

Motorcoach Fire Safety Analysis: The Causes, Frequency, and Severity of Motorcoach Fires in the United States

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Abstract:

The Federal Motor Carrier Safety Administration's (FMCSA) mission is to reduce crashes, injuries, and fatalities on our nation's roads involving motor vehicles, and to further its work the agency set out to identify ways to reduce motorcoach fire risk. FMCSA's Vehicle and Roadside Operations Division contracted the Volpe National Transportation Systems Center to perform a study to collect and analyze information from government, industry, and media sources on the causes, frequency, and severity of motorcoach fires in the United States, and to identify potential risk reduction measures. Volpe Center analysts only considered fires that were mechanical or electrical in origin, and that were neither the result of a collision nor arson. This study establishes an integrated incident database, allowing for a comprehensive analysis of risk trends and patterns, and provides recommendations that could result in fewer motorcoach fires and, in turn, safer roads and lives saved.

Volpe Center analysts created a database on reported motorcoach fire incidents between 1995 and 2008 as a basis for the study. The resulting database consists of 899 records from the sources cited below spanning the years 1995–2008, with the 2004–2006 data being the most complete. Analysts constructed the database to facilitate analysis by location of origin, point of ignition, geographic and vehicle characteristics, inspection and maintenance histories, vehicle damage, and human injuries and fatalities.

The data sources for this study included the U.S. Fire Administration's (USFA) National Fire Incident Reporting System (NFIRS), FMCSA's Motor Carrier Management Information System (MCMIS), the National Highway Traffic Safety Administration's (NHTSA) State Data System (SDS), and NHTSA's Fatality Analysis Reporting System (FARS). R.L. Polk and Co. provided summaries of motorcoach registrations and detailed characteristics data. Additional motorcoach fire records were compiled by two major carriers and two insurance firms. Volpe Center analysts used independent sources to verify that incidents were applicable, to address missing or unknown field values, and to derive non-reported elements.

Some of the key findings from the study include:

- 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. Together they comprise about 70 percent of reported fires.

- 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 model years 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 Motor Carrier Inspection and OOS criteria may not sufficiently identify all precursors of motorcoach fires.

These findings have important implications for reducing risk of motorcoach fires through improvements in data quality, inspection and enforcement, and vehicle and equipment design and training. With these improvements, research should continue efforts to identify critical inspection items associated with fire risk. Further recommendations include exploring the use of focused fire safety investigations and the development of wheel-well fire detection/suppression systems.

KEYWORDS: motorcoach, passenger carriers, fire safety, risk analysis, fire detection systems, fire suppression systems, passenger vehicle inspection, motorcoach maintenance, NFIRS, MCMIS

INTRODUCTION

As part of the Federal Motor Carrier Safety Administration's (FMCSA) mission to reduce motor-vehicle-related injuries and fatalities on our nation's roads, the agency set out to develop a profile of motorcoach fire risk and how it can be mitigated.

Federal agencies, industry, and the media have conducted research to shape a reliable, albeit general profile of bus fires, but motorcoach-specific fire data have not been so easily accessible. Neither a single, comprehensive, nationwide motorcoach fire database exists nor have other databases been designed to target this population. To expand the current body of research and lay the groundwork for such a database, FMCSA commissioned the Volpe National Transportation Systems Center (Volpe Center) to collect and analyze information from government, industry, and media sources on the causes, frequency, and severity of motorcoach fires and to identify potential risk reduction measures.

This study created an integrated Motorcoach Fire (MCF) database of reported fires between 1995 and 2008 as a basis for this profile. The database focused on spontaneous, for-hire motorcoach fires caused by electrical and mechanical failures. Fires caused by collisions with other vehicles and fixed objects were excluded from this study, as were those that resulted from passenger activity such as smoking or arson. The resulting MCF database consists of 899 records from the years 1995–2008, with the 2004–2006 data being the most complete. The database constructed facilitated analysis by location of origin, point of ignition, geographic and vehicle characteristics, inspection and maintenance histories, vehicle damage, and human injuries and fatalities.

The remainder of this paper presents the background information that formed the basis for this study, the development of the Volpe Center MCF database, and a discussion of key findings, including ways to prevent motorcoach fires and reduce their severity. The paper includes the following sections:

Background and Scope – outlines background information on motorcoach fires, including known causes, trends, and best practices that formed the basis for the study's data collection and compilation and analysis.

Data Collection and Compilation – summarizes the development of the MCF database, including a list of the data sources used and the methods for the collection, reduction, and validation of data.

Analysis – presents the analysis methodology and a discussion of the key findings.

Recommendations – provides direction for further development of data and countermeasures to reduce the risk of motorcoach fires.

BACKGROUND AND SCOPE

The following discussion presents an overview of the causes, frequency, and severity of motorcoach fires based on information obtained from seven recently published bus fire studies, reports, and interviews. For a complete, annotated list of these studies, consult the FMCSA project study report [1].

Overall, the literature on motorcoach fire risk cites a variety of common contributing factors to motorcoach fires, ranging from mechanical and electrical failures, overheating, combustible and non-retardant materials, to all of the demands placed on the driver. (For example, see [2, 3].) Engineering forensic studies indicate that the two most common ignition sources responsible for motorcoach fires are spark ignition and auto ignition. (For example, see [4].) Spark ignition can occur when a spark encounters the proper mixture of combustible material and air, whereas auto ignition can result when a combustible material heats to its auto ignition temperature. Motorcoaches contain a large variety of combustible materials, such as rubber, plastic, and fluids. These materials are typically located in the engine compartment, fuel system, bus interior, and wheel wells. For detailed catalogues of the

locations and conditions under which different ignition sources and combustible materials may coincide, refer to Table 1 and Table 2 [5].

The frequency of motorcoach fires in the U.S. has been harder to discern with confidence. The National Fire Prevention Association has estimated that the average frequency of motorcoach fires may be as high as six per day, but this figure includes transit buses, school buses, large vans, trackless trolleys, and motorcoaches [6]. Reliable estimates of motorcoach fire frequency do not exist for this study period because data collection organizations have not standardized the classification of motorcoach-only fires.

Whatever their actual frequency, the severity and consequences of motorcoach fires vary significantly, but can be disastrous. A motorcoach fire can consume a vehicle within 15 to 20 minutes, causing property damage ranging in cost from tens of thousands of dollars up to the replacement value of the bus – the average of which was estimated in 2008 to be \$450,000 [7]. Yet passenger injuries and fatalities due to fire are rare. In the vast majority of reported cases, passengers were able to evacuate the motorcoach safely, avoiding deaths and injuries. In spite of this fact, the Global Limo bus fire near Wilmer, TX in 2005 [8], which resulted in 23 fatalities and 15 injuries, stands out as an unprecedented example of the potential human toll of a motorcoach fire.

Recognized Countermeasures

The major stakeholders in commercial motor carrier safety are well-positioned to address important aspects of the motorcoach fire safety problem. 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 Commercial Vehicle Safety Alliance (CVSA), a nonprofit organization of State, Provincial, and Federal officials in the U.S., Canada, and Mexico. CVSA and other international organizations also provide a variety of educational materials and guidance for operators and drivers to minimize the fire risk on increasingly complex equipment. (For example, see [9, 10].) Carriers, manufacturers, and their industry associations often cooperate voluntarily in identifying solutions for safety-related problems and best practices for training carriers' staff. All of these stakeholders play a significant role in developing uniform standards and best practices for motorcoach fire safety.

Many different practices contribute to fire safety, from preventing fires through proper vehicle maintenance to safely evacuating passengers during an emergency. Types of practices frequently cited for their effectiveness in preventing, reducing the severity, and mitigating the consequences of motorcoach fires include: using fire-resistant materials to prevent the spread of fires from the point of ignition; installing automatic warning systems to detect equipment failures and fires; conducting pre-trip inspections to identify and repair any vehicle safety issues; and implementing safety management processes to provide maintenance staff and company inspectors with the knowledge and skills to identify and address motorcoach conditions that can lead to fires. (For example, see [11].)

DATA COLLECTION AND COMPILATION

Although credible, aggregate estimates of all types of bus fires exist, motorcoach-specific estimates are not easily accessible in State and Federal accident statistics, national fire databases, and general media sources. To improve and facilitate targeted analysis, the Volpe Center analysts created a MCF database comprised of motorcoach fire incidents from 1995–2008 as a basis for this study. The resulting MCF database consists of 899 records from the sources cited below spanning the years 1995–2008, with the 2004–2006 data being the most complete. Analysts constructed the database to facilitate analysis by location of origin, point of ignition, geographic and vehicle characteristics, inspection and maintenance histories, vehicle damage, and human injuries and fatalities.

The U.S. Fire Administration's National Fire Incident Reporting System (NFIRS) database and FMCSA's Motor Carrier Management Information System (MCMIS) database both served as primary

data sources for this study due to their breadth of motorcoach incident records. Additional data sources used include: the National Highway Traffic Safety Administration's (NHTSA) Fatality Analysis Reporting System (FARS); NHTSA's State Data System (SDS); NHTSA's vehicle defect database; the joint FMCSA and NHTSA bus fire analysis database; and State police accident reports, State DOT bulletins, and news reports. Analysts obtained vehicle mileage data from the Federal Highway Administration's highway statistics charts and motorcoach population and characteristics data from R.L. Polk and Co. Two major carriers and two insurance firms provided additional motorcoach fire records.

The Volpe MCF database was created through a multi-step process, which 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 State police accident reports; (4) filling in missing, unknown field values or unreported elements with the details available from the NFIRS "Remarks" field and police and media reports; (5) corroborating each vehicle and carrier represented in the data with inspection and review histories from FMCSA's MCMIS database; and (6) removing any Personally Identifiable Information from the resulting dataset. See Tables 9 and 10 in the full project study report [12] for a more detailed explanation of the data development process, the resulting numbers of incident records populated by data source, and the number of records missing values in key analysis fields.

The MCF database combines several data sources and therefore it inherits some of their limitations, including geographic and temporal skewing of data and, in some instances, issues with data completeness and quality. NFIRS provided the most extensive coverage and depth, but inherently lacks the precision of data on vehicle fires because it was structured for the reporting of fixed property fires. For example, the field values for identifying the vehicle as a motorcoach, i.e., Vehicle Identification Number (VIN), vehicle make, and vehicle model), are often conflicting, incomplete, or missing altogether, and there is no field for identifying the motor carrier. MCMIS, primarily a police accident reporting system, reliably identifies the motorcoach and its operator when there has been a collision. However, spontaneous fires or those attended to by fire departments only often go unreported in MCMIS even when they meet the 'crash' reporting criteria. Workarounds for overcoming some of these limitations were developed by matching common fields from multiple data sources and by using other reference sources. Nevertheless, the resulting coverage of applicable events and accuracy of key analysis fields were limited by the assumptions made in the process.

ANALYSIS

This study seeks to provide an informed basis for assessing the problem of motorcoach fires in the U.S. and for evaluating recommendations in terms of their preventive value and potential for reducing any consequences. Given the breadth of the incident records and related data on fires, carriers, and involved vehicles, the MCF database is suitable for such analyses.

For trend and causal analyses to be valid, data must be representative, accurate, and complete within estimated levels of confidence. This requires a determination of the minimum sample sizes and quality levels for each data source and entity. While such rigorous statistical analysis exceeds the scope of this study, Volpe analysts examined a subset of fields from the database, considered sufficiently populated to assess the relationships between various motorcoach fire risk factors. A variety of data sources contribute to these data fields. More than half of the 899 identified motorcoach fire records populate these data fields. However, nearly every field draws on a variety of data sources. No single record contains data in every field, and less than one-third of these records have specified values in six or more fields.

Considering these issues with data quality, the analysis uses the most complete data fields to focus on the following areas: incident identification, equipment characteristics, and fire severity. The most populated data fields include: data, State, VIN, vehicle make, model, year, engine manufacturer and

model, direct casualties, and property damage. Additional fields were derived to analyze fire origin, ignition points, and warning suppression systems.

Summary of Findings

Geographic Distribution

Seventy percent (627) of the records in the MCF database list the State in which the fire occurred. The most complete study period, 2004–2006, contains 15 States with the highest ratios of fire incident records relative to highway vehicle miles traveled (VMT). Eastern and Western regions each contain six of these records. The South follows with two records, and the Midwest with one record. For raw counts of motorcoach fire records by State, region, and highway VMT, see Table 12 and Table 13 in the complete project report [13].

Care must be taken in drawing conclusions regarding statewide or regional motorcoach fire risk from these distributions. An accurate portrait of State motorcoach fire risk must take a variety of additional factors into account. States with the highest fire incident record counts relative to VMT may reflect more thorough reporting standards and/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. These rates may also be skewed by the wide variability of motorcoach travel in proportion to applicable highway vehicle travel. For instance, Eastern States with greater population and route densities may incur more motorcoach VMT per highway than less populous States.

Frequency

Industry sources have estimated that motorcoach fires occur nationwide on at least a daily basis. However, the reported data compiled in the MCF database indicates a much lower rate. The most current and complete study period, 2004–2006, indicates about 160 reported motorcoach fires per year. Only 229 fires were reported from 1995–2003, resulting in an even lower annual average of 25. This lower rate reflects incomplete data for the earlier portion of the study period.

On the basis of current reporting, the MCF database shows no indication that the frequency of motorcoach fires is significantly increasing or decreasing. Recent annual averages support this finding. The years 2007–2008 show an average annual total of fire incident records less than 100; this number is comparable to that of the 2004–2006 average due to delays in incident reporting or verification by published reference sources. If this trend continues, 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.

However, 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. For instance, 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. Fires that occur on private property, in parking areas, or involve an OOS vehicle are also less likely to be publicly reported. It is understandable that fires that meet the towaway criteria (for reporting to MCMIS) but otherwise go unnoticed by the public would not be reported.

Even if reporting criteria could be enforced, the data compilation process outlined above still filters out an undetermined number of applicable fire incident records, such as those that do not have field values or reference data that accurately identify the involved vehicle as a motorcoach. The MCF database only provides a sample of verifiable incident records, not all reported incidents. Accordingly,

this study can only project that complete and accurate reporting by all sources would yield an average occurrence rate of at least 160 fires per year.

Severity

The average severity of motorcoach fires appears small compared to rare, disastrous incidents such as the Global Limo fire. Approximately 96 percent of the reported fires did not result in injuries or fatalities. Altogether, the data sources provided 28 fire records (3.6 percent) with values other than blank or zero for the injury and fatality fields. One of these was the Global Limo fire, which alone resulted in 15 injuries and 23 fatalities. Twenty-six fire records contained between one and three injuries (a total of 36 injuries) and no fatalities, and one fire record cited one fatality with no other injuries. Discounting the Global Limo fire and extrapolating this sample for all of the records in the database, one would expect to find 32 fire records, each citing between one and three injuries and fatalities, for a projected total of 42 injuries and fatalities.

Property damage proved similarly variable. NFIRS, one insurance company, and one carrier provided the 210 fire records with property damage estimates. 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 contains 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. For statistics on comparable damages from the applicable data sources, consult Table 11 in the project study report [14]. Total losses from those reported fires amount to about \$8.2 million.

Actual severity counts may be higher than the recorded values suggest, as they are often ambiguous or difficult to verify.

Fire Origin

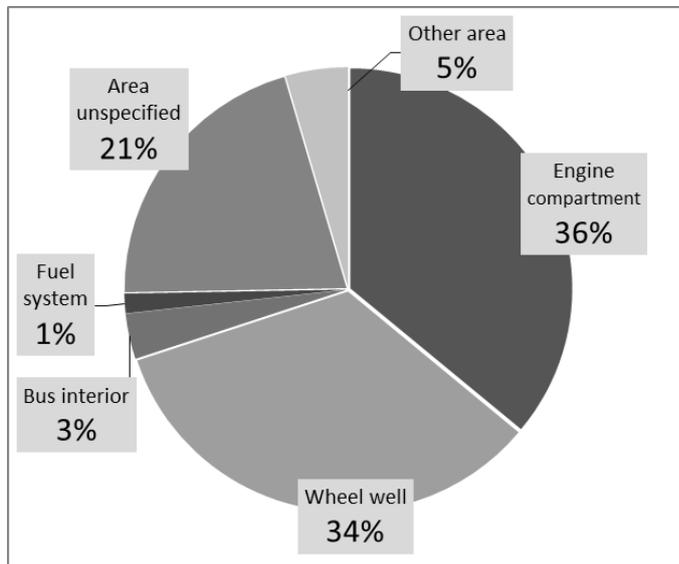


Figure 1 Percentage of motorcoach fire records by fire origin location, 2004–2006.

For the most complete study years, 2004–2006 (Figure 1), the MCF database shows that 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 originated in the engine or fuel system. However, due to the variation amongst data sources and the ambiguity of blank and zero values, there is no clear distribution of average damages per fire.

Specific Ignition Point

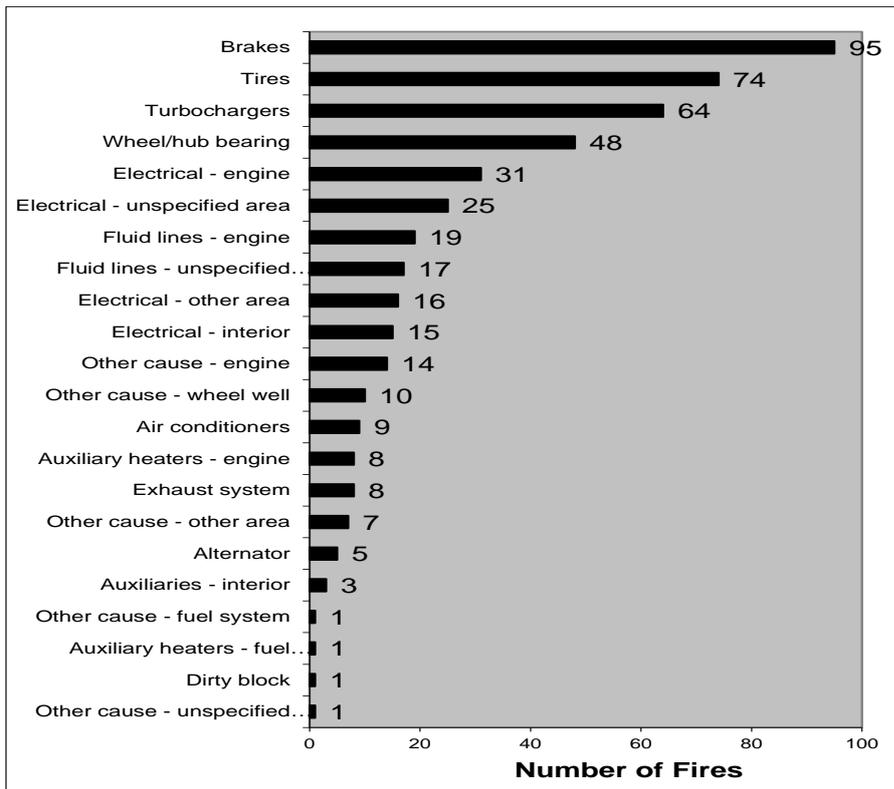


Figure 2 Reported ignition points, 1995–2008.

As shown above in Figure 2, the most frequently identified points of ignition 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. Only eight fire records, or 2 percent of the reported fires, specifically identified exhaust systems.

Model Year and Vehicle Age

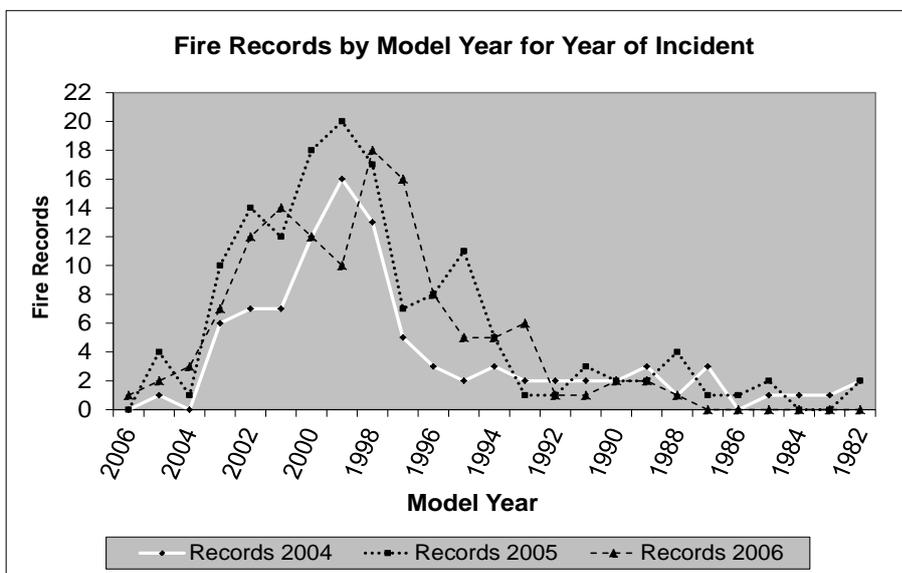


Figure 3 Fire records by model year, 2004–2006.

Figure 3 demonstrates that for the most complete study period, 2004–2006, more than 50 percent of the incident records involve motorcoaches with model years 1998–2002. These motorcoaches not only had a higher reported frequency of fire occurrences, but also a substantially higher reported incident rate relative to their peers than older motorcoaches. More powerful engines with higher fuel efficiency and lower emissions may have contributed to an increase in engine fires in 1998 and later-model-year engines.

Vehicle Make and Model

Volpe analysts calculated the rate of fire incidents for specific vehicle makes and models by dividing by 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 registration data 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.

Vehicle OOS Rate as Fire Risk Indicator

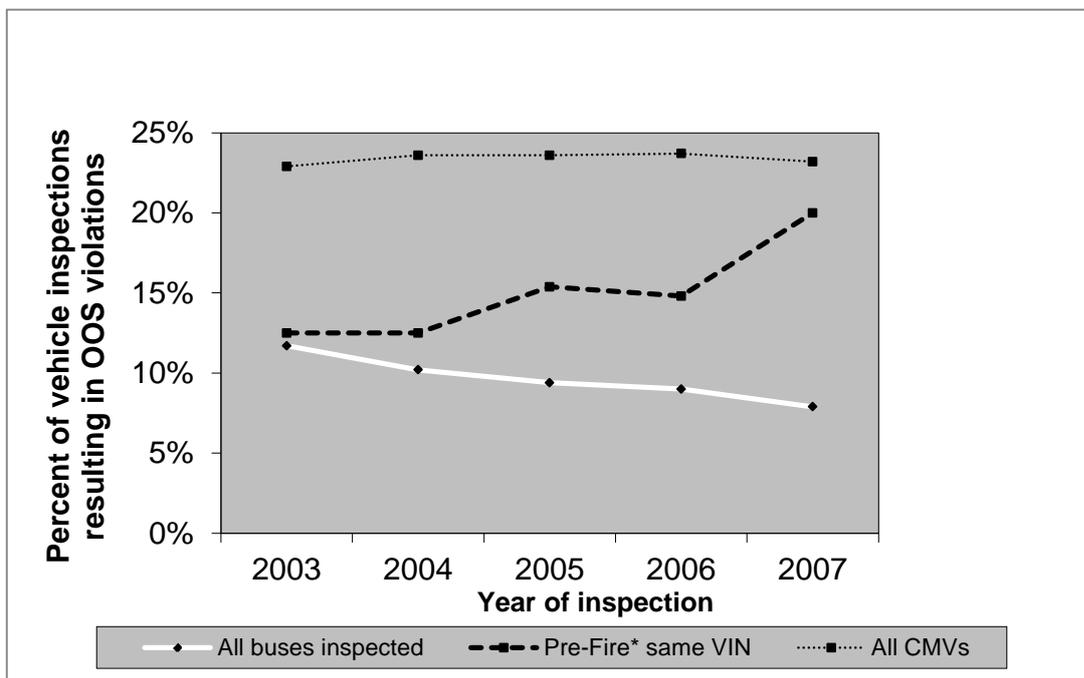


Figure 4 Motorcoach roadside inspection OOS rates in 2003–2007 as a percentage of inspections resulting in OOS violations.

Figure 4 above shows for the years 2003–2007 an increasing vehicle OOS rate for motorcoaches involved in a fire subsequent to an inspection. This trend may indicate vehicle maintenance and repair issues in those motorcoaches prone to fires. However, 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 point to the growing 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.

Carrier Safety Ratings as Fire Risk Indicator

Table 1 Compliance review (CR) 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

Table 1 above shows the safety ratings given to 161 carriers, identified in the MCF database over the course of 488 CRs conducted between 1990 and 2008. The majority of the carriers received satisfactory ratings. Relatively few carriers obtained less than satisfactory ratings (e.g., conditional or unsatisfactory), but those that did accounted for the majority of the Operational and Vehicle causal factors. However, 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.

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

In the past few years, there have been major additions to the North American Standard 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, have not yet been addressed as vehicle inspection items. In addition, 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.

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. The introduction of these systems in 2004 saw a potential for the major manufacturers to provide them for more than 10 percent of the entire U.S. motorcoach fleet by 2008. Although studies have projected that these failure detection systems will only marginally reduce injuries and fatalities, they could provide life-saving benefits for a rare catastrophe, such as the Wilmer bus fire.

RECOMMENDATIONS

Analysis of the literature and data on motorcoach fire risk supports recommendations to FMCSA, other agencies, and the passenger carrier industry in the areas of data quality and reporting; compliance inspection and review standards; vehicle inspection, repair, and maintenance; vehicle design, equipment development, and operational training; and directions for future study. At the level of data collection, standardization and collaboration with other data source organizations will be integral to developing and maintaining a robust dataset of motorcoach fire incidents. This analysis further suggests 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.

Research in the field should continue efforts to identify critical inspection items associated with fire risk. Recommended areas of exploration include the use of vehicle OOS rates as an indicator for focused fire safety investigations, the development of wheel-well fire detection/suppression systems, and methods to enhance fire-response equipment, fire safety procedures, and training requirements.

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