Risk of Commercial Truck Fires in the United States: An Exploratory Data Analysis

Jonathan Pearlman & Neil Meltzer

John A. Volpe National Transportation Systems Center, U.S. Department of Transportation Research and Innovative Technology Administration,

Cambridge, Massachusetts, United States

Title: Risk of Commercial Truck Fires in the United States: An Exploratory Data Analysis

Authors: Jonathan Pearlman and Neil R. Meltzer

Affiliation: John A. Volpe National Transportation Systems Center, U.S. Department of Transportation Research and Innovation Technology Administration, Cambridge, Massachusetts, United States

Abstract:

Large trucks are involved in only 8 percent of fatal crashes per year, but 17 percent of fatal fires. The scope of the current body of research is limited. Studies have treated truck fires generally as a subset of vehicle fires or in their own right on a smaller scale, confined to a limited pool of data. This study, commissioned by the Volpe National Transportation Systems Center (Volpe Center) for the Federal Motor Carrier Safety Administration (FMCSA), expands the current body of research to collect and analyze information from government, industry, and media sources on the magnitude, trends, and causes of truck fires in the United States and to identify potential risk-reduction measures.

This study succeeds FMCSA's *Motorcoach Fire Safety Analysis* (2009), furthering the agency's mission to improve commercial motor vehicle (CMV) safety on our nation's roads. Focusing on non-passenger CMVs with a Gross Vehicle Weight Rating (GVWR) of Class 4 and above, this study combines several government and industry data sources to investigate potential causal relationships across truck fire incidents, crash rates, and fatalities.

For this study, the Volpe Center developed several relatable databases of reported truck fire incidents between 2003 and 2008. These include records from the U.S. Fire Administration's National Fire Incident Reporting System (NFIRS), FMCSA's Motor Carrier Management Information System (MCMIS), and the National Highway Traffic Safety Administration's (NHTSA) Fatal Incident Reporting System (FARS) database. To obtain a preliminary representation of truck fire incidents, Volpe Center analysts matched data points across multiple datasets. The Volpe Center organized the resulting databases to facilitate analysis by geographic distribution, vehicle characteristics, fire origin, incident characteristics, and inspection and crash histories.

This study found that CMV fires are most common among GVWR Class 8 trucks with the frequency of truck fire fatalities six times greater than that of other motor vehicles. This figure is high, but when examined in conjunction with crash, inspection, and vehicle data, it offers insight into new areas of research. For example, analysis indicates that truck fires occur more often in the days following a crash. Trucks with compliance issues are also much more susceptible to fires. The truck is the striking vehicle in the majority of fatal fires. This portrait of truck fires may have significant implications for the future direction of truck fire safety.

KEYWORDS: CMV, commercial truck, motor carriers, fire safety, risk analysis, vehicle inspection, vehicle maintenance, NFIRS, MCMIS, TIFA, FARS, NFPA

INTRODUCTION

This paper documents the Federal Motor Carrier Safety Administration's (FMCSA) ongoing study conducted by the Volpe National Transportation Systems Center (Volpe Center) to assess the nature and severity of commercial truck fires in the United States. The agency has recognized that commercial truck fires have been under-researched even though they represent a significant threat to safety on our nation's roads. This study contributes to fulfilling that need and aims to further FMCSA's mission to improve highway safety by developing a comprehensive portrait of commercial truck fire trends using available data and analysis approaches. The insights gained through these findings and methodological approaches will not only inform existing recommendations for reducing the risk of commercial truck fires but will also aid in identifying new safety measures.

A preliminary data search reveals compelling comparisons of large truck (freight vehicles weighing greater than 10,000 lbs.) fire risk and crash risk of large trucks relative to all highway vehicles. As a well-studied phenomenon, crash risk provides a solid comparative baseline for fire risk. Aggregate data from published U.S. Department of Transportation (U.S. DOT) sources indicate that the rate of fatalities from large truck fires far outweighs their presence on our roads, to a greater degree than fatalities from crashes (see Table 1).

Table 1 2002-2007 annual average of vehicles registered and incident fatalities by vehicle type, vehicles registered fatalities from crashes, and fatalities from fires.

Vehicle type	Vehicles Registered (BTS)	Fatalities from Crashes (NHTSA)	Fatalities from Fires (NFPA)
All Highway Vehicles	248,059,515	42,639	441
Large Trucks	9,142,425	5,038	68
% Large Trucks / All Highway Vehicles	3.7	11.8	15.4

Sources: Bureau of Transportation Statistics (BTS) [1]; National Highway Traffic Safety Administration (NHTSA) [2]; National Fire Prevention Association (NFPA) [3]

On average, in 2003–2007, large trucks only accounted for 3.7 percent of all highway vehicles registered. Yet out of this pool of highway vehicles, they represented 11.8 percent of all fatal crashes, and, according to the National Fire Prevention Association (NFPA), an even more disproportionate 15.4 percent of fatal fires. The rate of fatal commercial truck fires is nearly four times the percentage of commercial trucks registered. These figures demonstrate that despite relatively low numbers, fire incidents involving large trucks pose a significant safety risk on the nation's highways, a proportionally greater risk than crash incidents without fire.

Since the scope of this study is limited to commercial trucks, a major challenge was extracting data involving only those trucks operating commercially. Some vehicles of Gross Vehicle Weight Rating (GVWR) Class 3 (10,001-14,000 lbs.) do not operate commercially, and are difficult to distinguish in the available datasets. Therefore, this paper focuses on known commercial trucks defined as GVWR Class 4-8 vehicles. In addition, Volpe Center analysts drew on a larger range of data sources for this study than were previously used in the *Motorcoach Fire Safety Analysis* [4] and the *Preliminary CMV Fire Analysis* [5] to explore a variety of topics on the risk of commercial truck fires. These topics address (a) the magnitude and severity of commercial truck fires between 2003–2008; (b) the characteristics that carriers, drivers, and vehicles involved in fire incidents may share; and (c) the contributing factors behind crash and non-crash fires, and fatal and non-fatal fires.

The remainder of this paper discusses data sources used for the study, approaches used to refine the data, results from analysis of key topics, and recommendations for enhancing this research.

DATA SOURCES AND DATA DEVELOPMENT

Establishing a national database on reported fire incidents has proven a difficult task for many researchers. For example, from 1996–1998 General Motors (GM) sponsored a series of analyses using government-maintained field collision data files, concluding that "existing sources contain insufficient information to satisfactorily understand the causes of motor vehicle fires" [6]. For the *Motorcoach Fire Analysis* [4] study, Volpe researchers were confounded by many of the same limitations cited by GM, but were able to fill in the gaps with other sources of information because of the publicity generated by a relatively small number of 'newsworthy' motorcoach fire incidents. This commercial truck fire study relied on primary field sources supplemented by a number of secondary sources to identify and verify the relevant incidents, and attributed values for the entities related to those incidents. These data sources are described below.

Primary Data Sources

The National Fire Incident Reporting System

The National Fire Incident Reporting System (NFIRS) is a nationwide database managed by the National Fire Data Center (NFDC) within the U.S. Department of Homeland Security, the Federal Emergency Management Agency, and the U.S. Fire Administration. NFIRS tracks and records data about all fire station-reported fires in the U.S. This includes structural fires in addition to the vehicular fires of interest to this study. NFIRS also provided a remarks field for select fire records, which may provide additional specifics about the fire record. NFDC originally designed this database as a tool to aid U.S. fire departments in the development of uniform fire reporting and data analysis practices.

Motor Carrier Management Information System

The Motor Carrier Management Information System (MCMIS) is a database administered by FMCSA, which stores commercial motor vehicle (CMV) census data and historical crash, inspection, and compliance review records. MCMIS contains census data on commercial motor carriers, including the type, the number of drivers, and number of power units.

Trucks Involved in Fatal Accidents

Trucks Involved in Fatal Accidents (TIFA) from the University of Michigan's Transportation Research Institute is a database that expands on National Highway Traffic Safety Administration's (NHTSA's) Fatal Accident Reporting System (FARS). FARS provides nationwide census data regarding fatal injuries from motor vehicle traffic crashes. TIFA supplements FARS medium and heavy truck records by including interviews with first responders, such as personnel from fire, police departments, and the admitting hospital. A typical TIFA entry contains basic information describing the incident, the people, and vehicles involved, and the vehicle damage and fatal injuries sustained by all parties.

Supplemental Data Sources

U.S. Vehicle Fire Trends and Patterns (National Fire Protection Association)

"U.S. Vehicle Fire Trends and Patterns" [7] is a periodic research report containing updated summary statistics on fire incidents involving transportation vehicles of all modes as well as more detailed statistics on highway vehicle fires. This report tabulates counts of incidents by year and distributions by vehicle types and variables representing contributing and occurrence factors. These numbers are total estimates for the U.S. based on NFIRS data and the NFPA's annual survey of fire departments.

Large Truck Crash Causation Study

The Large Truck Crash Causation Study [8], developed jointly by FMCSA and NHTSA, created a highly detailed study of a small number of CMV crashes. The study draws on a nationally representative sample of crashes involving CMV with GVWR 10,001+ pounds, and that resulted in at least one fatality or injury.

Vehicle Registration Data (R.L. Polk and Company)

R.L. Polk and Company is a private data collection and reporting firm, specializing in a wide range of automotive and commercial vehicle data. Specifically, its dataset contains directly applicable data on the vehicle population by GVWR, model, model year, and manufacturer. These figures provide a measure of exposure/normalization for CMV fires. These records allow stratification by vehicle make, model, and year.

FHWA Highway Statistics

The Federal Highway Administration's *Highway Statistics* [9] series consists of annual reports with analyzed statistical information on motor fuel, motor vehicle registrations, driver licenses, highway user taxation, highway mileage, travel, and highway finance.

Data Development

Several of the primary datasets for this research required significant refinement in the Oracle database prior to analysis. This development process pared the data down to only the records relevant for commercial truck research. This research focused on fires from the appropriate time period, from known large truck types, and trucks used by for-hire trucking companies and private commercial carriers. To that end, records were restricted by the analysis period (2003–2008), vehicle size (GVWR Class 4-8), and known CMV make/model. To the extent possible duplicate records were also eliminated from consideration.

TIFA and MCMIS required little additional development to identify applicable records. Out of all the primary data sets, NFIRS required the most involved refinement process, reducing the NFIRS dataset from 91,401 to a final count of 32,747 fires for analysis. The most time-consuming step involved identifying vehicle makes and models (a) translated from Vehicle Identification Numbers (VIN), and (b) identified by the firefighter at the scene. VINs and vehicle models were extrapolated in cases where the field value was unknown, a process that identified several thousand additional fire records suitable for analysis in this study.

ANALYSIS

Overall Magnitude and Trends

Over the study period, the risks associated with large commercial truck fires were significant when compared to other components of highway vehicle safety risk.

Table 2 shows that commercial trucks pose a significant fire safety risk on the nation's highways, disproportionally higher than commercial truck crash risk. Large commercial trucks account for about 7,000 fires annually, but less than 3 percent of fires involving all highway vehicles. These totals are less than would be predicted by the proportion of crashes and other measures of exposure. However, fatal fires involving commercial trucks represent 17 percent of all fatal highway fire incidents, and more than twice the proportion of all fatal crash incidents.

Table 2 Comparison of crashes and fires for all motor vehicles and commercial trucks.

	2003−2008 Annual Averages					
	Number of Vehicles Registered (Thousands)	**VMT* (Billions)**	**Number of Crashes**	**Number of Fatal Crashes**	**Number of Fires**	**Number of Fatal Fires**
All Highway Vehicles	246,478[a]	2,977[a]	10,709,000[c]	57,015[a]	267,600[b]	1,666[a]
Commercial Trucks	8,544[c]	223[c]	416,000[d]	4,551[e]	6,917[f]	284[e]
Percentage Involving Commercial Trucks	**3.5%**	**7.5%**	**3.9%**	**8.0%**	**2.6%**	**17.0%**

*Vehicle Miles Traveled (VMT); Sources: (a) FARS; (b) *U.S. Vehicles Fire Trends and Patterns*; (c) BTS; (d) MCMIS (e) TIFA; (f) Estimates from data development

Gross Vehicle Weight

Class 8 vehicles are involved in more fires and more fatal fires than any other class of vehicles greater than 14,000 lbs. GVWR. They also are involved in over twice the rate of fatal fires of any other weight class.

Table 3 presents the number and rates of vehicle fires and fatal fires by GVWR from 2003–2008 using data from the NFIRS and the TIFA databases.

Table 3 Fires and fatal fires by GVWR class from 2003–2008.

GVWR Class	GVWR Weight Range	Number of Fire Incidents[a]	Fires per Billion Miles Traveled (VMT)[c]	Number of Fatal Fire Incidents[b]	Fires per Billion Miles Traveled (VMT)[c]
4	14,001-16,000 lbs.	1,810	19	12	0.13
5	16,001-19,500 lbs.	950	21	14	0.31
6	19,501-26,000 lbs.	3,679	33	39	0.35
7	26,001-33,000 lbs.	3,335	27	81	0.66
8	33,000 lbs. and over	29,849	32	1560	1.69
Total	14,001 lbs. and over	39,624	31	1706	1.33

Sources: (a) *U.S. Vehicles Fire Trends and Patterns*; (b) TIFA; (c) VMT based on 2002 Vehicles in Use Survey [10]

As Table 2 shows, 75 percent of truck fires involve Class 8 vehicles, 29,849 Class 8 vehicles versus 39,624 total vehicles). Fatal fires are almost exclusively Class 8, with over 90 percent involving Class 8 vehicles.

Class 8 vehicles are also involved in a high rate of fire (fires per billion VMT) relative to most other weight classes. Class 6 and Class 8 trucks have the highest rates of fire per billion VMT, while Class 4 and Class 5 trucks have the lowest rates of fire. This proportion is even greater for fatal fires, where Class 8 vehicles have 2 to 5 times the rates of fire than any other weight class.

In summary, Class 8 vehicles are involved in more fire and fatal fire incidents than any other class of vehicles. They also are involved in over twice the rate of fatal fires per VMT of any other weight class. The largest and heaviest vehicles appear most vulnerable to frequent and serious fires.

Vehicle Age

Newer trucks encounter higher rates of fires and fatal fires per vehicle than trucks 5 years or older.

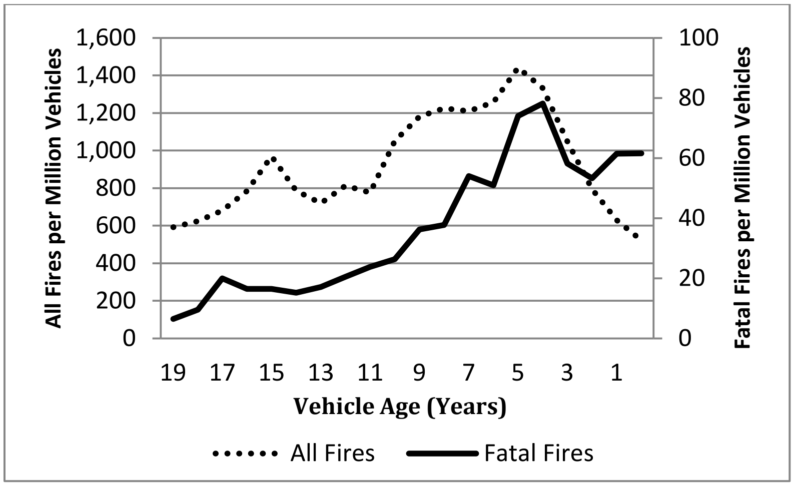

Figure 1 Fires and fatal fires by vehicle age, 2003–2008.

Generally, a higher incidence of fires and fatal fires exists among newer vehicles (up to 4- and 5-year-old vehicles), respectively. This trend may be due to a carrier's higher usage, and the corresponding higher exposure of its newer vehicles. However, while the newest vehicles have the highest rate of fatal fires, they have lower rates of non-fatal fires. The effectiveness of advanced electronic safety systems on the very newest model years in this study may prevent smaller fires but may not provide timely notice of or protection from, more serious fires. The relationships between recent model year commercial trucks' susceptibility to fires and fatal fires in particular warrant further study.

Driver Age

Proportionally, younger truck drivers are more likely to be involved in fires than older drivers, whereas the opposite is true for fatal fires.

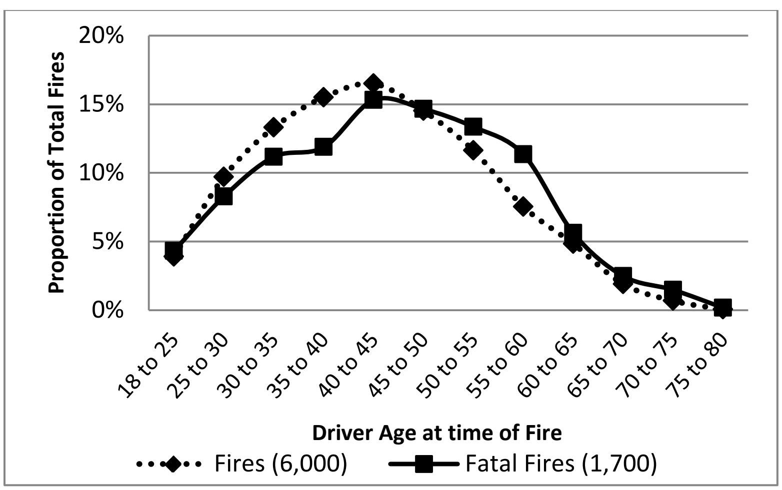

Figure 2 Driver age at time of fire by proportion of total fires, 2003–2008.

Each point in the graph represents the proportion of total fires involving drivers in its age bracket. For example, the left-most square indicates that 4.3 percent of fatal fires involved drivers aged 18-25, the second that 8.3 percent of fatal fires involved drivers aged 26-30, etc. Accordingly, the area under each curve is 100 percent, representing all fires and fatal fires with meaningful driver age information.

Younger drivers are proportionally more likely to be involved in fire incidents than older drivers, but older drivers are more likely to be involved in fatal fires. However, no similar such dichotomy was found with crashes and fatal crashes. This finding may reflect the inexperience of younger drivers as well as older drivers' relative physical or medical limitations. On the other hand, this may be a byproduct of older drivers being assigned, by virtue of their experience, to the riskiest operations. The observation that younger fleet drivers are often given older equipment (less "seniority") could also contribute to the results.

Results may also reflect age-related biases in the data source. The driver age data presented in this analysis were obtained by matching NFIRS records to corresponding FMCSA inspection records. Only records with driver age data were used in this analysis. This may over-represent certain classes of drivers. Long-haul carriers, for example, are subject to a higher proportion of FMCSA inspection, so may be over-represented in these results. If long-haul drivers tend to be younger, that could explain these results, as TIFA fatal fire records were not subject to the same matching with MCMIS.

Likelihood of a Fire Following a Crash

A commercial truck fire is more than twice as likely to occur within the first 100 days following a crash than would be expected if no crash had occurred.

The analysis team developed a hypothesis to explore whether commercial trucks are more susceptible to fire following a crash. To investigate this question, each of the 32,747 NFIRS fire records was matched by VIN and plate/state combination to MCMIS to determine if that vehicle crashed in the 1,000 days prior to the fire. This resulted in 730 matches, which were grouped by time between crash and fire in 25-day increments. These findings are displayed in Figure 3, below.

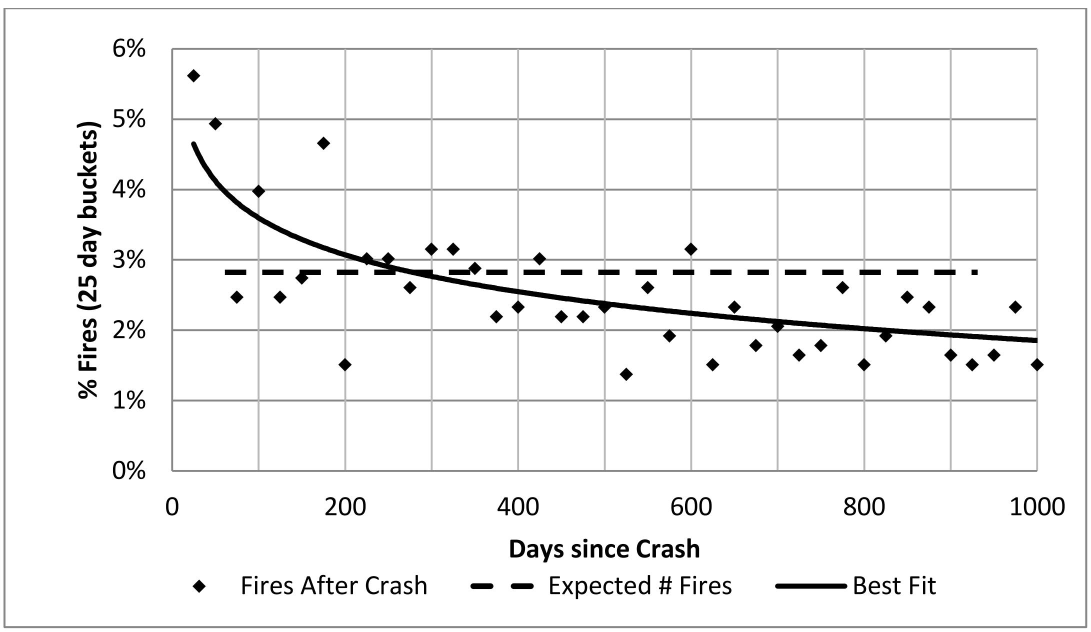

Figure 3 Number of days since crash by fire proportion, 2003–2008.

Each diamond in the graph represents the proportion of the 730 fire-crash matches that occur within that 25-day period, with the sum total adding to 100 percent. Thus the upper left diamond represents the 5.6

percent of fires that occur within 25 days of a crash, the next represents that 4.9 percent of the fires occur from 26-50 days following a crash, etc. The solid line corresponds to a best fit for these points.

The dashed line in the graph represents the expected distribution if the fires were uncorrelated with crashes. As there are 40 data points, an even distribution of 2.5 percent of fires per period would be the expected result. Note that this result presumes that no vehicle catches fire more than once in the analysis period. As repeated vehicle fires were extremely rare in the dataset, this assumption appears quite reasonable.

As the graph demonstrates, fires occur more frequently immediately following a crash. In fact, the rate of fire occurrence is at or above the expected flat level (2.5 percent) until 200 days after the crash. The trend-lines show an even more pronounced effect, with the solid line consistently above the flat level until 450 days after the crash. Put simply, a commercial truck fire is much more likely to occur in the period following a crash. In the first 100 days, that vehicle is more than twice as likely to be involved in a fire (and 1.5 times as likely in the first 200 days) as would be expected if no crash had occurred.

These results can be explained in a number of ways. First, vehicles in a crash can sustain unrepaired or improperly repaired damage. This damage may increase the fire risk when that vehicle resumes operation.

Second, high rates of crash and fire may both be due to another variable, such as high truck usage. Vehicles that cover high mileage, such as over-the-road trucking firms that employ team drivers, may be more susceptible to both crash and fire due to high levels of exposure. If high utilization carriers are overly represented in this dataset, this would lead to the results seen in the graph.

Striking versus Struck

Commercial trucks are the striking vehicle in over 50 percent of multi-vehicle fatal fires in which they are involved.

Vehicle fault encompasses a range of factors from unsafe driving behaviors to the basic mechanics of collisions. This portion of the analysis focuses on the striking versus struck component of vehicle fault based on whether the vehicle was labeled ‘striking’ or ‘struck’ in TIFA. Comparable data on crash roles were only available from TIFA, so it was the sole dataset used in this analysis. Table 4 compares commercial truck involvement in multi-vehicle fatal fires and multi-vehicle fatal crashes to approximate accident fault. Single vehicle accidents usually result in a unilateral determination of fault, and were thus excluded from this analysis. The vehicle role field also contains information on non-collisions and collisions; however, these data fields were excluded from this analysis because no clear distinction could be made between the striking and struck roles.

Table 4 Commercial truck involvement in multi-vehicle fatal crashes and multi-vehicle fatal fires, 2003–2008.

Commercial Truck Crash Role	Multi-Vehicle Fatal **Crashes**	Multi-Vehicle Fatal **Fires**
Striking	11,249	676
Struck	12,545	513
Striking %	47%	57%

Source: TIFA

As Table 4 demonstrates, commercial trucks are the striking vehicle in 47 percent of fatal **crashes**, which is 10 percent less than the proportion for fatal **fires** (57 percent). When vehicle role is accepted as a reasonable proxy for fault, this suggests that commercial trucks are at fault in a higher proportion of fatal fires. This discrepancy is even more apparent when compared with recent literature estimating crash fault. The *Large Truck Crash Causation Study* [8] specifically investigated crash fault from injury and fatal accidents and found truck drivers to be at fault in 28 percent of such crashes. Several State-funded studies found similar rates for crashes such as those from California (25 percent) and Florida (31 percent), as presented in FMCSA's webinar "Large Truck Crash Misconceptions," held in Boston, MA, April 5, 2011 [11]. These studies further support the finding that truck drivers are much more likely to be in the striking vehicle than a struck vehicle during a fatal fire.

Correlation to Safety Regulation Compliance

Motor carriers with poor Vehicle Maintenance BASIC percentiles are more likely to be involved in fires.

The Vehicle Maintenance Behavior Analysis and Safety Improvement Category (BASIC) is one of seven safety categories that FMCSA uses to group its Safety Measurement System (SMS) data, now part of the Compliance, Safety, and Accountability (CSA) program. The percentiles associated with the BASICs range from 0 to 100; the higher the percentile, the lower a motor carrier's compliance with the Federal Motor Carrier Safety Regulations. This analysis focuses on the Vehicle Maintenance BASIC in particular because of the strong correlation found between poor performance in this BASIC and motorcoach fires in the *Motorcoach Fire Safety Analysis* study.

Figure 4 shows the correlation between carriers' rate of fires and those carriers' Vehicle Maintenance BASIC percentile.

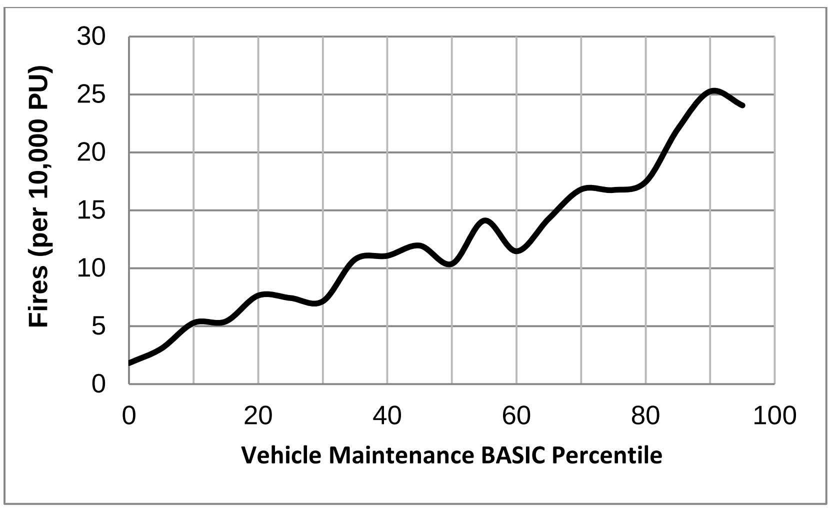

Figure 4 Fires (per 10,000 power units) by Vehicle Maintenance BASIC percentile.
Sources: fires; NFIRS; Vehicle Maintenance BASIC percentile; SMS

As shown in the figure above, the higher a motor carrier's percentile in the Vehicle Maintenance BASIC, the higher that carrier's rate of fire involvement. This means that carriers that have vehicles with the most vehicle-related safety issues as identified through vehicle roadside inspections are also involved in the most fires. Carriers with the lowest levels of compliance have five times the rate of fires (25 fires per 10,000 PU) as vehicles that are the most compliant (under 5 fires per 10,000 PU).

The analysis of compliance data indicates that a carrier's low CSA Vehicle Maintenance BASIC percentile is associated with greater fire risk for carriers and the vehicles they operate. This suggests that investigations of these carriers and inspections of their vehicles be expanded to target the discovery of fire-precursor conditions and to encourage fire preventive and mitigating practices.

RECOMMENDATIONS FOR FURTHER RESEARCH

The findings presented reflect the depth of research possible with available datasets. A closer look at each analysis shows the potential for data improvements. These data could take the form of a more complete census of CMV fires and/or additional granularity and precision in record detail. These details will in turn provide a more complete picture and less potential for bias, respectively.

Stronger vehicle identification data would significantly improve the data refinement process, for one. Many NFIRS fire records could not be identified as CMV, and were therefore preemptively excluded.

Additionally, many of the results in this paper reflect underlying differences in driver or carrier behavior, a topic out of scope for this paper. For example, in the case of fire rates by vehicle age or driver age, owners of newer vehicles and/or younger drivers may drive a different distribution of routes. Data on the relationship between these variables and carrier business model, number of hours driven per day, and similar variables could all further explain these differences.

Correlation of fires to future crash could also have a behavioral link that could be further explored with more detailed behavior-level data. Business model and driving patterns may identify classes of drivers who are at higher risk of both crash and fire due to high on-road exposure (e.g., the high hours of team driving operations). These hypotheses all deserve further exploration with more granular behavioral data.

The ‘striking/struck’ analysis could also be significantly improved. This could involve partnering with large carriers to harness their own more extensive datasets, focusing research more on the frequency / likelihood of reporting for parked vehicle fires and crashes. Also, directly accessing data from police accident reports will provide a direct measure of ‘fault.’

Finally, the fire rates presented in this paper could also be significantly refined with stronger normalization data. The reason for using exposure data is to accurately reflect true on-road risk. Higher quality VMT or vehicles-in-operation information, especially captured on an individual -truck basis, would provide a more solid grounding for determining the fire rates. Taken together, these examples point to data improvement as an essential step towards understanding, preventing, and mitigating the consequences of future CMV fires.

REFERENCE LIST

1. U.S. DOT Research and Innovative Technology Administration (RITA) Bureau of Transportation Statistics (BTS), National Transportation Statistics, 2011 Table 1-11, 2012. Available at http://www.bts.gov/publications/national_transportation_statistics/pdf/entire.pdf.
2. U.S. DOT National Highway Traffic Safety Administration, *Traffic Safety Facts*, data from 2003, 2004, 2005, 2006, 2007. Available at http://www-nrd.nhtsa.dot.gov/CATS/listpublications.aspx?Id=E&ShowBy=DocType.
3. Ahrens, M., *U.S. Vehicle Fire Trends and Patterns*, National Fire Protection Association (NFPA), June 2010. Available at http://www.nfpa.org/assets/files/pdf/vehicleexecsum.pdf.
4. Meltzer, N., Ayers G., and Truong, M., *Motorcoach Fire Safety Analysis*, prepared by U.S. DOT Volpe National Transportation Systems Center for the Federal Motor Carrier Safety Administration, July 2009. Available at http://www.fmcsa.dot.gov/facts-research/research-technology/analysis/Motorcoach-Fire-Study.pdf.
5. U.S. DOT Research and Innovative Technology Administration (RITA) Volpe National Transportation Systems Center, *Commercial Motor Vehicle Fire Safety Analysis Phase 1: Preliminary Analysis Results*, August 2010.

6. Lavelle. J., Kononen D., Nelander J., *Field Data Improvements for Fire Safety Research*, General Motors Corporation, Proceedings of the 16th International Technical Conference on the Enhanced Safety of Vehicles (ESV), June 1998.
7. Ahrens, M. op. cit.
8. U.S. DOT Federal Motor Carrier Safety Administration and National Highway Traffic Safety Administration, *Large Truck Crash Causation Study*, *2007.* See study website at http://ai.fmcsa.dot.gov/ltccs/default.asp**.**
9. U.S. DOT Federal Highway Administration, *Highway Statistics 2010,* Available at http://www.fhwa.dot.gov/policyinformation/statistics.cfm.
10. U.S. Census Bureau, *Vehicles in Use Survey*, *2002.* Available at http://www.census.gov/svsd/www/vius/products.html.
11. Craft, R. U.S. DOT Federal Motor Carrier Safety Administration Office of Analysis, Research and Technology, Large Truck Crash Misconceptions, webinar transcript, April 5, 2011. Available at http://www.fmcsa.dot.gov/facts-research/media/webinar-11-04-05-transcript.pdf.