore, the NTSB used vehicle age as an imperfect surrogate to learn more about tire age and service life. Figure B-2 shows the relative distribution (as expressed in percentages) of passenger vehicles with tire-related factors during the period 2000–2013 by age of vehicle (red line), compared to all passenger vehicles involved in fatal crashes (blue line).[6] There is no distinctive peak of vehicle age for all passenger vehicles involved in fatal crashes. In general, the most frequent vehicle ages range from 5 to 7 years. After this peak in vehicle age, there is a steady decline in the percentages of vehicles 8 years and older.

When the data were limited to passenger vehicles involved in a tire-related fatal crash, the results indicate that a large portion of these vehicles were between 8 and 10 years old. About 7.2 percent of all tire-related passenger vehicle crashes occurred at 8 years, followed closely by 10 and 9 years (7.1 percent and 7.0 percent, respectively). This suggests that the service life of passenger vehicle tires roughly corresponds with the replacement schedule recommended by vehicle and tire manufacturers.

[6] Age of vehicle is derived by subtracting the model year from the crash year. For example, a 2014 model year vehicle involved in a crash in late 2013 would yield a vehicle age of -1.

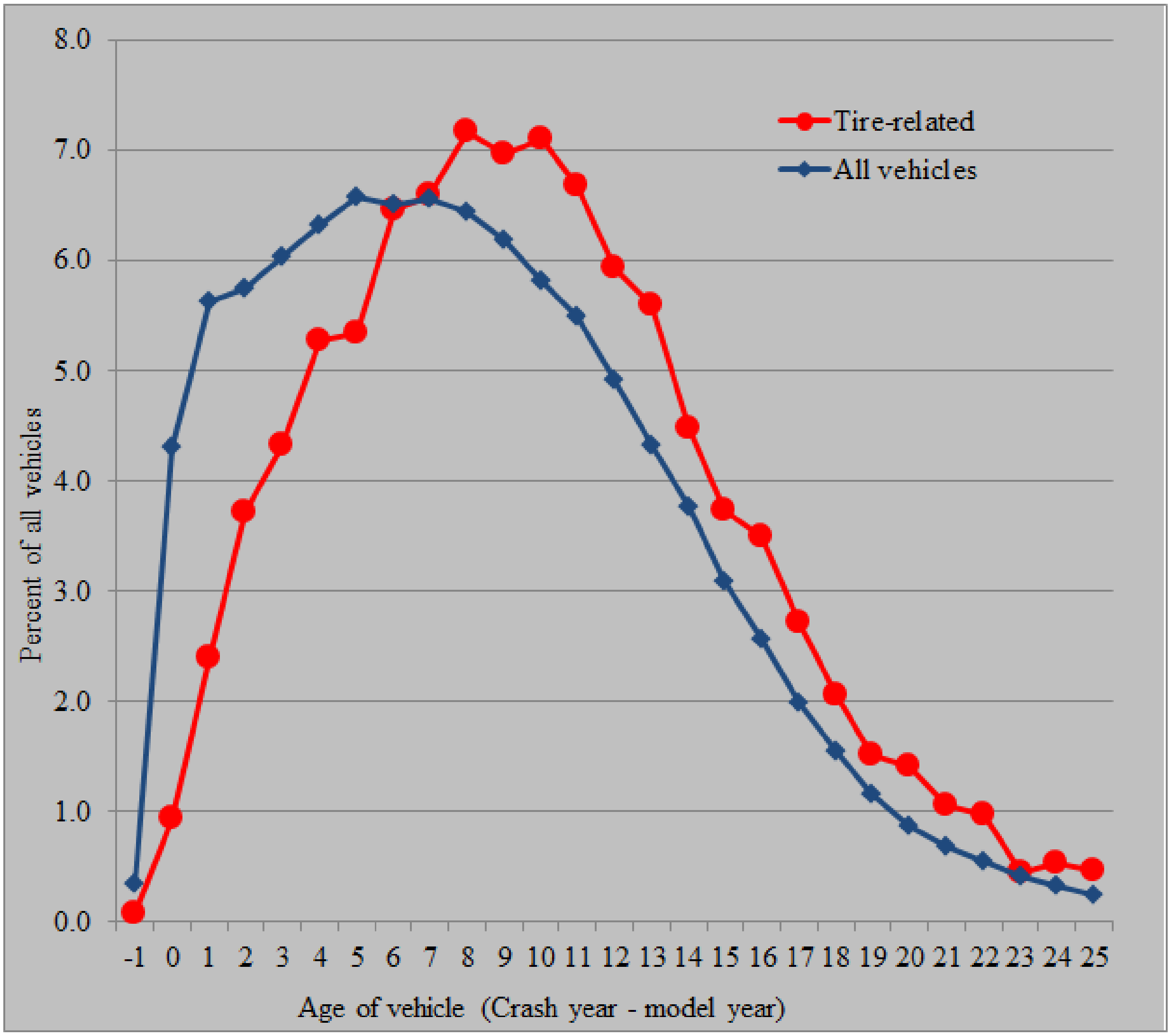

Figure B-2. Relative frequency distribution of vehicles involved in fatal crashes by age of vehicle, FARS 2000–2013.

B.3 Geography and Tire-Related Crashes (2007–2013)

Figure B-3 shows the fatality rates of tire-related passenger vehicle crashes per 100 million VMT by states during the period 2007–2013.[7] The average fatality rate of tire-related passenger vehicle crashes in the United States is 0.019 deaths per 100 million VMT. With a few exceptions (such as the northern states of Vermont and Alaska, which have unusually

[7] VMT data were obtained from FHWA VMT data tables.

high fatality rates), a general north–south division can be seen in the map.[8] Two of the top three states with the highest tire-related fatality rates (Arizona and Louisiana) are considered Sun Belt states. In fact, with the exception of Mississippi, all the Sun Belt states (including California and Nevada, of which only their southern halves are considered to be within the Sun Belt) had tire-related fatality rates at or higher than the US average. In figure B-3, those states in blue have tire-related fatality rates below the average tire-related fatality rate for the United States.

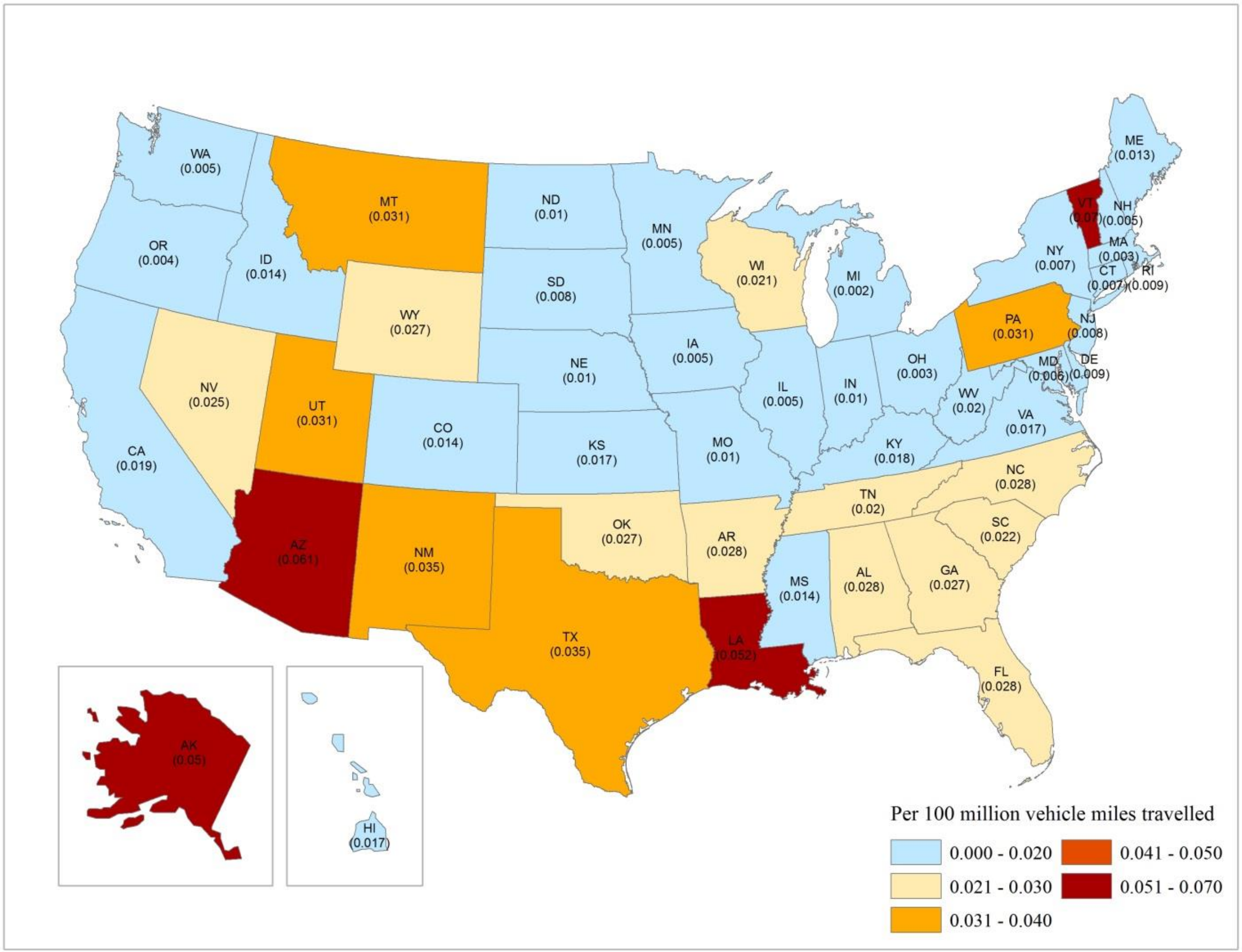

Figure B-3. Fatality rates of tire-related passenger vehicle crashes by state per 100 million VMT, per FARS and FHWA data for 2007–2013.

[8] Vermont and Alaska are outliers in the overall pattern, with both having very high tire-related fatality rates. Although the reasons why these two states have such high rates were not examined, it should be noted that the VMTs in these two states are small when compared to most states. Only the District of Columbia has a lower VMT value, but it also has no tire-related fatalities.

B.4 Crash and Injury Estimates

In addition to FARS data, NHTSA collects a nationally representative sample of all police-reported motor vehicle crashes to estimate the number of crashes and crash-related injuries that occur annually. About 50,000 police-reported crashes from 60 different geographic sites are sampled every year for the National Automotive Sampling System/General Estimates System (NASS/GES).

At the request of the NTSB, NHTSA analyzed the NASS/GES data for tire-related crashes and presented the results at the symposium in December 9, 2014 (Kindelberger 2014). According to NHTSA, tire factors were coded for about 0.6 percent of NASS/GES crashes. These data indicated that about 38,000 tire-related crashes and about 24,000 injuries occurred annually in the period 1995–2006.[9] In the period 2007–2012, the estimated annual number of tire-related crashes was 33,000, with about 19,000 people injured each year (see table B-2).

Table B-2. Average number of tire-related crashes and injuries per year, based on NASS/GES data, 1995–2012 (95 percent confidence interval in parentheses).

	1995–2006	2007–2012
Crashes	38,000 (33,000–44,000)	33,000 (29,000–36,000)
% of crashes	0.61% (0.52%–0.69%)	0.58% (0.51%–0.66%)
Injured	24,000 (18,000–30,000)	19,000 (14,000–24,000)

B.5 Estimates Published in NHTSA's Tire-Aging Summary Report

In its 2014 summary report on tire aging, NHTSA estimated that during the period 2007–2010, about 11,000 tire-related crashes occurred annually. These crashes resulted in about in 6,400 injuries and 200 fatalities annually (NHTSA 2014). (See table B-3.) When compared to yearly estimates for the period 1995–2006, NHTSA reported a 35 percent reduction in tire-related crashes, a 42 percent reduction in injuries, and a 50 percent reduction in fatalities. NHTSA had chosen 2007 as the dividing point because, in 2007, new federal regulations to improve tire performance (FMVSS Nos. 138 and 139) went into effect.

[9] NASS/GES produces estimates based on a sample of reported crashes. Therefore, these numbers should be considered a best guess based on the data. Confidence intervals (95 percent) are included to indicate that there is a 95 percent chance that the real number is within the range of numbers shown.

Table B-3. NHTSA-reported estimates of light vehicle tire-related crashes, fatalities, and injuries (annual averages), based on data from NASS/CDS, 1995–2010.

	1995–2006	2007–2010
Tire-related crashes	17,019	11,047
Fatalities	386	195
Injuries	11,005	6,361

NHTSA believed that the reduction in the number of tire-related crashes, injuries, and fatalities was due in part to more stringent tire regulations that went into effect in 2007. NHTSA did not publish the methodology it used to arrive at these estimates, and the 2014 summary report on tire aging did not indicate whether the agency accounted for other factors that might explain the observed trends. Moreover, it did not discuss estimates of market penetration for those tires meeting the new regulations during the period 2007–2010.

In arriving at the estimates in its tire-aging summary report (NHTSA 2014), NHTSA relied on data collected for the National Automotive Sampling System/Crashworthiness Data System (NASS/CDS) database. NASS/CDS data originate from police accident reports as well as detailed NHTSA investigations on a representative sample of about 4,600 crashes a year, in which at least one light passenger vehicle was towed due to disabling damage. Trained crash investigators are sent to the crash sites to study vehicle wreckage and physical evidence on the highway. They interview crash victims and review medical records to determine the nature and severity of injuries. The NASS/CDS database provides detailed information on the crash event, the crash forces involved, the damage to the vehicle, and the occupant injuries and injury mechanisms. In cases where tire failure is suspected, specific tire information is recorded, including the TIN. NHTSA chose to analyze NASS/CDS data to arrive at its estimates of tire-related injuries and fatalities because tire-related crashes could be verified and examined in more depth. However, NASS/CDS data are collected primarily to study the crashworthiness of vehicles less than 10 years old, so the data do not represent the population of all passenger vehicles (the average age of vehicles on the road today is 11 years), and their focus is not crash causation. Additionally, the relatively small size of the sample reduces the amount of confidence researchers can have in the statistical results.

In preparation for the 2014 NTSB tire symposium, NHTSA reanalyzed the NASS/CDS data. The results of its analyses are shown in table B-4, table B-5, and figure B-4.

Table B-4. Estimates of fatalities and injuries by calendar year for 1995–2012, based on NASS/CDS data. The “unweighted” columns show the actual numbers of deaths and injuries used to derive national estimates (“weighted” columns).

Year	Deaths (unweighted)	Injuries (unweighted)	Deaths (weighted)	Injuries (weighted)
1995	1	25	62	5,908
1996	6	48	799	12,021
1997	3	39	328	8,985
1998	6	37	235	8,535
1999	3	44	116	12,849
2000	10	47	1,134	7,047
2001	2	31	62	2,744
2002	2	37	113	7,962
2003	4	24	241	17,168
2004	5	59	463	13,765
2005	2	39	144	8,282
2006	6	52	306	8,335
2007	6	47	379	7,846
2008	5	27	295	5,461
2009	0	33	0	4,165
2010	2	48	44	3,952
2011	0	12	0	2,161
2012	1	14	5	4,278

Table B-5. Average number of tire-related crash fatalities and injuries, based on NASS/CDS data, 1995–2012 (95 percent confidence intervals in parentheses).

	1995–2006	2007–2010	2011–2012
Tire-related crashes	16,600 (9,200–24,100)	8,800 (3,000–14,600)	13,400 (0–28,600)
Fatalities	300 (0–700)	200 (0–500)	2 (0–8)
Injuries			
Visible or incapacitating	9,500 (2,800–16,200)	5,400 (500–10,200)	3,200 (0–6,600)
Minor	3,500 (1,200–5,800)	2,600 (300–4,800)	2,000 (0–5,300)
Total	13,000	7,900	5,200

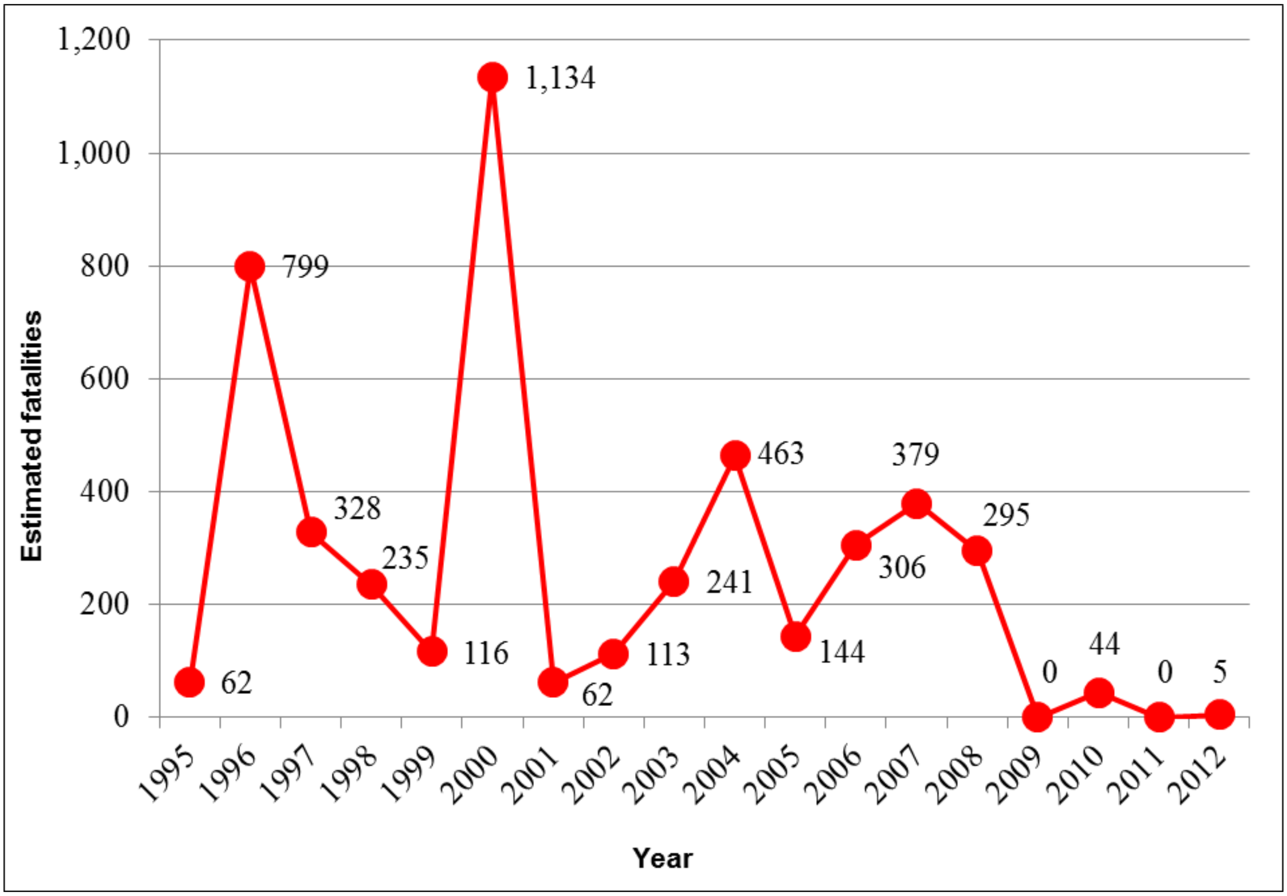

Figure B-4. Tire-related crash fatality estimates for 1995–2012, based on NASS/CDS representative sample data.

When compared to the estimates in NASS/GES and FARS data, the NASS/CDS data appear to underestimate the number of tire-related crashes, injuries, and fatalities. Additionally, the relatively small sample produced annual estimates that were based on very few actual crashes, resulting in unreliable estimates and trends that were more likely due to statistical noise rather than to true yearly difference. Finally, a vast majority of the fatal tire-related crashes in NASS/CDS during the period 1995–2012 were located in Arizona (41 of 64 fatal crashes), which suggests that for this particular factor, NASS/CDS did not provide a representative distribution of tire-related crashes across the United States.[10]

[10] NHTSA does not report the identities of states that have primary sampling units within NASS/CDS. From prior research, the NTSB determined the states in which primary sampling units were located. State estimates cannot be derived from NASS/CDS.

Appendix C: Summary of Additional Tire-Related Incidents

C.1 Eloy, Arizona

About 6:04 p.m. on March 29, 2014, near Eloy, Arizona, a Ford F-250 pickup truck occupied by a 47-year-old driver and five passengers, ranging in age from 7 to 49, was traveling westbound in the left lane of Interstate 10 (I-10) at a driver-estimated speed of 80 mph. Near milepost 213, the left front tire of the pickup truck experienced a partial tread separation and blowout. The driver lost control of the vehicle, and it veered to the left. The pickup truck crossed the center median and began to roll over. As it was doing so, it was struck by a 2014 Freightliner tractor-semitrailer traveling eastbound on I-10 in the right lane. The front left corner of the tractor-semitrailer's bumper struck the roof of the pickup truck. The pickup truck rotated off the front right of the tractor-semitrailer and struck the sidewall and undercarriage of the semitrailer. The cab of the pickup truck separated from the frame, and the frame was bisected. A 2005 Honda Civic coupe traveling eastbound in the left lane also collided with the pickup truck.

As a result of the crash, the driver of the pickup truck, who was wearing a seat belt, sustained serious injuries. Two unrestrained front seat passengers were ejected from the vehicle and died. All three restrained passengers in the back seat also died as a result of the crash. The driver of the Freightliner sustained serious injuries, and the co-driver was not injured. All four occupants of the Honda were uninjured.

The left front tire was a BFGoodrich Rugged Terrain manufactured in the fourth week of 2012 (making it 2 years old at the time of the crash). The tire was installed on the vehicle with the complete tire identification number facing the inboard side; this was also the case for the other tires on the vehicle. The tread was still attached to the tire after the crash and was about 3 feet 7 inches long. The tire also had a cut in its sidewall that measured about 8 inches long. An examination of the photos taken by the Arizona Highway Patrol revealed that the initial tread separation began along the outboard shoulder of the tire. There were no visually apparent wear patterns on the tread, indicating that the separation progressed comparatively quickly. About 7 inches of tread were missing where the separation initiated. Evidence suggested that the blowout occurred after the tread separation. Photos of the left front tire did not suggest a cause for the tread separation; nevertheless, an uneven wear pattern was found on one of the rear tires. Investigators queried the NHTSA tire recall database, which returned no recalls for the failed tire.

C.2 Patterson, California

About 1:07 p.m., on May 22, 2014, near Patterson, California, a 1999 Ford Explorer SUV was traveling north on Interstate 5 in the left-hand lane, at a witness-estimated speed of 70 mph (the posted speed limit), when the right rear tire of the vehicle experienced a tread separation. A witness behind the SUV stated that the vehicle went out of control immediately after the tire failure. The SUV traveled about 117 feet across the right-hand lane, departed the roadway to the right, collided with an embankment, and overturned. The SUV came to rest on its left side on the right-hand shoulder facing east, about 235 feet from where the initial loss of control occurred. The driver, who was wearing a lap/shoulder belt, was partially ejected and died as a result of the crash.

The subject tire was a BFGoodrich Radial Long Trail T/A tire manufactured in the 42nd week of 2001 (making it 12.5 years old at the time of the crash). The tire remained inflated during the loss of control and rollover sequence. A piece of the tread about one-third the circumference of the tire separated completely from the tire carcass. Tread depth indicators were visible just below the top of the tread, indicating that the tread depth was slightly greater than 2/32 inch. In contrast, the front tires had deep tread grooves and appeared relatively new. Investigators queried NHTSA's tire recall database, which returned no recalls for the subject tire. An examination of the photos taken by the California Highway Patrol revealed visible belt edge separation. There was cracking along the shoulder and in the grooves of the tread.

Appendix D: Tire Safety Alert

NTSB
SAFETY ALERT
National Transportation Safety Board

Drivers: Manage Tire Risks for a Safer Ride

Tire Maintenance and Registration Can Decrease Crash Risk

The Problem:

- 539 people were killed in tire-related passenger vehicle crashes in 2013. About 19,000 people are injured each year in such crashes.
- Many of these crashes resulted from poor tire maintenance, including failure to maintain proper inflation, check for adequate tread, monitor for damage, or have repairs made properly.
- According to a survey conducted in 2014 by the Rubber Manufacturers Association, 69 percent of vehicles had at least one underinflated tire.
- Very few motorists register their tires with the manufacturer, making it less likely that the manufacturer will contact them in the event of a tire recall.

What to Do:

- Register your new tires with the manufacturer, so you receive tire recall notices.
- You can't tell if your tires are properly inflated just by looking at them. Check your tire pressure at least once a month. If your tire pressure monitoring system activates, check your tires as soon as possible.

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- Inflate your tires to the pressures indicated in your vehicle owner's manual or on the "Tire and Loading Information" label located on the driver's side door edge (or post) of your vehicle. Do not use the pressure printed on the tire sidewall.

- When checking your tire pressure, also examine your tires for punctures, signs of uneven tread wear, bald spots, bulges or bumps, cuts or cracks in the sidewall, or any other abnormalities. These problems can lead to tire failure.

- Don't forget your spare! Tires can degrade even when not in use, so keep your spare tire properly inflated and check it monthly for problems.

- To prolong the life of your tires, remember to rotate, balance, and align your tires in accordance with the information in your vehicle owner's manual.

- If you hear an unusual sound coming from a tire, slow down and have your tires checked immediately.

Interested in More Information?

Education is critical to maintaining your tires properly. Refer to your vehicle owner's manual for tire information specific to your vehicle. The US Department of Transportation, tire manufacturers, tire retailers, and others have published helpful tips online about properly maintaining, replacing, and registering your tires, as well as about checking for safety recalls. You can find valuable information at the following websites:

- US Department of Transportation (http://www.safercar.gov/tires)

- Rubber Manufacturers Association (http://www.rma.org/tire-safety)

- Tire Industry Association (http://www.tireindustry.org/consumer-safety)

This NTSB safety alert and others can be accessed from the NTSB's Safety Alerts web page at http://www.ntsb.gov/safety/safety-alerts.

SA-044-Oct-2015 (revised)

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