Motorcoach Fire Safety Analysis

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Federal Motor Carrier Safety Administration
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This purpose of this study was to collect and analyze information from Government, industry, and media sources on the causes, frequency, and severity of motorcoach fires in the U.S., and to identify potential risk reduction measures. The Volpe Center created a database on reported motorcoach fire incidents between 1995 and 2008. Independent reference sources were used to verify that incidents were applicable, to address missing or unknown field values, and to derive non-reported elements. Preliminary analysis of the data suggests that: (a) approximately 160 motorcoach fires are reported annually, with average damages of $65,000; (b) with the exception of a single catastrophic fire, which resulted in 23 fatalities and 15 injuries, approximately 95 percent of the reported fires resulted in no direct injuries or fatalities; (c) about 70 percent of fires originate in the engine compartment and wheel wells; (d) frequency of motorcoach fires for model years 1998–2002 compared to older models was disproportionately greater than their relative populations; (e) vehicle out-of-service (OOS) rates for fire-involved motorcoaches have exceeded rates for all buses, and the gap has widened in recent years; and (f) North American Standard (NAS) Motor Carrier Inspection and OOS criteria may not sufficiently identify all precursors of motorcoach fires.</td></tr>
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Acronyms and Abbreviations

ABA	American Bus Association
APTA	American Public Transportation Association
ASTM	ASTM International (originally known as the American Society for Testing and Materials)
CDL	Commercial Driver's License
CMV	commercial motor vehicle
CR	compliance review
CSA	Comprehensive Safety Analysis 2010 program
CVINA	Complete Vehicle Identification Number Analysis
CVSA	Commercial Vehicle Safety Alliance
CVSP	Commercial Vehicle Safety Plans
DVIR	driver vehicle inspection report
ECE	Economic Commission of Europe
EPA	Environmental Protection Agency
EWR	Early Warning Reporting
FAA	Federal Aviation Administration
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMCSR	Federal Motor Carrier Safety Regulations
FMVSS	Federal Motor Vehicle Safety Standards
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
FY	Fiscal Year
GSA	General Services Administration
GVWR	gross vehicle weight rating
MCF	Motorcoach Fire
MCI	Motorcoach Industries

MCMIS	Motor Carrier Management Information System
MCSAP	Motor Carrier Safety Assistance Program
MMUCC	Model Minimum Uniform Crash Criteria
MY	Model Year
NAS	North American Standard
NFDC	National Fire Data Center
NFIRS	National Fire Incident Reporting System
NFPA	National Fire Protection Association
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
NYDOT	New York State Department of Transportation
ODI	Office of Defects Investigation (NHTSA)
OEM	original equipment manufacturer
OOS	out of service
PII	Personally Identifiable Information
PTSB	Public Transportation Safety Board
SafeStat	Motor Carrier Safety Status Measurement System
SDS	State Data System
SEA	Safety Evaluation Area
TREAD	Transportation Recall Enhancement, Accountability and Documentation Act
UL	Underwriters Laboratories
UMA	United Motorcoach Association
USDOT	U.S. Department of Transportation
USFA	U.S. Fire Administration
VIN	Vehicle Identification Number
VIO	Commercial Vehicles in Operation database
VMT	vehicle miles traveled
Volpe MCF	Volpe Center Motorcoach Fire database

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Members of the motor carrier safety oversight community were instrumental in this study in many ways. The FMCSA Passenger Technical Advisory Group, chaired by Wes Barber, provided considerable technical guidance, follow-up contacts, and critical review of the methods and analyses. Bob Kettenheim and Tim Davis supplied us with numerous accounts of and data from recent motorcoach fire incidents and insight into the related regulatory and investigation processes. Tim Davis, representing the Commercial Vehicle Safety Alliance (CVSA) and chair of its Passenger Carrier Committee, also facilitated our continued involvement with the CVSA Bus Fire Subcommittee. This provided us with both a forum for discussing our evolving approaches and findings and access to industry and government leaders who are tackling various aspects of the motorcoach fire safety problem. While those who offered their expertise are too numerous to list, they include Bonnie Bass, formerly of FMCSA’s Passenger Carrier Division, Alex Guariento, formerly of Greyhound Lines, Graham Dunnege of Adirondack Trailways, Chris Crean of Peter Pan Bus Lines, Larry Yohe, formerly of the National Transportation Safety Board, Bob Crescenzo of Lancer Insurance, Matt Daecher of Daecher Associates, and Norm Littler of the Bus Industry Safety Council.

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Executive Summary

This report documents a recent U.S. Department of Transportation (USDOT) motorcoach fire safety analysis study. The Volpe National Transportation Systems Center performed the study for the Federal Motor Carrier Safety Administration (FMCSA), Vehicle and Roadside Operations Division. The primary objective of this study was to gather and analyze information regarding the causes, frequency, and severity of motorcoach fires that are caused by mechanical or electrical failure.

A motorcoach is a bus with integral construction designed for long-distance passenger transportation. It measures at least 35 feet long and can seat 30 or more passengers on an elevated passenger deck over a baggage compartment.

Fires start when flammable or combustible materials with an adequate supply of oxygen are subjected to enough heat. The common fire-causing sources of heat include a spark, another fire, and sources of intense thermal radiation. Mechanical and electrical machinery may cause fire if combustible materials used on or located near the equipment are exposed to intense heat. Fires sustain themselves by the further release of heat energy in the process of combustion and may propagate, provided there is a continuous supply of oxygen and fuel. Motorcoach fires can start in the engine compartment, the bus interior, the fuel system, or the wheel wells. All of these locations have multiple sources of flammable and/or combustible material and potential ignition sources.

A motorcoach fire can consume a vehicle within 15 to 20 minutes, causing hundreds of thousands of dollars in property damage. In the vast majority of reported cases, passengers were able to evacuate safely, thereby avoiding deaths and injuries. A 2005 fire on a motorcoach operated by Global Limo, which resulted in 23 fatalities and 15 injuries, was a singular event that demonstrated the death and injury potential of a motorcoach fire.

Data Collection and Compilation

Although there are credible estimates of the frequency of fires on all types of buses combined, motorcoach-specific estimates are not easily found in State and Federal accident statistics, national fire databases, and general media sources.

Sources used in this analysis included the National Highway Traffic Safety Administration's (NHTSA) Fatality Analysis Reporting System (FARS), the U.S. Fire Administration’s (USFA) National Fire Incident Reporting System (NFIRS) database, FMCSA’s Motor Carrier Management Information System (MCMIS) database, NHTSA’s State Data System (SDS), NHTSA's vehicle defect database, the joint FMCSA/NHTSA bus fire analysis database, State police crash reports, State DOT bulletins, and news reports. Information obtained from industry sources included motorcoach fire records compiled by two major carriers and two insurance firms, as well as industry service bulletins and general media sources.

Vehicle mileage data were obtained from annual Federal Highway Administration (FHWA) highway statistics charts, and summaries of motorcoach population and detailed characteristics data were provided by R.L. Polk and Co.

Data collection for creating and updating the Volpe Center Motorcoach Fire (MCF) database involved (1) querying the national public and industry data sources listed above for motorcoach fires, (2) verifying and classifying the query results, (3) obtaining and analyzing police accident reports from States, (4) filling in details available from NFIRS remarks, police and media reports, (5) finding inspection and review histories, from the FMCSA MCMIS database, pertaining to each vehicle and carrier represented in the data, and (6) removing Personally Identifiable Information (PII). The data in the Volpe MCF database were then analyzed in an attempt to identify trends and common features.

The Volpe MCF database used in this report consists of 899 records from the sources cited above from 1995 through 2008, with the 2004–2006 data being the most complete. The database was structured to facilitate analysis by location of origin, point of ignition, geographic and vehicle characteristics, inspection and maintenance histories, damage to the vehicle, and human injuries and fatalities.

Data from the FARS, NFIRS, MCMIS, and SDS databases required specific queries to find motorcoach fires. The results of each query were reviewed to remove any records that were not clearly relevant to non-collision motorcoach fires. These records were then combined with the data obtained from other public and industry sources into the Volpe MCF database.

Ten States were selected from those identified as having the most numerous fires in the Volpe MCF database. Police reports available from eight of those States were gathered and reviewed to provide a more complete sampling of motorcoach fires, verify details, and remove any incidents not clearly associated with non-collision motorcoach fires.

Registration information corresponding to license tags and/or Vehicle Identification Numbers (VINs) was requested from those States and was included in the Volpe MCF database. Vehicle roadside inspection data and compliance review (CR) histories for all carriers and vehicles identified in the Volpe MCF database were obtained by querying MCMIS a second time. The inspection and review data were then added to the Volpe MCF database, and motor carrier names, PII, and duplicate records were eliminated.

Data attributable to each record were examined to (1) identify the age, manufacturer, make, model, and other characteristics of each motorcoach, (2) characterize each vehicle’s geographic location and its maintenance and inspection history, and (3) describe each fire’s origin location, ignition point, vehicle damage, and resultant injuries and fatalities.

Data fields identified as key to analysis were populated for the majority of fire incidents. For the data-collection years 1995–2008, the Volpe MCF database fire records contain:

- 899 motorcoach fire records
- 719 records that specify the bus manufacturer
- 732 records that specify the bus model year
- 458 records that specify the bus model name
- 606 records that identify the State where the fire occurred
- 549 records that identify the fire’s origin location
- 472 records that identify the fire’s ignition point
- 28 records that identify injury and/or fatality counts greater than zero

- 210 records that specify vehicle damage estimates, including zero
- 8 records that identify fire-involved motorcoaches that may have been equipped with an automatic failure detection and/or automatic fire detection and suppression system

The Volpe MCF database has several limitations, including (1) geographic and temporal skewing of some data, (2) missing or incomplete data for some fields, and (3) in some instances, issues with data completeness and quality. Nevertheless, it is sufficiently comprehensive for exploratory analysis.

Key Findings

- Motorcoach fires have occurred with an approximate frequency of 160 per year, based on the most complete and current reporting years.
- Although a single catastrophic motorcoach fire resulted in 23 fatalities and 15 injuries, approximately 95 percent of the reported fires over the study period resulted in no direct injuries and fatalities.
- The most frequently identified location of fire origin was the engine compartment, followed closely by wheel wells.
- The most frequently specified points of ignition were the brakes, turbocharger, tires, electrical system, and wheel/hub bearings.
- The frequency of fires on motorcoaches of MYs 1998–2002 relative to older models was disproportionately greater than their relative populations.
- Vehicle out-of-service (OOS) rates for fire-involved motorcoaches have exceeded those for all buses, and the gap has widened in recent years.
- Analysis of inspection data suggests that the frequency of roadside inspections with OOS violations may be an indicator of future motorcoach fire risk.
- Current North American Standard (NAS) Motor Carrier Inspection and OOS criteria may not be capable of addressing fire prevention during routine inspections of the normal inspection items during an NAS Level 1 or 5 inspections.

Recommendations

Analysis of the literature and data on motorcoach fire risk supports recommendations to FMCSA and the industry in the areas of data quality; inspection and enforcement; and vehicle design, equipment development, and operational training. These recommendations are outlined below.

Data Quality and Reporting

- Collaboration with data-source organizations to improve their coverage, depth, and quality of reporting of key elements related to motorcoach fire incidents
- Promotion of adherence to regulatory guidance for reporting motorcoach fires to MCMIS
- Support of data standardization initiatives for defining common data elements and coding for crash reports

Inspection Standards and Enforcement Procedures

- Continuation of collaborative efforts to identify critical inspection items associated with contribution to fire risk

- Increase in the frequency of on-the-road inspections of motorcoaches to expand compliance data
- Exploration of the use of vehicle OOS rates for a carrier as an indicator for conducting focused fire safety investigations
- Enhancement of training given to passenger-carrier inspectors and investigative specialists
- Revision of the safety rating system for passenger carriers to include a broader range of vehicle violations

Improved Vehicle Design, Equipment Development, and Operational Training

- Consideration of design changes that could improve the fire safety of brakes, turbochargers, tires, electrical systems, wheel/hub bearings, and exits
- Evaluation of the effectiveness of automatic failure warning systems and fire detection/suppression systems
- Support of research and development in technologies for wheel-well fire detection/suppression systems
- Enhancement of fire-response equipment, safety procedures, and training requirements for drivers and maintenance personnel

1. Introduction

This report documents a U.S. Department of Transportation (USDOT) motorcoach fire safety analysis study performed by the Volpe National Transportation Systems Center for the Federal Motor Carrier Safety Administration (FMCSA), Vehicle and Roadside Operations Division. The objective of this study was to gather and analyze information regarding the causes, frequency, and severity of motorcoach fires. This report also identifies potential ways to prevent, reduce, or mitigate the severity and frequency of motorcoach fires.

The data for this study were compiled in two separate efforts. The first phase, conducted from July 2006 through April 2007, documents the reporting years 1995–2004. The original timeline for Phase 1 included 2005–2006, but the data collected for these years proved incomplete. The second phase, conducted in 2008, was undertaken to resolve gaps in the data from Phase 1. Phase 2 also added more recent records (2007–2008), but these remain incomplete at the time of this writing.

Section 1 presents background information on motorcoach fires, including known causes, trends, standards, and best practices, which formed the basis for the study's data collection and analysis. This information provides a snapshot of Federal, State, and industry safety standards and fire prevention, mitigation, and warning practices from 1995 to 2008.

The remainder of the report describes the development of the Volpe Motorcoach Fire (MCF) database and related findings. Because a single, comprehensive, nationwide motorcoach fire database was not available, data collection involved fire records from industry, government, and media sources. Section 2 provides a survey of those motorcoach fire data sources. Section 3 presents methods for the collection, reduction, and validation of the data, which include the cause and severity of fires, motorcoach details, and other relevant factors. Section 4 presents an analysis and discussion of the data, including ways to prevent motorcoach fires and reduce their severity. Section 5 concludes with recommendations for regulators and stakeholders to identify potential methods for improving motorcoach fire data collection and to provide ideas on more effective ways to prevent, reduce, and mitigate the severity and frequency of motorcoach fires.

Scope and Background

This study focused on fires that occurred spontaneously on full-size, for-hire motorcoaches due to onboard sources of ignition, in terms of the components described below.

Vehicles. The American Bus Association (ABA) defines a motorcoach as a bus that is designed for the long-distance transport of more than 30 passengers, that has integral construction with an elevated passenger deck located over a baggage compartment, and that is at least 35 feet long.

All motorcoaches on the road in the United States today comprise just eight major makes: Motorcoach Industries (MCI), Prevost Car (part of Volvo Bus Corp.), Setra (part of Daimler Buses North American), Van Hool, Blue Bird, Neoplan, Dina (part of MCI), and Eagle. Only the first five makes were offered for sale in the United States in model year (MY) 2007. These motorcoaches are equipped with engines produced by one of three key engine manufacturers: Caterpillar Inc., Cummins Inc., and Detroit Diesel Corp. As a result, manufacturing or design flaws in a single vehicle, engine, or other component can potentially affect a large portion of the existing motorcoach fleet.

Fires. For the purposes of this study, a motorcoach fire is one that occurs spontaneously due to typical onboard sources of ignition (heat or sparks) and flammable or combustible material. The fires are caused by mechanical failures and malfunctions. Fires caused by collisions with other vehicles and fixed objects were excluded from this study, as were those that resulted from passenger activity (e.g., smoking) or arson.

Carriers. This study focused on for-hire motorcoach carriers, which comprise charter, scheduled, contract and private commuter, tour, sightseeing operations, and airport shuttles. According to the ABA's 2006 Motorcoach Census,[1] these carriers operate most motorcoaches on the road today. (Some firms and individuals operate tour buses, promotional vehicles, motor homes, and other conversions that are not for hire.)

Industry. According to the U.S. Department of Commerce, the motorcoach transportation industry posted $4.7 billion in sales in 2003.[2] According to the *2006 Motorcoach Census,* passenger carriers operated 39,068 commercial motorcoaches in the United States and Canada in 2005. Commercial motorcoaches provided 631 million passenger trips, covering 2.44 billion miles in the United States and Canada in 2005.

The number of passenger trips in the United States and Canada decreased from 863 million in 1999 to 631 million in 2005. However, the 2005 numbers are still comparable with the number of passengers carried annually by all commercial airlines and commuter rail/Amtrak in the United States.[3]

Small- and medium-sized fleets dominate the motorcoach passenger-carrier industry. Three-quarters of motorcoaches operating in the United States and Canada in 2005 belonged to fleets of fewer than 100 motorcoaches.[4] Thus, it is important to note that the safety of a large number of motorcoach travelers depends on the operational and maintenance practices of a large number of small motorcoach carriers located throughout the country.

Causes, Frequency, and Severity of Motorcoach Fires

A fire occurs when flammable or combustible material mixes with the correct amount of air in the presence of an ignition source, either sparks or heat. The area of the bus where a fire takes place is called the origin location, and the specific component that supplies either the combustible material or the ignition source is called the ignition point.

The following discussion presents an overview of the causes, frequency, and severity of motorcoach fires, based on information obtained from previous bus fire studies. Those studies suggest that the frequency of motorcoach fires may be as high as six per day. However, no reliable estimate of motorcoach-only fire frequency is currently available because motorcoach fires were not routinely classified as accidents for statistical purposes. Literature and media reports suggest that the cost of fire damage to the motorcoach is sometimes high, ranging from tens of thousands of dollars up to the replacement value of the bus, yet passenger injuries and fatalities due to fire are rare.

Bus fire studies. The analysis described in this report was developed on the basis of the causes of motorcoach fires, as discussed in seven recently published bus fire studies, reports, and interviews:

- *Americoach Systems* (2007). Christopher W. Ferrone, president of Americoach Systems, Inc., published a paper that includes a mechanical analysis of motorcoach fires and a discussion of preventive measures.[5]
- *Daecher Consulting Group* (2006). Daecher published the results of a fire survey of motorcoach operators, based on data from 30 respondents that covered 10 years of operation. The report grouped the factors identified into two categories: origin location and ignition point.
- *National Fire Protection Association (NFPA)* (2006). NFPA published a study of causes of commercial and school-bus fires,[6] based on data collected from the National Fire Incident Reporting System (NFIRS) database described in Section 2 of this report. NFPA grouped causal factors into categories defined by NFIRS.
- *Greyhound Lines* (2006). Greyhound published a report at the request of the National Highway Traffic Safety Administration (NHTSA), detailing its experience and observations on motorcoach fires in the last few years. The report presented data collected from initial incident reports obtained from drivers, as well as the results of post-incident investigations. The factors identified were grouped into origin location and ignition point categories.
- *Commercial Vehicle Safety Alliance (CVSA Passenger Carrier Committee Report*-2006). A CVSA passenger-carrier subcommittee on motorcoach fire-causation issues produced a report on common fire origin locations and ignition points, based on field experience. In 2007, the CVSA Passenger Carrier Committee and Executive Committee approved this report as an addendum to CVSA Passenger Vehicle Inspector course materials[7].
- *Lancer Insurance* (2002). *Bus Ride Magazine* published an interview with Bob Crescenzo of Lancer Insurance that detailed common origin locations and ignition points of motorcoach fires.
- *Bus Fires in Finland during 2000* (2000). Finland's Accident Investigation Board published a study of 33 fires involving city, charter, and long-distance buses that occurred in a one-year period.[8]

Ignition sources. On the basis of past fire investigations, the studies reviewed indicate that two types of ignition sources are responsible for motorcoach fires: spark ignition and auto ignition. Spark ignition can occur when a spark encounters the proper mixture of combustible material and air. Auto ignition can occur when a combustible material is heated to its auto-ignition temperature.

Table 1 shows motorcoach ignition sources by location, ignition type, and the conditions under which the source may encounter air and combustible material. Ignition sources are generally shielded or contained. Heat or sparks are the result of component failure.

Table 1: Ignition Sources on Motorcoaches

Location	Ignition Source	Ignition Type	Conditions
Engine compartment	Air-conditioner compressor	Spark	Improperly shielded clutch coil or wires
	Air-conditioner compressor or blower	Heat	Failure
	Alternator	Heat	Diode failure
	Auxiliary generator	Heat	Operating normally; especially hot when dirty
	Auxiliary heater/exhaust	Heat	Operating normally; especially hot when dirty
	Diesel particulate filter	Heat	During regeneration
	Electrical accessories	Heat	Overtaxed electrical system
	Electronic modules, control panels	Heat	Short circuits, faults, improper installation
	Engine block, muffler, turbocharger	Heat	Operating normally; especially hot when dirty
	Exhaust system	Heat	Operating normally; especially hot when dirty
	Wires and cables, especially high-amperage cables (alternator, starter, jumper)	Spark	Short circuit or wire arcing due to insulation breach, improperly routed or supported wires, bad connections, wear
Fuel system	Diesel fuel heater	Spark	Improperly shielded
Bus interior	Electronic equipment[9]	Heat	Failures, faults, improper installation
	Electric heaters, defrosters, motors	Heat	Malfunctioning or improperly installed
	Wires and cables	Heat	Overtaxed electrical system, improper accessory installation
	Wires and cables	Spark	Short circuit or wire arcing due to insulation breach, improperly routed or supported wires, bad connections, wear
	Electric heaters, defrosters, motors	Spark	Malfunctioning or improperly shielded
Wheel wells	Brakes	Heat	Overused or malfunctioning (seized, frozen, incompletely released, dragging)
	Tires	Heat	When underinflated, especially in dual configuration
	Wheel bearings/hubs	Heat	Malfunctioning due to insufficient lubrication or wear

Combustible materials. A large variety of combustible or flammable materials, including rubber, plastic, and fluids, is found on motorcoaches. These materials are present in the engine compartment, fuel system, bus interior, and wheel wells. Federal Motor Vehicle Safety Standard (FMVSS) 49 CFR 571.302, “Flammability of interior materials,” specifies burn-resistance requirements for materials used in the occupant compartments of motor vehicles. This is the only FMVSS or Federal Motor Carrier Safety Regulation (FMCSR) that deals with the flammability of motorcoach components. Table 2 lists these materials by location, components involved, and conditions under which the materials encounter air and ignition sources.

Table 2: Combustible Material Sources on Motorcoaches

Location	Component	Material	Conditions
Engine compartment	Alternator	Cooling oil	Failing oil-cooled alternator
	Lines running from coolant reservoir to engine, auxiliary heater, generator	Coolant	Leaking hoses, housings, couplings, fittings, filters, sensors
	Lines running from fluid reservoir to power-steering pump	Power-steering fluid	Leaking hoses, housings, couplings, fittings, filters, sensors
	Lines running from fluid reservoir to transmission	Transmission fluid	Leaking hoses, housings, couplings, fittings, filters, sensors
	Lines running from oil reservoir to engine, turbocharger, generator, alternator (if oil-cooled)	Lubricating/ cooling oil	Leaking hoses, housings, couplings, fittings, filters, sensors
	Lines running to engine, auxiliary heater, generator	Diesel fuel	Leaking hoses, housings, couplings, fittings, filters, sensors
	Turbocharger	Lubricating oil	Failing turbocharger
Fuel system	Lines running from fuel tank to engine compartment	Diesel fuel	Leaking hoses, housings, couplings, fittings, filters, sensors
Bus interior	Floors, seats, etc.	Wood, carpeting, upholstery, padding	Combustible when exposed to high heat or flame
	Floors, window frames, etc.	Rubber	Combustible when exposed to high heat or flame
	Seats, dashboard, panels, etc.	Plastic	Combustible when exposed to high heat or flame
Wheel well	Brake pads and shoes	Laminate and other materials	Brake dragging, wheel bearing failure
	Tires	Rubber	Low tire pressure, overheating, flat
	Wheel bearings	Lubricating oil or grease	Loss of lubricant, bearing failure

No recent bus fire study includes frequency analysis for motorcoach fires alone. A 2006 NFPA study, prepared for a National Transportation Safety Board (NTSB) hearing, presents frequency calculations for fires on all types of buses, including motorcoaches, from 1980 to 2003. The analysis was based on data collected by the U.S. Fire Administration's NFIRS and on NFPA's annual fire department experience survey. A proportional share of vehicle fires in which the mobile property type was unknown or not reported is also included in the NFPA analysis.

Because NFIRS reporting is voluntary, it does not capture every eligible fire in the United States. The type of property (vehicle) involved is not specified in every NFIRS record; therefore, a simple count of bus fire records does not account for all potential bus fires that may be in the records. To address these issues, the NFPA authors developed projections based on NFPA fire surveys and other sources. First, the total count of bus fire records found in the NFIRS database for a given year was multiplied by a factor to project the total number of reported bus fires, including those for which property type was not specified. Then the result was multiplied by a second factor to project the total number of bus fires nationwide, including those that were not reported.

The NFPA study covered all bus types, including motorcoaches. NFPA projected an average frequency of 2,520 bus fires per year in the United States from 1993 to 2003. The annual totals varied over that period, peaking at 3,100 fires in 1980 and 1981. Reported bus fires rose 4 percent from 2002 to 2003, but the overall trend in recent years was flat. Some type of mechanical failure or malfunction contributed to 59 percent of these fires. Because motorcoaches are only a fraction of the buses on the road, the frequency of motorcoach fires during this time period is likely far lower than these values calculated for all buses.[10]

Typical consequences of a motorcoach fire are limited to property damage involving the vehicle, baggage, and personal effects. According to one insurance firm, fire is the second most expensive type of motorcoach claim.[11] A vehicle fire can be hotter than 1,500 degrees Fahrenheit (816 ºC). Once a fire starts, it can spread rapidly and consume a motorcoach within 15 to 20 minutes.[12] A stationary bus fire can spread quickly to other vehicles, especially if they are parked close together.

Buses are rarely operable after a fire. In almost half of the motorcoach fire incidents included in the responses to the Daecher Consulting Group survey, fire damage was so severe that the affected motorcoaches were a total loss.[13] The cost of replacing a motorcoach, especially a newer model, is several hundred thousand dollars.

While property damage losses can be large, deaths and injuries related to fire are rare. In fact, between 1995 and 2006, only one motorcoach fire resulted in direct fire-related fatalities: a 2005 fire that raised awareness about the possible consequences of a motorcoach fire for passengers, especially those who cannot evacuate quickly due to age, disability, or language barrier. On September 23 of that year, a motorcoach operated by Global Limo, Inc., caught fire on Interstate 45 near Wilmer, Texas. The motorcoach was transporting 44 assisted-living-facility residents and nursing staff to Dallas as part of the evacuation in advance of Hurricane Rita. When the fire broke out in the right-rear wheel well, the driver stopped the bus. Heavy smoke and flames entered the bus interior. As a result, 23 passengers died, two were seriously injured and 19 passengers and the driver received minor injuries.

Safety Compliance

The States, Federal agencies, manufacturers, and carriers work together to ensure passenger carrier safety. Federal agencies develop and enforce safety standards and regulations. States cooperate with the Federal government in conducting inspections, taking enforcement actions, and setting inspection procedures and out-of-service (OOS) criteria through the CVSA, a not-for-profit association of State, Provincial, and

Federal officials in the United States, Canada, and Mexico. Carriers and manufacturers often cooperate voluntarily in identifying solutions for safety-related problems and training carriers' staff. The following discussion clarifies how these roles affect motorcoach fire safety.

National Highway Traffic Safety Administration (NHTSA)

In contrast to FMCSA, which develops, maintains, and enforces Federal Motor Carrier Safety Regulations (FMCSRs) NHTSA issues and enforces Federal Motor Vehicle Safety Standards (FMVSS) that establish performance criteria for new motor vehicles and vehicle equipment. NHTSA is responsible for establishing and enforcing FMVSS 49 CFR 571.101 through 571.500, to which manufacturers of all motor vehicle and equipment items must conform and certify compliance at the time of original manufacture. Two of the FMVSS Standards, 49 CFR 571.217 and 571.302, apply to motorcoach fire safety.

- ***FMVSS 217, Bus Emergency Exits and Window Retention and Release.*** This standard establishes requirements for the retention of windows other than windshields in buses, as well as operating forces, opening dimensions, and markings for pushout bus windows and other emergency exits. Its purpose is to minimize the likelihood of occupants being thrown from the bus and to provide a means of readily accessible emergency egress.
- ***FMVSS 302, Flammability of Interior Materials.*** This standard specifies burn-resistance requirements for materials used in the occupant compartments of motor vehicles. Its purpose is to reduce deaths of and injuries to motor vehicle occupants caused by vehicle fires, especially those originating in the interior of the vehicle from sources such as matches or cigarettes.

Both of these standards fail to address all motorcoach fire safety needs. For instance, FMVSS 302 does not address fires that originate outside the passenger compartment, such as those analyzed in this study. No FMVSS addresses the flammability of exterior components, which may allow fires to propagate quickly into the passenger compartment.[14]

NHTSA's Office of Defects Investigation (ODI) conducts safety defect investigations and responds to safety-related consumer complaints. To address safety-related defects in the design of vehicles and components, ODI has the authority to force manufacturers of motor vehicles and motor vehicle equipment to issue recalls based on safety issues identified during defect investigations. In addition, Technical Service Bulletins may be initiated by the manufacturer to identify problems or issues with vehicles and are also available through NHTSA's publicly accessible website. A search of Technical Service Bulletins for motorcoach makes and models revealed only two potentially fire-related items, as identified by the involved equipment types and components addressed in this section: (1) product improvement on automatic heat alarm/heat sensors, and (2) front and tag axle hub grease application.

In the past 10 years, major motorcoach manufacturers have recalled thousands of coaches due to fire safety concerns. MCI recalled 8,384 coaches due to concerns related to turbocharger failures, electrical shorts, and auxiliary heater fires; Van Hool, 2,338 coaches because of concerns about turbocharger failures and battery equalizer/auxiliary heater fires; Prevost, 2,758 coaches due to concerns about turbocharger and battery equalizer failures; and Detroit Diesel, more than 12,000 engines, many of which were installed in motorcoaches, due to turbocharger failures.[15]

Federal Motor Carrier Safety Administration (FMCSA)

FMCSA assigns USDOT numbers to all interstate carriers and grants operating authority to all interstate, for-hire motor carriers. The agency determines the safety fitness of interstate motor carriers and prohibits unfit carriers from operating vehicles. It also enforces standards for interstate motorcoach safety equipment and inspections.

The safety fitness standard requires demonstration of adequate, effective management controls to ensure compliance with safety regulations, including vehicle safety equipment and vehicle inspection, repair, and maintenance. Motorcoach safety equipment is covered in 49 CFR 393, Parts and Accessories Necessary for Safe Operation, which details required components and their design and installation. Mandatory fire safety equipment includes either a fire extinguisher with an Underwriters Laboratories (UL) rating of 5 B:C or more, or two fire extinguishers, each of which has a UL rating of 4 B:C or more.

FMCSA has promulgated Federal regulations (49 CFR 396.13) requiring drivers to be satisfied, through a pre-trip inspection, that a prescribed list of parts and accessories are in safe and proper operating condition. The pre-trip inspection must also include verification that required emergency equipment as required in 49 CFR 393.95, such as fire extinguishers, spare fuses, and warning devices for stopped vehicles, is in place and ready to use. Furthermore, at the completion of each day’s work, drivers must sign a written driver vehicle inspection report (DVIR), covering a prescribed list of parts and accessories, on each vehicle operated.

FMCSA regulations (49 CFR 396) also require the inspection, repair, and maintenance of a prescribed list of items on all interstate motor vehicle carriers. Every carrier is responsible for maintaining, in safe operating condition, all vehicle parts specified in Part 393, as well as frame assemblies, suspension and steering systems, and axles, wheels, and rims, Motor carriers are also subject to periodic self-inspection and recordkeeping and to retention requirements that document proper preventive maintenance and repair. Inspection of most items is required at least every 12 months. Ninety-day inspections are required for certain motorcoach fire safety items, such as pushout windows, emergency doors, and emergency door-marking lights. Inspectors conducting motorcoach carrier compliance reviews (CRs) must certify that required driver vehicle inspection reports and any corrective maintenance resulting from those reports are kept for at least 3 months and that all copies of periodic inspection reports are kept for 14 months.

FMCSA and its State partners use the roadside inspection program to monitor the compliance of motor vehicle carriers and drivers with the safety regulations. To minimize disruptions to passenger travel, inspectors from FMCSA and its State partners usually conduct roadside inspections of motorcoaches at terminal or destination locations. As with all commercial motor vehicle carriers, any vehicle and driver violations, including moving violations, are recorded and citations are issued. Records of all roadside violations are transmitted to and maintained in the Motor Carrier Management Information System (MCMIS). Whenever a roadside inspection determines that the condition of the vehicle is likely to cause an accident or breakdown, the vehicle is declared OOS and cannot be operated without verification of suitable repair.[16]

FMCSA and its State partners further evaluate the safety fitness of passenger carriers through safety CRs. FMCSA uses a Federal scoring system called SafeStat (Motor Carrier Safety Status Measurement System), based on OOS and selected moving violations recorded in the MCMIS central database, to identify poorly performing passenger carriers. High-scoring carriers, as well as others meeting various criteria, such as involvement in frequent or serious crashes, are slated for CRs. These CRs are investigations of a company’s compliance with all safety regulations, primarily using a comprehensive audit and further inspections of vehicles, drivers, and required records. The safety investigator uses an algorithm based on designated acute and critical violations found during the CR in order to determine the carrier’s overall safety fitness rating. As a result of all findings, carriers may also be subject to enforcement action, and a rating of unfit may result in suspension of operations. The CR program is resource-intensive and typically reaches only a small percentage of motor carriers.

Some industry observers have questioned the reliability of the SafeStat scores and crash (incident) data, especially for small passenger carriers (those with fewer than 25 motorcoaches). Because a small fraction of vehicles are inspected, small carriers may not have a sufficient set of inspection data in MCMIS. As a result, SafeStat scores may vary widely among carriers with similar overall safety performance. In addition, since not every crash or fire is reported to MCMIS, small carriers may not have a statistically significant set of incident data on which to base further regulatory investigation and response.

Under the Comprehensive Safety Analysis (CSA) 2010 program, FMCSA is currently field-testing a new operational model for measuring, promoting, and enforcing safety compliance by its regulated carriers. CSA 2010 is designed to reach a more universal sampling of motor vehicle carriers with increased efficiency and effectiveness. All roadside violations and crash incidents will be factored into a carrier's safety scores, and a series of progressive interventions will be conducted on the basis of the carrier's scoring and history of corrective actions. Interventions based on offsite and onsite investigations may allow discovery of new violations, but pending proposed rulemaking, these violations will not determine the carrier's fitness to operate. Instead, expanded roadside measurement data indicating deficiencies in any of seven safety behavioral areas[17] will determine both the extent of further intervention and the ratings for safety fitness. Unlike the current SafeStat system, crash history will be integrated into the safety analysis as a statistical indicator for focused attention by Federal investigators and enforcement agents.

Implementation of CSA 2010 is expected to result in more accurate monitoring and more effective control of passenger-carrier safety compliance. However, that control will rely increasingly on the completeness and accuracy of data received from inspections and reportable incidents, including motorcoach fires. Data quality is, and will continue to be, a major issue for Federal intervention in order to improve the safety compliance and performance of passenger carriers.

National Transportation Safety Board (NTSB)

The National Transportation Safety Board (NTSB) is an independent Federal agency charged by Congress with investigating significant accidents in the various transportation modes. NTSB conducts the investigations, convenes boards of inquiry, makes determinations of probable causes, and issues safety recommendations to the regulatory agencies in an effort to prevent the occurrence of similar future accidents. NTSB conducted an investigation into the probable causes surrounding the 2005 Wilmer Texas Motorcoach fire in which 23 passengers died.[18]

States

Each State institutes requirements, either by adopting the Federal Motor Carrier Safety Regulations (FMCSR) or by establishing its own rules, for intrastate passenger carriers operating within it. Many States have mandatory annual motorcoach inspection programs that apply to both interstate and intrastate motor vehicle carriers. FMCSA has determined that the annual inspection programs in 24 States plus the District of Columbia satisfy the Federal annual inspection requirements.[19]

Since FY 2007, States that receive Motor Carrier Safety Assistance Program (MCSAP) grant funds must formalize their inspection programs in their Commercial Vehicle Safety Plans (CVSP), which describe the State's inspection and enforcement activities for the coming year. In FY 2006, more than 100,000 bus inspections were conducted, which was more than double the number of the previous fiscal year (FY). This increase was mainly attributable to an FMCSA-led strike force to inspect buses in States that had no formal motorcoach inspection program.

Most States participate in the Commercial Vehicle Safety Alliance (CVSA), which was established to promote uniformity, compatibility and reciprocity of commercial motor vehicle inspections and enforcement activities throughout North America, for example, by facilitating uniformity in inspection procedures. Notably, CVSA establishes North American Standard (NAS) OOS criteria that are used during inspections to remove unsafe commercial motor vehicles (CMVs) from operation until critical OOS items are repaired.

CVSA is increasingly involved in motorcoach fire safety issues. The CVSA Passenger Carrier Committee and Bus Fire Subcommittee hold regular semiannual meetings to review motorcoach-specific inspection criteria and procedures to help reduce the risk of bus fires. These meetings have resulted in recommendations for the development of standards for fire detection, monitoring, and suppression; endorsement of research studies; enhancement of motorcoach inspection training modules; and development of new and revised OOS criteria.

Enforcement

Both State and Federal enforcement officers take action against passenger carriers found to be out of compliance with applicable State and Federal regulations. Violations discovered at roadside, destination, or terminal facilities are subject to fines, warnings, and OOS orders prescribed by the regulatory agency or jurisdiction. Violations are reported to FMCSA via a distributed data-entry system called SAFETYNET; from there, they are processed into the SafeStat system.

Preventing and Mitigating Motorcoach Fires

Effective motorcoach fire prevention and mitigation each rely on key safety practices and design considerations. Industry groups and associations have a significant role to play in the development of uniform standards and best practices for motorcoach fire safety.

Fire Safety Practices

Many different practices contribute to fire safety, from preventing fires through proper vehicle maintenance to safely evacuating passengers during an emergency. Four types of practices, frequently cited for their effectiveness in preventing, reducing the severity, and mitigating the consequences of motorcoach fires, are: conducting pre-trip inspections, using fire-resistant materials, training staff, and installing automatic detection equipment. Examples of these practices are listed in Table 3.

Table 3: Common Motorcoach Fire Safety Practices

Type	Prevention	Severity Reduction and Consequence Mitigation
Pre-trip inspections	Identify and correct any vehicle safety issues, including fire safety	Verify that the fire extinguisher is fully charged
Fire-resistant materials	Prevent fires from spreading from point of ignition when installed near high-temperature surfaces in and around the engine compartment	Install materials in the engine firewall, wheel wells, and other shields between the passenger compartment and common fire origin locations
Training	Provide maintenance staff and company inspectors with skills to identify motorcoach conditions that can lead to fires	Train drivers to make safety announcements and evacuate the bus properly in an emergency
Automatic warning systems	Detect equipment failures and fires, e.g., turbocharger and tire failure sensors and warning lights	Install fire detection and suppression systems, including automatic fire sensing and suppressant delivery

Fire-resistant materials and automatic warning systems are described in more detail below.

Alternate Standards for Motorcoach Components and Equipment

Carefully designed interior and exterior components and fire safety equipment can help to prevent, reduce the severity, and mitigate the consequences of motorcoach fires. There were no DOT-required comprehensive fire safety standards for motorcoach construction and equipment beyond those covered in 49 CFR 571 (FMVSS) and 49 CFR 393 (Parts and Accessories Necessary for Safe Operation) found during this study. As described above, 49 CFR 571 does not address fires that originate outside the engine compartment or the flammability of exterior components. The small handheld fire extinguishers specified in 49 CFR 393 may be ineffective in battling tire fires.

Motorcoach buyers could specify fire-resistant materials on new vehicle orders, using standards written for other vehicles, such as aircraft, railcars, and transit buses, or those published by foreign governments and regulatory bodies. The examples listed below go beyond the scope of 49 CFR 571 FMVSS:

- Federal Aviation Administration (FAA), 49 CFR 25.853, *Airworthiness Standard for Flammability of Seat Cushions*
- Federal Railroad Administration (FRA) 49 CFR 238.103, *Fire Safety, Flammability, and Smoke Emission Tests*
- Federal Transit Administration (FTA), *Recommendations for Testing the Flammability and Smoke Emission Characteristics of Transit Bus and Van and Rail Transit Vehicle Materials* (see Appendix E)

- Economic Commission of Europe (ECE) Regulation 118, *Uniform Technical Prescriptions Concerning the Burning Behavior of Materials Used in the Interior Construction of Certain Categories of Motor Vehicles*
- ECE Regulation 36, *Uniform Provisions Concerning the Approval of Large Passenger Vehicles with Regard to Their General Construction*

Motorcoach Industry Association Standards

Motorcoach industry associations, notably the United Motorcoach Association (UMA) and the American Bus Association (ABA), each represent thousands of commercial motorcoach carriers and bus supplier organizations. Unlike the American Public Transportation Association (APTA), which represents the bus, rapid transit, and commuter rail systems industry, UMA and ABA do not currently publish procurement guidelines that ensure a minimum level of fire safety on new motorcoaches. APTA’s Standard Bus Procurement Guidelines specify the following fire safety features on all new transit buses, all of which are compatible with motorcoaches:

- ***Fire-retardant/low-smoke materials.*** Passenger-compartment and insulation materials conforming to FTA’s Recommended Fire Safety Practices (see Appendix E), as well as fire-resistant wheel-well materials and fireproof passenger-lighting modules
- ***Fire detection systems.*** At least two temperature sensors strategically located in the engine compartment and additional sensors in other potentially critical areas that activate a fire alarm bell and warning light in the driver’s compartment when extreme temperatures are detected
- ***Firewalls.*** A bulkhead separating the passenger and engine compartments, constructed of materials conforming to FTA’s Recommended Fire Safety Practices for Transit Bus and Van Materials Selection (see Appendix E)
- ***Facilitation of passenger evacuation***. Two door exits, an escape hatch, and other evacuation features

Motorcoach manufacturers already include some of these features on U.S. models, and it is possible for motorcoach buyers to specify others. For instance, some manufacturers include full-steel engine firewalls as standard equipment. In the absence of U.S. motorcoach association standards, each manufacturer makes its own design choices.

Automatic Warning and Suppression Systems

Two types of automatic warning systems, which could help to prevent or reduce the severity of motorcoach fires, are currently available: component failure warning systems and fire warning systems. Some of these warning systems also include automatic fire suppression.

Component Failure Warning Systems

Component failure warning systems detect the imminent failure of a system and alert the driver. To identify turbocharger failures, some carriers (e.g., Adirondack Trailways) have developed simple detectors on turbocharger waste gates to check the operation of the boost-limiting devices.[20] Some conditions leading to turbocharger failures, such as waste gate failures, cannot be detected during routine maintenance or pre-trip inspections.

Active tire pressure monitoring devices can detect failures of multiple wheel-well components. For instance, in 2005, MCI introduced the SmarTire pressure temperature monitoring system as an option on its motorcoaches. Wheel-well and wheel-end heat sensors have been developed and are being introduced into the market.

Fire Detection/Suppression Systems

Currently available fire warning systems include sensors that detect the heat of a fire in the engine compartment and activate a warning to the driver. These are included in the APTA Standard Bus Procurement Guidelines described above. More advanced systems may extend temperature sensors to the wheel-well area. When these sensors detect high temperature and radiant energy indicative of a thermal hotspot or fire, an audible or visible alarm is triggered to alert the driver. In the event that the driver does not take immediate action, the vehicle control system may reduce engine power and trigger automatic engine shutdown.

Other fire warning systems focus on specific flammable agents or other ignition points surrounding the engine block. These include optical flame and smoke indicators and fuel vapor sensors that can be installed in the engine and/or passenger compartment. Some newer systems include pneumatic tubing that can quickly detect the heat of a small fire originating in any of several bus locations, alert the driver, and automatically release suppressant.

There are two major types of fire suppression systems:

Active fire suppression systems. When a fire sensor is activated, an automatic fire suppression system causes fire suppressant to be delivered to the fire's location. Currently, automatic fire suppression is available only for engine-compartment fires; other areas pose severe feasibility problems. No nozzles are available that meet the durability requirements of motorcoach wheel wells, due to the potential damage of road debris.

Motorcoach-based suppression systems present technical, commercial, and environmental challenges. Considerable research into fire suppression technology, some applicable to motorcoaches, is ongoing. The 10-year-old Department of Defense Next Generation Fire Suppression Technology program[21] has made significant progress in evaluating flame suppressant agents and their delivery systems for aircraft, combat vehicles, and critical support facilities. Its principal goal is to develop technology alternatives to the chlorofluorocarbon Halon. Many of the research products could help industry to develop more effective active suppression systems for CMVs.

Passive fire suppression systems. Passive fire suppression measures include implementation of fire-resistant barriers, fuel tank fire protection, improved standards for flammability of interior materials, and improved wire insulation materials and techniques that may reduce the incidence of fires from electrical shorts.

2. Data Sources

One of this study's objectives was to create a new motorcoach fire database, the Volpe MCF database, suitable for analysis of motorcoach fire trends and risks and for prevention and mitigation measures. The MCF database contains information identifying each fire incident's characteristics and outcomes and, if available, the vehicle's and carrier's inspection histories and any contributing or mitigating factors. The data in the MCF database come from a number of government, industry, and media sources. The remainder of this section describes these data sets and provides a rationale for their selection.

Federal Sources

Fatality Analysis Reporting System (FARS). In order to improve traffic safety, NHTSA created FARS in 1975. FARS includes motor vehicle traffic crashes that result in the death of an occupant of a vehicle or a non-motorist within 30 days of the crash. FARS data are available from NHTSA.

FARS has some limitations. For instance, it does not provide a coded motorcoach value in its vehicle-type definitions. The closest vehicle-type value covers all buses with seats for more than 15 passengers, with motorcoaches representing only a fraction of that population.[22] Also, there is no coded value for a fire due to mechanical failure. However, codes do exist that describe the first harmful event, and that event can be coded as a fire or explosion.

U.S. Fire Administration (USFA)–National Fire Incident Reporting System (NFIRS). NFIRS was developed by the National Fire Data Center (NFDC), part of the U.S. Department of Homeland Security, as a means of assessing the nature and scope of the fire problem in the United States. It is maintained and managed jointly by USFA and a user group of State agencies and metropolitan fire departments. Although the responsibility for data collection is voluntary, NFIRS is the single most comprehensive source of data for incidents requiring a fire department response, capturing incidents from all but eight States and an estimated 44 percent of the national total.[23] [24]

NFDC extracted NFIRS records on incidents involving buses, including motorcoaches, transit buses, school buses, and trackless trolleys, and provided key fields of interest for the years 1999 to 2006.[25] These fields included the standard Vehicle Identification Number (VIN) for identification of motorcoach incidents.[26] [27] Every VIN contains a unique sequence of alphanumerical codes that identify the vehicle's manufacturer, model details (model year, body style, engine, etc.), and serial number.
NFIRS has some limitations. For instance, it does not provide a coded motorcoach value in its vehicle-type definitions. The closest mobile-property-type value covers all buses, school buses, and trackless trolleys, with motorcoaches representing only a fraction of that population.[28] Furthermore, NFIRS's "make" codes include only one motorcoach make (Eagle); the others are classified as "other make." As a result, motorcoach record identification relies on accurate VINs, which are not provided for every record.

NFIRS includes another field, Remarks, which contains narrative information not collected elsewhere and is used to capture textual comments. This field has been used to glean additional information for the purposes of this study, and it is also included for the large majority of the records.

FMCSA–Motor Carrier Management Information System (MCMIS). MCMIS is the central repository for State-reported crash data. It also contains census data on U.S.-registered motor vehicle carriers, government field inspection data of vehicles and drivers, and company safety profiles combining histories of crashes, inspections, audits, and CR and enforcement cases. The crash file contains electronically submitted records from State police department accident reports on drivers, carriers, and vehicles involved in reportable crashes. Reportable crashes include fire incidents, but reporting is subject to certain threshold criteria that exclude some incidents from MCMIS.

The MCMIS inspection file contains detailed data on actions by State and Federal field enforcement agents on U.S. commercial carriers. Each inspection may find vehicle- or driver-related violations of FMCSR, hazardous material (HM) regulations, and State regulations or statutes. Critical violations may result in the driver or vehicle being placed OOS.

MCMIS also maintains the dates and results of regulatory CRs, which are performed on carriers identified by a high score according to SafeStat. The results of the CR may be satisfactory, unsatisfactory, or conditional, depending on prescriptive actions by the carrier; an unsatisfactory rating may result in suspension of operations.

The MCMIS database has some inherent limitations; for instance, it does not provide a specific "motorcoach" value in its vehicle-type definitions. The closest coded vehicle configuration and cargo-body-type values cover all buses with seats for more than 15 passengers, with motorcoaches representing only a small fraction of that population.[29] Motorcoach fire identification relies on accurate VINs and carrier names, which are not provided for every record. Vehicle inspection histories are available only for the most recent four years.

Industry and Government Sources

FMCSA/NHTSA Bus Fire Database. From April 2005 to June 2006, FMCSA's Passenger Carrier Division worked with NHTSA to capture some bus fire investigation results. In this time period, these agencies had documented 11 fires, including six motorcoach fires. FMCSA's Eastern Regional Service Center coordinates data collection, and the New Jersey Division maintains the records.[30] The database contains fields for the origin location and the cause of the fire, as determined by official investigation. In addition, the Eastern Regional Service Center maintains a listing of bus crashes from 1997 to 2005 that have been reported to MCMIS, as well as a compendium of media reports; both of these resources were made available to the study team. That effort has been suspended pending completion of this study.

NHTSA's Office of Defects Investigation (ODI). ODI collects information and performs analyses relevant to vehicle and component defects that could lead to motorcoach fires and other safety concerns. ODI collects consumer complaints, industry information, and Early Warning Reporting (EWR) data. The office maintains several public databases, including Complaints, Defects Investigations, Safety Recalls, and Technical Service Bulletins. However, very little of ODI's publicly available information lists specific bus fire details.

ODI enhanced its data collection as a result of the Transportation Recall Enhancement, Accountability and Documentation (TREAD) Act, enacted in late 2000. TREAD directed NHTSA to set up a EWR system to collect, from vehicle and tire manufacturers, information related to defects, reports of injury or death related to their products, and other relevant data. However, because manufacturer-submitted data are currently kept confidential unless a recall campaign is initiated and are reported as summary data (e.g., property damage) without detailed information, EWR provides no specific incident records. Manufacturers that produce over 500 vehicles per year are required to submit EWR data to NHTSA; however, many motorcoach manufacturers do not fall into this category and are exempt from the requirement.

Despite these limitations, two motorcoach fire records were found in connection with an ODI investigation. One carrier's bus fire study[31] identified two motorcoach fires associated with NHTSA Recall Notices 06E0190000 and 06V14000, concerning turbocharger failures on Detroit Diesel Series 60 engines.[32]

State DOT. The New York State DOT Public Transportation Safety Board (PTSB) provided descriptions of four incidents involving fires resulting from electrical malfunctions of fluorescent light ballasts on interior luggage racks of MCI motorcoaches.

Motorcoach passenger carriers (operators). Three major motorcoach carrier groups furnished records of fire incidents that they had tracked in the last few years.[33] Carrier 1 furnished records of incidents occurring from November 2003 through December 2005; Carrier 2**,** from January 2004 through July 2008; and Carrier 3, from December 2005 through July 2008.

Insurance firms. Insurance companies that underwrite motorcoach carriers have a vested interest in fire safety. Two major motorcoach insurers[34] provided details on specific fire incidents: Insurer 1, from October 2000 through June 2008, and Insurer 2, from July 2003 through July 2008. In addition, Daecher Associates, a consultant for the TRAX group of captive insurers, provided summary data for a set of incidents that were not individually identified. Daecher also provided an analysis of fire origin locations, losses, and causes (summarized in Section 1 of this report).

Media

The Volpe Center's Technical Reference Center collected media reports from several sources for the period from 1997 through June 2008, capturing a variety of data on U.S. motorcoach fire incidents that relate the reported location, carrier, manufacturer, cause, and other factors.

State Crash Reports

NHTSA manages the State Data System (SDS), which contains coded crash records from selected States. In many States, crash reports are generated for motorcoach fires and other non-collision incidents. Some States make entire crash reports available to the public. There is no standard State crash report format, although most States strive to conform to the NHTSA Model Minimum Uniform Crash Criteria (MMUCC). (MMUCC criteria related to motorcoach fires are shown in Appendix D.)

The SDS has a number of limitations. Currently, it offers no simple interface and requires all queries to be written in SQL code. Database fields in the SDS vary in structure and definition from State to State, reflecting the lack of a uniform traffic crash report used in all States. Because a single-vehicle fire is not a crash, it is unclear how many motorcoach fires in these States are reported as crashes, and under what circumstances.

Furthermore, some State descriptors are more precise than others, due to more relevant vehicle and crash definitions. For instance, California includes a value for "non-collision" in its vehicle definitions but no "fire" value in its crash definitions. In other States, fire or fire/explosion must be specified as the crash's first harmful event. In this study, only Pennsylvania was found to provide vehicle and crash details precise enough to identify fires related to motorcoaches (described as cross-country/intercity buses). In the other States, motorcoach identification required a review of each individual crash record and/or report.

For these reasons, a different query was needed for each State. To reduce the time required to complete this step, Phase 1 involved selection of only eight States: California, Florida, Illinois, New Jersey, North Carolina, Ohio, Pennsylvania, and Wisconsin. These are the highest-ranking States in terms of the total number of fires reported to the Federal, industry, and media sources that also participate in SDS reporting. New Jersey SDS files were not populated at the time of this study, but authorities in that State provided selected traffic crash reports. To further reduce data querying time, only 2001 and later (up to 2006, the latest year available) data files were queried. Michigan was added in Phase 2.

Records supplied were for the following time periods:

North Carolina	2004 and 2005
Ohio	2004 and 2005
Illinois	2004 and 2005
Pennsylvania	2004 and 2005
Wisconsin	2005
Florida	2005
Michigan	2004, 2005, and 2006
California	2005 and 2006

Table 4 shows the specific descriptors used to query the SDS in each State. In this sample, only Pennsylvania has adequate descriptors for motorcoaches and fires. Other States' data define motorcoaches in a category that includes other types of buses and/or collision related fires.

Table 4: Vehicle and Crash Descriptors Used to Query NHTSA State Data System, 2001–2006

State	Date	VIN	Vehicle Descriptors	Crash Descriptors
California	Yes	No	Other bus, tour bus, other commercial bus	Non-collision
Florida (2001)	Yes	Yes	Bus	Fire
Florida (2002 and later)	Yes	Yes	Bus (driver + seats for over 15)	Fire
Illinois	Yes	Yes	Bus over 15 passengers, mass transit, other transit	Fire occurred, fire/explosion
Michigan	Yes	Yes	CDL truck/bus	Fire/explosion
North Carolina	Yes	Yes	Commercial bus, activity bus, other bus, bus (seats for 16 or more, including the driver)	Fire/explosion
Ohio	Yes	Yes	School bus, church bus, public bus, other bus	Fire/explosion
Pennsylvania	Yes	Yes	Bus, commercial passenger carrier, cross-country/intercity bus	Fire
Wisconsin	Yes	Yes	Passenger bus	Fire/explosion

*CDL = Commercial Driver's License

Vehicle Statistics

Vehicle Population

Each quarter, R.L. Polk and Co. compiles vehicle data from State vehicle registration records and manufacturer information. For this study, Polk provided two types of data. First, from its compilation of commercial vehicle registration data, it provided the number of vehicles on the road, in December 2006, by make and model name, year, and series, for MYs 1980 to 2007. Also, for all complete VIN numbers in the MCF database, it provided make; model name, year, and series; engine make, model, and size; and brake type.

During the first phase of data collection, Polk generated counts of full-size (Classes 7 and 8) buses (all types except school buses), by make, model, series, and model year (1980 through 2007), that were in use in December 2006. (Counts are archived for prior years and were not readily available.) Motorcoaches were then identified by model name and series. The result was an estimated U.S. motorcoach fleet of 38,672 vehicles, not including Blue Bird Corp. motorcoaches, which could not be identified by model name and series in the vehicle population data. Polk reported that the total population of all types of buses (including school buses) on the road in December 2006 was 657,930; thus, MY 1980 and later motorcoaches accounted for about 5.4 percent of buses on the road at that time.

For comparative purposes and future study updates, Polk also provided preliminary data from the Commercial Vehicles in Operation database (VIO) as of December 2007, during Phase 2. The 2007 numbers, however, have not been updated and are withheld from this study pending verification by Polk. The 2006 Polk census data by manufacturer are shown in Table 5.

Table 5: Motorcoach Population in December 2006, by Manufacturer

Manufacturer	No. of Vehicles
Motor Coach Industries (including TMC)	21,808
Prevost	8,621
Van Hool	4,657
Eagle	1,596
Fahrzeugwerk (Setra)	951
Dina	763
Neoplan	276
Total	**38,672**

The Polk motorcoach population data agree well with the 2006 Motorcoach Census[35], which reported that motorcoach carriers operated 39,068 motorcoaches in the United States in 2005. It should be noted that the Polk counts in Tables 5 and 6 include only the manufacturers for which models could be verified as motorcoaches. The Motorcoach Census, on the other hand, excludes certain owners, such as transit agencies and school-bus operators.

It should also be noted that verified counts for 2007 are not yet available. These will provide a measure of confidence for evaluating 2006 incident rates by manufacturer and model year. The motorcoach population in December 2006, by model year, is shown in Table 6.

Table 6: Motorcoach Population in December 2006, by Model Year (1981–2007)

Model Year	No. of Vehicles	Model Year	No. of Vehicles
2007	376	1994	1,244
2006	1,007	1993	1,139
2005	1,128	1992	692
2004	727	1991	644
2003	1,490	1990	891
2002	1,803	1989	1,286
2001	2,228	1988	1,038
2000	2,531	1987	1,023
1999	2,687	1986	684
1998	2,590	1985	1,012
1997	1,832	1984	998
1996	1,683	1983	1,037
1995	1,437	1982	1,245
		1981	878

Vehicle Miles Traveled

Vehicle population provides one normalizing factor for comparing fire incident rates. Vehicle miles traveled (VMT) is another factor that was considered important because of the expected roles of vehicle wear and tear and environmental exposure in fire risk.

Vehicle mileage data used in the analysis were obtained from the 2006 edition of the FHWA publication *Highway Statistics.*[36] While this census provides VMT by functional highway category and not by vehicle characteristics, the breakout provides a useful surrogate for comparing motorcoach travel by States and regions.

3.
Database Compilation

This section describes the data collection, reduction, and validation processes used to populate the MCF database and the methods used to structure the records for analysis of motorcoach fire trends and risk.

Data Collection Phases

The data for this study were compiled in two separate efforts. The preliminary study (Phase 1), which was conducted in 2006 and 2007, collected approximately 750 incident records from the years 1995 through 2006. After research, cross-referencing, and validation were performed, the data were reduced to 539 unique records. When Phase 1 collection was complete, it became clear that 2004 was the year for which the most comprehensive information was available. The 110 records for incidents in that year became the foundation for many of the original Phase 1 analyses.

The second phase, conducted in 2008, was undertaken to resolve gaps in the data from Phase 1, adding more recent records (from 2007 and 2008). Phase 2 collected new data for approximately 800 records dated from 2004 through 2008. Both efforts yielded a total of 899 unique records. Phase 2 generated 375 additional unique records covering 2005 and 2006 that were comparable with records from 2004 in terms of completeness. When the Phase 1 database and the Phase 2 unique records were merged into the combined master database, the data for these three years totaled 477 unique records. Similar to Phase 1, the primary analyses for the remainder of this final study were based on the three years (2004, 2005, and 2006) that were the most nearly complete of all the data sets.

Data Collection Process

The data collection methods used in this study were structured around a step-by-step process that resulted in a successful compilation of disparate motorcoach fire records, obtained from State and Federal crash and fire databases, State police accident reports, industry, and the news media, into the MCF database. Then, missing vehicle and carrier details were researched with use of data from State vehicle registration administrations, R.L. Polk and Co., and vehicle manufacturers. Finally, roadside and CR inspection records were added, where available, for all identified vehicles and carriers.

The successful compilation of records from a wide variety of sources relied on complete and accurate information in each source. If a record did not contain sufficient detail to clearly indicate that the vehicle involved was a motorcoach and that the fire was not the result of a collision, it was not included in the MCF database. It is therefore likely that a number of motorcoach fire records from the Federal crash and fire databases or the SDS were not included due to missing VIN, carrier, and/or fire details.

Today, Blue Bird Corp. is one of the lowest-volume manufacturers of motorcoaches sold in the United States, with fewer than 350 vehicles delivered between 1998 and 2006. It is not possible to identify a Blue

Bird motorcoach from its VIN, which contain the same character sequences in the vehicle description sections as do some school- and activity-bus VINs. Due to the large number of Blue Bird vehicles in the crash, fire, and State sources used for this study, it was not practical to ask the manufacturer to identify each motorcoach by serial number. For this reason, Blue Bird motorcoaches were excluded from the database.

Any two or more records describing the same fire were combined into a single MCF database record. The records were checked to ensure that they contained no personally identifiable information (PII).

Data Collection by Source

Federal Crash and Fire Databases

Federal crash databases, including FARS, NFIRS, and MCMIS, were searched for motorcoach fires. Query terms and outputs varied for each, as described below.

- ***FARS.*** The FARS database was queried for accidents involving cross-country and intercity buses, with the first harmful event described as a fire or explosion. The outputs included all 1994 and later data available, which covered accidents through 2006. This query returned one record.
- ***NFIRS.*** The NFIRS database was queried for fires involving buses (transit, school, and trackless trolley) due to onboard ignition sources (failure of equipment, heat source, or mechanical/electrical malfunctions). For ease of data interpretation, the query included only data conforming or converted to the definitions in NFIRS Version 5.0, which covers 1999–2006, the latest years available. Queries for these years produced over 4,000 records.
- The NFIRS database was one of three sources that included a Remarks field. When populated, this field often provided information on specific origin locations and ignition points that was not available from the coded NFIRS data. For example, one common NFIRS value for origin location was "engine area, running gear, wheel area," which did not distinguish between engine and wheel-well fires. Many of the coded values were ambiguous; instead of providing specific ignition points, NFIRS provided information on the cause of ignition, the heat source, and the item and material first ignited. Only 19 States included Remarks data in more than 50 percent of their NFIRS motorcoach fire records.
- ***MCMIS.*** The MCMIS crash file was queried for incidents involving passenger buses (buses with seats for more than 15 people, including the driver) with a gross vehicle weight rating (GVWR) greater than 26,000 pounds. The first event was described as a non-collision explosion or fire only. The outputs included all data available, which covered 1995 through mid-2008. This query returned 127 records.

After FARS and NFIRS queries were completed, the data were converted from numerical codes to text. The NFIRS and MCMIS outputs were filtered to include only identified motorcoaches.

Because no database used motorcoach as a vehicle-type descriptor, motorcoaches were identified from make and model information contained in available VINs or carrier names. In the latter case, the carrier's fleet was researched to determine the likelihood that the vehicle was a motorcoach. Records were included that pertained to carriers running mostly motorcoach fleets.

The NFIRS and MCMIS queries contained fire records with no VIN or carrier name and were initially not included in the MCF database. Moreover, records that contained VINs with incorrect characters or sequences of characters were included, but not all vehicle-related details could be discerned.

Industry and Government Data

Data were collected from published and unpublished government and industry sources, including the FMCSA/NHTSA Fire Data Analysis team, a State DOT, NHTSA ODI, three passenger carriers, and two insurance carriers. For sources having a mixture of vehicle types, motorcoaches were identified with use of VINs. Collectively, these sources provided 17 records from 2000 through 2006.

Data obtained from a consultant were not added to the MCF database because the records contained insufficient detail to identify any fire uniquely.

News Media Reports

A professional librarian searched nationwide online news sources for reports of motorcoach fires from 1996 through 2008. This search resulted in 123 records, many of which provided meaningful descriptive information which helped identify additional fires or confirm data from other sources.

State Crash Reports

After potential motorcoach fire records were found in the SDS, crash reports were requested from 10 States. The States chosen for this step were the eight listed in Table 4 plus New Jersey and New York. In each State, the FMCSA Division Office's State programs coordinator contacted the appropriate State government office to help collect crash reports corresponding to any fires identified from the Federal, State, and industry sources described above. This effort yielded more than 100 crash reports from eight States (California, Florida, Illinois, New Jersey, North Carolina, Ohio, Wisconsin, and Michigan) and a document describing four motorcoach fires in New York. Pennsylvania was unable to send reports due to legal restrictions. All crash reports found to pertain to motorcoach fires were entered into the MCF database.

Compliance/Inspection Histories

The final data collection step was to query the MCMIS database for two types of inspection data: those from roadside inspection records and those from CR records. The roadside inspection database was queried for all inspection records corresponding to all vehicles identified by VIN and all carriers identified by USDOT number in the MCF database. The CR database was queried for review and vehicle inspection records corresponding to all carriers identified by USDOT number in the MCF database. All available years were included in the queries, which covered FYs 2003 through 2007 for roadside inspections and 1990 through 2007 for CRs.

Addressing Missing Data

No source used in this study, except State traffic crash reports, provided the make, model name and year, engine make and model, or engine size of involved motorcoaches. To obtain this information, data from R.L. Polk and Co. were used. Polk queried its coach database by VIN, and the Polk Complete Vehicle Identification Number Analysis (CVINA) utility was used to identify details for vehicles that failed the initial search due to VIN errors. The CVINA utility has a VIN repair function that was used for this purpose. For vehicles that failed the Polk search and utility, manufacturers and distributors of motorcoaches were contacted to help identify make, model name, and model year. These details were then added to the MCF database.

Tire and turbocharger failure warning systems and engine-compartment fire detection and suppression systems became commercially available only for MY 2004 vehicles. The VIN contains no characters to indicate the presence of these systems or to specify which systems are on board. Given the small number of vehicles in the data sources that were MYs 2004 and later, it was practical to ask the manufacturers to identify the motorcoaches with these systems by serial number.

Carriers identified in the MCF database without USDOT numbers were researched, and the correct USDOT numbers were added to the MCF database. In Phase 1 only, some unidentified carriers were identified with use of vehicle registration data obtained from 10 States (Florida, Georgia, Illinois, Massachusetts, New Jersey, New York, North Carolina, Pennsylvania, Texas, and Wisconsin). For a given MCF record, the States were asked to identify registration name by VIN and/or license tag number. The passenger carrier that was designated as last registrant (before the fire date) of an involved vehicle was added to the database as each was identified.

Fatalities and injuries reported by data sources such as MCMIS and NFIRS were researched and verified. Some of these data referred to fatalities and injuries that did not occur as a direct result of the motorcoach fire but in a subsequent event. Fatalities and injuries suffered by passengers while they were on motorcoaches or were leaving them due to fire were identified in the MCF database under the Direct Injuries and Direct Fatalities fields.

The State in which the fire occurred was one of only two fields that were always filled in by almost all sources. Fire data obtained from industry sources (carriers and insurance providers) provided no State information. Federal crash and fire databases provided more records for some States than for others. Important categorical information was derived from the textual remarks, which are provided only by NFIRS, State crash reports, and media reports.

Two important data analysis fields for the purposes of this study were fire origin location and ignition point. The records for 27 States in the MCF database indicated the fire origin locations more than half the time, whereas only 12 States specified ignition points for the majority of their records. States indicating both included Florida and North Carolina, whose crash reports coded these details.

Because complete, accurate VINs allow several key analysis fields to be populated, including those for make, model name, model year, vehicle age, engine manufacturer, and detection/suppression system information, the ability to identify a vehicle's VIN ensures data quality. Full VINs were available in more than 50 percent of MCF database records for only 28 States. Some VINs for New York, North Carolina, and Wisconsin vehicles came from State data sources.

Derived Data

Fire Origin Locations and Ignition Points

For ease of data analysis, fire origin locations and ignition points use a common and consistent set of descriptors for all records. Table 7 shows the codes assigned to each record in the MCF database, using the details given by the original sources. The different levels of detail in the codes result directly from the level of detail provided in each source.

Table 7: Fire Location and Ignition Point Classification Scheme

Origin Location	Ignition Point	Code
Engine compartment	Unspecified ignition point	1A
	Turbochargers	1B
	Air conditioners	1C
	Alternator	1D
	Electrical wiring	1E
	Combustible liquid lines	1F
	Dirty engine block	1G
	Auxiliary heaters	1H
	Exhaust system	1J
	Other ignition point	1K
Wheel well	Unspecified ignition point	2A
	Brakes	2B
	Tires	2C
	Wheel/hub bearing failure	2D
	Other ignition point	2E
Bus interior	Unspecified ignition point	3A
	Electrical system (e.g., lights, power plugs, dashboard)	3B
	Auxiliaries and electronics (e.g., defroster, VCR, onboard generator)	3C
	Other ignition point	3D
Fuel system	Unspecified ignition point	4A
	Fuel lines outside engine compartment	4B
	Auxiliary fuel heaters and filters	4C
	Other ignition point	4D
Area unspecified	Unspecified ignition point	5A
	Combustible liquid or gas	5B
	Electrical	5C
	Auxiliaries	5D
	Other ignition point	5E
Other area	Unspecified ignition point	6A
	Electrical wiring outside engine or bus interiors	6B
	Other ignition point	6C

Availability of Warning/Suppression Systems

Warning and fire suppression systems of various types have been available for installation on motorcoaches for several years but have been offered as optional equipment on most makes and models only since 2004. The current study originally purported to include the presence of particular systems for each vehicle in the MCF database, but this proved impractical. When contacted for verification of acceptance of this option by carriers, several manufacturers provided only makes, models, and years for which the systems were offered but not a specific customer's acceptance of that option for any of its vehicles. Collecting this information from carriers and matching records by VIN was beyond the scope of this study. Instead, a field was inserted into the database to mark vehicles whose make and model were available with these systems at point of sale.

Baseline for Analysis

The primary objective of this study is to provide an informed basis for assessing the problem of motorcoach fires in the United States and for evaluating recommendations in terms of their preventive value and potential for a reduction in consequences. Given the extent of the incident records compiled and the breadth of related data on fires, carriers, and involved vehicles, the MCF database is assumed to contain data sets suitable for such analyses. These sets are determined by record selection criteria and by what are termed, in this study, the key analysis fields.

Key Analysis Fields

For trend and causal analyses to be valid, data must be representative, accurate, and complete within estimated levels of confidence. This requires determination of minimum sample sizes and quality for each data source and entity. Although such rigorous statistical analysis is beyond the scope of this study, it was deemed useful to select and examine a subset of fields from the database. These key analysis fields are considered sufficiently populated to provide reasonable estimates of the relationships between various motorcoach fire risk factors. The data in these fields come from a number of different sources.

Given that data quality for key analysis fields varied from source to source, the challenge was to simultaneously (1) resolve the discrepancies between two sources on what might have been the same fire, in order to avoid duplication, and (2) fill in as many missing analysis fields as possible. The choice was made to make each analysis independent of all others. Further verification of the accuracy of the data was outside the scope of this study.

The key analysis fields, at least some of which are common to all data sources, organize the information in the database. Each key analysis field is populated in more than half of the 899 records, yet less than one-third of the records have specified values in six or more fields. No single record contains data in every key field. Also, nearly every field is populated by six or more sources.

Table 8 lists each key analysis field included in the MCF database and indicates the frequency of notation in each field for the data sources. Only two fields (fire date and State where the fire occurred) were consistently filled out in the records of any of the sources. The date of the incident was provided by all sources. The State where the incident occurred was missing only in records from industry (carrier and insurance) sources.

Table 8: Source Fire Documentation, by Key Analysis Field*

Field	Media	Carriers	Insurance	States[†]	NFIRS	FARS	MCMIS	FMCSA/ NHTSA	NHTSA ODI
Fire date	A	A	A	A	A	A	A	A	A
State where fire occurred**	A	S	S	A	A	A	A	A	A
Fire origin location	S	S	S	S	S	N	N	S	S
Fire ignition point	S	S	S	S	S	N	N	S	S
Vehicle model year/age	S	S	S	S	S	N	S	S	S
VIN	N	S	S	S	S	N	S	S	S
Vehicle make/mfg.	S	S	S	S	S	N	S	S	S
Vehicle model name	S	S	S	S	S	N	S	S	S
Engine mfg.	S	S	S	S	S	N	S	S	S
No. of direct injuries	S	N	N	N	S	A	N	N	N
No. of direct fatalities	S	N	N	N	S	A	N	N	N
Value of damaged property	S	N	S	N	S	N	N	N	N
Warning/ suppression systems avail.	S	N	N	N	S	N	N	N	N

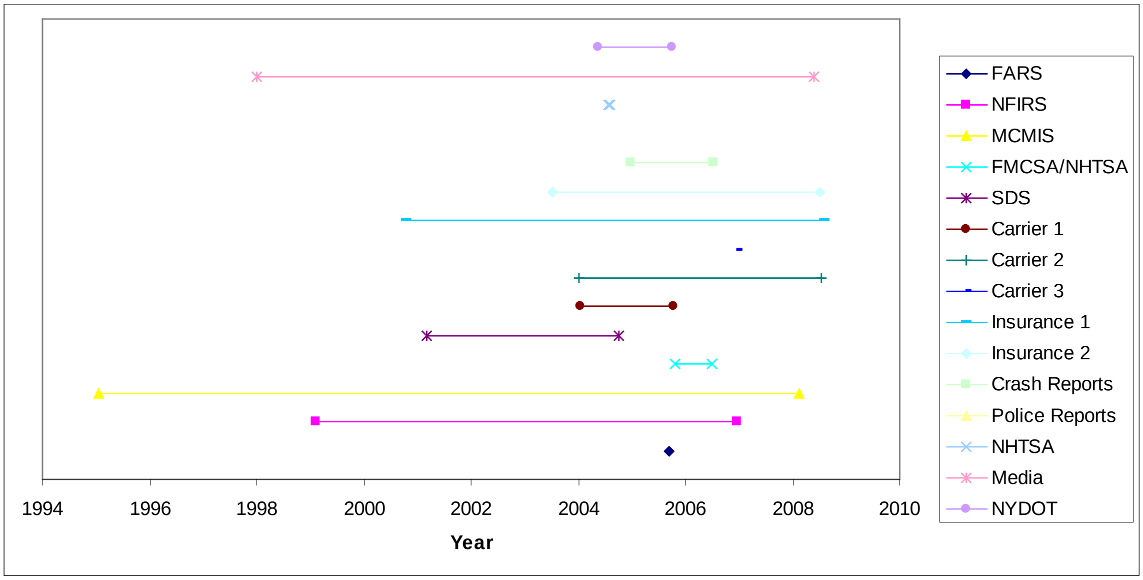
*A = always, S = sometimes, and N = never.
**Including the District of Columbia
†Including State DOTs.

Selection of Records for Analysis

Given the undetermined quality of the source data, it is difficult to frame a reliable sample for analysis of motorcoach fires. The only years that are covered at least partially by every data source are 2004, 2005, and 2006, as shown in Figure 1.

The coverage timeline obscures the variability of incident record completeness and accuracy over the different collection years. A more detailed account is needed to determine the number of significant records collected from each source. Table 9 shows the number of records in the MCF database, obtained from the major source groups, by year of incident[37].

Figure 1: Timeline of Data Collection, by Source



The counts in Table 9 are aggregated for 1995 through 2003, primarily because the compiled records for these early collection years are, on average, less than 20 percent of each of the years from 2004 to 2008. This is in part due to the lack of data from carrier and insurance sources. In addition, the applicability and accuracy of the records for this period have not had the benefit of corroborating information from either NFIRS remarks or references linked to the SDS. Such links could have provided, for example, a basis for the inclusion of records that were removed due to inaccurate coding in the originally collected data.

Records from the most recent years, 2007 and 2008, are also aggregated, but both years could be discounted because of incomplete collection or lags in reporting by each source. In addition, as is the case with the 1995–2003 data, valuable reference data from the NFIRS remarks field and the SDS have not been made available during the study period.

Table 9: Motorcoach Fire Records, by Source*

Source	1995–2003 (229 Fires)			2004 (109 Fires)		2005 (186 Fires)		2006 (182 Fires)		2007–2008 (193 Fires)			Total (899 Fires)	
	No.	Avg./ Year	%	No.	%	No.	%	No.	%	No.	Avg./ Year	%	No.	%
FARS	0	0.0	0.0	0	0.0	1	0.5	0	0.0	0	0.0	0.0	1	0.1
NFIRS	144	16.0	62.9	50	45.9	109	58.6	89	48.9	0	0.0	0.0	392	43.6
MCMIS	66	7.3	28.8	8	7.3	17	9.1	14	7.7	22	11.0	18.6	127	14.1
FMCSA/ NHTSA	0	0.0	0.0	2	1.8	1	0.5	4	2.2	0	0.0	0.0	7	0.8
States[†]	11	1.2	4.8	7	6.4	15	8.1	6	3.3	0	0.0	0.0	39	4.3
Media	8	0.9	3.5	14	12.8	27	14.5	43	23.6	31	15.5	26.3	123	13.7
Carriers	0	0.0	0.0	17	15.6	33	17.7	22	12.1	100	50.0	84.7	172	19.1

Source	1995–2003 (229 Fires)			2004 (109 Fires)		2005 (186 Fires)		2006 (182 Fires)		2007–2008 (193 Fires)			Total (899 Fires)	
	No.	Avg./ Year	%	No.	%	No.	%	No.	%	No.	Avg./ Year	%	No.	%
Insurance	20	2.2	8.7	18	16.5	24	12.9	38	20.9	55	27.5	46.6	155	17.2

*Some fires are documented in more than one source.
†Including State DOTs.

The absence of both sets of remarks impacts the completeness of information within each record, which is critical for analysis. However, the effect on missing detail is not as straightforward as the effect on gross records counts. Table 10 counts records with missing, unknown, or unspecified values in key analysis fields.[38] The three fields with numerical values—damages, injuries, and fatalities—are not considered here because of a separate and confounding issue of whether a blank value indicates "zero" or "not found." Values for "availability of warning/suppression systems" are not listed because preliminary counts indicate that only 8 involved vehicles have known values for a make and model that was offered with manufacturer-installed systems.

Table 10: Motorcoach Fire Records with Missing, Unknown, or Unspecified Values in Key Analysis Fields*

Field	1995–2003 (229 Records)			2004 (109 Records)		2005 (186 Records)		2006 (182 Records)		2007–2008 (193 Records)			Total (899 Records)	
	#	Avg/ Year	%	#	%	#	%	#	%	#	Avg./ Year	%	#	%
Date	0	0.0	0.0	0	0.0	0	0.0	0	0.0	0	0	0.0	0	0.0
State†	16	1.8	7.0	38	34.9	35	18.8	41	22.5	141	70.5	73.1	271	30.1
Origin location	156	17.3	68.1	35	32.1	54	29.0	56	30.8	49	24.5	25.4	350	38.9
Ignition point	151	16.8	65.9	45	41.3	76	40.9	84	46.2	71	35.5	36.8	427	47.5
Model year	33	3.7	14.4	14	12.8	40	21.5	56	30.8	24	12	12.4	167	18.6
VIN	69	7.7	30.1	52	47.7	82	44.1	99	54.4	74	37	38.3	376	41.8
Make	44	4.9	19.2	13	11.9	39	21.0	61	33.5	23	11.5	11.9	180	20.0
Model	61	6.8	26.6	41	37.6	63	33.9	83	45.6	45	22.5	23.3	293	32.6
Engine mfg.	85	9.4	37.1	54	49.5	103	55.4	112	61.5	76	38	39.4	430	47.8
Warning/ suppression	NA			TBD		TBD		TBD		TBD			TBD	

*NA = not applicable, and TBD = to be determined.
†Including State DOTs.

One impact is indicated by the counts of records with unknown fire-involvement locations. In the years without any reference data from Remarks and the SDS, the percentage of missing origin location information is significantly greater than that between 2004 and 2006. Although differences in ignition point information are less noticeable, the accuracy of the values attributed to fires with missing location data is suspect.

The records with unknown vehicle and engine identifiers are not similarly affected, even having a slightly smaller percentage in the outlying years. One could argue, however, about the accuracy of attributed values for the earlier period of coded fields, such as model name and, to a lesser extent, VIN. (Newer VINs had a higher percentage of validation by R.L. Polk.)

On balance, the observed counts in both tables suggests that, within the 1995–2008 timeline, the years 2004–2006 offer the most reliable and complete data set for analysis of the magnitude, trends, and causal factors of motorcoach fires in the United States. The records collected for a broader timeframe, including or excluding the 2007–2008 period, may be applicable to specific analyses or provide a comparative context for viewing the results of the primary years.

The next section presents the objectives and results of these analyses of the MCF database, as well as the rationale for and limitations of the use of selected data sets for each analysis. It also discusses findings, including the evaluation of trends and factors contributing to the frequency and severity of motorcoach fires and the potential effectiveness of countermeasures.

4. Analysis and Discussion

This study uses data from multiple sources, received between 1995 and 2008, to estimate the scope of the motorcoach fire risk problem in the United States as well as the potential of means to mitigate these risks. The fires of interest are those that occur spontaneously due to mechanical failures and malfunctions. The study looks at national trends in motorcoach fires and their known risk factors.

Section 3 discussed the data collected and variations in their completeness and reliability. A retrospective study is seemingly straightforward, involving collecting and tabulating data comprising yet-to-be-verified information from various reporters working at available source organizations at a particular point in time. Analysis becomes challenging when data are difficult to collect, missing, open to interpretation, or unverifiable. Of note, this study had no control data against which all incident data might have been compared. Lastly, the human factor comes into play if reporting agents and authorities, upon whom the study relies, have various methodologies, perceptions, and motivations—for example, if a reporter deems a fire not reportable or causes a lag in the reporting time.

Specific data flaws and limitations have been discussed in Section 3. One significant example has to do with interpretation of a blank or negative field. Possible reasons for a negative field are non-entry by the reporter/source because the item was missing from the report or overlooked by the reporter, or a deliberate entry of zero.

Although the two phases of this study collected and evaluated data from the years 1995 through 2008, it was decided that 2004, 2005, and 2006 were the years having the most complete data for most analyses. Several conclusions are based on these core years, but the exact timeframe examined for each point depended on the relevant analysis.

Recognizing the limitations of the database, the study makes use of cross-sectional subsets of the data to provide insights into the frequency and severity of motorcoach fires, as well as causal and contributing factors. The analysis of the data also sheds light on the effectiveness of measures offered to prevent motorcoach fires, reduce their severity, and decrease their consequences.

The conclusions drawn in this section are not to be interpreted as definitive or even verifiable within set boundaries of statistical certainty. Instead, they represent inferences suggested by exploratory analysis. Discussions within each topic area include an explanation of the assumptions associated with the data used in deriving the results. Also included are suggestions for strengthening the analysis with future improvements in data quality.

Overall Observations and Trends

Frequency

Although it has been estimated that motorcoach fires occur nationwide with at least daily frequency, study data indicate a lower rate. As shown in Tables 9 and 10, for the most complete data years of 2004–2006 an average of 159 fires per year were identified as reportable, spontaneously generated incidents on motorcoaches. Only 229 fires were reported over the 1995–2003 period, an average of just over 25 per year. This lower rate reflects the lack of coverage of source data in the earlier portion of the study period.

On the basis of current reporting, this study has found no evidence that motorcoach fire incidence is significantly increasing or decreasing. As of December 2008, the average annual total of fire incident records for 2007–2008 was less than 100; it differed from that of the 2004–2006 core years primarily because of time lags in incident reporting or verification by later published data by reference sources. This conclusion is consistent with the observed 53 percent increase in the count of 2005–2006 incident records, from the study's Phase 1 to the current, Phase 2 compilation, with no change in the total for 2004. On the basis of this trend, another data collection phase ending in 2010 would be expected to yield an additional 190 records for the years 2007–2008, resulting in a relatively constant annual count of about 160 records for 2004–2008.

There are reasons to suspect that actual fire occurrence may be far greater than the number of records collected per year would suggest. Reporting criteria for motorcoach fires are less clear and less enforceable compared with the criteria for other types of roadway incident reporting. A fire that is extinguished before it causes injury or that does not meet some arbitrary threshold of monetary damages is less likely to be documented to employers, insurance companies, or government authorities. It is understandable that fire incidents that meet the towaway criteria but otherwise go unnoticed by the public would not be reported. Fires that occur on private property, in parking areas, or when a vehicle is OOS are less likely to be reported to any public source.

Even if incident reporting could be made more enforceable, the compilation process outlined in the previous section weeds out an undetermined number of applicable fire incidents, such as those that do not have field values or reference data that accurately identify the involved vehicle as a motorcoach. The MCF database contains a sample of verifiable incident records but is not a precise sampling of all reportable incidents. Accordingly, we can surmise only that complete and accurate reporting by all sources would yield an average occurrence rate of at least 160 fires per year.

Severity

As explained in Section 3, reporting of known numerical values for injuries, fatalities, and damage or material loss as a direct result of the fire incident is lacking for most of the incident records. Injuries and fatalities are available from all sources except the insurance companies, but there is no validation check to distinguish blanks that represent unknown values from values of zero.

Altogether, sources provided 28 fire records (3.6 percent) with injury and fatality fields with values other than blank or zero. One of these was the Global Limo fire (15 injuries, 23 fatalities). Twenty-six fire records documented between one and three injuries (a total of 36 injuries) and no fatalities, and one fire record cited a fatal accident (one fatality) with no other injuries. Extrapolating the injuries and fatalities reported in this sample for all 899 fire records in the database, we would expect to find 32 fire records, each with between one and three injuries and fatalities, for a projected total of 42 injuries/fatalities. The occurrence of a single catastrophic fire with large numbers of injuries and fatalities—for example, the Global Limo incident—is considered anomalous for the purposes of statistical projection.

The average consequences of reported fire incidents appear small, particularly in comparison with the rare disastrous incident that produces large numbers of casualties. These worst-case scenarios, like airline crashes and bridge collapses, represent a component of risk that needs to be considered in further analysis of contributing factors underlying the incidence of motorcoach fires. Attendant injuries and fatalities that result only from passenger egress or the response of emergency personnel could be discounted because they may be considered random events or might be reduced by measures other than fire risk mitigation. An analysis of direct injuries and fatalities is presented in the subsection on risk factors below.

Property loss or damage estimates—fields in the database having non-zero values—are provided for 210 fires by three sources: NFIRS, one insurance company, and one carrier. For all of these sources, the positive-value damages range from $100 to $400,000, with a mean value of $64,647 and a median of $31,548. The ranges and averages vary significantly between sources. NFIRS provides damage values for 151 of the 210 records and shows losses over the entire range, with a mean value of $51,076 and a median of $6,500. Comparable statistics for all of the sources are shown in Table 11. Total losses from those reported fires amount to about $8.2 million.

Table 11: Property Loss/Damage Reported, by Data Source

		Damage Value ($)			
Data Source	**Records**	**Minimum**	**Maximum**	**Mean**	**Median**
NFIRS	151	100	400,000	51,076	6,500
Carrier	16	500	247,000	45,719	9,867
Insurance company	43	3,449	312,881	113,093	95,740

Geographic Distribution

The States in which the fires occurred are listed in 626 (70 percent) of the MCF database records. Counts of these incidents by State and region, over the 2004-2006 time interval are shown in Table 12. The first column in each regional table lists the States in that region (including the District of Columbia.) A second subtotal column was added to exclude records derived exclusively from querying State data sources, such as the SDS and police and crash reports for the nine specific States queried. The inclusion of those incidents without similar queries to other States having been made would skew the counts for those States. The applicable VMT totals reported by FHWA for all highway vehicles during these years are shown in the last column. To reflect proportional motorcoach travel, these totals include VMT on urban and rural interstate highways, freeways, expressways, and other major arterials. (Motorcoach-only VMT by State is not available.)

The 2004–2006 subtotals for each region and the National total provide insight into the rates of reported fire incidence, given FHWA statistics on major highway traffic in each State. There were totals of 351 incidents and 7,902,299 million VMT in the United States during these years—an average of 4.44 per 100 billion VMT. The proportions of motorcoach fire incident records to total applicable VMT (100 billion) for each region are as follows: Eastern = 6.74, Midwestern = 3.53, Southern = 4.31, and Western = 3.43.

Table 12: Motorcoach Fire Records and All Vehicle Highway/Major Arterial Travel from 2004 to 2006, by Region and State

Region/State*	Fires	Excluding State Sources	Highway VMT (All Vehicles (in millions)	Region/State	Fires	Excluding State Sources	Highway VMT (All Vehicles) (in millions)
Eastern				**Southern**			
Total	**113**	**112**	**1,660,672**	**Total**	**116**	**114**	**2,644,773**
New York	29	29	324,881	Texas	27	27	670,536
Pennsylvania	8	7	276,698	Florida	36	34	470,696
Virginia	14	14	221,927	Georgia	6	6	254,624
New Jersey	18	18	219,355	North Carolina	15	15	217,418
Maryland	7	7	174,319	Tennessee	7	7	187,435
Massachusetts	17	17	164,525	Alabama	5	5	133,580
Connecticut	10	10	90,365	Kentucky	3	3	126,832
West Virginia	3	3	50,780	South Carolina	5	5	121,552
New Hampshire	0	0	32,631	Louisiana	6	6	112,323
Maine	2	2	29,419	Oklahoma	1	1	109,147
Rhode Island	0	0	28,004	Mississippi	2	2	88,353
Delaware	1	1	24,412	Arkansas	2	2	82,392
Vermont	0	0	14,396	New Mexico	1	1	69,884
Dist. of Columbia	4	4	8,961				

Region/State	Fires	Excluding State Sources	Highway VMT (All Vehicles) (In millions	Region/State	Fires	Excluding State Sources	Highway VMT (All Vehicles) (In millions)
Midwestern				**Western**			
Total	**66**	**59**	**1,671,745**	**Total**	**67**	**66**	**1,925,109**
Illinois	19	19	281,579	California	21	20	1,063,514
Ohio	15	11	280,401	Arizona	5	5	171,733
Michigan	10	8	266,726	Washington	6	6	161,504
Missouri	7	7	186,626	Colorado	5	5	145,135
Indiana	3	3	162,008	Oregon	3	3	96,989
Wisconsin	4	3	153,108	Utah	5	5	66,595
Minnesota	3	3	133,041	Nevada	7	7	51,542
Iowa	1	1	79,965	Idaho	3	3	35,814
Kansas	4	4	79,453	Montana	0	0	29,617
Nebraska	0	0	48,837	Wyoming	1	1	25,489
				Hawaii	6	6	23,955
				South Dakota	1	1	23,139
				North Dakota	2	2	19,072

*Includes the District of Columbia

The 15 States with the highest ratios of fire incident records relative to highway VMT for 2004 through 2006 are shown in Table 13; six States are in the East; two, in the South; one, in the Midwest; and six, in the West. Care must be taken in drawing conclusions regarding statewide or regional motorcoach fire risk from these numbers. A higher frequency of records for one State or region may indicate more thorough reporting standards or a confluence of data sources. An omission in reporting one or two incidents over a three-year period in a State with few reported incidents could also easily change its ranking. For this reason, in further analyses of geographic influence, it might be prudent to focus on States already reporting a significant number of incidents. The rates of incidents also may be skewed by wide variability of motorcoach travel in proportion to the applicable highway vehicle travel. Eastern States with greater population and route densities, for example, may incur more motorcoach VMT per highway vehicle VMT than less populous States. Nevertheless, it is informative to list both the States with the highest incidences of motorcoach fire incidents and those with the highest ratios of fire incident records per highway VMT.[39]

Table 13: Motorcoach Fire Records by State: Top 15, by Ratio of 2004–2006 Fires to All Vehicle Highway/Major Arterial Travel

	1995–2008	2004–2006		
State*	**Total Fire Records**	**Fires Excluding State Sources**	**Highway VMT (All Vehicles)) (In millions)**	**Records per Billion Highway VMT (All Vehicles)**
District of Columbia	5	4	8,961	0.45
Hawaii	6	6	23,955	0.25
Alaska	3	2	11,010	0.18
Nevada	10	7	51,542	0.14
Connecticut	17	10	90,365	0.11
North Dakota	2	2	19,072	0.10
Massachusetts	19	17	164,525	0.10
New York	62	29	324,881	0.09
Idaho	5	3	35,814	0.08
New Jersey	33	18	219,355	0.08
Utah	8	5	66,595	0.08
Florida	42	34	470,696	0.07
North Carolina	22	15	217,418	0.07
Maine	2	2	29,419	0.07
Illinois	20	19	281,579	0.07

* Includes District of Columbia

Fire Origin

The origin of a motorcoach fire is characterized by two key analysis fields: area of location, and specific ignition point. Accordingly, the data for each characteristic value is indicative of motorcoach fire risk, as analyzed below:

Location on Motorcoach

Frequency. The origin locations of the fires on the involved vehicles are listed in 716 (80 percent) of the MCF database records, including 650 (72 percent) with specific origin locations. Because 125 of the 183 records with location unknown are for fires occurring before 2004 or after 2006, only the 2004–2006 reporting period is considered here.

Figure 2 shows that the two most common origin locations were the engine compartment (36 percent) and the wheel well (34 percent), where multiple sources of combustible material and ignition are present. Locations designated as “other” include the battery compartment, the transmission, baggage compartment, and illuminated signage.

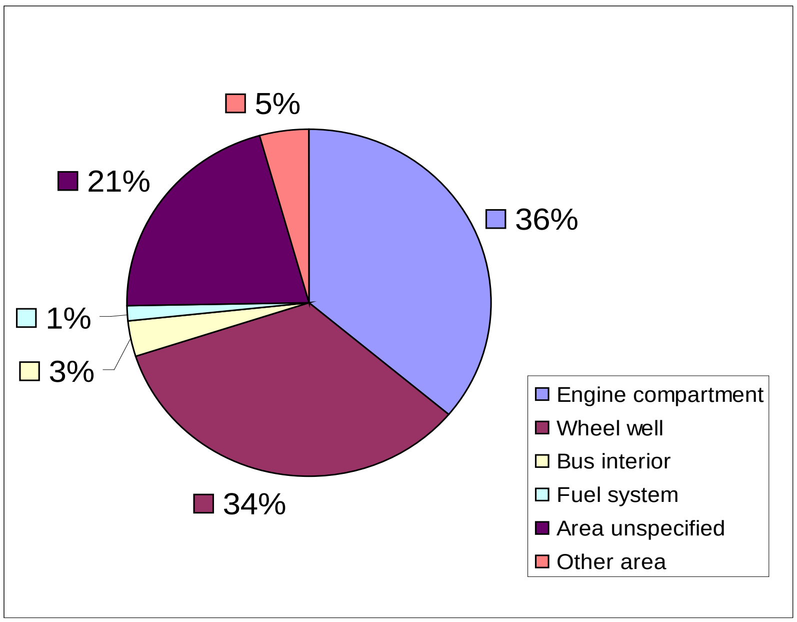


Figure 2: Percentage of Motorcoach Fire Records by Fire Origin Location, 2004–2006

***Injuries and fatalities*.** Deaths and injuries suffered by passengers while on board or while leaving a burning motorcoach are called direct fatalities or injuries. The direct-injury counts are listed in 316 (35 percent) of the MCF database records. Only 12 fire records cited injuries with a value greater than zero, and only the 2005 Global Limo fire in Wilmer, Texas, resulted in fatalities directly attributed to the fire. These numbers clearly show that the vast majority of bus fires do not result in direct injuries or fatalities.

Table 14 shows the numbers of direct injuries and fatalities by fire origin location over the entire period of the study. Engine and wheel-well fires accounted for 10 of the 12 direct-injury fires. Direct injuries were recorded for only one fuel-system fire and no bus-interior fires. A single fatality recorded for one fire of unspecified origin, which also had no attributable injuries, could not be verified as a direct fatality.

According to the data, only 12 of 316 fires resulted in direct injuries (31and only one, the Global Limo fire, in direct fatalities (23). Simply stated, an occupant of a motorcoach involved in a fire has a 96 percent chance of not being injured or dying as a result of the fire or the evacuation of the motorcoach.

Of the 31 direct injuries, 12 were due to smoke inhalation and five occurred during bus evacuation. In those five instances, the rush to get out of the door and the long drop from the bus window to the ground, were cited as the main reasons for injury. In the Global Limo fire, 15 passengers were injured and 23 were killed because they were unable to exit the bus, partially due to their lack of mobility.

Table 14: Motorcoach Fire Fatalities and Injuries from 1995 to 2008, by Fire Origin Location

Origin Location	Total Fires	Fires with Reported Casualties*	Fires with Casualties >0	Fires with Direct Fatalities >0	Total Direct Fatalities	Fires with Direct Injuries >0	Total Direct Injuries
Engine compartment	238	92	14	0	0	6	7
Wheel well (*including* Global Limo)	242	91	5	1	23	4	22
Wheel well (*excluding* Global Limo)	241	90	4	0	0	3	7
Bus interior	23	8	1	0	0	0	0
Fuel system	10	4	1	0	0	1	1
Unspecified	350	109	5	0	0	1	1
Other area	36	12	1	0	0	0	0
Total (including Global Limo)	899	316	27	1	23	12	31
Total (excluding Global Limo)	898	315	26	0	0	11	16

*Number of civilian injuries or fatalities, including zero.

Vehicle damage. Vehicle damage due to fire is often expensive. Costs associated with motorcoach fire damage vary greatly with the source reporting the damage. Sources use different methods to calculate damage; where one source might count expenses such as warranty repairs and lost baggage, another might exclude them. Figure 3 depicts the costs of motorcoach fire damage in relation to the location of the fire. Vehicle damage estimates are listed in 210 (23.3 percent) of the MCF database records. These include only non-zero, non-blank entries; 75 records with zero-value damage estimates are ignored here. In Figure 3, average damage estimates are shown separately by reporting source, due to potentially significant differences in the way that damage is estimated in each. Variation is considerable among the average values reported by each source.

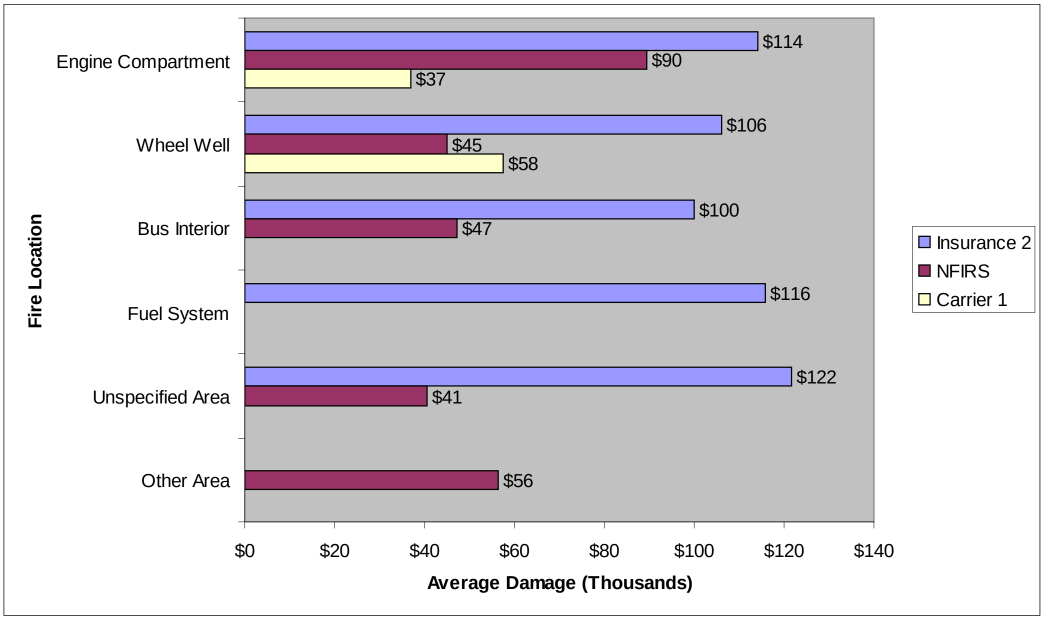


Figure 3: Average Estimated Damage per Vehicle from 1995 to 2006, by Fire Location

The data suggest no clear relationship between vehicle damage and fire origin location. The three data sources (NFIRS, one carrier, and one insurance company) report average damages of between $37,000 and $122,000. The insurance data indicates somewhat greater losses from unspecified and fuel system origins than engine compartment and wheel-well fires, but are not reported by each of the data sources. Bus interior fires show lesser relative damages, but there are significantly fewer of these reported. In fact, only six fires originating in the interior compartment or fuel system were identified in the MCF database. Average damage estimates from engine compartment and wheel-well fires, each accounting for approximately 35 percent of all motorcoach fires, are well reported by all three data sources, and range between $37,000 and 114,000, depending on the source.

Specific Ignition Point

The specific ignition points for fires are listed in 472 (52.5 percent) of the MCF database records. Figure 4 shows the number of records with and without specific ignition points associated with each fire origin location.

Figure 5 ranks the most common ignition points, beginning with the categories of brakes, tires, turbochargers, electrical systems, and wheel/hub bearings. Ignition points designated as “other” include a loose engine-oil-fill cap, a failed battery, a failed power-steering pump, a loose firewall-insulating pad, and an improperly routed air-vent hose. Figure 5 also shows the number of motorcoach fires associated with specific ignition points.

Figure 5 shows that, of 472 fires, 95 (20.1 percent) had designated ignition points that were brakes; 74 (15.6 percent), tires; 64 (13.6 percent), turbochargers; 48 (10.2 percent), wheel bearings; and 31 (6.6 percent), electrical sources in the engine. Other wheel-related, fluid, and electrical system ignition points contributed a total of 24 percent. Exhaust systems were specifically designated in only 2 percent of the fires.

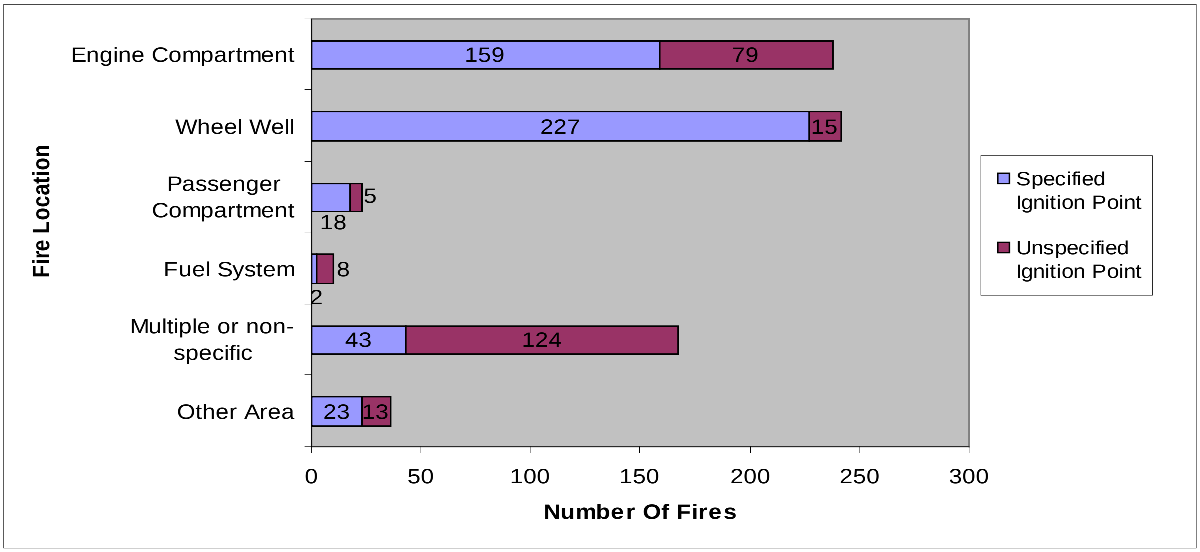


Figure 4: Motorcoach Fire Records with and without Specified Ignition Points, 1995–2008

Involved-Vehicle Characteristics

Model Year and Vehicle Age

The model years for vehicles involved in fires from 1995 to 2008 are listed in 731 (81 percent) of the MCF database records. About half of these records (367) were from the core period 2004–2006, for which annual counts are the most complete; hence, this period is considered a reliable sample for analyzing occurrences of involved motorcoaches by model year. Figure 6 shows 2004–2006 fire record counts by model year.

Each calendar year period in Figure 6 depicts a similar pattern, showing few fires for brand-new vehicles, increasing significantly for MY 2003 vehicles, reaching a maximum in the 1997-2000 time period, then tapering off to a steady value at the 1982 through 1992 model years. In each case, more than 50 percent of the fire incident records involve motorcoaches of model years between 1998 and 2002. This pattern corresponds with the increased complexity of engines built to provide greater power and fuel efficiency for larger and heavier buses that were introduced in those model years. Some of the engine design changes may also be attributed to constraints that were mandated by the Environmental Protection Agency (EPA). Beginning with the 1998 model, all heavy-duty diesel engines, including motorcoach engines, were required to comply with stricter emissions standards. These required levels were met initially by changes in engine design and performance parameters and were followed by exhaust-gas recirculation and turbocharger modifications to meet reduced nitrous-oxide-emissions and particulate-matter requirements, starting in 1994 and continuing through 2006. Some of these changes led to increased engine-compartment temperatures, and changes in bus design have necessitated increased engine horsepower requirements.

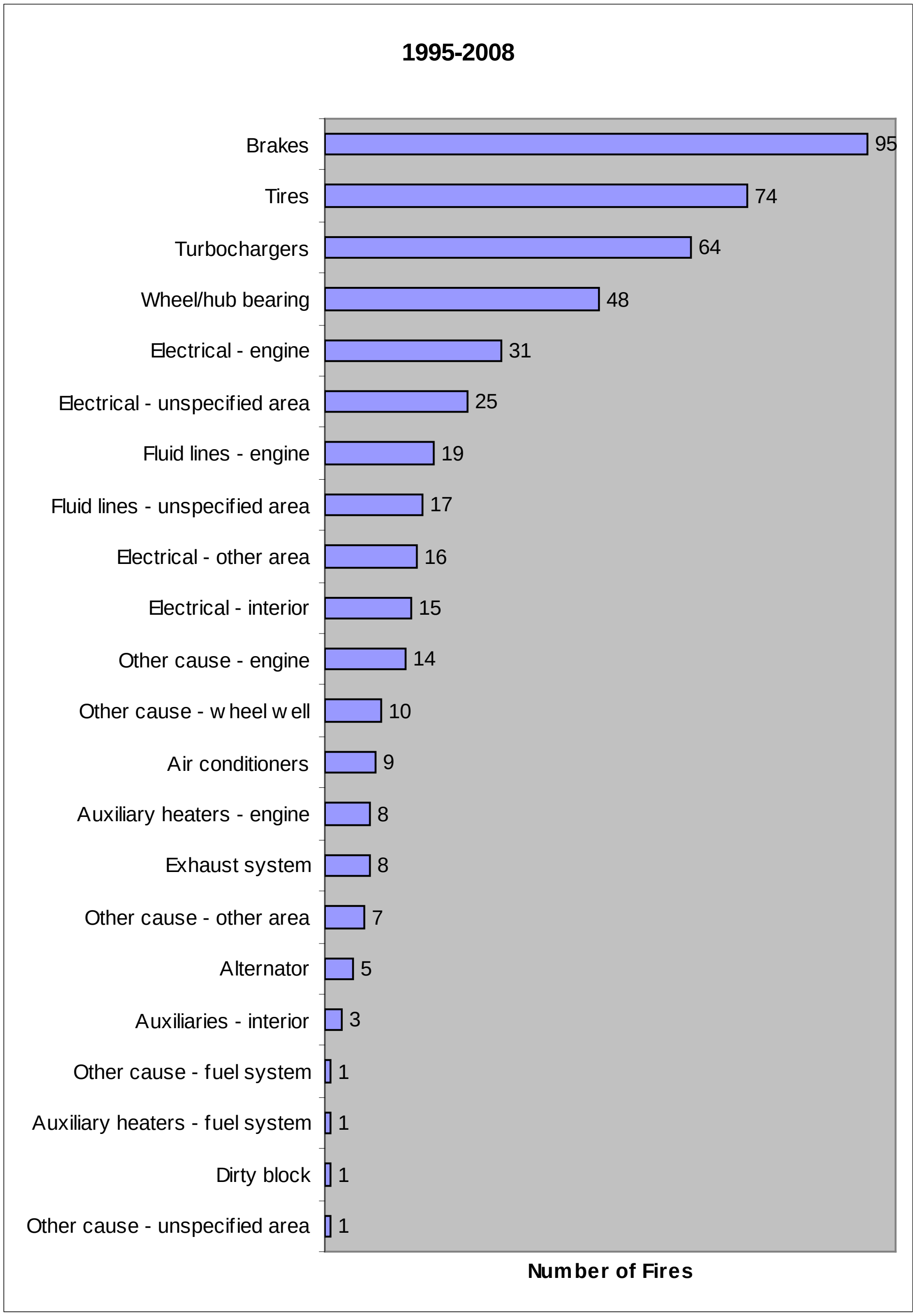
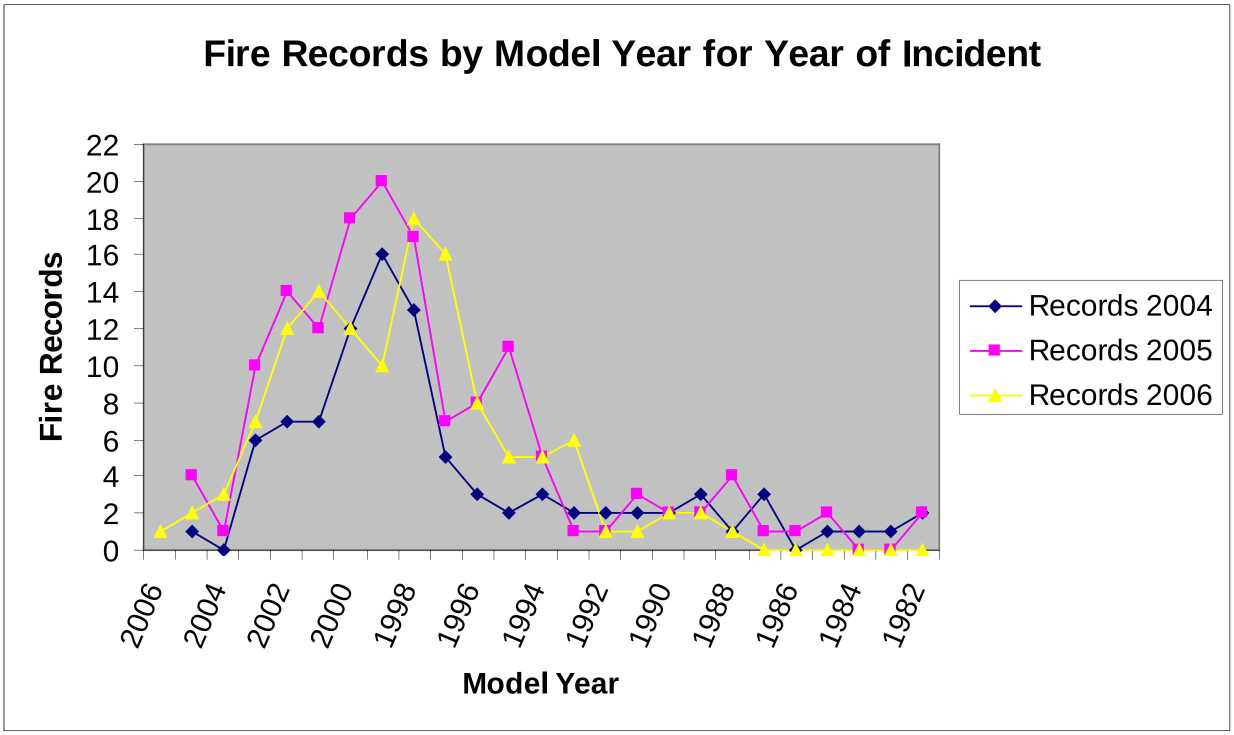


Figure 5: Motorcoach Fire Records by Specific Ignition Point, 1995–2008



Note: Of the three series of motorcoach fires, only the 2004 series involved a motorcoach of a model year (2005) introduced during the preceding calendar year.

Figure 6: Motorcoach Fire Records for 2004–2006, by Model Year

This pattern may also be attributed to the increased complexity of engines built to provide greater power and fuel efficiency for larger and heavier buses that were introduced in those model years. That the increase in the frequency of engine-originating fires appears to account for the increase in all reported fires supports the notion that these recent engine changes may be a significant contributing factor to motorcoach fires.

The possibility that the pattern is attributable to more complex engines built for heavier buses with greater fuel consumption and emission efficiency is supported by comparing the distribution of fire records by age of vehicle with vehicle-in-operation statistics from R.L. Polk. Figure 7 plots the number of fires recorded in the core 2004–2006 period, overlaid with a scaled motorcoach population total based on the 2006 motorcoach population. Vehicle age was calculated with use of the model year and fire date.

Since vehicle census data were not available for 2004 and 2005, it was assumed that the age distribution for those years was the same as that for 2006—that is, that the number of 2005 (one-year old) motorcoaches on the road in 2006 was equal to that of one-year old (2004) models in 2005.

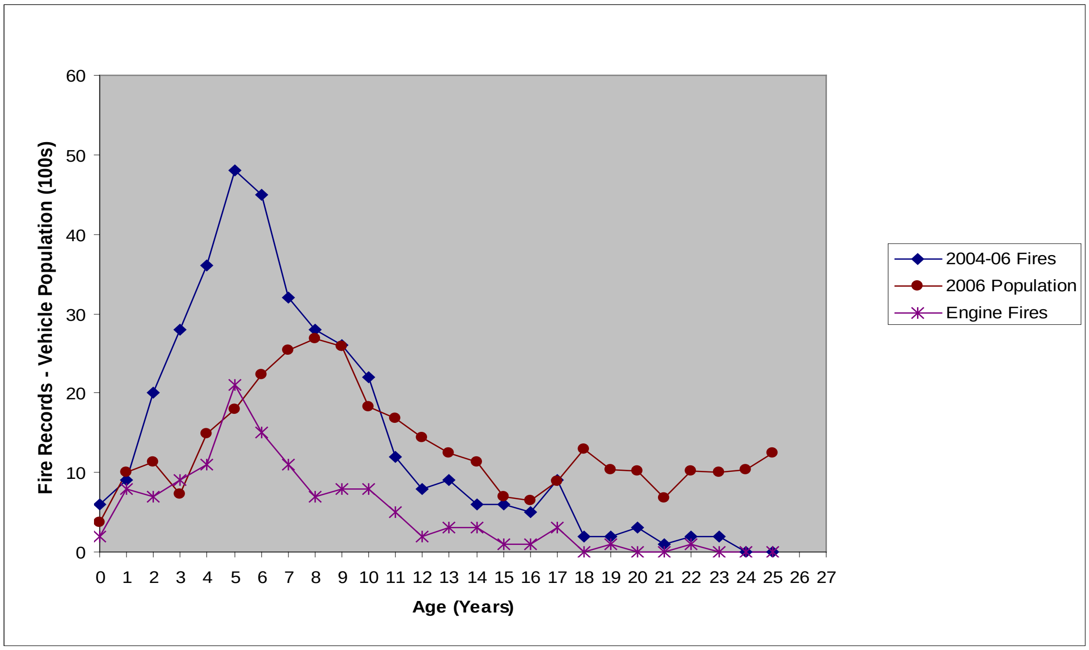


Figure 7: 2004–2006 Motorcoach Fire Records and 2006 Population, by Vehicle Age

Figure 7 shows the extent to which reported fires correspond with the number of vehicles on the road. While the motorcoach population peaks at age eight, the number of fire records is at its highest at about age five. The number of fires reported on buses in the age-range of three to seven years, relative to the total population, is disproportionately larger than for any other five-year age-range. After the age of seven years, the trend for reported occurrences closely matches that of the scaled population, with values running slightly below the population for each vintage year. In summary, motorcoaches in the age-range corresponding to MYs 1998–2002 not only had a higher reported frequency of occurrences but also a substantially higher reported incident rate, relative to their population, than did older motorcoaches.

The same patterns are evidenced by occurrences of engine fires. Of the 198 vehicles of known model year in the MCF database that had engine fires, 136 (69 percent) were 1998 models or later, a higher proportion than for any other location of origin. That the increase in the frequency of engine-originating fires appears to account for the increase in all reported fires supports the notion that these recent engine changes may be a significant contributing factor to motorcoach fires.

Make and Model

The vehicle manufacturers are listed in 719 (80 percent) of the MCF database records. Table 15 shows the total number of 1995–2008 and 2004–2006 motorcoach fire records, by major manufacturer.

Table 15: Motorcoach Fire Records by Major Manufacturer

Vehicle Manufacturer	Motorcoach Fire Records	
	1995–2008	2004–2006
MCI	490	227
Van Hool	109	71
Prevost	83	44
Dina	17	12
Eagle	4	2
Fahrzeugwerk (Setra)	8	6
Neoplan	5	1

The MCF database includes 606 (67 percent of the 899) records of 1995–2008 fires that specify each involved vehicle model name. Table 16 shows the total number of 1995–2008 and 2004–2006 motorcoach fire records for selected models.

Table 16: Motorcoach Fire Records by Selected Model

Model	Motorcoach Fire Records	
	1995–2008	2004–2006
MCI 102DL3	186	74
MCI 102EL3	46	23
MCI 102GL3	59	35
Van Hool T800	6	6
MCI 102D3	46	22
Van Hool T2100	15	5
Prevost H3-45	31	17
MCI 96A3	15	1
Van Hool C2045	3	3
MCI 102C3	14	5
Prevost Lemirage XL	16	6
MCI MC-12	25	7
MCI 102A3	10	6
Dina Viaggio 1000	13	10
MCI J4500	12	8
Van Hool T900	2	2

Model	Motorcoach Fire Records	
	1995–2008	2004–2006
MCI MC-9	13	9
Neoplan Cityliner	2	0
Prevost H3-41	3	2
Prevost Lemirage	2	1
Prevost XL2	4	2
Prevost H3-40	1	0
Setra S215HDH	3	3

Fire incidence rate for a vehicle make or model can be calculated with use of the number of fires and the number of vehicles in service at the time of the fires, but those numbers are not available. However, the 2006 vehicle population statistics in Table 5 (see Section 3) show that MCI represented the largest number of coaches on the road in late 2006, followed by Prevost, Van Hool, Eagle, Setra, Dina, and Neoplan. The order in Table 16 approximately follows the order in Table 5, suggesting that a manufacturer's exposure to fire incidence correlates with the number of vehicles of that make in operation. Sample sizes of incidence for individual models are too small to make a similar observation.

Engine Manufacturer

There are three major manufacturers of motorcoach engines: Detroit Diesel, Cummins, and Caterpillar. The vehicle manufacturers are listed in 469 (52 percent) of the 899 incidents in the entire 1995–2008 time span in the MCF database records and in 208 (44 percent) of the 477 incidents recorded for the core period of 2004–2006. Table 17 shows the number of involved motorcoaches, with each engine make and model listed in the database for each time period.

Table 17: Motorcoach Fire Records, by Engine Make and Model

Engine Make/Model	Fire Records	
	1995–2008	2004–2006
Detroit Diesel		
6V92	32	15
8V71	4	1
8V92	8	4
Series 50	18	2
Series 60	343	151
Unknown	6	5
TOTAL	**411**	**178**
Cummins		
6C	1	1

Engine Make/Model	Fire Records	
	1995–2008	**2004–2006**
L10	21	9
M11	27	17
Unknown	1	0
TOTAL	**50**	**27**
Caterpillar		
3176	3	1
C12	4	2
C13ACERT	1	0
TOTAL	**8**	**3**
TOTAL KNOWN	**469**	**208**

Although engine model is unspecified for only seven of the 469 records in which the manufacturer is known, the sample sizes for all but the most popular engine series are too small to make informed inferences about their propensity for fire risk. It is noted, however, that the Detroit Diesel Series 60 engine was the subject of Recall No. 06E-019 for turbocharger compressor wheel failure. Over a longer period and with more complete reporting, it would be useful to compare the frequencies of fire origin location by engine type.

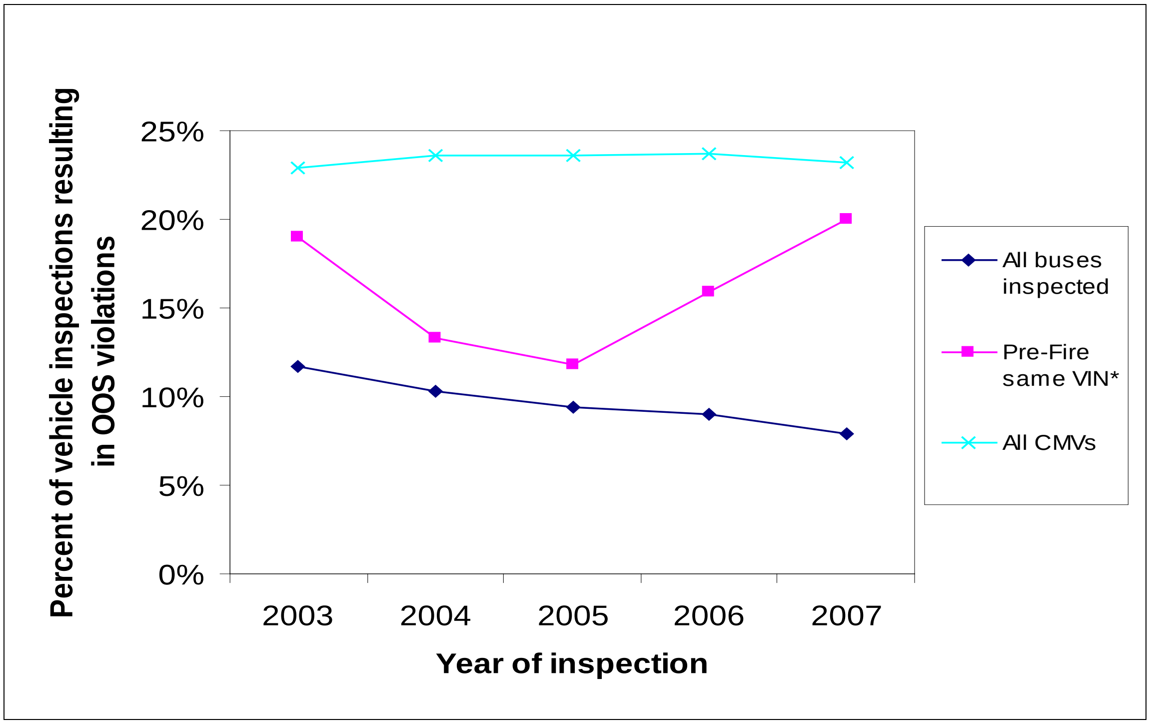
As is the case with vehicle make and model, the fire incidence rate for a given engine make or model can be calculated with use of the number of fires and the number of vehicles in service at the time of the fires. Such population counts for years through 2006 are not available. (2007 population counts by engine characteristics are being compiled and verified for use in future iterations of this study.)

Compliance Data Indicators

Roadside Inspection Data Analysis

This study examined whether there was a correlation between motorcoach fires and the general condition of the vehicle, as determined by roadside inspections. A reported fire occurred in 127 motorcoaches identified as having had a roadside inspection during FY 2003–2007. An important measure of the safety condition of a vehicle is its OOS rate. Vehicle OOS rate is defined as the percentage of vehicle inspections in which serious violations that resulted in the issuance of a vehicle OOS order were identified.[40]

Figure 8 illustrates the values and trends of vehicle OOS rates for involved buses, all buses, and all CMVs from 2003 to 2007. Figure 8 shows increasing OOS rates for motorcoaches involved in a fire subsequent to an inspection as contrasted with OOS rates for all buses inspected. This trend may be indicative of the relationship between the general state of repair and maintenance of motorcoaches, as identified by critical vehicle inspection criteria, and their later fire involvement. However, it does not necessarily imply that vehicle OOS rate is a reliable indicator of motorcoach fire risk. Additional analysis is required to show that the risk of fire involvement for motorcoaches with higher OOS rates is greater than that for those with lower OOS rates.



*Vehicle OOS rates for motorcoaches involved in a fire after inspection.

Figure 8: Motorcoach Roadside Inspection OOS Rates in FY 2003–2007 as a Percentage of Inspections Resulting in OOS Violations

Estimates of the risk of an imminent motorcoach fire for a motor carrier with an OOS order can be derived from the following statistics[41]:

- Number of total motorcoach inspections (taken from the MCMIS inspection file)
- Number of reported motorcoach fires (total counts from the MCF database)
- Overall rate of motorcoach fires per inspection (derived from the two preceding statistics, and itself a measure of risk)
- Number of inspections identified as recently preceding a reported motorcoach fire (determined from queries on individual inspections for involved motorcoaches in the MCF database)
- Percentage, among fire-involved motorcoaches, of prior inspections that resulted in a vehicle OOS order (pre-fire OOS rate, determined from queries on individual inspections for involved motorcoaches in the MCF database)
- Percentage of all motorcoach inspections resulting in an OOS order (passenger-carrier OOS rate, extracted from MCMIS summaries and shown in Figure 8)
- Probability of fire involvement for a motorcoach that had a recent inspection that did not result in an OOS order
- Probability of fire involvement for a motorcoach that had a recent inspection that did result in an OOS order

The statistics described above can be used to estimate the relative risk of fire involvement for a motorcoach that had an inspection resulting in an OOS order as opposed to one that did not result in an OOS order. The assumption made, for this analysis, is that the OOS rate for involved motorcoaches not found in the inspection records is the same as that for those found in the inspection records. These statistics from 2004 to 2007 are shown in Table 18.

Table 18: Estimates of Motorcoach Fire Risk Indicated by a Vehicle OOS Order from 2004 to 2007

Percentage/Risk Estimate	2004	2005	2006	2007	Average
No. of motorcoach inspections	9,889	10,957	11,541	12,391	11,194
No. of motorcoach inspections without OOS violations	8,870	9,905	10,548	11,412	10,184
No. of reported motorcoach fires	109	186	182	182	165
Overall rate of motorcoach fires per inspection	1.1%	1.7%	1.6%	1.5%	1.5%
No. of inspections identified as preceding a reported motorcoach fire	47	17	83	27	44.5
No. of inspections identified as preceding a reported motorcoach fire, without OOS violations	41	15	70	21	36.8
Percentage of inspections with OOS violations preceding a reported motorcoach fire	12.8%	11.8%	15.7%	22.2%	15.5%
Percentage of all motorcoach inspections with OOS violations	10.3%	9.6%	8.6%	7.9%	8.7%
Probability of fire involvement given recent inspection without OOS violations	0.0046	0.0014	0.0061	0.0017	0.0033
Probability of fire involvement given recent inspection with OOS violations	0.0059	0.0017	0.0120	0.0056	0.0061
Relative risk of fire involvement for motorcoaches with vs. without OOS inspections (odds ratio)	1.27	1.25	1.97	3.33	1.85

The last row in Table 18 shows the relative risk for fire involvement associated with an inspection with OOS violations versus one without such violations, known as the odds ratio. That the odds ratio for each of these years is substantially greater than 1.0 is consistent with the observation that the fire risk of a motorcoach after an OOS order is consistently greater than (and, on average, nearly double) that of a motorcoach with an inspection that did not result in an OOS order. The magnitude of probabilities may be small, but the odds ratio is substantial and appears to be growing, as the OOS rates of fire-involved motorcoaches diverge from those of the general motorcoach population.

The probabilities used to calculate the relative risk range from 0.1 to 1.4 percent and average less than 0.5 percent. The average overall rate of fire involvement is less than 1.5 percent, or one fire for every 67 vehicle inspections. Each of these numbers represents a small but significant level of risk. To show how these probabilities compare with similar measures of risks, the estimated rates of all bus crashes as a proportion of bus inspections are illustrated in Table 19.

Table 19: Estimates of Motorcoach Crash Risk, 2004–2007[42]

Percentage/Risk Estimate	2004	2005	2006	2007	Average
No. of bus inspections	43,874	45,254	116,754	124,972	82,714
No. of buses involved in crashes	9,172	11,146	12,507	13,506	11,583
Overall rate of bus crashes per inspection	20.9%	24.6%	10.7%	10.8%	14.0%

The rates range from 10.7 to 24.6 percent for 2004 through 2007, with an average of 14.0 percent. This average risk estimate is equivalent to one crash per seven vehicle inspections. Normalized by the number of inspections, the risk of a motorcoach fire is approximately 10 percent that of a bus crash. This difference suggests that motorcoach fire risk rates are within a single order of magnitude of those for bus crashes.

Implications of Roadside Inspection Data Analysis

The previous section indicates that the risk of motorcoach fires may be linked to measures of non-compliance with vehicle-related regulations. Specifically, a higher OOS rate from roadside inspections corresponds with a greater fire risk for the inspected motorcoach. Furthermore, diverging rates for involved versus non-involved vehicles over the last five-year inspection period imply an increasing risk of motorcoach fires in the future.

Given this link, one could infer the potential benefits of targeting motorcoaches and carriers that have high occurrences of vehicle-related violations to identify specific fire risk factors. For example, in a CR or focused investigation of a carrier with motorcoaches that have high vehicle inspection OOS rates and are of high-occurrence model years and engine types, the carrier could be subjected to further scrutiny of turbocharger and engine inspection, repair, and maintenance records. Further violations directly indicative of fire risk might be discovered and abated. Even in cases where violations are not discovered, a responsible carrier may take note of the warning signals for fire risk and be more vigilant in performing the manufacturer- and industry-suggested procedures recommended for mitigating that risk.

Carrier Compliance Review Data Analysis

Table 20 shows the ratings given to 161 carriers, identified in the MCF database, during 488 CRs conducted between 1990 and 2008. The vast majority of ratings in all categories were satisfactory for passenger carriers that had experienced or were about to experience motorcoach fires. Relatively few less-than-satisfactory (conditional or unsatisfactory) ratings were given in any category, but there were sizeable proportions of less-than-satisfactory ratings in the two categories representing major causal factors for motorcoach fires, namely Factor 3, Operational (15 percent), and Factor 4, Vehicle (17 percent). These percentages are approximately the same as for all passenger-carrier reviews in the 2003–2007 period: 15.4 percent of all passenger-carrier ratings were less than satisfactory for Factor 3 and 17.5 percent, for Factor 4.

It appears, from the comparative statistics, that carriers involved in fires have no higher rates of operational or vehicle-related compliance problems than do those without fire involvement. By analogy with the previous analysis of OOS orders for vehicle-related inspections, one would expect those carriers to have a higher rate of compliance problems commensurate with a greater fire risk. One possible explanation for this anomaly is that current protocols for CRs, as well as for roadside inspections, are not designed to discover some factors related to fire risk.

Table 20: Compliance Review Ratings for 161 Carriers in the MCF Database

Safety Rating Level	Factor 3 Rating: Operational	Factor 4 Rating: Vehicle
Satisfactory	407	398
Conditional	8	69
Unsatisfactory	64	12
No rating	9	9
TOTAL	**488**	**488**
Rated less than satisfactory	72	81

Of these reviews, 236 resulted in 509 inspection, repair, and maintenance violations. Most were cited for poor recordkeeping rather than for actual inspection, repair, and maintenance problems. Table 21 shows that 151 (29.7 percent) of these CR violations (depicted in boldface) were cited for problems not having to do primarily with poor recordkeeping. Four of these violations (3.0 percent) were acute: one was for failure to correct safety defects reported by the driver, and three were for operating OOS vehicles before making repairs. There were 59 (11.6 percent) critical violations, but these included only 12 (9.2 percent) of the 131 violations that did not primarily involve recordkeeping. The critical violations were all given for using a motorcoach that had not been adequately inspected by the carrier in accordance with regulations.

Table 21: Compliance Review Inspection, Repair, and Maintenance Violation Counts for 161 Fire-Involved Carriers in the MCF Database*

Section Description	Violations		
	Total	Acute	Critical
Failing to require driver to prepare vehicle inspection report	63		33
Failing to keep inspection form for 12 months	48		
Failing to certify that repairs were made or were not necessary	**40**		
Failing to keep a record of tests conducted on pushout windows	33		
Failing to keep a maintenance record identifying the vehicle	32		
Failing to ensure inspection report is complete and accurate	28		
Failing to retain vehicle inspection report for at least 3 months	27		
Failing to inspect pushout windows every 90 days	**25**		
Failing to keep minimum records of inspection and maintenance	23		
Failing to keep a record of inspections and repairs	23		
Failing to retain evidence of brake inspector's qualifications	22		14
Using a CMV not periodically inspected	**21**		**12**
Failing to have a means of indicating maintenance due dates	**20**		
Failing to require driver to sign vehicle inspection report	19		
Failing to maintain evidence of inspector's qualifications	16		

Section Description	Violations		
	Total	Acute	Critical
Failing to retain periodic inspection report for 14 months	13		
Vehicle wheel or rim bent, sprung, or mismatched	**13**		
Failing to correct safety defects reported by driver	**11**	**1**	
Using a vehicle not periodically inspected	**5**		
Operating vehicle likely to cause accident or breakdown	**5**		
Failing to prepare inspection report in correct form and manner	4		
Other (failing to keep minimum records of inspection and maintenance)	4		
Operating OOS vehicle before making repairs	**3**	**3**	
Using an inspector who is not qualified	**2**		
Failing to retain inspection/maintenance records for 1 year	2		
Other (failing to correct safety defects reported by driver)	**1**		
Operating a CMV without periodic inspection	**1**		
Brake inspector does not meet minimum qualifications	**1**		
Failing to ensure each brake inspector is qualified	**1**		
Inspection, repair, and maintenance	**1**		
Failing to ensure vehicle is free of oil and/or grease leaks	**1**		
Other (failing to adhere to roadside inspection directives)	1		

*Violations shown in **boldface** were not primarily recordkeeping in nature.

Out-of-Service Criteria

In the past few years, there have been major additions to the NAS OOS criteria regarding inspection of major engine electrical components and wheel hubs and bearings, two main origin locations of motorcoach fires. However, this study found that important fire origin locations and ignition points, such as auxiliary electrical systems, air conditioners, and turbochargers, are not yet addressed as vehicle inspection items. Also, inspection items involving brakes, tires, and fuel and exhaust systems may need a more in-depth review to determine if enhanced inspection criteria might be implemented for motorcoaches. This means that some conditions that can lead to motorcoach fires are not currently detected during inspections intended to verify vehicle safety. Table 22 illustrates the relationship between some operational inspection practices outlined in the April NAS operational criteria and the motorcoach fire ignition points identified in this report.

Table 22: North American Standard Operational Inspection Criteria*

Fire Ignition Point	Critical Vehicle Inspection Item	OOS Criteria	Additional Fire Precursors
Brakes	Brake systems	Defective brakes – 20 percent rule Improperly adjusted Air loss rate Low air pressure warning device Hydraulic lines leaking or damaged	Defective brakes Frozen or sticking air valves Wheel bearing failure
Turbochargers	None	None	Propeller, bearing, turbine, or compressor failure Waste-gate failure
Tires	Tires	Underinflated or leaking Rubbing part of vehicle Visually observable bump or knot Worn/damaged Overloaded Dual touching its mate	Internal tire defect
Electrical – engine compartment, bus interior, other area	None	Chafed, frayed cable insulation; worn protective insulation* Loose or corroded battery connections or unprotected alternator, starter* Unsecured mounting of electrical component* Leaking of engine lubricant from electrical component*	Auxiliary motor malfunction Passenger compartment accessory malfunctions
Wheel/hub bearings	Wheels, rims, and hubs	Missing/broken axle bearing cap Smoking hub assembly due to bearing failure Wheel seal leak* Hub seal failure/no lubricant in hub*	Axle flange gasket or seal failure (check) Bearing failure with no smoke
Fluid lines – engine compartment, other areas	Fuel system	Leaking fuel system Includes auxiliaries	Leaking coolant or lubrication system Cracked fuel, coolant, or lubrication lines and fittings
Air conditioners	None	None	Compressor failure
Combustible fluid accumulation	None	None	Combustible accumulation on transmission, engine components
Axles	Suspension	Broken tag axle	

Fire Ignition Point	Critical Vehicle Inspection Item	OOS Criteria	Additional Fire Precursors
Exhaust systems	Exhaust system	Exhaust system located too close to wiring, fuel supply, combustibles, etc.	Improper parts Auxiliary power unit exhaust located too close to wiring, fuel supply, or combustibles MY 2007 and later diesel particulate filter malfunctions

*Revised as of April 2008.

Impacts of Fire Warning and Suppression Systems

The development of automatic detection and suppression systems was discussed in Section 1. Detection systems have been designed to provide direct notification of the presence of active fire and identification of various malfunctions that could lead to a fire. Devices that detect impending component failures are currently available for tires and turbochargers. For motorcoaches equipped with tire pressure warning systems, abnormal tire pressure or sensor failure due to heat will trigger a warning to the driver. The abnormal pressure could result from a failure of the tire itself or from heat buildup due to a failure of wheel-end components such as brakes or hub bearings.

Turbocharger failure detection systems are designed to trigger a warning to the driver that the turbocharger is malfunctioning or delivering insufficient boost pressure. This may give sufficient advance warning of a fire precursor situation, such as a turbocharger bearing failure or a lubrication leak in the turbocharger.

Automatic engine-compartment fire detection/suppression systems represent a different approach, an alternative to detection-only systems. These systems detect the heat or flames of an engine fire, alert the driver, initiate an engine shutdown process and deliver suppressant agent to the fire.

Market Penetration of Original Equipment Manufacturer (OEM) Systems

A query of major motorcoach manufacturers revealed that only buses produced in MY 2004 and later were available at sale equipped with automatic fire warning and suppression systems.[43] These systems included combinations of tire pressure monitoring and engine-compartment fire detection/suppression. (They did not include turbocharger failure detection.) Of the 731 records in the MCF database that specify model year, only 19 (2.6 percent) involve motorcoaches of MY 2004 or later, and only 11 (1.5 percent) of these have full VINs that allow for identification of systems on the vehicle.

OEM representatives were contacted to identify which of these motorcoaches were offered or delivered with fire warning and suppression systems. Of the 19 involved motorcoaches, eight were identified as models on which these systems were offered as an option, and none were verified as having been delivered with them.

The number of vehicles in operation nationally on which fire warning and suppression systems were offered can be derived from the R.L Polk population data. Of the four major manufacturers of motorcoaches of MY 2004 or later, 3,424 motorcoaches of MYs 2004–2007 were in operation as of December 31, 2006. Preliminary totals as of December 31, 2007, indicate that, with the introduction of MY 2008, the total number of motorcoaches in operation from the same manufacturers grew to over 4,700. These numbers indicate that there was a potential for the major manufacturers to have provided fire warning and suppression systems for more than 10 percent of the entire U.S. motorcoach fleet. The number of motorcoaches that could be retrofitted with these systems could amount to a much higher percentage.

The actual availability of these systems at point of sale, however, was limited to the specific models for which they were offered. Thus far, only seven of the 11 models of the applicable model years have been verified by the manufacturers as having been offered with fire-detection or detection/suppression systems. Totals of vehicle models sold with these systems were not provided by the manufacturers.

Potential Benefits of Widespread Installation

Over the 2004–2006 period, wheel-well ignition points accounted for about 34 percent of recorded motorcoach fires, and turbocharger failures accounted for another 8 percent. Thus, it is reasonable to conclude that component failure warning systems, if installed on every motorcoach and properly used and maintained, could potentially prevent up to 42 percent of all motorcoach fires.

Engine fires accounted for 36 percent of fires in the same period. Thus, it is reasonable to conclude that engine-compartment detection/suppression systems could help to reduce the severity and mitigate the consequences of up to 36 percent of all motorcoach fires in the United States.

Taken together, the impact of these systems on fire risk reduction could be significant. Automatic failure detection and automatic fire detection/suppression systems could be powerful tools for preventing motorcoach fires. They could also reduce the severity and mitigate the consequences of the fires that do occur. By some estimates, nearly every motorcoach in service today could be retrofitted with both systems. If used together on every motorcoach, they might be able to prevent or mitigate wheel-well and engine fires, which account for 70 percent of all fires in the MCF database.[44]

On an annual basis, assuming a projected frequency of 160 fires, 58 are projected to be engine fires and 54 would originate in a wheel well. Assuming that there were no fire detection/suppression systems on any of the involved motorcoaches, the introduction of these systems would be expected to prevent or reduce the consequences of up to 112 reported fires annually.

Reduction in injuries and fatalities. Given the statistics for injuries and fatalities and property damage examined earlier in this section, the potential benefits of a reduction in the consequences of motorcoach fires nationally could be estimated. Excluding the Global Limo fire, there were a total of 14 direct injuries from the 899 reported fires: seven, from six fires (0.67 percent) originating in the engine compartment and another seven, from three fires (0.33 percent) originating in a wheel well. An annual total of 160 fires are expected to result in about two direct injuries. If fire warning and suppression systems had been installed on all involved motorcoaches, those injuries could have potentially been averted.

More significant are the potential benefits of mitigating the injuries and fatalities of a rare catastrophe, such as the Global Limo fire that resulted in 23 direct fatalities and 15 injuries. In a similar circumstance, there is a potential to avert a large number of injuries and fatalities. In the case of the Global Limo fire, a tire pressure monitoring and warning system could have alerted the driver to an abnormal heat buildup in the wheel well, providing a warning to stop and evacuate the motorcoach before the fire spread. Even given the number of severely infirm passengers, it is estimated that many more could have been evacuated safely. If advanced systems can be successfully developed to detect abnormal temperatures in the wheel well, their installation could warn the driver even before conditions deteriorate to the point of ignition.

Reduction in damages. On the basis of all sources reporting property loss or damage, engine fires accounted for $2.9 million and wheel-well fires, for $1.8 million, not adjusted for inflation. Together, these two types of fires accounted for damages of $4.7 million. This total does not reflect damages from fires of unknown or unspecified origin, a portion of which are likely to have started in those areas.

With limited samples of fires for which damages were reported in recent years, it is difficult to project the damages to be expected from motorcoach fires of any origin location. Nevertheless, the totals reported provide an order of magnitude for expected losses and an estimate for reduction of losses from detection and suppression systems. The benefits of property-damage reduction are expected to vary more widely than those for injuries and fatalities, considering that early detection or suppression would be expected only to reduce the maximum damage for each fire incident as opposed to preventing any damage.

System effectiveness. The achievable percentage of risk mitigation is determined by a number of factors, not the least of which is the actual effectiveness of a particular system in dealing with a spectrum of possible fire scenarios. Issues relevant to system effectiveness include driver attentiveness and reaction time (for warning systems), the reliability of the suppression agent, and the comparative and complementary effects of passive measures, such as fire barriers and fire-resistant materials. Further research and testing are needed to estimate the effectiveness of automatic fire warning and detection/suppression systems in real-world situations.

Summary of Findings

***Frequency*.** Given the current incident-reporting systems and the limited number of sources available for this study, an average of about 160 motorcoach fire records are collected annually for the most current and complete period. From the reported data compiled in the MCF database, there is no indication that the frequency of motorcoach fire incidents is significantly increasing or decreasing.[45]

***Severity*.** The average consequences of reported fire incidents appear small when rare disastrous events are excluded. Discounting the Global Limo fire, the study projects only 42 injuries, one fatality, and a total property loss of about $10 million occurring over the 1995─2008 period. Approximately 96 percent of the reported fires resulted in no direct injuries and fatalities, and the average reported property damage per incident was a fraction of the total cost of the vehicle. That having been said, the reporting of motorcoach fire severity and consequence data is lacking in completeness and the recorded values are often ambiguous or unverified.

***Geographic distribution*.** A higher frequency of records for one State or region may indicate more thorough reporting standards or the confluence of data sources. Rates may be skewed by wide variability of motorcoach travel in proportion to applicable highway vehicle travel. Eastern States, with greater population and route densities, may incur more motorcoach VMT per highway VMT than less populous States.

Fire origin on motorcoach. The two most common origin locations of reported fires were the engine compartment and the wheel well, with each contributing about 35 percent of the fires respectively, and 10 of the 12 fires resulting in direct injuries and/or fatalities. Only nine fires were reported to have originated in the engine or fuel system. Because of the data sources' varying numbers and the ambiguity of blank and zero values, there is no clear distribution of average damages per fire.

Specific ignition point. For incidents for which area of origin was specified, the most commonly designated ignition points were brakes, tires, turbochargers, wheel bearings, and electrical sources in the engine, which accounted for 66 percent of the reported ignition points. Other wheel-related, fluid, and electrical system ignition points contributed an additional 24 percent. Exhaust systems were specifically designated in only 2 percent of the fires.

Model year and vehicle age. For the core 2004–2006 fire incident period, more than 50 percent of the incident records involve motorcoaches of MYs 1998 through 2002. These motorcoaches not only had a higher reported frequency of fire occurrences but also a substantially higher reported incident rate relative to their population than did older motorcoaches. More powerful engines having higher fuel efficiency and lower emissions are suspected to have contributed to an increase in engine fires in 1998 and later-model-year engines.

Make and model. The rate of fire incidents for a vehicle make or model can be calculated with use of the number of fires and the number of vehicles in service at the time of the fires. Application of the R.L. Polk 2006 national vehicle population profile to the core incident years suggests that manufacturers' exposure to fire incidents correlates with the number of vehicles of that make in operation. Sample sizes of incidents for individual models are too small to make a similar observation.

Fire risk indicator derived from roadside inspections. The years 2003-2008 show an increasing vehicle OOS rate for motorcoaches that were involved in a fire subsequent to an inspection. This may be indicative of growing problems with general repair and maintenance of motorcoaches that are prone to fires. More significantly, analysis of all motorcoach OOS rates shows that the OOS rate for any group of inspected motorcoaches is an indicator of future fire risk. Furthermore, diverging rates for involved versus non-involved vehicles over the last five-year inspection period imply an increasing risk of motorcoach fires. Given additional years of inspection data, one could infer potential benefits of targeting motorcoaches and carriers that have high occurrences of vehicle-related violations in order to identify specific fire risk factors.

Fire risk indicator derived from carrier safety ratings. Compliance ratings of fire-involved motorcoach carriers show no apparent association with higher levels of deficiencies in a carrier's own inspection, repair, and maintenance practices. However, this may be more a reflection of current deficiencies in the assessment standards than actual differences in practices for fire safety. The number of violations related to inspection, repair, and maintenance found in CRs for all carriers is low, particularly for violations not primarily recordkeeping in nature.

OOS criteria. There have been major additions to the NAS OOS criteria regarding inspection of major engine electrical components and wheel hubs and bearings, the two main origin locations of motorcoach fires. Other fire origin locations and ignition points that may be able to be addressed include auxiliary electrical systems, air conditioners, turbochargers, and other items involving brakes, tires, and fuel and exhaust systems.

Fire warning and suppression systems. Failure detection systems, currently available for tire and turbocharger malfunctions, could prevent 42 percent of all motorcoach fires. Engine-compartment detection/suppression systems could help to reduce the risk of 36 percent of all motorcoach fires. If used together on every motorcoach, they might be able to prevent or reduce the consequences of wheel-well and engine fires, which account for 70 percent of all fires in the MCF database. With the introduction of these systems in 2004, there was a potential for the major manufacturers to provide them for more than 10 percent of the entire U.S. motorcoach fleet by 2008. Although only marginal reductions in injuries and fatalities are projected from widespread application, these systems could provide major life-saving benefits for a rare catastrophe, such as the Global Limo fire.

5. Recommendations

The recommendations in this section are based on the results of the background study, the identification of sources, the assessments of data sufficiency, and the findings from data analyses presented in this report. They cover data quality and reporting; compliance inspection and review standards; industry practices for vehicle inspection, repair, and maintenance; vehicle and component design; and priorities for further study and investigation of the motorcoach fire problem.

These analyses suggest that current vehicle inspection standards and CR practices could be strengthened to provide greater focus on issues related to fire safety. While significant progress has been made in recent years, roadside inspection criteria may be further revised to include more fire precursors.

Data Quality and Reporting

Our analyses of data completeness, data reporting, and data quality in the Volpe MCF database lead us to make the following recommendations.

Collaboration with data-source organizations to improve their coverage, depth, and quality of reporting of key elements related to motorcoach fire incidents

Data collectors, including FMCSA, USFA, NHTSA, and the States, should be encouraged to include more key analysis fields, such as fire origin location, ignition point, and complete VIN, in their databases. Every key analysis field was found to be well populated, but not fully populated, in the Volpe MCF database. Other key analysis fields that are missing or ill-defined in the databases used in this study include:

- Non-collision fires in crash definitions
- Motorcoaches in vehicle-type definitions (e.g., NFIRS, MCMIS, States)
- Specific location and ignition point coding (e.g., some NFIRS codes indicate several origin locations and ignition points), including sequence of events
- Specific make and model coding for motorcoaches (e.g., NFIRS includes many vehicle make and model codes, but none refer to motorcoaches)
- Full, 17-character VIN (many VINs are incomplete or incorrect)
- Direct-injury counts specifying injuries sustained on the bus or during evacuation
- Damage estimates that specify the items included (e.g., bus, contents, property damage)
- Remarks-field data indicating the sequence of fire-related events and other identifying information

NFIRS in particular has considerable potential as a primary source for motorcoach fire data. As shown in the previous section, NFIRS provides the bulk of the incident data; it is the most reliable source for fire origin and injury and fatality data. Although they are less reliable for data on vehicle identification, ignition point, and property loss and they do not specify the name of the carrier, NFIRS data formats and quality control provide the basis for improving the reporting of these elements.

As a voluntary reporting system, NFIRS relies on statistical extrapolation to estimate the complete universe of fire incidents. NFPA has used its own survey data to enhance statistical precision, but its methodology has not yet separated motorcoach fires from other bus fires. Moreover, NFPA has not specifically projected values for each combination of the contributing factors used in this study. FMCSA should work with USFA and NFPA to enhance reporting and sample expansion methods that can better specify all U.S. motorcoach fires. These efforts could be leveraged using MCMIS reporting as a corroborating source.

Promotion of adherence to regulatory guidance for reporting motorcoach fires to MCMIS

The MCMIS data contain known deficiencies in completeness and quality.[46] A problem for the study was that fire incidents were not universally reported as accidents because Federal regulations did not require it. In fact, only 95, or fewer than 20 percent, of the fires in the Volpe MCF database were found in MCMIS. On July 24, 2007, FMCSA published regulatory guidance concerning the definition of a reportable "accident." Fires have been included in the definition of "accidents" since 1962; however, in an effort to simplify the regulatory text, the agency removed specific references to fires, rollovers, and other non-collision accidents in 1972.

As the agency indicated, its intent was to include all of these items as crashes. A fire or explosion in a CMV operating on a highway in interstate or intrastate commerce is considered a "crash" if it results in a fatality, a bodily injury requiring the victim to be transported immediately to a medical facility away from the scene, or disabling damage requiring the CMV to be towed. A collision is not a prerequisite for a "crash" under the FMCSR. MCMIS data recorded after July 24, 2007, should now reflect all fires on motorcoaches operating on a highway in interstate or intrastate commerce.

Support of data standardization initiatives for defining common data elements and coding for crash reports

Much of the difficulty in combining sources and comparing values of motorcoach fire data can be traced to variant data standards—for example, data element names, definitions, sub-elements, and field codes. Several DOT agencies are involved in MMUCC, which is a continuing effort to standardize crash data. The MMUCC guideline provides a conceptual and detailed framework for crash reporting and coding standards that can be used by a broad range of agencies and jurisdictions. MMUCC standards are applicable to most motorcoach fire incidents in this study, at least those that meet the MCMIS criteria for crashes. In fact, FMCSA is already actively participating in MMUCC development for use by States reporting crashes and has enhanced its SAFETYNET design requirements to include "Bus Use" as a sub-element for a passenger vehicle involved in a crash. Addition of this element to SAFETYNET will allow for further attribution of a bus—for example, intercity coach (scheduled, charter, etc.).

Although VIN is a required MCMIS data element, this field is often incorrect or incomplete, and even the most sophisticated VIN decoders do not provide a fix that is completely reliable. Without specific make and model data, validation that the vehicle is a motorcoach is often impossible with use of the recorded VIN or any other descriptive information provided by the data sources. Conversely, without a valid VIN, make and model often cannot be derived. For these reasons, it is recommended that the SAFETYNET data quality group designate make and model as required data elements for all CMVs and that it recommend that MMUCC adopt these as primary elements in its vehicle schema.[47]

Inspection Standards and Enforcement Procedures

This study shows that motorcoach fire prevention and risk mitigation depend on proper vehicle inspection, repair, and maintenance by carrier personnel. It follows that enforcement agents can help to reduce the risks of motorcoach fires by using inspection standards and compliance procedures that target known precursors of fire risk. The following recommendations are consistent with the findings of this study. Motorcoach fire prevention efforts could become more effective through revised inspection criteria, with an emphasis on inspector training.

Continuation of collaborative efforts to identify critical inspection items associated with contribution to fire risk

Proper inspections require the right inspection criteria. Gaps remain in the FMCSR and the NAS inspection criteria with respect to addressing fire safety in common motorcoach fire ignition points. These gaps could be filled as follows.

- Rules for driver pre-trip and post-trip inspections (driver vehicle inspection reports [DVIRs]) should include a set of specific fire prevention checks on parts and accessories critical to fire-safe operation. Checks that cannot be accomplished daily by a driver should be added to the carrier's periodic inspection requirements as appropriate.

  It should be noted that some parts are not visible to a driver or inspector during a pre- or post-trip inspection. Due to the need for special tools and specific expertise, it may not be practical or possible to inspect items such as turbocharger components or internal tire defects during a roadside inspection

- CVSA may consider expanding vehicle OOS criteria to address the following potential fire precursors:
  - Brakes
    - Defective brakes (below the 20 percent threshold)
    - Frozen or sticking air valves
    - Wheel bearing failures
  - Electrical system
    - Auxiliary electric motor malfunction
    - Passenger-compartment accessory malfunctions
  - Wheel/hub bearings
    - Axle flange gasket (check) or seal failure
    - Bearing failure with no smoke

- Fluid lines
  - Leaking coolant or lubrication system
  - Cracked fuel, coolant, or lubrication lines and fittings
- Air conditioners—compressor failure
- Engine compartment
  - Combustible accumulation on transmission and engine components
  - Turbocharger propeller bearing, turbine, or compressor failure
  - Turbocharger waste-gate failure
- Exhaust system
  - Improper parts
  - Auxiliary heater improperly installed
  - Auxiliary power-unit exhaust located too close to wiring, fuel supply, or combustibles
  - MY 2007 and later diesel particulate-matter filter malfunctions

- Verification that NHTSA Safety Recalls have been performed on each inspected vehicle

As a result of the continuing work of the Passenger Carrier Committee, the Bus Fire Subcommittee, and the Vehicle Committee, CVSA has added a number of new, critical inspection items associated with fire prevention on motorcoaches to its OOS criteria during the past two years. These include defective electrical components and wiring systems as well as wheel-seal failures and lack of hub lubricant. The same committees are continuing to look at remaining issues, working toward defining new inspection and OOS criteria that may address gaps in fire safety.

Increase in the frequency of on-the-road inspections of motorcoaches to expand compliance data

Regardless of the inclusion of new, critical inspection items, this study has shown that motorcoaches with vehicle OOS violations after a roadside inspection are more likely to be involved in a fire than those without such violations. These results, however, are based on a relatively small sample of inspected vehicles that could be matched with VIN-identified fires. The relative risk of OOS versus “clean” inspections could be estimated with greater certainty if more fire-involved motorcoaches had been inspected.

In addition, as a result of recent FMCSA enforcement initiatives, passenger carriers have been increasingly prioritized for comprehensive CRs regardless of past on-the-road performance. These efforts have yielded benefits, but they may have diluted investigative resources that could otherwise be targeted to specifically indicated problems, such as mechanical and maintenance deficiencies associated with fire risk. A larger sample of roadside data can more accurately identify specific safety risks associated with individual carriers that merit intensive investigation.

Exploration of the use of vehicle OOS rates for a carrier as an indicator for conducting focused fire safety investigations

Given the relationship between a vehicle’s OOS rate and its risk of future fire involvement, it stands to reason that the fire risk exposure of a carrier would correlate with the OOS rate of its vehicles. A carrier with a high vehicle OOS rate would deserve assignment priority for the limited resources available to investigate fire vulnerabilities and possible countermeasures.

This strategy is consistent with the CSA 2010 approach for conducting focused investigations in a given compliance area, except that it uses OOS violations as an indicator instead of measurement scores in the Vehicle Maintenance BASIC. As CSA 2010 is rolled out, and as a greater sample of passenger-carrier inspections in the safety measurement system becomes available, the Vehicle Maintenance BASIC score may prove to be a sufficient indicator for investigating fire risk for each carrier's fleet. Onsite vehicle inspections, performed as part of a focused vehicle maintenance investigation, could be the basis for intensive investigation by trained fire risk specialists.

Enhancement of training given to passenger-carrier inspectors and investigative specialists

Training for inspection of motorcoaches, both roadside and during CRs, is provided by FMCSA and CVSA through the NAS Passenger Vehicle Inspection Course. Current procedural guidelines for vehicle interior, exterior, and undercarriage inspection cover existing critical inspection items but do not detail procedures for checking many fire precursor conditions, including operational risk determined by past inspection performance. As mentioned earlier, determination of these fire risk factors will need further research. Meanwhile, consideration might be given to adding rudimentary fire investigation training to the current course offerings.

Revision of the safety rating system for passenger carriers to include a broader range of vehicle violations

Currently, safety ratings for CMV carriers are based on counts of critical and acute violations found during CRs. As this study has shown, a small number of critical/acute violations for fire-involved carriers have been recorded in the vehicle repair and maintenance Safety Evaluation Area (SEA). Including a broader range of vehicle-related violations in the safety fitness calculation in proportion to their impact on crash risk would help to identify operators that pose severe vehicle-maintenance-related risks and would force changes to essential fire safety practices, using the threat of removing operating authority. The system that is being designed for CSA 2010 may be a useful starting point.

CSA 2010 is developing a safety fitness determination process for CMVs on the basis of all roadside inspections. Violations are weighted in proportion to their impact on crash incidence. This determination is similar to that for a BASICs deficiency but uses a higher threshold for an unsatisfactory rating. For carriers whose roadside performance is deficient but not to a level meriting an unfit rating, further investigation that reveals specific fundamental safety violations or a lack of essential safety management practices in any BASICs area may also trigger a less-than-satisfactory fitness rating. Currently, an unsafe rating in the Vehicle SEA alone does not result in a notice of unfit. With the new rating system, the safety rating is based on a broad sampling of inspections and does not rely on violation thresholds for an arbitrary, small set of violations being exceeded across multiple evaluation areas.

Vehicle Design, Equipment Development, and Operational Training

This study has examined the contribution of various vehicle and equipment characteristics to the risk of motorcoach fires, leading to the following recommendations.

Consideration of design changes that could improve the fire safety of brakes, turbochargers, tires, electrical systems, wheel/hub bearings, and emergency exits

These components were found to be the most common motorcoach fire ignition points. Design changes might include:

- Replacing dual tires with wide-base single tires
- Improving wire/cable routing, including eliminating troughs that could expose wires to water
- Relocating the air intake to reduce smoke entering a bus interior due to engine fire
- Using heat-shielding turbocharger covers
- Using more effective electrical shielding and insulation
- Using heat-resistant hub/wheel seals and axle flange gaskets
- Replacing oil-lubricated wheel bearings with those that are grease-lubricated

The two most prevalent sources of motorcoach fires are the wheel wells and the engine compartment. When these areas become fully involved in a fire, the fire spreads to the passenger compartment, either through the bus floor separating the wheel well and the engine compartment or through the side windows of the bus. Two design improvements that could reduce these effects are the installation of fire-resistant materials to create a firewall between the wheel well or engine compartment and the bus interior and the installation of fire-resistant exterior-body-cladding materials and side windows to help keep wheel-well and engine-compartment fires from entering the passenger compartment externally.

From the data available, it was found that only 12 of 899 fires resulted in known direct injuries. Only five direct injuries were incurred during a fire evacuation, while passengers were in the process of exiting the bus through the normal motorcoach exit or were falling from a window emergency exit. When improvements in emergency-exit egress are considered for motorcoaches, the needs of mobility-impaired passengers need to be addressed. These passengers may not have sufficient upper-body strength to open emergency-egress windows and may be more subject to injury when they impact the ground after exiting the bus. It may be necessary to outfit emergency-exit windows with gas-strut assistance or other measures to help weak passengers escape.

Evaluation of the effectiveness of automatic failure warning systems and fire detection/suppression systems

This study found a potential for preventing or mitigating up to 70 percent of fires on motorcoaches equipped with failure-detection and engine fire-detection/suppression systems. Damage and injury and fatality reductions may be small on average, but these systems could help to avert the most severe consequences in an extreme or catastrophic fire scenario. Achievable benefits, however, are limited by the effectiveness of these systems in operation, including any required operator interaction. For example, a “smart” tire pressure monitoring system may detect only a small fraction of failures leading to wheel-well fires, and the driver may be able to respond successfully only in limited instances.

Many of these detection/suppression systems are expensive to operate and difficult to maintain. Research should be conducted to determine the extent of benefits relative to their cost and compared with other countermeasures. This research could include laboratory tests and simulations. Efforts should be made to involve carriers and vendors who have both test and operational experience in order to obtain useful data.

Support of research and development in technologies for wheel-well fire detection/suppression systems

Wheel-well fires account for over one-third of the estimated total of motorcoach fires. There are no known practical systems that can automatically detect and suppress a fire that has ignited in the wheel area. The development of fire detection/suppression systems for this area may require hardened materials capable of surviving the day-to-day operational abuse caused by road debris and the environment while still able to function in the event of a fire. Research to develop and test such systems that could prevent future tragic fire events should be encouraged.

Enhancement of fire response equipment, safety procedures, and training requirements for drivers and maintenance personnel

The current U.S. requirement for motorcoach fire extinguishers is one 5-B:C or two 4-B:C fire extinguishers, as rated by UL. Several motorcoach operators currently equip their vehicles with 20-B:C-rated fire extinguishers, which are effectively four times the minimum requirement. Fully involved engine-compartment or wheel-well fires can easily overwhelm a 20:BC-rated fire extinguisher. A motorcoach operator’s first priority should be the safe evacuation of passengers before an attempt is made to extinguish the fire. Unless properly trained, the motorcoach operator should leave the fire-fighting to experienced fire-fighting personnel.

Mechanics and technicians need to be trained and qualified to perform motorcoach system inspection, repair, and maintenance to ensure that all parts and accessories meet fire safety standards. Their supervisors and management need to be adequately apprised of communications requirements, such as the need to delay dispatch of the motorcoach until all scheduled preventive maintenance is completed, including periodic verification of wheel-end lubrication levels.

Inspectors, drivers, and technicians at all levels should be properly trained to recognize fire precursors. This is especially important in regard to subtle conditions like frayed or improperly installed wiring or cracked fluid lines. This recommendation applies to both CVSA and industry training programs.

Appendix A

Tabulations of Reported Motorcoach Fire Incidents by State

Table A-1: Motorcoach Fires, by Source and State[48]

State*	FARS	NFIRS	MCMIS	FMCSA/ NHTSA	States	Media	Carriers	Insurance	Total Fires
AK	0	2	0	0	0	1	0	0	3
AL	0	5	6	0	0	0	0	0	10
AR	0	7	1	0	0	0	0	2	8
AZ	0	3	8	0	0	1	2	0	11
CA	0	13	8	0	4	8	2	4	31
CO	0	5	2	0	0	2	0	0	7
CT	0	15	0	0	0	2	2	0	17
DC	0	3	0	0	0	2	1	1	5
DE	0	0	1	0	0	1	0	0	2
FL	0	28	1	0	6	14	0	3	43
GA	0	17	0	0	0	1	0	1	18
HI	0	3	0	0	0	3	0	0	6
IA	0	2	0	0	0	1	0	0	3
ID	0	4	0	0	0	1	0	0	5
IL	0	13	1	1	1	5	0	1	20
IN	0	2	2	0	0	4	1	0	8
KS	0	4	4	0	0	1	0	0	8
KY	0	1	1	0	0	2	0	1	5
LA	0	6	0	0	0	2	1	0	8
MA	0	23	0	0	0	8	0	1	30
MD	0	8	0	2	0	4	0	1	14
ME	0	0	2	0	0	1	0	0	2
MI	0	15	1	0	2	3	2	1	21
MN	0	3	1	0	0	0	0	0	3

State*	FARS	NFIRS	MCMIS	FMCSA/ NHTSA	States	Media	Carriers	Insurance	Total Fires
MO	0	4	6	0	0	3	1	2	10
MS	0	1	0	0	0	2	0	0	3
MT	0	0	1	0	0	0	0	0	1
NC	0	16	4	0	7	2	2	3	22
ND	0	1	0	0	0	2	0	0	2
NE	0	2	1	0	0	0	0	0	3
NH	0	0	0	0	0	1	0	0	1
NJ	0	23	2	1	4	9	1	2	33
NM	0	0	0	0	0	1	0	0	1
NV	0	8	2	0	0	0	0	1	10
NY	0	27	29	0	4	4	1	2	62
OH	0	24	4	1	13	2	2	0	33
OK	0	2	0	0	0	0	0	0	2
OR	0	3	0	1	0	2	0	0	5
PA	0	7	16	0	4	4	1	2	28
RI	0	0	0	0	0	1	0	0	1
SC	0	5	0	0	0	3	0	2	7
SD	0	1	0	0	0	0	0	0	1
TN	0	9	0	0	0	2	0	0	10
TX	1	41	6	0	0	5	4	5	47
UT	0	8	0	0	0	0	0	0	8
VA	0	16	0	0	0	4	0	1	19
VT	0	0	0	0	0	1	0	0	1
WA	0	6	1	0	0	1	3	0	6
WI	0	2	13	1	4	2	0	1	17
WV	0	3	0	0	0	3	0	0	5
WY	0	0	2	0	0	0	0	0	2

* Includes District of Columbia (DC).

Table A-2: Motorcoach Fires with Specified Origin Locations, Ignition Points, Full VINs, and NFIRS Comment Data, by State

State*	Records with Specified Origin Locations	Records with Specified Ignition Points	Records with 17-Character VINs	NFIRS Records with Comment Data	Total NFIRS Records	Total Fires
AK	2	2	1	1	2	3
AL	4	2	7	1	5	10
AR	2	2	4	2	7	8
AZ	4	4	5	3	3	11
CA	19	12	8	13	13	31
CO	4	3	5	3	5	7
CT	7	8	7	5	15	17
DC	4	2	1	2	3	5
DE	0	0	1	0	0	2
FL	29	17	19	12	28	43
GA	9	12	14	3	17	18
HI	5	4	1	3	3	6
IA	0	2	2	0	2	3
ID	4	3	3	2	4	5
IL	13	10	13	6	13	20
IN	5	3	3	1	2	8
KS	3	2	6	1	4	8
KY	1	1	2	1	1	5
LA	7	3	7	3	6	8
MA	12	10	19	6	23	30
MD	7	7	6	0	8	14
ME	1	0	2	0	0	2
MI	11	8	14	6	15	21
MN	3	2	1	2	3	3
MO	4	2	6	1	4	10
MS	1	1	0	1	1	3
MT	0	0	1	0	0	1
NC	16	15	18	6	16	22
ND	1	0	0	1	1	2
NE	0	0	3	0	2	3

State*	Records with Specified Origin Locations	Records with Specified Ignition Points	Records with 17-Character VINs	NFIRS Records with Comment Data	Total NFIRS Records	Total Fires
NH	1	0	0	0	0	1
NJ	14	9	17	3	23	33
NM	0	0	0	0	0	1
NV	6	5	7	5	8	10
NY	25	22	36	12	27	62
OH	17	19	20	7	24	33
OK	2	1	0	1	2	2
OR	3	4	1	0	3	5
PA	10	5	0	0	7	28
RI	1	1	0	0	0	1
SC	4	5	4	1	5	7
SD	0	0	0	0	1	1
TN	4	3	4	1	9	10
TX	30	25	32	15	41	47
UT	4	5	7	3	8	8
VA	13	9	9	8	16	19
VT	1	0	0	0	0	1
WA	5	3	3	5	6	6
WI	4	4	15	1	2	17
WV	3	3	3	1	3	5
WY	0	0	2	0	0	2

* Includes District of Columbia (DC).

Table A-3: Motorcoach Fires in Volpe MCF Database, Excluding State Data Sources, and VMT, by State

State*	Motorcoach Fire Records, Excluding State Sources		Million Highway VMT (All Vehicles), 2004–2006	Fires per Billion VMT (All Vehicles), 2004–2006
	1995–2008	2004–2006		
Dist. of Columbia	5	4	8,961	0.4464
Hawaii	6	6	23,955	0.2505
Alaska	3	2	11,010	0.1817
Nevada	10	7	51,542	0.1358
Connecticut	17	10	90,365	0.1107
North Dakota	2	2	19,072	0.1049
Massachusetts	30	17	164,525	0.1033
New York	62	29	324,881	0.0893
Idaho	5	3	35,814	0.0838
New Jersey	33	18	219,355	0.0821
Utah	8	5	66,595	0.0751
Florida	40	34	470,696	0.0722
North Carolina	21	15	217,418	0.0690
Maine	2	2	29,419	0.0680
Illinois	20	19	281,579	0.0675
Virginia	19	14	221,927	0.0631
West Virginia	5	3	50,780	0.0591
Louisiana	8	6	112,323	0.0534
Kansas	8	4	79,453	0.0503
South Dakota	1	1	23,139	0.0432
South Carolina	7	5	121,552	0.0411
Delaware	2	1	24,412	0.0410
Texas	47	27	670,536	0.0403
Maryland	14	7	174,319	0.0402
Wyoming	2	1	25,489	0.0392
Ohio	28	11	280,401	0.0392
Missouri	10	7	186,626	0.0375
Alabama	10	5	133,580	0.0374
Tennessee	10	7	187,435	0.0373
Washington	6	6	161,504	0.0372

State*	Motorcoach Fire Records, Excluding State Sources		Million Highway VMT (All Vehicles), 2004–2006	Fires per Billion VMT (All Vehicles), 2004–2006
	1995–2008	2004–2006		
Colorado	7	5	145,135	0.0345
Oregon	5	3	96,989	0.0309
Michigan	19	8	266,726	0.0300
Arizona	11	5	171,733	0.0291
Pennsylvania	27	7	276,698	0.0253
Arkansas	8	2	82,392	0.0243
Kentucky	5	3	126,832	0.0237
Georgia	18	6	254,624	0.0236
Mississippi	3	2	88,353	0.0226
Minnesota	3	3	133,041	0.0225
Wisconsin	15	3	153,108	0.0196
California	30	20	1,063,514	0.0188
Indiana	8	3	162,008	0.0185
New Mexico	1	1	69,884	0.0143
Iowa	3	1	79,965	0.0125
Oklahoma	2	1	109,147	0.0092
Nebraska	3	0	48,837	0.0000
New Hampshire	1	0	32,631	0.0000
Montana	1	0	29,617	0.0000
Rhode Island	1	0	28,004	0.0000
Vermont	1	0	14,396	0.0000

* Includes District of Columbia (DC).

Appendix B

NFIRS Data Collection Sheets for Vehicle Fires

NFIRS–1 Basic

A FDID ☆ | State ☆ | Incident Date (MM DD YYYY) ☆ | Station | Incident Number ☆ | Exposure ☆
☐ Delete ☐ Change ☐ No Activity

B Location Type ☆
☐ Check this box to indicate that the address for this incident is provided on the Wildland Fire Module in Section B, "Alternative Location Specification." Use only for wildland fires.
Census Tract
☐ Street address
☐ Intersection
☐ In front of
☐ Rear of
☐ Adjacent to
☐ Directions
☐ US National Grid
Number/Milepost | Prefix | Street or Highway | Street Type | Suffix
Apt./Suite/Room | City | State | ZIP Code
Cross Street, Directions or National Grid, as applicable

C Incident Type ☆
Incident Type

D Aid Given or Received ☆ ☐ None
1 ☐ Mutual aid received
2 ☐ Auto. aid received
3 ☐ Mutual aid given
4 ☐ Auto. aid given
5 ☐ Other aid given
Their FDID | Their State
Their Incident Number

E1 Dates and Times Midnight is 0000
Check boxes if dates are the same as Alarm Date.
Month Day Year Hour Min
Alarm ☆ — ALARM always required
☐ Arrival ☆ — ARRIVAL required, unless canceled or did not arrive
☐ Controlled — CONTROLLED optional, except for wildland fires
☐ Last Unit Cleared — LAST UNIT CLEARED, required except for wildland fires

E2 Shifts and Alarms Local Option
Shift or Platoon | Alarms | District

E3 Special Studies Local Option
Special Study ID# | Special Study Value

F Actions Taken ☆
Primary Action Taken (1)
Additional Action Taken (2)
Additional Action Taken (3)

G1 Resources ☆
☐ Check this box and skip this block if an Apparatus or Personnel Module is used.
Apparatus | Personnel
Suppression
EMS
Other
☐ Check box if resource counts include aid received resources.

G2 Estimated Dollar Losses and Values
LOSSES: Required for all fires if known. Optional for non-fires. None
Property $ ☐
Contents $ ☐
PRE-INCIDENT VALUE: Optional
Property $ ☐
Contents $ ☐

Completed Modules
☐ Fire–2
☐ Structure Fire–3
☐ Civilian Fire Cas.–4
☐ Fire Service Cas.–5
☐ EMS–6
☐ HazMat–7
☐ Wildland Fire–8
☐ Apparatus–9
☐ Personnel–10
☐ Arson–11

H1 ☆ Casualties ☐ None
Deaths | Injuries
Fire Service
Civilian

H2 Detector Required for confined fires.
1 ☐ Detector alerted occupants
2 ☐ Detector did not alert them
U ☐ Unknown

H3 Hazardous Materials Release ☐ None
1 ☐ Natural gas: slow leak, no evacuation or HazMat actions
2 ☐ Propane gas: <21-lb tank (as in home BBQ grill)
3 ☐ Gasoline: vehicle fuel tank or portable container
4 ☐ Kerosene: fuel burning equipment or portable storage
5 ☐ Diesel fuel/fuel oil: vehicle fuel tank or portable storage
6 ☐ Household solvents: home/office spill, cleanup only
7 ☐ Motor oil: from engine or portable container
8 ☐ Paint: from paint cans totaling <55 gallons
0 ☐ Other: special HazMat actions required or spill > 55 gal (Please complete the HazMat form.)

I Mixed Use Property ☐ Not mixed
10 ☐ Assembly use
20 ☐ Education use
33 ☐ Medical use
40 ☐ Residential use
51 ☐ Row of stores
53 ☐ Enclosed mall
58 ☐ Business & residential
59 ☐ Office use
60 ☐ Industrial use
63 ☐ Military use
65 ☐ Farm use
00 ☐ Other mixed use

J Property Use ☆ ☐ None

Structures
131 ☐ Church, place of worship
161 ☐ Restaurant or cafeteria
162 ☐ Bar/tavern or nightclub
213 ☐ Elementary school, kindergarten
215 ☐ High school, junior high
241 ☐ College, adult education
311 ☐ Nursing home
331 ☐ Hospital
341 ☐ Clinic, clinic-type infirmary
342 ☐ Doctor/dentist office
361 ☐ Prison or jail, not juvenile
419 ☐ 1- or 2-family dwelling
429 ☐ Multifamily dwelling
439 ☐ Rooming/boarding house
449 ☐ Commercial hotel or motel
459 ☐ Residential, board and care
464 ☐ Dormitory/barracks
519 ☐ Food and beverage sales
539 ☐ Household goods, sales, repairs
571 ☐ Gas or service station
579 ☐ Motor vehicle/boat sales/repairs
599 ☐ Business office
615 ☐ Electric-generating plant
629 ☐ Laboratory/science laboratory
700 ☐ Manufacturing plant
819 ☐ Livestock/poultry storage (barn)
882 ☐ Non-residential parking garage
891 ☐ Warehouse

Outside
124 ☐ Playground or park
655 ☐ Crops or orchard
669 ☐ Forest (timberland)
807 ☐ Outdoor storage area
919 ☐ Dump or sanitary landfill
931 ☐ Open land or field
936 ☐ Vacant lot
938 ☐ Graded/cared for plot of land
946 ☐ Lake, river, stream
951 ☐ Railroad right-of-way
960 ☐ Other street
961 ☐ Highway/divided highway
962 ☐ Residential street/driveway
981 ☐ Construction site
984 ☐ Industrial plant yard

Look up and enter a Property Use code and description only if you have NOT checked a Property Use box. ⇨ Property Use — Code
Property Use Description

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K1 Person/Entity Involved
Local Option

Business Name (if applicable) | Area Code | Phone Number

☐ Check this box if same address as incident Location (Section B). Then skip the three duplicate address lines.

Mr., Ms., Mrs. | First Name | MI | Last Name | Suffix

Number | Prefix | Street or Highway | Street Type | Suffix

Post Office Box | Apt./Suite/Room | City

State | ZIP Code

☐ **More people involved? Check this box and attach Supplemental Forms (NFIRS–1S) as necessary.**

K2 Owner
Local Option

☐ Same as person involved? Then check this box and skip the rest of this block.

Business Name (if applicable) | Area Code | Phone Number

☐ Check this box if same address as incident Location (Section B). Then skip the three duplicate address lines.

Mr., Ms., Mrs. | First Name | MI | Last Name | Suffix

Number | Prefix | Street or Highway | Street Type | Suffix

Post Office Box | Apt./Suite/Room | City

State | ZIP Code

L Remarks:
Local Option

Fire Module Required?

Check the box that applies and then complete the Fire Module based on Incident Type, as follows:

☐ Buildings 111	Complete Fire & Structure Modules
☐ Special structure 112	Complete Fire Module & Section I, Structure Module
☐ Confined 113–118	Basic Module Only
☐ Mobile property 120–123	Complete Fire & Structure Modules
☐ Vehicle 130–138	Complete Fire Module
☐ Vegetation 140–143	Complete Fire or Wildland Module
☐ Outside rubbish fire 150–155	Basic Module Only
☐ Special outside fire 160	Complete Fire or Wildland Module
☐ Special outside fire 161–163	Complete Fire Module
☐ Crop fire 170–173	Complete Fire or Wildland Module

ITEMS WITH A ☆ MUST ALWAYS BE COMPLETED!

☐ **More remarks? Check this box and attach Supplemental Forms (NFIRS–1S) as necessary.**

M Authorization

Officer in charge ID | Signature | Position or rank | Assignment | Month | Day | Year

Check box if same as Officer in charge. ☐

Member making report ID | Signature | Position or rank | Assignment | Month | Day | Year

A

FDID ☆ | State ☆ | Incident Date (MM DD YYYY) ☆ | Station | Incident Number ☆ | Exposure ☆

☐ Delete ☐ Change

NFIRS–2 Fire

B Property Details

B1 Estimated number of residential living units in building of origin *whether or not all units became involved* ☐ Not Residential

B2 Number of buildings involved ☐ Buildings not involved

B3 Acres burned (outside fires) ☐ None ☐ Less than one acre

C On-Site Materials or Products ☐ None

Complete if there were any significant amounts of commercial, industrial, energy, or agricultural products or materials on the property, *whether or not they became involved*

Enter up to three codes. Check one box for each code entered.

On-site material (1)

On-site material (2)

On-site material (3)

On-Site Materials Storage Use (for each material)

1 ☐ Bulk storage or warehousing
2 ☐ Processing or manufacturing
3 ☐ Packaged goods for sale
4 ☐ Repair or service
U ☐ Undetermined

D Ignition

D1 Area of fire origin ☆

D2 Heat source ☆

D3 Item first ignited ☆ 1 ☐ Check box if fire spread was confined to object of origin.

D4 Type of material first ignited — Required only if item first ignited code is 00 or <70

E1 Cause of Ignition ☆

☐ Check box if this is an exposure report. ⇨ Skip to Section G

1 ☐ Intentional
2 ☐ Unintentional
3 ☐ Failure of equipment or heat source
4 ☐ Act of nature
5 ☐ Cause under investigation
U ☐ Cause undetermined after investigation

E2 Factors Contributing to Ignition ☆ ☐ None

Factor contributing to ignition (1)

Factor contributing to ignition (2)

E3 Human Factors Contributing to Ignition ☆

Check all applicable boxes ☐ None

1 ☐ Asleep
2 ☐ Possibly impaired by alcohol or drugs
3 ☐ Unattended person
4 ☐ Possibly mentally disabled
5 ☐ Physically disabled
6 ☐ Multiple persons involved
7 ☐ Age was a factor

Estimated age of person involved

1 ☐ Male 2 ☐ Female

F1 Equipment Involved in Ignition

☐ None ⇨ If equipment was not involved, skip to Section G

Equipment involved

Brand

Model

Serial #

Year

F2 Equipment Power Source

Equipment Power Source

F3 Equipment Portability

1 ☐ Portable
2 ☐ Stationary

Portable equipment normally can be moved by one or two persons, is designed to be used in multiple locations, and requires no tools to install.

G Fire Suppression Factors ☐ None

Enter up to three codes.

Fire suppression factor (1)

Fire suppression factor (2)

Fire suppression factor (3)

H1 Mobile Property Involved ☐ None

1 ☐ Not involved in ignition, but burned
2 ☐ Involved in ignition, but did not burn
3 ☐ Involved in ignition and burned

H2 Mobile Property Type and Make

Mobile property type

Mobile property make

Mobile property model

Year

License Plate Number | State | VIN

Structure fire? Please be sure to complete the Structure Fire form (NFIRS–3).

Local Use

☐ Pre-Fire Plan Available

Some of the information presented in this report may be based upon reports from other agencies:

☐ Arson report attached
☐ Police report attached
☐ Coroner report attached
☐ Other reports attached

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Appendix C

Executive Summary of the NTSB Report on the Global Limo Fire near Wilmer, Texas, on 9/23/2005

The following is the executive summary from the NTSB report on the Global Limo motorcoach fire that occurred near Wilmer, Texas. The report itself can be found on the internet at http://www.ntsb.gov/publictn/2007/HAR0701.pdf.

Safety Board publications may also be purchased, by individual copy or by subscription, from the National Technical Information Service. To purchase this publication, order report number PB2007-916202 from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(800) 553-6847 or (703) 605-6000

Executive Summary

On September 23, 2005, a 1998 Motor Coach Industries, Inc. (MCI), 54-passenger motorcoach, operated by Global Limo Inc., of Pharr, Texas, was traveling northbound on Interstate 45 (I-45) near Wilmer, Texas. The motorcoach, en route from Bellaire to Dallas, Texas, as part of the evacuation in anticipation of Hurricane Rita, was carrying 44 assisted living facility residents and nursing staff. The trip had begun about 3:00 p.m. on September 22, 2005. Fifteen hours later, about 6:00 a.m. on the following day, a motorist noticed that the right-rear tire hub was glowing red and alerted the motorcoach driver, who stopped in the left traffic lane and then proceeded to the right shoulder of I-45 near milepost 269.5. The driver and nursing staff exited the motorcoach and observed flames emanating from the right-rear wheel well. As they initiated an evacuation of the motorcoach, with assistance from passersby, heavy smoke and fire quickly engulfed the entire vehicle. Twenty-three passengers were fatally injured. Of the 21 passengers who escaped, 2 were seriously injured and 19 received minor injuries; the motorcoach driver also received minor injuries.

The National Transportation Safety Board determines that the probable cause of the accident was insufficient lubrication in the right-side tag axle wheel bearing assembly of the motorcoach, resulting in increased temperatures and subsequent failed wheel bearings, which led to ignition of the tire and the catastrophic fire. Global Limo Inc. had failed to conduct proper vehicle maintenance, to do pre-trip inspections, and to complete post-trip driver vehicle inspection reports, thereby allowing the insufficient wheel bearing lubrication to go undetected. Contributing to the accident was the Federal Motor Carrier

Safety Administration's ineffective compliance review system, which resulted in inadequate safety oversight of passenger motor carriers. Contributing to the rapid propagation and severity of the fire and subsequent loss of life was the lack of motorcoach fire-retardant construction materials adjacent to the wheel well. Also contributing to the severity of the accident was the limited ability of passengers with special needs to evacuate the motorcoach.

The following safety issues were identified in this investigation:

- Vehicle fire reporting and inconsistent data within Federal accident databases,
- Federal Motor Carrier Safety Administration's ineffective compliance review program,
- Emergency egress from motorcoaches,
- Fire resistance of motorcoach materials and designs,
- Manufacturer maintenance information on wheel bearing components,
- Transportation of partially pressurized aluminum cylinders, and
- Emergency transportation of persons with special needs.

As a result of this accident investigation, the Safety Board makes recommendations to the Federal Motor Carrier Safety Administration, the National Highway Traffic Safety Administration, the Pipeline and Hazardous Materials Safety Administration, the Fraternal Order of Police, the International Association of Chiefs of Police, the International Association of Fire Chiefs, the International Association of Fire Fighters, the National Association of State EMS Officials, the National Sheriffs' Association, the National Volunteer Fire Council, Motor Coach Industries, Inc., and other motorcoach manufacturers, the United Motorcoach Association, and the American Bus Association. The Safety Board reiterates two recommendations to the U.S. Department of Transportation.

Appendix D

Mapping between Motorcoach Fire Key Analysis Fields and MMUCC Standard Data Elements

Table D-1: Preliminary Mapping between Motorcoach Fire Key Analysis Fields and MMUCC Standard Data Elements[47]

Key Analysis Field	Closest Matching Existing MMUCC Data Element		Proposed New MMUCC Data Element or Additional Attributes and Values for Existing Data Element	
	Identifier–Name	Definition	Name	Definition
Fire date	**C1 Crash Date and Time**	The date (year, month, and day) and time (00:00–23:59) at which the crash occurred		
State where fire occurred	**C3 Crash County**	The county or equivalent entity in which the crash occurred *(may include full State/county/city GSA locator code)*	**Crash State**	The FIPS identifier or GSA locator code of the State where the incident occurred
Fire origin location	**C6 First Harmful Event**	The first injury or damage-producing event that characterizes the crash type; *attribute for non-collision/fire or explosion*	***Attribute*: Suspected Fire Origin Location**	The area of the vehicle where reporting official estimated that fire originated; values include engine compartment, wheel well

Key Analysis Field	Closest Matching Existing MMUCC Data Element		Proposed New MMUCC Data Element or Additional Attributes and Values for Existing Data Element	
	Identifier–Name	**Definition**	**Name**	**Definition**
Fire ignition point	**C6 First Harmful Event**	Same as above	***Attribute*: Fire Ignition Point**	The specific vehicle system or component where ignition occurred
Number of direct injuries	**CD5 Number of Non-Fatally Injured Persons**	The total number of persons injured, excluding fatalities within 30 days of the crash	***Attribute* (for non-collision/ fire or explosion): Number of Non-Fatally Injured Directly from the Fire**	Same as CD5, excluding injuries due to response activities
Number of direct fatalities	**CD6 Number of Fatalities**	The total number of fatalities within 30 days of the crash (motorists and non-motorists) that resulted from injuries sustained as the result the crash	***Attribute* (for Non-Collision/ Fire or Explosion): Number of Fatally Injured Directly from the Fire**	Same as CD5, excluding fatalities due to response activities
Value of damaged property	**None**		**Property Damage**	Value of property loss in crash, excluding property outside the vehicle(s) involved
Vehicle model year/age	**V6 Motor Vehicle Model Year**	Year assigned to a motor vehicle by the manufacturer		
Vehicle Identification Number	**V1 Motor Vehicle Identification Number (VIN)**	A unique combination of alphanumerical or numerical characters assigned to a specific motor vehicle that is designated by the manufacturer		

Key Analysis Field	Closest Matching Existing MMUCC Data Element		Proposed New MMUCC Data Element or Additional Attributes and Values for Existing Data Element	
	Identifier–Name	**Definition**	**Name**	**Definition**
Vehicle make/manufacturer	**V5 Motor Vehicle Make**	The distinctive (coded) name applied to a group of motor vehicles by a manufacturer. *Attribute: Name Assigned by Motor Vehicle Manufacturer Using NCIC Standard*	**V5 Motor Vehicle Make**	Include additional values for bus manufacturers not in NCIC standard
Vehicle model name	**V7 Motor Vehicle Model**	Manufacturer-assigned code denoting a family of motor vehicles (within a make) that have a degree of similarity in construction, such as body, chassis, etc.		
Engine manufacturer	**None**		**Engine Manufacturer**	Name or DUNs code for engine manufacturer
Vehicles with identifiable failure detection and/or fire detection and suppression systems	**None**		**Equipped with failure or fire detection and suppression systems**	*Values: Yes/No*
No. of pre-fire roadside inspection(s) performed on motorcoach(es) in 2003 and later	**N/A**			
No. of pre-fire roadside inspections(s) performed on same-carrier motorcoach(es) in 2003 and later	**N/A**			
No. of pre-fire compliance review(s) conducted on carrier up to 2 years before fire	**N/A**			

Appendix E

ASTM Testing Standards for Flammability and Smoke Emission Characteristics of Transit Bus and Van Materials

Table E-1: Recommendations for Testing the Flammability and Smoke Emission Characteristics of Transit Bus and Van Materials 13

Category	Function of Material	Test Procedure	Performance Criteria
Seating	Cushion	ASTM* D-3675	$I_S \leq 25$
		ASTM E-662	D_S (1.5) ≤ 100; D_S (4.0) ≤ 200
	Frame	ASTM E-162	$I_S \leq 35$
		ASTM E-662	D_S (1.5) ≤ 100; D_S (4.0) ≤ 200
	Shroud	ASTM E-162	$I_S \leq 35$
		ASTM E-662	D_S (1.5) ≤ 100; D_S (4.0) ≤ 200
	Upholstery	FAR 25.853 (vertical)	Flame time ≤ 10 secs.; burn length ≤ 6 in.
		ASTM E-662	D_S (1.5) ≤ 100; D_S (4.0) ≤ 200
Panels	Wall	ASTM E-162	$I_S \leq 35$
		ASTM E-662	D_S (1.5) ≤ 100; D_S (4.0) ≤ 200
	Ceiling	ASTM E-162	$I_S \leq 35$
		ASTM E-662	D_S (1.5) ≤ 100; D_S (4.0) ≤ 200
	Partition	ASTM E-162	$I_S \leq 35$
		ASTM E-662	D_S (1.5) ≤ 100; D_S (4.0) ≤ 200
	Windscreen	ASTM E-162	$I_S \leq 35$
		ASTM E-662	D_S (1.5) ≤ 100; D_S (4.0) ≤ 200
	HVAC ducting	ASTM E-162	$I_S \leq 35$
		ASTM E-662	D_S (4.0) ≤ 100
	Light diffuser	ASTM E-162	$I_S \leq 100$
		ASTM E-662	D_S (1.5) ≤ 100; D_S (4.0) ≤ 200
Flooring	Wheel well and structural	ASTM E-119	Pass

Category	Function of Material	Test Procedure	Performance Criteria
	Carpeting	ASTM E-648	C.R.F. $\geq$ 0.5 w/cm^2
Insulation	Thermal	ASTM E-162	$I_S \leq 25$
		ASTM E-662	D_S (4.0) $\leq$ 100
	Acoustic	ASTM E-162	$I_S \leq 25$
		ASTM E-662	D_S (4.0) $\leq$ 100
Miscellaneous	Firewall	ASTM E-119	Pass
	Exterior shell	ASTM E-162	$I_S \leq 35$
		ASTM E-662	D_S (1.5) $\leq$ 100; D_S (4.0) $\leq$ 200

* ASTM International (originally knows as the American Society for Testing and Materials).

Appendix F

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Appendix G

Endnotes

[1] 2006 Motorcoach Census. R.L. Banks & Associates, Inc., for the American Bus Association. Available at http://www.buses.org/files/download/Motorcoach%20Census%20Update%202006%2009-21-20061.pdf.

[2] Nathan Associates, Inc. *Impacts of the Motorcoach Industry on Society and the Economy*. Technical report. Submitted to the American Bus Association Foundation, Washington, DC, January 2007. Available at http://www.buses.org/files/download/2006%20Impact%20of%20Motorcoaches.pdf

[3] The Nathan Associates report notes that many motorcoaches carry passengers who may be unable to evacuate a bus quickly because they are very young or elderly. In 2004, 27.1 percent of passengers were 55 years or older. Another 26.9 percent were student-aged. Some industry observers believe that lifting an exit window is difficult for some young, elderly, and disabled passengers.

[4] *2006 Motorcoach Census,* op. cit.

[5] Ferrone, Christopher. “Only you can prevent motorcoach fires.” *Bus Ride Magazine,* Aug. 2005; available at http://www.busride.com/Page.cfm/PageID/2303.

[6] Ahrens, Marty. *Vehicle Fires Involving Buses and School Buses.* Technical report. Quincy, MA: National Fire Protection Association, 2006. Available at http://www.nfpa.org/itemDetail.asp?categoryID=426&itemID=18432&URL=Research%20&%20Reports/Fire%20reports/Vehicles.

[7] Barber, W.F. *Technical Briefing: Bus Fires*. Washington, DC: Federal Motor Carrier Safety Administration, June 27, 2006.

[8] Accident Investigation Board of Finland. *Bus Fires in Finland during 2000.* Helsinki, 2000. Available at www.onnettomuustutkinta.fi/uploads/6hdieo2.pdf.

[9] For example, control panels, VCRs, GPS, and PA systems.

[10] According to R.L. Polk & Co. data, in December 2006 motorcoaches accounted for only 5.4 percent of buses on the road of the types included in the NFPA study.

[11] Crescenzo, Robert, Lancer Insurance. Report in *Bus Ride Magazine*, 2002.

[12] Barber, W.F. *Technical Briefing: Bus Fires*. op. cit.

[13] Daecher, Matthew. NTSB Public Hearing on Wilmer, TX Motorcoach Fire. TRAX Bus Fire Data. Presentation by Daecher Consulting Group, Aug. 8, 2006.

[14] Appendix E lists ASTM testing standards for flammability and smoke emission characteristics of transit bus and van materials, which may be applicable to motorcoach fire protection standards.

[15] Greyhound Lines, Inc., provided this publicly available material.

[16] http://www.fmcsa.dot.gov/rules-regulations/administration/fmcsr/fmcsrruletext.asp?chunkKey=090163348002397c.

[17] The terminology for the CSA 2010 behavioral measurement areas is Behavioral Analysis and Safety Improvement Categories (BASICs). The BASICs are Unsafe Driving, Fatigued Driving, Driver Fitness, Controlled Substances and Alcohol, Vehicle Maintenance, Improper Loading/Cargo Securement, and Crash Indicator.

[18] A summary of the Global Limo NTSB investigation appears in Appendix C.

[19] NY State document.

[20] One example is Adirondack Trailways in Hurley, NY; see Graham Dunnege, "Maintaining Your Fleet," *National Bus Trader,* April 2006, p. 32.

[21] Gann, Richard. "Next Generation Fire Suppression Technology Program: FY2004 Progress." National Institute of Standards and Technology, Gaithersburg, MD, 2005.

[22] http://www.transtats.bts.gov/Fields.asp?Table_ID=1045.

[23] U.S. Fire Administration (USFA), National Fire Data Center. Uses of NFIRS, Report No. FA171, 1997, p. 2. As of 2006, all States were reporting, but not the District of Columbia. For current State reporting status, see http://www.usfa.dhs.gov/fireservice/nfirs/status/index.shtm.

[24] NFIRS data collection sheets relevant to reporting vehicle fires are shown in Appendix B.

[25] Pre-1999 NFIRS data cannot easily be compared with later data due to field changes.

[26] U.S. Fire Administration (USFA) National Fire Incident Reporting System. Available at http://209.85.165.104/search?q=cache:U24E-Ry-PQIJ:www.usfa.dhs.gov/nfirs/+U.S.+Fire+Administration+(USFA)+National+Fire+Incident+Reporting+System&hl=en&ct=clnk&cd=1&gl=us. Accessed April 17, 2007.

[27] NFTA extracted NFIRS records for the years 1999–2004. Available at http://209.85.165.104/search?q=cache:laRwWjfaSGUJ:nfirs.fema.gov/+nfirs&hl=en&ct=clnk&cd=1&gl=us

[28]http://nfirs.fema.gov/jsps/nfirsdownload.jsp?url=/documentation/reference/NFIRS_Complete_Reference_Guide_2008.pdf.

[29] http://mcmiscatalog.fmcsa.dot.gov/beta/Catalogs&Documentation/documentation/Crashes/crash3.asp.

[30] Barber, W.F. *Technical Briefing: Bus Fires*. op. cit.

[31] Guariento, Alex.Greyhound Lines, Inc., letter to FMCSA and NHTSA, May 9, 2006, describing Greyhound's experiences and observations on motorcoach fires. Available at trb.org/publications/ctbssp/ctbssp_syn_2.pdf.

[32] Greyhound Lines, Inc., provided this publicly available material.

[33] Company data were not verified and were provided for summarization purposes only.

[34] Insurance data were not verified and were provided for summarization purposes only.

[35] *2006 Motorcoach Census*, op. cit

[36] FHWA. *Highway Statistics*, 2006 ed. Available at http://www.fhwa.dot.gov/policy/ohim/hs06/index.htm.

[37] Records that were derived from multiple sources are attributed to each of those sources. A complete listing for all States of reported fires by source appears in Table 22 of Appendix A.

[38] A complete listing for all State with specified values for key fields appears in Table 23 of Appendix A.

[39] A complete listing for all States of reported fires for the entire collection period (1995-2008), and fires, highway VMT, and the ratio of fires to VMT appears in Table 24 of Appendix A.

[40] Criteria for OOS violations are listed in the FMCSR and are also published in *North American Standard Out-of-Service Criteria* by CVSA.

[41] Conditional probability $P(A/B_1)$, where A is the occurrence of a fire, $B1$ is an inspection with an OOS order, and B_2 is an inspection without an OOS order is calculated according to the Bayesian formula:

$$P(A) = P(A \setminus B_1) * P(B_1) + P(A / B_2) * P(B_2); \_if \ \_P(B1) + P(B2) = 1.$$

[42] Bus crashes are taken from the *2007 National Summary Report*, available at http://www.ai.fmcsa.dot.gov/CrashProfile/n_overview.asp. Bus crashes and inspections are used because the MCMIS crash file does not distinguish between motorcoaches and other types of passenger carriers.

[43] Representatives from MCI, Prevost, and Van Hool were queried on model year availability of warning and suppression system options.

[44] This total excludes the 8 percent originating from turbochargers because engine fire detection would include those fires caused by turbocharger failure.

[45] This observation is tempered by the compliance data analysis, which indicates that increasing vehicle OOS rates may result in more frequent motorcoach fires over the next few years.

[46] See, for example, Blower, D., and A. Matteson, *Evaluation of the Motor Carrier Management Information System Crash File, Phase 1,* Report No. DTMC75-020R-0090, March 2003.

[47] Appendix D shows a preliminary mapping between a number of key analysis fields and data elements defined in the MMUCC standard. This mapping may be useful in expanding and ensuring data quality for future data reporting.

[48] Records that were derived from multiple sources are attributed to each of those sources.