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16. Abstract

The objective of this research is to identify the issues that contribute most to commercial motor vehicle crashes, fatalities, and injuries in Michigan through analysis of available data, and to identify strategies to help reduce these crashes and their consequences. Data from 2001-2005 were used, and included the Michigan vehicle crash files, Trucks Involved in Fatal Accidents file, and Motor Carrier Management Information System Inspection and Carrier files. The Michigan FACT file was also used. Harm was measured by overall CMV crash costs. Angle, rear-end, and head-on crashes were found to contribute most to overall CMV crash costs. Analysis of vehicle condition and crash risk found brake defects to be associated with fatal CMV rear-end, head-on, and angle collisions, and lighting defects to be associated with fatal rear-end crashes where the CMV was struck. Analysis of CMV inspection records shows that brake and lighting system violations are the most frequent violations. The average number of violations is highest for small fleets. The inability to stop in assured distance, (i.e., following too closely) is the CMV driver hazardous action that contributes most to overall CMV costs. Strategies proposed to address these issues include enforcement, preventive maintenance programs, training, consultation, and other help to fleet safety managers, incentives for deployment of advanced in-vehicle technology, and public information and education programs to "share the road."

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Strategies to Reduce CMV–Involved Crashes, Fatalities and Injuries in Michigan

Executive Summary

Objective

In light of its mission *to improve truck safety by providing Michigan's trucking industry and citizens of Michigan with effective educational programs, and by addressing significant truck safety issues*, the Michigan Truck Safety Commission (MTSC) has asked the University of Michigan Transportation Research Institute (UMTRI) to identify key issues associated with CMV-involved crashes, injuries, and fatalities through the analysis of available data, and to propose practical and feasible strategies and solutions consistent with the four E's of traffic safety - *Enforcement, Education, Engineering, and Emergency Medical Services*.

Data and Methods

UMTRI undertook this task by analyzing crash data from the State of Michigan from 2001-2005, the Trucks in Fatal Accident (TIFA) from 2001-2005, the Michigan Fatal Accident Complaint Team[1] (FACT) file, and administrative data from the Inspection and Carrier files of the Federal Motor Carrier Safety Administration (FMCSA) Motor Carrier Management Information System (MCMIS).

Crash data were used to characterize the CMV traffic safety problem by identifying the primary sources of harm from CMV crashes and the factors related to the incidence and severity of crashes. A metric of harm—developed from medical costs, emergency services, property damage, lost productivity to injured person and monetized quality-adjusted life years lost, but not including lost productivity due to congestion delays—was used to compare different types of CMV crashes and circumstances of CMV crashes. The Michigan FACT data were used to examine the effect of vehicle condition on crash risk. The MCMIS data on vehicle inspections and carriers were used to examine the relationship between carrier size and type, and compliance with the regulations that govern vehicle condition. Highway data linked to a geographic information system and to crash data was used to examine the geographic distribution of CMV crashes. A literature review of CMV strategies and crash countermeasures that have been applied in the United States was used to identify strategies for CMV safety issues in Michigan.

[1] The FACT file contains detailed description of crash events and conditions, and an intensive evaluation of the mechanical condition of the truck for each fatal truck crash in Michigan from 1996-2001.

Summary of Results

In 2005 there were 16,553 CMV crashes in Michigan, resulting in 120 deaths and 2,857 injuries. While this is an eleven percent decrease in crashes and a nine percent decrease in fatalities from 2001, paralleling the downward trend in all vehicle crashes in Michigan, CMVs were still disproportionately involved in serious crashes. Three percent of all vehicles involved in crashes between 2001 and 2005 were CMVs, but CMVs accounted for nearly seven percent of vehicles involved in crashes in which at least one person was killed. The annual cost of CMV crashes in Michigan from 2001 through 2005 was estimated at $662.3 million. Of this amount, 54 percent was attributed to fatal crashes. Only 18 percent of the total cost was due to property-damage-only crashes.

Analyses of crash data, post fatal-crash inspections, and MCMIS inspection and carrier records together with a weighting based on crash harm indicate that:

1. The most costly CMV crashes, and therefore most harmful to society, are fatal crashes, with angle crashes, head-on crashes, and rear-end crashes contributing most to overall CMV crash costs.

2. When crashes of all severity levels are considered, angle crashes, rear-end crashes, head-on crashes, same-direction sideswipe, and single-vehicle crashes contribute most to overall CMV crash costs, in the order presented.

3. Brake system defects have been associated with rear-end crashes, opposite direction crashes (head-on, opposite direction sideswipes), and intersecting path crashes (including angle collisions).

4. Lighting defects have been associated with rear-end collisions, where the CMV was the vehicle struck.

5. Steering defects have been associated with opposite-direction collisions in which CMV was the encroaching vehicle.

6. Brake and lighting system violations are the most frequent violations in CMV inspections.

7. Violation rates in inspections are highest for CMVs from small fleets.

8. CMVs from intrastate carrier’s fleets have higher rates and more serious violations in inspections than CMVs from interstate carrier fleets.

9. The CMV driver hazardous actions that contribute most to overall CMV crash costs are, “unable to stop in assured distance” (i.e., following too closely), “failed to yield,” “speed too fast,” “careless/negligent,” and “disregard for traffic control.”

10. The most costly individual CMV driver hazardous actions (compared to the average hazardous action) are: “reckless driving,” “drove left of center,” “disregard of traffic control,” “careless/negligent,” “speed too fast,” “unable to stop in assured distance,”(i.e., following too closely).

11. Younger crash-involved CMV drivers are more likely to be with coded with hazardous actions, particularly “unable to stop in assured distance,” (i.e., following too closely), and “speed too fast,” (i.e., speeding).

12. Younger CMV drivers are more likely to be involved in backing-up crashes than older drivers.

13. In approximately one-half of CMV crashes, a hazardous action is coded for the driver of the other vehicle.

14. Fatigue-related CMV crashes tended to be severe single-vehicle crashes in which the CMV ran off the road, or rear-end crashes. Most CMV fatigued driver crashes occurred at night, between midnight and 6 a.m. on Interstate roads, and involved tractor-semitrailers or doubles operated by interstate carriers. Fatigue-related crashes account for two to three percent of total CMV crash costs in Michigan.

15. Eight counties (Wayne, Oakland, Kent, Macomb, Berrien, Washtenaw, Genesee, and Ottawa) accounted for almost one-half of Michigan’s annual CMV crash costs. Wayne County alone accounted for 19 percent of the costs.

16. Four of the above eight counties were not among the top eight counties when CMV inspections were considered.

Strategies to Enhance CMV Safety in Michigan

Strategies to increase safety will have to work on many fronts, including programs to improve the performance and condition of CMVs, CMV drivers, the safety culture of carriers, and other drivers on the road.

Improve Maintenance of CMVs

Maintenance is critical for safe management of CMV fleets. Vehicle defects in brake and lighting systems as well as in steering systems have been found in CMV vehicles involved in crashes which contribute significantly to the overall CMV crash cost in Michigan. Furthermore, the brake and light systems violations are the most frequent violations in CMV inspections, although the frequency of all violations is high. Carriers with small fleets and intrastate carriers appear to have more problems with vehicle maintenance than large fleets. Approaches for improving CMV maintenance may include targeted enforcement, mandating preventive maintenance programs, and improving fleet safety management.

Targeted Enforcement - Given the relationship between vehicle condition and crash risk, it is important that CMVs mechanical conditions at minimum meet the required standards. Enforcement is necessary for regulatory compliance by motor carriers and drivers. However, enforcement resources are limited and should be optimized for maximum effect. Thus, allocating resources to areas with the most safety problems is a reasonable strategy. The eight counties that account for close to one-half of all CMV crash costs should get special consideration when enforcement and inspection resources are allocated in the state.

Mandating Preventive Maintenance Programs - Regularly scheduled vehicle inspections and maintenance are part of safety programs practiced by many fleets. However, not all motor carriers voluntarily implement strong fleet maintenance programs. Strategies to get carriers to develop and sustain good preventive maintenance practices should be considered.

The state of Maryland has a program that in addition to meeting the FMCSS regulations requires that carriers conduct and document an ongoing preventive maintenance program for their vehicles. Enforcement officers in the state of Maryland can enter the premises of any motor carrier at any time during regular business hours to inspect equipment and also to review and copy records relating to the carrier's preventive maintenance program. The program has resulted in improved vehicle inspection performance both for vehicle inspections conducted at carrier sites and those conducted at the roadside. The program in Maryland is mandated by legislation specified in the Code of Maryland Regulations. Applying this strategy in Michigan would first require legislative action and then resources from an already limited source, thus either new sources of funds would have to be found, or taken from current enforcement activity.

Proactive Approach to Avoiding Safety and Compliance Problems - The state of New York uses a "**compliance letter**" approach for safety compliance. Instead of issuing a citation to carriers or conducting a full compliance review, the state may simply require that problem carriers write a letter to the state, stating that they are aware of the regulation(s) in question and current deficiencies in their operations and describe their plans to get into full compliance. Otherwise, these fleets receive no punishment at this stage. The state has found that this non punitive approach often gets the attention of the fleet managers and motivates them to improve their safety and compliance practices, prior to experiencing any major fines or other sanctions.

The Tennessee Department of Safety has an **Alternative Commercial Enforcement Strategies** program that provides compliance-related information to fleets in a non threatening way. Specially trained officers visit fleets using an advisory rather than enforcement approach. The officers provide as much information as possible to help fleets become more proactive in avoiding safety and compliance problems. Training services provided range from demonstrating vehicle inspection procedures to reviewing compliance paperwork requirements to training new drivers. Later visits may be enforcement-oriented, but the initial visit is advisory and permits fleet operators to improve their practices.

Educational, Training, and Consultation Programs - Educational, training, and consultation programs can also help carriers manage their safety compliance and safety programs. However, these programs are voluntary and do not have the weight of enforcement behind them.

Colorado has a **Circuit Rider** program. It is an industry-based initiative to provide free consultation to fleets on their safety compliance and management practices. Veteran carrier safety managers visit motor carriers that have requested a consultation. The program does not result in punitive actions to the carrier. Consultation might include: review of carrier operations, staffing levels, equipment, driver files, and insurance; review of fleet's approach to compliance with key FMCSA regulations; advice on building a stronger safety program for the fleet. In addition the program offers safety workshops for motor carrier managers, drivers, and dispatchers.

FMCSA provides educational and outreach programs to the motor carrier industry. Educational material targeted for small motor carriers covers the full range of safety practices that fleet owners can implement to reduce crashes and stresses the high costs of crash involvement and the benefits of crash prevention.

Michigan has a training and consultation program in the **Michigan Center for Truck Safety** (MCTS). The MCTS provides free and low-cost training and consultation to truck drivers and carrier safety managers. Training includes driver coaching, "decision" driving courses (conducted on skid pad to teach drivers dynamic safety maneuvers such as pulling out of a jackknife) defensive driving, fatigue management, inspection training, load securement, and safety manager training. There is also an Annual Truck Exposition and Safety Forum.

A training need was identified through our analysis of crashes. Younger CMV drivers were more likely than others to be involved in back-up crashes. Though these crashes are not severe, and are not the top contributors to the cost of CMV crashes in the state, it seems that additional training could reduce these crashes, given that a training facility and programs already exist.

Another role for the MCTS could be in helping develop preventive maintenance programs for carriers through workshops, consultations, and site visits.

Deployment of Truck Safety Technologies

All new trucks must meet the Federal Motor Carrier Safety Standards (FMCSS), but beyond compliance with these standards, buyers have considerable options in the safety features they select for their vehicles. Improved braking systems including electronic braking systems, higher performance tires, conspicuity lighting, and convex and fender-mounted side mirrors are among these safety-related features. In addition to these safety-related components, various advanced technology systems are now available for trucks. These include radar-based collision avoidance systems, adaptive cruise control, back-up camera systems, side-object detection, driver monitoring systems, electronic vehicle speed regulation, vehicle and cargo tracking systems, roll-stability advisors and controllers, on-board-recorders for driver hours-of-service verification, and lane-departure warning systems. Other advanced technology systems are on the horizon.

While truck safety vehicle technology promises to increase safety, it does add to the cost of the vehicle, and will require active maintenance, and driver safety management. There is often resistance to new technology. Tax incentives would be a way of getting fleet managers to use and consider some of the advanced systems. FMCSA has an active program to promote some of these advanced technologies. The advances in technology show promise in reducing CMV crash involvements. However, it is important that they be tested and evaluated through pilot studies before they are widely deployed.

Increase Knowledge on Sharing the Road

There is a need for a broad-based public understanding of the hazards associated with driving too close to large trucks. Public information and education (PIE) campaigns and driver manuals and handbooks as well as CDL licensure are ways of increasing this understanding. The “No Zone” was an earlier PIE campaign and “Share the Road” is the current one. Both contain clear messages about behaviors that create hazardous car-truck interactions. However, experience gained from PIE campaigns for using safety-belts and on drinking and driving, indicates that it will take some time for the message of sharing the road safely with trucks to get through to the public. The MCTS manages the Share the Road PIE program in Michigan. It should continue to do so, and take advantage of all the resources provided by FMCSA and NHTSA.

Incorporating how to drive safely near CMVs into light vehicle driving courses and the licensing process is a way of reaching the next generation of drivers. The organization of traffic safety educators (ADSTEA) has a model curriculum for novice drivers that includes topics on truck driver fatigue, truck wide right turns, side blind areas and safe passing, other No-Zone areas, and being able to see the driver in the truck’s mirrors.

Another strategy is to promulgate “Share the Road” information through print and electronic media. This means finding a way to involve and interest the media on a regular basis in reporting on the dangers of hazardous maneuvers in the vicinity of trucks when reporting on car/truck crashes. The media did this for safety belts, by reporting whether or not a person involved in a crash was using a safety belt.

Strengthen CDL Program

Although the CDL status of crash-involved drivers was not analyzed in this research because the required data could not be obtained in a timely fashion, common sense indicates that making sure that the CDL program runs effectively is a good strategy for CMV safety. Fraudulent issuing of licenses is a concern throughout the United States. Strategies identified for strengthening the

CDL program include improving the administration of the knowledge test to minimize the opportunity to “cheat” and by increasing fraud detection among third party testers and state examiners.

Use of computer software and hardware for the knowledge test portion of the CDL exam will decrease opportunities for cheating. A system of regular reviews and audits of examiners is essential for reducing fraud in the CDL exams. Overt and covert surveillance of driving tests can also be used to discourage and detect fraud. Statistical analysis of test scores and failure rates of individual examiners should be conducted. Furthermore, candidate examiners should be thoroughly evaluated, including a criminal check and driver history check, and should be recertified annually.

Improve Crash Data

Much of this report was based on the analysis of Michigan crash data that is extracted from UD-10 reports filled out by the police officers who investigated the crashes. Generally, these data were found to be well-documented and well-prepared. However, there are some inherent problems can be traced to the complexity involved in coding some of the fields in the original UD-10 report. The following problem areas and suggested solutions have been identified.

- It is not possible to distinguish trucks from buses, because the vehicle type variable on the UD-10 combines trucks and buses into a single code level. There is a “special use” variable that might be used to identify buses, but it is not coded in almost 60 percent of cases. A simple change in the vehicle type variable on the main page of the UD-10 would improve the situation.

- The vehicle type variable in the CMV supplemental data is very complicated and combines several distinct dimensions, including the type of CDL, if any, required, and the type of endorsements required. Although some features of the vehicle can be inferred, many important characteristics of the vehicle cannot be recovered. A simpler approach that breaks out the different dimensions of information collected into separate variables would be easier for the reporting officer to complete accurately and also provide more detailed descriptive information.

- It is difficult to distinguish tractors from straight trucks, and to identify the multi-axle combinations. Although the CMV supplemental data section of the UD-10 includes variables to record the unit type and number of axles for each unit in a combination, the information entered into the variables is incomplete, inconsistent, and in many cases missing. A variable that so many officers are unable to complete correctly likely should be reformed.

- Data on CDL license status of crash-involved drivers was frequently missing and inconsistent, and when present could not be considered reliable. A different approach, such as automated data collection using bar coded licenses and readers, could reliably capture such details and allow the reporting officer to focus on areas that require judgment.

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1 Introduction

Truck-related crash harm, comprising fatalities, injuries and property damage, directly affects all road users, the freight industry and its industrial partners, and parties involved in transportation infrastructure and management. In 2005 in the United States (US), 442,000 large trucks (gross vehicle weight rating greater than 10,000 pounds) were involved in traffic crashes in which 5,212 people were killed (12 percent of all traffic fatalities reported in 2004) and 114,000 were injured (NHTSA, 2006a).

Michigan's large-truck crash numbers reflect the national experience. In Michigan in 2005 there were 16,553 vehicle crashes involving large trucks resulting in 2,857 injuries, and 120 fatalities. While crashes involving large trucks constituted four percent of all vehicle crashes, they accounted for ten percent of all fatal crashes in the state in that year. A large portion of Commercial Motor Vehicles (CMVs) weigh over 10,000 pounds and crashes involving these large vehicles are often more severe than those involving smaller vehicles, thus CMVs are over represented in the fatal crashes, given their involvement in crashes.

Crashes involving CMVs also carry higher economic costs than other crashes and tend to be more disruptive to other road users than other crashes by creating significant road closures and traffic delays. They disrupt freight services and tend to be expensive with respect to infrastructure clean-up and repair costs.

In light of its mission *to improve truck safety by providing Michigan's trucking industry and citizens of Michigan with effective educational programs, and by addressing significant truck safety issues*, the Michigan Truck Safety Commission (MTSC) has asked the University of Michigan Transportation Research Institute (UMTRI) to identify key issues associated with CMV-involved crashes, injuries, and fatalities through the analysis of available data, and to propose practical and feasible strategies and solutions consistent with the four E's of traffic safety - *Enforcement, Education, Engineering, and Emergency Medical Services*.

UMTRI undertook this task, and the results of our research are presented in this report. The next section describes the methods and data sources we used. The third section presents the results of our data analyses, and the fourth section summarizes the CMV safety issues. Countermeasures and strategies to address the identified problems are discussed in the fifth section.

2 Methods and Data

The identification of CMV safety issues is empirically-based, and relies on the analysis of crash and other available data resources. The resources include crash data from the State of Michigan and other sources, and data from administrative files that provide information about the compliance of CMVs with current regulations and the types of carriers that are operating the vehicles. We also use estimates of the total social, medical, and other costs related to CMV crashes. The crash data are used to characterize the traffic safety problem relating to CMVs to identify the primary sources of harm from CMV crashes and the factors that are related to the incidence and severity of crashes. Some of the crash data are used to explore the effect of vehicle condition on crash risk. The data on vehicle inspections and carriers are used to examine the relationship between carrier size and type, and compliance with the regulations that govern vehicle condition. Highway data linked to a geographic information system were linked to the crash data and used to examine the locations of CMV crashes.

We had planned to use driver history files from the Michigan Department of State but were unable to obtain them in time for this report. We had also planned to use driver history records obtained through the Commercial Driver License Information System for analysis of out-of-state CMV drivers. However, the amount of missing data in the Michigan crash data on driver license number for out-of-state drivers was too high to make the effort productive.

Strategies for addressing CMV safety issues were obtained through a review of the literature of strategies and countermeasures that have been applied throughout the US to reduce CMV crashes and enhance CMV safety.

2.1 Crash data

The primary crash data used for this report is the Michigan crash file, covering all motor vehicle crashes from 2001-2005. These data are extracted from form UD-10, which is completed by police officers on traffic crashes that result in a fatality, injury, or property damage over $400 (raised to $1,000 effective January 1, 2004). These data which form the core of the analysis are presented. UMTRI obtained a total of five years of the UD-10 data, 2001 through 2005. Five years of data were used to increase the number of cases used in the analysis and improve the robustness of the findings. The data files include records on almost 3 million vehicles involved in reportable crashes over this five-year period. This includes about 2.2 million passenger vehicles, 580,000 pickups and vans, and about 87,000 commercial vehicles.

The data were supplied in eight separate data files, covering different aspects of the crash. The files can be linked together to join information from the different files as needed.

- Crash file, with one record per crash. This file contains crash-level descriptive information, such as weather, time of day, road type, number of vehicles involved, as well as measure of severity in terms of number of fatalities, and numbers of injuries of different severities.

- Crash location, also one record per crash, identifying the location of the crash using latitude and longitude coordinates.
- Unit file, with one record per unit. Most units are motor vehicles, but a unit can also include a non-motorist such as a pedestrian or bicyclist, and non-road vehicle such as a train engineer. The file includes variables with vehicle-specific information, such as make and model, but also counts of occupants by injury level.
- Party file, with one record per individual involved in the crash, both drivers, passengers, and non-motorists. The data in this file describes the individual and his injury level.
- Harmful event file, with one record per harmful event per unit involved in the crash. In other words, for each unit in the crash, this file contains records for each successive harm-inducing event in the crash.
- Driver license file, with one record per driver, providing the driver’s license type.
- Driver condition file, with one record per condition for each driver. This file provides information about the driver’s condition prior to the crash, and records fatigue, sleep, illness, medication use, and other factors. More than one condition may be recorded for a driver.
- Commercial vehicle file, with one record for each commercial vehicle involved in a crash, provided the crash meets a threshold severity level. These data are entered on a supplemental area of the UD-10, and are collected primarily in response to a US DOT mandate. Trucks and buses involved in a crash that results in a fatality, injury transported for immediate medical attention, or a vehicle towed due to disabling damage must be reported to the MCMIS Crash file. The data in the commercial vehicle file (CMV file below) include some carrier identification information, vehicle description, and driver licensing information.

We also used the Trucks Involved in Fatal Accidents (TIFA) file, which is compiled by UMTRI for the Federal Motor Carrier Safety Administration (FMCSA). The TIFA file is a survey of all medium and heavy trucks (gross vehicle weight rating [GVWR] over 10,000 pounds) involved in a fatal accident in the US. Candidate truck cases are extracted from the National Highway Traffic Safety Administration’s Fatality Analysis Reporting System (FARS) file, which is a census of all traffic accidents involving a fatality in the United States. To collect data for the TIFA survey, police reports are acquired for each crash, and UMTRI researchers contact drivers, owners, operators, and other knowledgeable parties about each truck. The TIFA survey collects a detailed description of each truck involved, as well as data on the truck operator and a variable on the truck’s role in the crash. Survey data includes the physical configuration of the truck, such as the GVWR, weights and lengths of each unit, cargo body style, type of cargo (including hazardous materials), and cargo spillage. Motor carrier data includes carrier type (private/for-hire) and area of operation (interstate/intrastate). The analysis file constructed from this data includes all variables from the FARS file, which captures the crash environment and all other vehicles and persons involved in the crash.

The final crash file used was the Michigan FACT file. The FACT file was the product of a special crash investigation program conducted by the Motor Carrier Enforcement Division of the Michigan State Police from 1996 to 2001. The goal of the program was to conduct an in-depth but highly structured investigation of each fatal crash involving a truck in Michigan. The data collected included a detailed description of crash events and conditions, and an intensive evaluation of the mechanical condition of the truck. The FACT data include records on over 500 trucks involved in a fatal crash. In many ways, the FACT program was a forerunner of the Federal Motor Carrier Safety Administration's (FMCSA) Large Truck Crash Causation Study (LTCCS) project (Craft and Blower, 2002). The LTCCS adopted many of the same methods that were pioneered by the FACT program. The FACT data will be described in more detail in the section on vehicle condition below (section 3.10) where they are used extensively to examine the relationship of vehicle condition to crash risk.

2.2 Motor Carrier Management Information System (MCMIS) Files

We used two national administrative files that are part of FMCSA's Motor Carrier Management Information System (MCMIS). The files were the Inspection file, which contains records on CMV inspections, and the Carrier file, which contains information on all registered motor carriers operating in interstate commerce.

The Inspection file contains records on all CMV inspections conducted under the Motor Carrier Safety Assistance Program (MCSAP). These include Level 1 inspections, walk-around, driver-only, terminal, and special inspections. We obtained Inspection file records for 2001-2005 which include approximately 156,000 inspections in Michigan. These data provide the most detailed and comprehensive information available about the compliance of drivers and vehicles with regulations governing driver hours of service and licensing, and the mechanical condition of the vehicles.

The Carrier file is also part of FMCSA's MCMIS program. All operators of commercial vehicles in interstate commerce, or carriers of hazardous materials, must register with FMCSA and obtain a US DOT number. Basically, all vehicles that fall under the regulatory domain of the FMCSA must register with the Carrier file. The MCMIS Carrier file provides information about the type of operations of the carrier, the number of vehicles operated in different categories, the number of drivers, and the types of cargo transported. This information is used to characterize the size of the fleet operating vehicles and the type of operations.

2.3 Crash Costs

Estimates of costs resulting from crashes involving CMVs used in this report were developed from a recent assessment of costs of large-truck crashes (Zaloshnja and Miller, 2002). They present crash costs per victim injured in truck and bus involved crashes. The crash costs estimated include medical costs, emergency services, property damage, lost productivity (to the injured person), and monetized QALY (quality-adjusted life years) lost. However, the figures computed do not include lost productivity due to congestion delays.

The costs are computed on a per-victim basis. Total costs increase with the severity of the injury. It should be emphasized that, while the figures are computed in terms of dollars, that is for convenience only. In no sense do we imply that a human life is worth a certain number of dollars or imply that loss of life could be in some sense "paid for." Instead, the costs should be regarded as a system of weights, to identify the most pressing targets for reduction.

It should be noted that in the Zaloshnja et al. study, costs are estimated separately for truck crash involvements and bus crashes. Using the UD-10 vehicle type variable, it is not possible to separate out trucks. We estimate the proportion of trucks using the more detailed information available from the MCMIS truck supplemental data. In those data, the proportion of buses is 11.7 percent, on average over the five years of crash data. That proportion was used to estimate a per victim crash cost for the mix of vehicles in the Michigan crash data. Table 1 shows the resulting estimated costs. These costs were used to calculate the total costs for CMV-involved crashes in Michigan.

Table 1 Crash Costs for CMVs

Injury severity	Estimated costs
Fatal	$2,671,000
A-injury	$98,800
B-injury	$36,900
C-injury	$31,900
PDO*	$4,400

* Property damage only

Since the costs given are on a per-victim basis, costs for any particular crash were determined using the following equation:

Crash cost = (Number of fatalities*2671000) +
(Number of A-injured*98800) +
(Number of B-injured*36900) +
(Number of C-injured*31900) +
(Number uninjured*4400)

2.4 Identifying Commercial Vehicle Types

The structure of the data collected on the UD-10 does not make it possible to identify trucks, as trucks are usually defined in traffic safety research. The common definition of a truck is a vehicle designed to transport property or pull trailers with a gross vehicle weight rating over 10,000 pounds. The vehicle type variable on the UD-10 combines trucks with buses, into a "truck/bus" category.

There is no other information in the crash data that can be used to separate trucks from buses in this category. The vehicle identification number (VIN) may become available, but VIN is not adequate. VIN describes the vehicle as manufactured, not as operated. Many truck producers also make chassis for buses. Many small vans are operated either as buses or as cargo vans, and the VIN cannot indicate how the vehicle was modified after manufacture.

The vehicle type in the truck/bus supplementary data is very detailed, but not adequate for a number of reasons. First, there is significant underreporting of crashes, even for those that qualify by crash severity for the supplementary data collection (Blower and Matteson, 2004).[2] Secondly, the configuration variable is focused on vehicles that require a commercial driver license (CDL), not all trucks as defined above. CDLs are required primarily for trucks with a GVWR over 26,000 pounds, smaller vehicles transporting quantities of hazardous materials requiring a placard, or commercial buses. A simpler variable would be more useful and likely more reliable.

Because of the limitations in the structure of vehicle identification in the Michigan crash data, it is not possible to separate trucks with a GVWR over 10,000 pounds from buses for analysis. The "truck/bus" category in the UD-10 vehicle type variable is the most feasible method of identifying CMVs, but the category includes an unknown quantity of buses. Based on the experience of other states and the General Estimates System (NHTSA, 2006b) national data file of police-reportable crashes, the percentage of buses in the category is estimated at about 10 to 12 percent. Clearly trucks dominate in the category, so the distributions primarily reflect the crash experience of trucks.

Trucks and buses can be more readily distinguished in the supplemental data that must be reported to FMCSA's MCMIS Crash file. The supplementary data incorporates a complex variable that classifies vehicles by the type of CDL and endorsements required to operate it. This variable includes information on the GVWR of the vehicle, certain cargo body types, certain configurations, size of bus in terms of the number of passengers, and whether the vehicle was transporting amounts of hazardous materials that require a placard. But the supplementary data is only required for trucks (and buses) involved in a crash of qualifying severity, that is, a fatality,

[2] Blower, D., and Matteson (2004) found that about 73.7% of reportable cases were reported in 2003.

an injured person transported for immediate medical attention, or a vehicle towed due to disabling damage sustained in the crash. These crashes are relatively serious and account for about 50 percent of all truck and bus crash involvements.

3 Results

Several sets of results are presented. Section 3.1 provides descriptive statistics about the overall patterns of CMV crashes by when and where they occur. In this section the distributions for CMVs are compared with automobiles and pickup trucks. The purpose of this comparison is to illustrate similarities as well as some of the unique characteristics of CMV operations. It is important to bear in mind that trucks are working vehicles and used for work purposes. For commercial for-hire truck operators, the truck is the driver’s office, his work place. This influences many aspects of the truck’s operations, from when and where it is operated, to the conduct of the driver while at his place of business, just as it does the operators of private automobiles. Automobiles are used primarily for private transport, and are used more often for personal transportation than as part of the work life. Automobile drivers, and increasingly, drivers of pickups, use their vehicle primarily for transportation to work, for private purposes, and as part of recreational activities, such as “going out” in the evening and on weekends. Trucks are used for work purposes, and the driver’s condition and behavior while on the job is more comparable to the condition and behavior of car drivers while at their place of work, rather than car drivers actually driving on the road. Section 3.2 presents results on recent trends in CMV crashes. Sections 3.3 and 3.4 show the distribution of crashes by environmental and roadway characteristics. Section 3.5 identifies the primary crash types involving CMVs, and presents the results of work to identify the most serious crash types, in terms of fatalities, injuries, and total costs.

Next, results relating to CMV drivers are presented, including the primary actions that contribute to CMV involvements in section 3.6, the effect of driver age (section 3.7) and the contribution, insofar as it can be identified, of driver fatigue (section 3.8). The contribution of vehicle condition and the factors associated with vehicle condition, as determined by CMV inspections, are presented in sections 3.10 and 3.11. Finally, the geographic distribution of CMV crashes is presented, to identify locations with high concentrations of crash involvements and the associated harm.

3.1 Background

Table 2 shows the annual average number of vehicles involved in traffic accidents in Michigan, by crash severity (most severe injury in the crash) and vehicle type. The estimates of involvements shown are the average of the five years of Michigan crash data used in this report. On average, almost 575,000 vehicles are involved in a reported crash in Michigan. Passenger vehicles are the most numerous vehicle type involved, of course, with over 440,000 involvements, followed by pickups with nearly 116,000 involvements, and CMVs with around 17,000 annually.

Table 2 Average Annual Number of Vehicles Involved in Traffic Crashes, by Vehicle Type and Severity

Crash severity	Vehicle type			Total
	Auto	Pickup	CMV	
Fatal	1,098	348	128	1,574
A-injury	8,080	2,193	426	10,699
B-injury	21,378	5,424	805	27,607
C-injury	67,344	14,368	1,938	83,649
PDO*	343,211	93,555	14,031	450,798
Total	441,110	115,889	17,328	574,326
	Percentage by crash severity			
Fatal	0.2	0.3	0.7	0.3
A-injury	1.8	1.9	2.5	1.9
B-injury	4.8	4.7	4.6	4.8
C-injury	15.3	12.4	11.2	14.6
PDO*	77.8	80.7	81.0	78.5
Total	100.0	100.0	100.0	100.0

* property-damage-only

Figure 1 shows graphically the relative crash involvement rates for CMVs and other vehicle types. The chart on the left shows that CMVs account for 2.6 percent of all vehicles involved, while about two-thirds are automobiles. Pickups account for 17.7 percent and “other” vehicle types, such as vans, motor homes, and motorcycles, are about 12 percent of the total. Thus CMVs constitute a relatively small proportion of the total number of vehicles involved. However, the contrast between the chart on the left in Figure 1 and the chart on the right illustrates the seriousness of the traffic safety problem related to CMVs. The chart on the right shows the proportion of involvements in the most serious crash type, i.e., where at least one person was fatally injured. In such crashes, the proportion of CMVs increases to 6.8 percent, or almost three times the proportion in all crashes. CMVs are disproportionately involved in the most serious crashes.

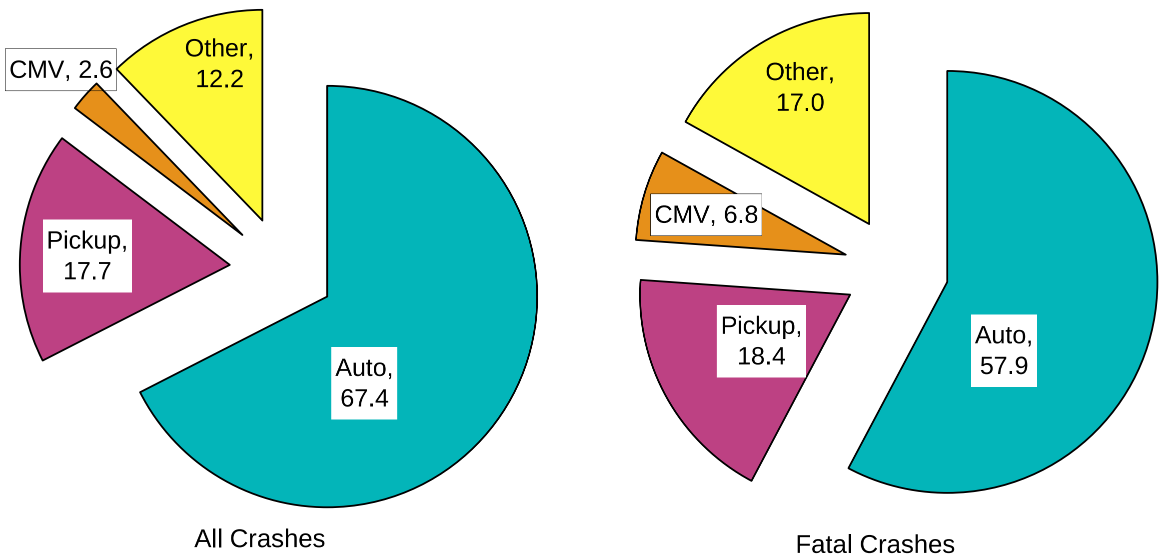

Figure 1 Involvements by Vehicle Type in All Crashes and Fatal Crashes Only

Table 3 provides another perspective on the impact of CMV crashes and how disproportionately the most serious crashes dominate in terms of their cost. It shows the number of involvements and estimated annual associated crash costs by crash severity for CMVs. Annually, only 128 of the roughly 17,000 CMV involvements are in fatal crashes, which is 0.7 percent of all crash involvements. A-injury and B-injury involvements are also few. Based on recent data, about 426 CMVs are involved in A-injury crashes and 805 CMVs in B-injury crashes. These two crash severities account only for an additional 7.1 percent (2.5+4.6 percent = 7.1 percent) of all CMV involvements. But in terms of the total effect on society, as measured by costs, the impact of those 1,359 involvements is enormous. By themselves, the 128 annual CMV involvements in a fatal crash account for over half, or 54.4 percent, of the total annual average of $662.31 million in crash costs associated with CMV traffic accidents. This is by far the largest impact. Added to the costs associated with A-injury and B-injury costs, those three crash severities account for almost 70 percent of all CMV crash costs. The 14,031 CMVs involved in a PDO crash only account for 17.8 percent of total crash costs.

Table 3 Annual CMV Involvements and Crash Costs in Michigan

Crash severity	Involve-ments	%	Costs (millions)	%
Fatal	128	0.7	$360.14	54.4
A-injury	426	2.5	$56.01	8.5
B-injury	805	4.6	$43.04	6.5
C-injury	1,938	11.2	$85.37	12.9
PDO	14,031	81.0	$117.74	17.8
Total	17,328	100.0	$662.31	100.0

3.2 Trends

In recent years, the number of crash involvements for CMVs and the two comparison vehicle types—automobiles and pickups—has declined consistently. Figure 2 shows the number of total crash involvements for each vehicle type from 2001 through 2005. In the figure, the number of CMV and pickup crash involvements are graphed on the left axis and the number of automobile involvements are on the right axis, because there are so many more of them. CMV crash involvements declined from about 18,000 in 2001 to 16,251 in 2005; pickup crash involvements declined from 121,000 in 2001 to 106,000 in 2005; and passenger car involvements declined from 456,000 in 2001 to 407,000 in 2005. The figure compares the vehicle types in terms of the frequency of involvements to give the reader an idea of the difference in magnitude of involvements between the three.

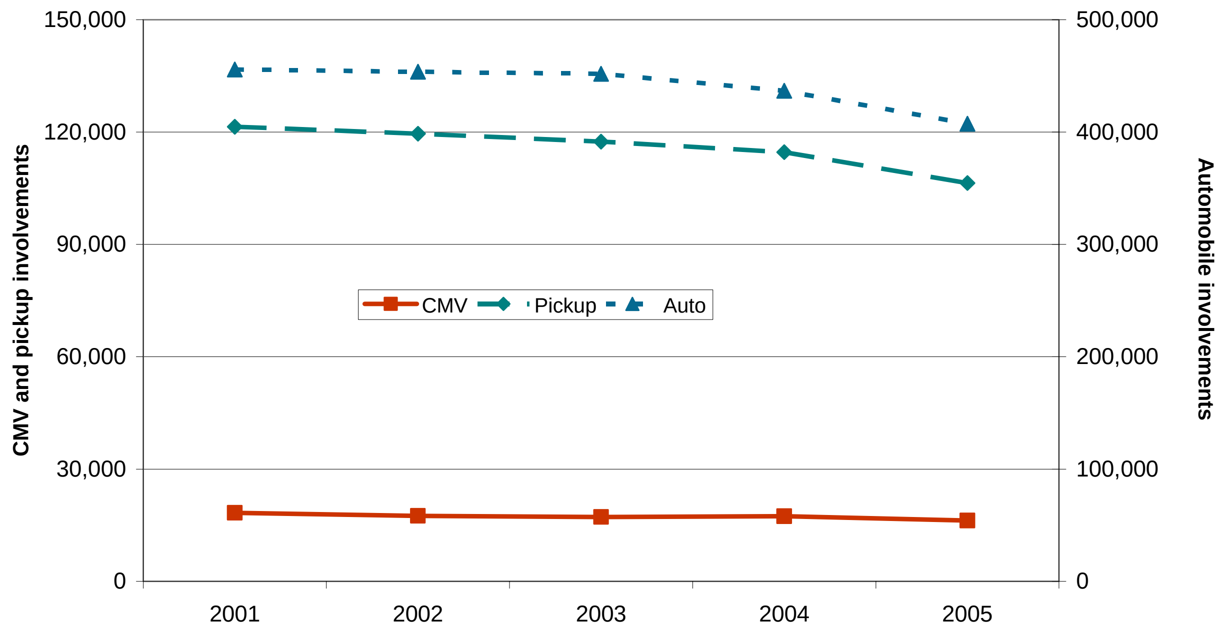

Figure 2 CMV, Automobile, and Pickup Crash Involvements 2001-2005

Figure 3 shows the decline from the base year, 2001, in percentage terms for each of the three types. Note that the decreases for automobiles and pickups are about the same for each year over the period. The two lines describing the change also overlay each other. However, CMVs follow a different pattern. The decline from 2001 to 2002 was much greater—a decline of almost 5 percent, compared with about 1 percent for the other two—and a further decline in 2003. This different pattern may be due to the effect of the economic slowdown in 2002, which was not reflected to the same extent for automobiles and pickups. But the overall trend for all vehicle types is the same and by the end of the period, all three types were declining at very similar rates.

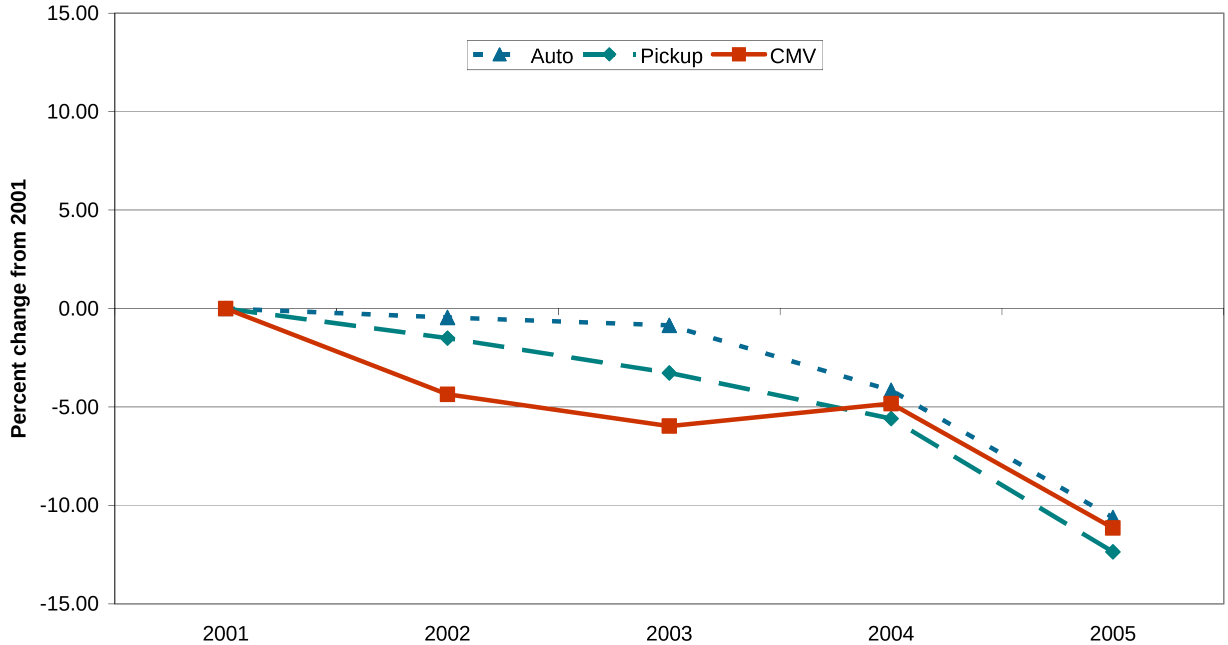

Figure 3 Percentage Change from 2001 in Crash Involvements

Table 4 shows annual CMV involvements by crash severity from 2001 to 2005 and, in the bottom half of the table, the total percentage difference from the number of involvements in 2001. Note that the rate of change is not the same for all three crash severities. The number of fatal and injury involvements actually increased in 2002 over 2001, though the number of PDO involvements declined substantially. But in 2003, fatal involvements declined significantly and at a much higher rate than injury or PDO crash involvements. And the number of fatal involvements then increased substantially in 2004, almost to the level of 2001 and 2002, followed by another decline in 2005. Fatal crash involvements can be quite variable from year to year, while injury and especially PDO involvements better reflect the overall decrease in the number of crash involvements over the period.

Table 4 CMV Annual Crash Involvements by Crash Severity

Crash severity	2001	2002	2003	2004	2005
Fatal	134	137	117	132	122
Injury	3,217	3,264	3,184	3,216	2,959
PDO	14,939	14,092	13,897	14,058	13,170
Total	18,290	17,493	17,198	17,406	16,251
Percentage difference in involvements from 2001					
Fatal	0.0	2.2	-12.7	-1.5	-9.0
Injury	0.0	1.5	-1.0	0.0	-8.0
PDO	0.0	-5.7	-7.0	-5.9	-11.8
Total	0.0	-4.4	-6.0	-4.8	-11.1

3.3 Time and Circumstance

The set of figures and tables in this section show the distribution of CMV involvements across several environmental dimensions, and capture the where, when, and in what circumstances CMV involvements occur. The distributions for CMVs are contrasted with those of the primary passenger vehicle types, automobiles and pickups.

Figure 4 shows the distribution of the light condition at the time of the crash, for each of the three vehicle types. For all of the vehicle types, a large majority of the crash involvements occurred during the day. But what is most notable is that a significantly higher proportion of CMV involvements occur during the day, compared with either automobiles or pickups. Over 78 percent of CMV involvements occurred in the daylight, compared with 66.3 percent of automobile and 63.7 percent of pickup crash involvements. Both automobiles and pickups have correspondingly higher percentages of dark/lighted and dark/unlighted conditions. Dark/unlighted accounted for over twice the percentage of pickup crash involvements, compared with CMVs. Almost 18 percent of pickup crash involvements occurred in dark/unlighted (likely rural) conditions, compared with only 8.4 percent of CMV crashes. The predominance of daylight involvements for CMVs is likely partly explained by exposure. Since CMVs are work vehicles, they are mainly operated during working hours, which are typically daylight. Passenger vehicles—automobiles and, often, pickups—are also operated for recreational purposes, which includes after-work hours.

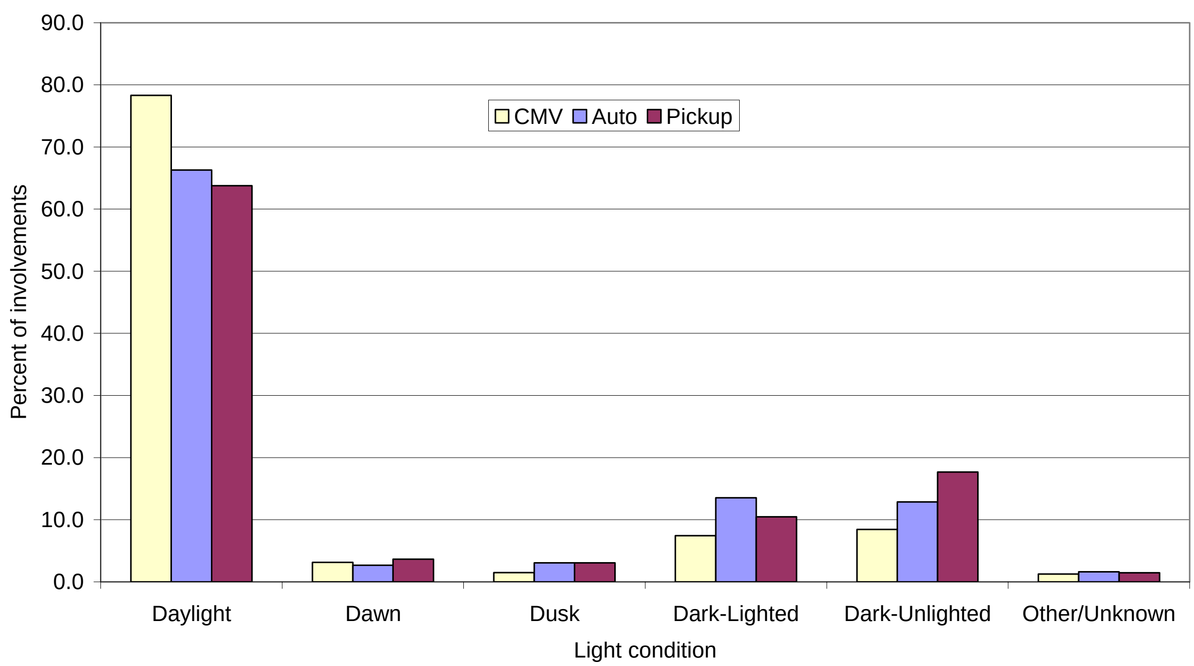

Figure 4 Light Condition by Vehicle Type in Michigan Crashes, 2001-2005

Figure 5 shows the distribution of crash involvements by weather condition for CMVs, autos, and pickup trucks. There are two notable points. The distributions for all the vehicle types are very similar. And the great majority of crash involvements occur in clear or cloudy weather, that is, when there is no precipitation. For each of the vehicle types, about 80 percent of crash involvements occur in good weather. Less than 10 percent involve rain and less than 10 percent involve snow. The "other severe" weather category includes fog or smoke, sleet, and hail. Inclement weather is not present in most crashes and does not appear to be a greater problem for trucks than other vehicle types. Data on operations by vehicle type are not available, but since trucks are working vehicles, it might be expected that truck operations are less affected by weather than other vehicle types. But if CMVs are exposed to more bad weather than other vehicles, the exposure does not result in more truck and bus crash involvements, relative to autos and pickups.

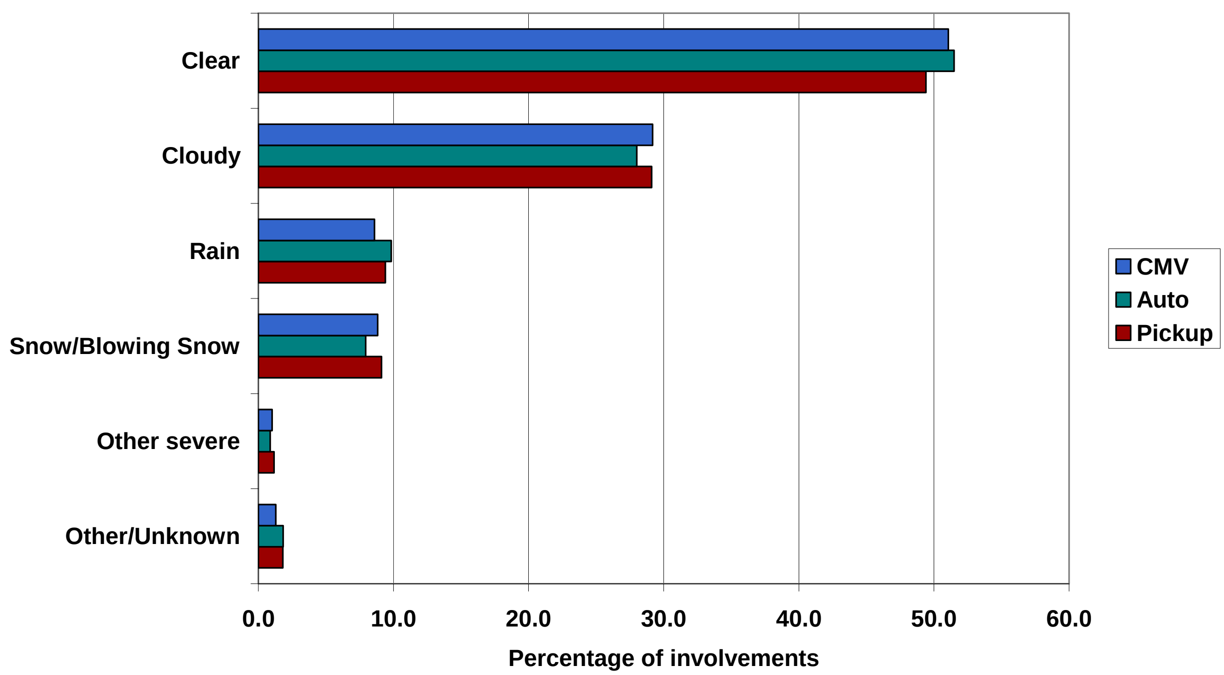

Figure 5 Weather Condition by Vehicle Type in Michigan Crashes, 2001-2005

Figure 6 shows the distribution of crash involvements for the three vehicle types by time of day. The distribution of automobile and pickup involvements is very similar, with the two curves virtually lying on top of one another across the 24 hour cycle. This is implies that the two vehicle types are used for similar purposes. CMV involvements occur primarily during the day. For automobiles and pickups, there is a peak in the early morning, between 7 a.m. and 8 a.m., then a reduction during the morning, following by a gradual increase to an afternoon peak from 3 p.m. to 6 p.m., after which the relative frequency of crash involvements decreases to the night time low. In contrast, CMV involvements peak at around 8 a.m., followed by a slight reduction but still relatively high through the morning, and then increase to a second peak around 3 p.m., at which point it decreases to a low around 7 p.m., which is maintained overnight. Note, however, that all three vehicle types have virtually identical proportions of crashes from midnight to about 4 a.m., with steady increases thereafter to their respective morning peaks. Figure 6 clearly shows how CMV operations are closely tied to the rhythms of work.

Figure 6 Hour of Day by Vehicle Type in Michigan Crashes, 2001-2005

Though CMVs have a lower percentage of their total crashes overnight than the other vehicle types, their night time crashes tend to be more serious than their crash involvements in the day. CMVs tend to operate at night more on high speed roads than during the day, so crash speeds are higher. More of their crashes are single-vehicle at night, and a higher percentage of the other drivers on the road are alcohol-impaired. The crash cost metric introduced above can be used to demonstrate that CMV crash involvements at night are on average significantly more serious than during the day. Figure 7 shows the ratio of the proportion of CMV crash costs to the proportion of crash involvements by time of day. Ratios over one identify times where the cost per crash is greater than the average; ratios under one show times where crash costs are less than average. CMV crash involvements between midnight and 4 a.m. are from 1.5 to almost 2.5 times more serious than the average. The cost ratio stays above one until about 8 a.m. Crash involvements after about 7 p.m. again tend to be more serious than average, though the ratio fluctuates within a wide range. Costs are heavily influenced by fatal involvements, so small changes can cause large swings.

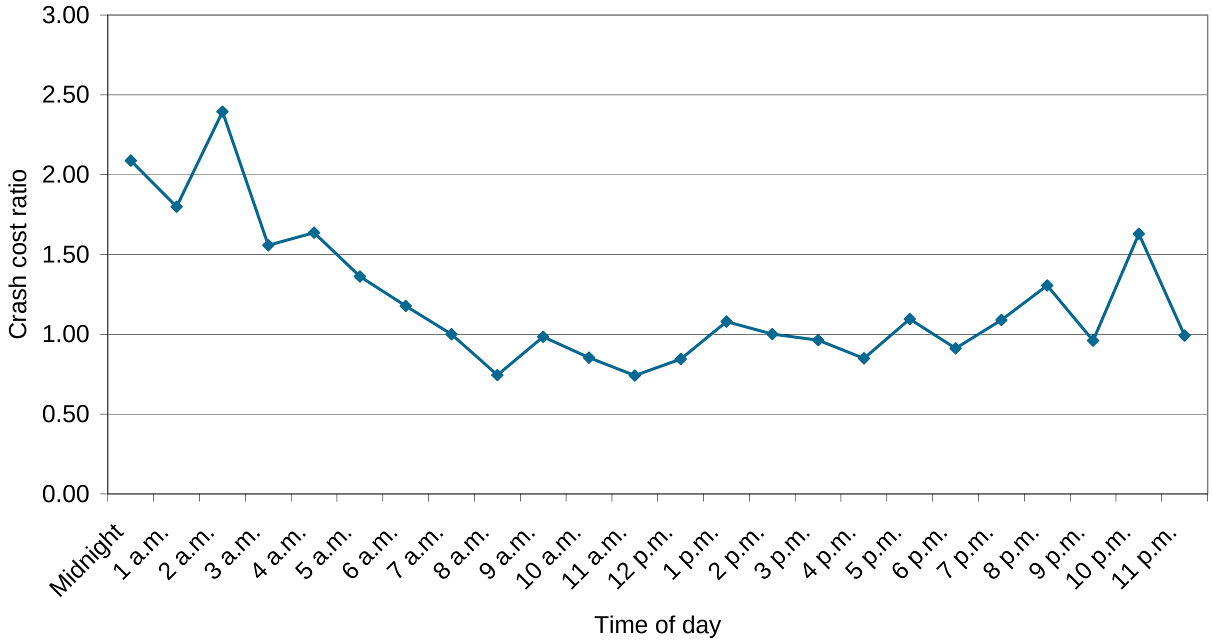

Figure 7 CMV Crash Ratio of Costs to Involvements

While CMV crash involvements at night tend to be significantly more serious than crashes during normal working hours, it is still the case that most of the harm related to crashes involving CMV occurs in the day. CMV crashes at night are more serious on average, but there are fewer of them. The number of CMV involvements during normal working hours is so great that the great majority of the harm occurs during the day. Figure 8 shows the distribution of CMV crash costs and involvements by time of day. Two points are illustrated in the figure. The relative lengths of the bars in any particular time period show the balance of severity. The fact that the cost bars are longer than the corresponding involvement bars in the periods from 8 p.m. to midnight, midnight to 4 a.m., and 4 a.m. to 8 a.m. shows that those involvements tend to be more serious. On the other hand, the involvement bars are much longer from 8 a.m. to 8 p.m. Over 70 percent of the costs, and therefore harm, associated with CMV crash involvements occurs during that period. Almost 80 percent of the involvements occur over that time period.

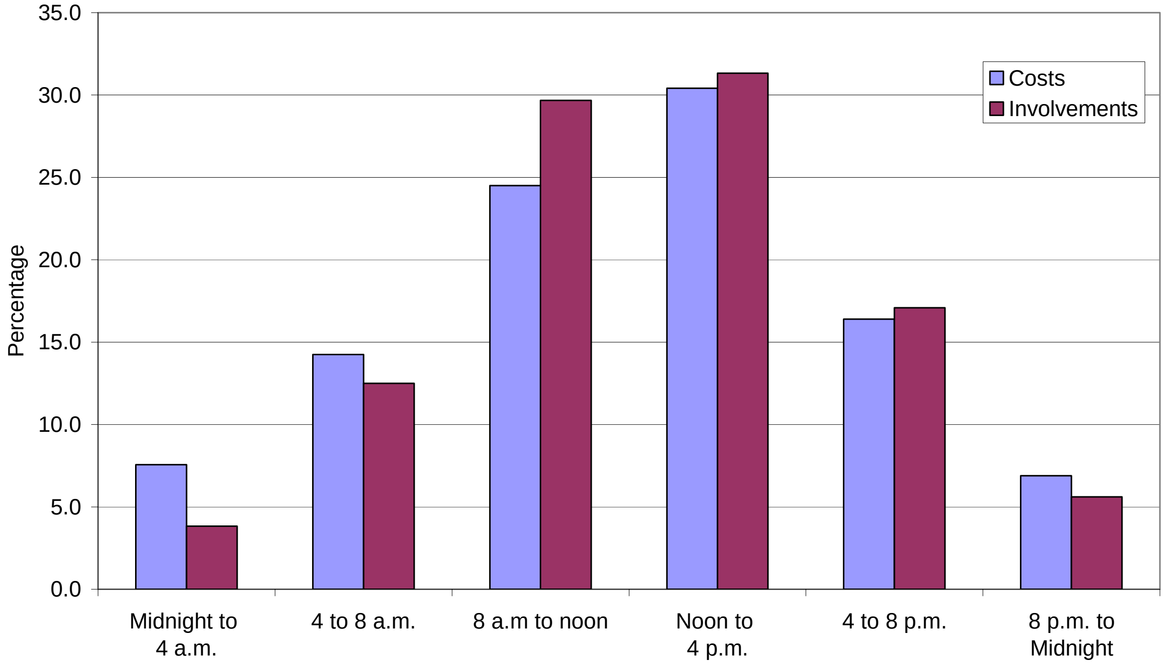

Figure 8 Distribution of CMV Crash Costs and Involvements by Time of Day

The relative frequency of crash involvements across the year is very similar for each of the three vehicle types. Figure 9 shows that the patterns for CMVs, automobiles, and pickups follow each other, trending lower from February to September and higher for October through January. The only notable difference is that a lower proportion of CMV involvements occur in November and December, compared with automobiles and pickups. It is not known why this divergence occurs then, though it may be related to the holiday season. Only 8.5 percent of CMV involvements occurred in November and 8.6 percent in December, compared with over nine percent for both autos and pickups in November, and about ten percent in December. The difference is not great, but it is striking because the monthly distributions are so similar otherwise.

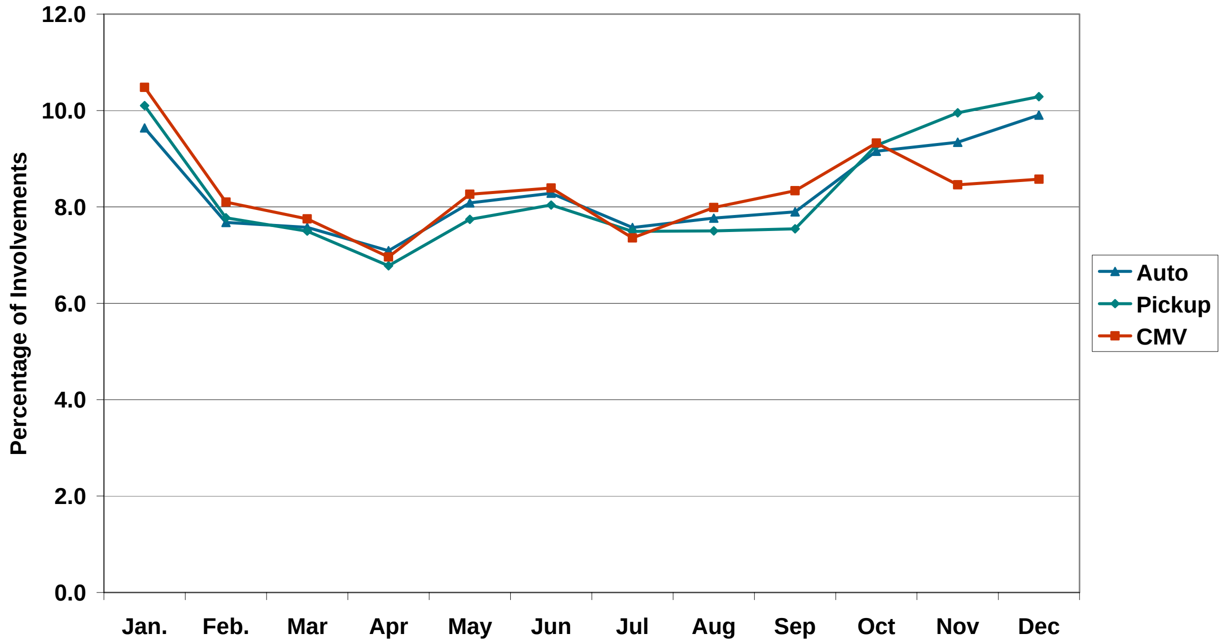

Figure 9 Crash Month by Vehicle Type in Michigan Crashes, 2001-2005

In contrast, the percentage distribution of crash involvements for the three types across the day of week is quite marked. Figure 10 graphically illustrates the differences in usage patterns for CMVs and for automobiles and pickups. Note that autos and pickups have virtually the same distribution across the week, indicating that operationally they are used in very similar ways. The percentage of involvements increases each day from Monday through Friday, reaching a peak on Friday. There is a reduction on Saturday and Sunday, but the percentage is much higher than CMVs for both. Increasingly, pickups are simply another mode of personal transportation. But CMV crash involvements, and likely operations, follow the rhythm of the work week. The percentage of CMV involvements ranges in a narrow band, from 18.0 percent to 18.7 percent, from Monday through Friday. The percentage decreases to only 5.5 percent on Saturday and 2.8 percent on Sunday. Many businesses are closed over the weekend, particularly those that use trucks for other than for-hire cargo haulage. It is likely that most of the CMV travel on the weekend is by long-haul for-hire operations on Interstates and similar quality roads, which are the safest in the system.

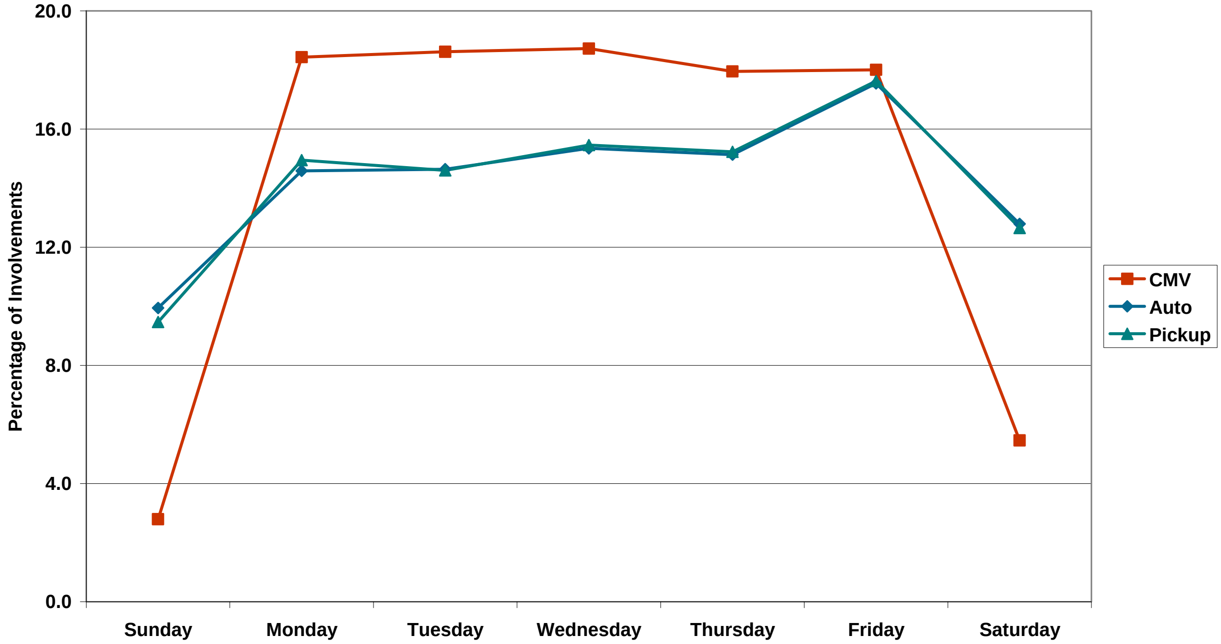

Figure 10 Day of Week by Vehicle Type in Michigan Crashes, 2001-2005

3.4 Roadway

There are important differences in the distribution of crash involvements of the three vehicle types across the different types of roads. These differences reflect the operations of the vehicles. Table 5 shows that most crash involvements for all three vehicle types occur on local roads and city streets, though such roads are much more predominant for automobiles and pickups than CMVs. Local roads and city streets account for 45.1 percent of the involvements of CMVs, but almost 60 percent of the crash involvements of autos and pickups. The percentage of crash involvements on M routes is about the same for each vehicle type. The biggest difference is in the proportion of involvements on Interstate highways. About 20 percent of CMV crash involvements occur on the Interstate system, compared with only about 8 percent for automobiles and pickups. The percentage of involvements on US highways is also somewhat higher for CMVs than for automobiles or pickups.

These differences likely reflect differences in the distribution of travel, which is in turn related to differences in the operations of the vehicles. CMVs accumulate substantial amount of travel on the main high-speed roads, because they are used to transport goods long distances. They also are used in all aspects of work and so are operated on local roads and streets, making deliveries or moving goods and equipment related to other business. Automobiles and pickups tend to operate more in urban areas on local roads. Thus, the differences probably reflect differences in exposure, rather than safety.

Table 5 Crash Involvements by Route Signing and Vehicle Type
Michigan 2001-2005

Route signing	Auto	Pickup	CMV	Total
Interstate Route	176,190	44,215	17,472	237,877
US Route	149,505	45,500	8,377	203,382
M Route	441,330	121,179	16,400	578,909
Interstate Business loop	40,013	10,075	1,457	51,545
US Business Route	27,332	6,754	873	34,959
M Business Route	641	204	21	866
Connector	5,041	1,011	225	6,277
Road, City Street	1,310,161	333,342	39,086	1,682,589
Unknown	55,422	17,200	2,727	75,348
Total	2,205,635	579,480	86,638	2,871,752
Percentage by vehicle type				
Interstate Route	8.0	7.6	20.2	8.3
US Route	6.8	7.9	9.7	7.1
M Route	20.0	20.9	18.9	20.2
Interstate Business loop	1.8	1.7	1.7	1.8
US Business Route	1.2	1.2	1.0	1.2
M Business Route	0.0	0.0	0.0	0.0
Connector	0.2	0.2	0.3	0.2
Road, City Street	59.4	57.5	45.1	58.6
Unknown	2.5	3.0	3.1	2.6
Total	100.0	100.0	100.0	100.0

The crash cost metric can be used to compare the relative safety of different road types. This information may be used in identifying targets for countermeasures or enforcement. Roads with a higher proportion of crash costs relative to involvements may be targeted for increased enforcement or other countermeasures because crash reduction would pay off disproportionately. Figure 11 shows the distribution of CMV involvements and crash costs by the different route types identified in Michigan. Most crash involvements and the greatest share of costs occur on local roads and city streets. Such roads account for almost 50 percent of all CMV involvements and almost 40 percent of the total harm as measured by crash costs. But the relative length of the bars for costs and involvements shows that CMV involvements on that road type tend to be less serious. In contrast, note that CMV involvements on US routes and especially M routes have a disproportionate share of costs. US routes account for less than 10 percent of total CMV involvements but almost 13 percent of the associated harm. Less than 19 percent of CMV involvements occur on M routes, but those involvements produce almost 28 percent of the crash costs and therefore harm. Much of the mileage of M routes is two-lane, undivided rural roads, which have a higher risk of more serious crashes. Reducing CMV crashes on US routes and especially M routes would contribute disproportionately to reducing the total harm from CMV crashes.

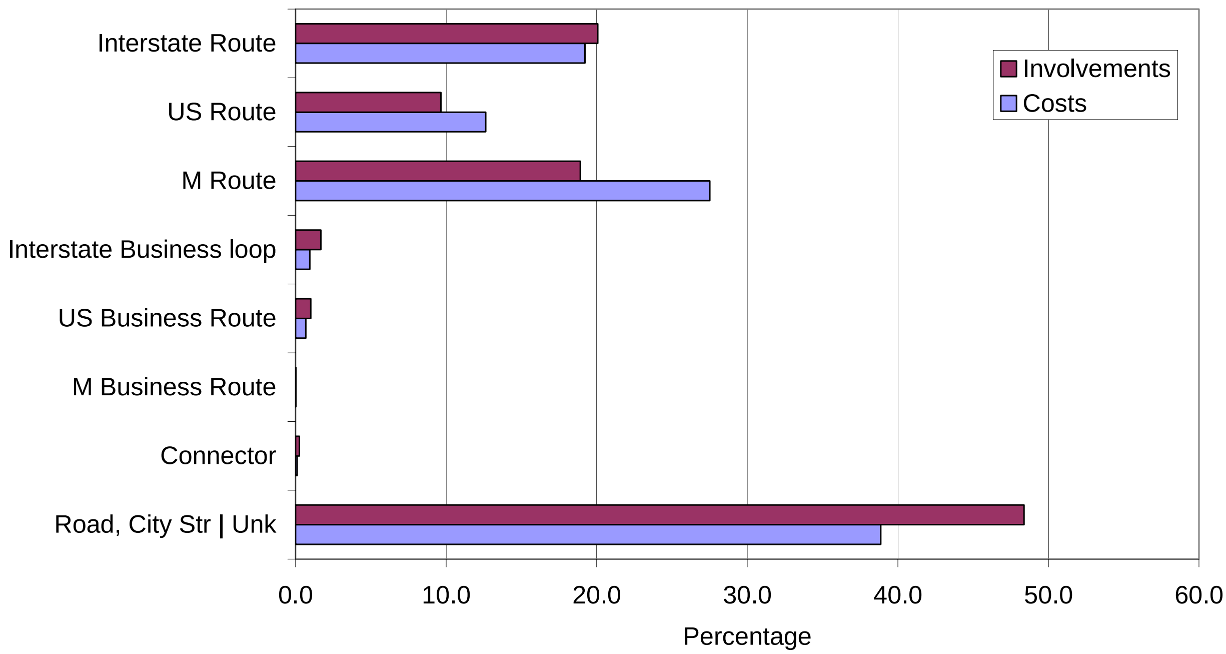

Figure 11 Distribution of CMV Involvements and Crash Costs by Route Signing

Table 6 shows the distribution across freeway locations for the three vehicle types. Only freeway crashes are included in this table. (Freeways are access-controlled divided highways.) Freeways are of interest because much of the operation of CMVs occurs on high-speed limited access roads, as they transport people and cargo long distances. Ramps are often considered to be particularly dangerous for CMVs, and from one perspective, the table certainly supports that view. Considering just crash involvements that occur on freeways, somewhat over 22 percent of CMV involvements on freeways occur on ramps. Clearly, this is a high percentage and a primary target for crash reduction. Even without VMT estimates for ramps and other freeway segments, it is clear that ramps must be significantly over-represented—the crash rate must be much higher on ramps than other freeway segments, since ramps account for only a small proportion of the total length of freeways. But compare the proportion of CMV involvements on freeway ramps with those of pickups and autos. These two vehicle types, with lower centers of gravity and higher rollover thresholds, actually have a higher proportion of their freeway crash involvements on ramps than CMVs do. In comparison with other vehicle types, CMVs have a lower proportion of crash involvements on ramps than other vehicle types. But in comparison with the roadway distance covered, ramps clearly are substantially over involved and a clear target for crash reduction. It can also be noted that most roadway measures that would lower the risk for CMVs would also benefit other vehicle types, and so would have a strong benefit for traffic safety in general.

Table 6 Crash Involvements on Freeways by Location and Vehicle Type Michigan 2001-2005

Freeway location	Auto	Pickup	CMV	Total
Enter/exit ramp	64,365	16,401	4,560	85,326
Median crossing	3,817	846	214	4,877
Transition	16,892	3,677	1,363	21,932
Rest area	1,348	273	100	1,721
Scale/weigh station	1,206	261	106	1,573
All other freeway	158,222	39,611	14,244	212,077
Total	245,850	61,069	20,587	327,506
Percentage by vehicle type				
Enter/exit ramp	26.2	26.9	22.1	26.1
Median crossing	1.6	1.4	1.0	1.5
Transition	6.9	6.0	6.6	6.7
Rest area	0.5	0.4	0.5	0.5
Scale/weigh station	0.5	0.4	0.5	0.5
All other freeway	64.4	64.9	69.2	64.8
Total	100.0	100.0	100.0	100.0

Table 7 shows the distribution of roadway locations for involvements off the freeways. The first three locations—intersection, driveway, and intersection-related—may be aggregated to identify places where traffic flow intersects. Intersections and areas influenced by intersections are substantially represented in the crash data. For CMVs, 49.7 percent or almost half of their crash involvements off freeways occurs at or near intersections. The proportions are similarly high for autos and pickups, 48.8 percent and 42.6 percent respectively. Straight roads account for the next highest proportion of non-freeway involvements for all three vehicle types, though the lowest for CMVs. Only 3.6 percent of all CMV non-freeway involvements occur on curves.

Table 7 Crash Involvements on Non-Freeway Roads by Location and Vehicle Type Michigan 2001-2005

Non-freeway location	Auto	Pickup	CMV	Total
Intersection	422,625	90,641	14,221	527,487
Driveway	235,779	58,297	7,346	301,422
Intersection related	263,413	65,058	10,105	338,576
Straight	814,877	246,800	24,817	1,086,494
Curved	55,573	17,408	2,312	75,293
Parking	50,926	12,222	1,570	64,718
Other	39,185	9,253	2,628	51,066
Non-traffic area	4,439	1,930	681	13,290
Unknown	883	208	17	1,108
Total	1,887,700	501,817	63,697	2,459,454
Percentage by vehicle type				
Intersection	22.4	18.1	22.3	21.4
Driveway	12.5	11.6	11.5	12.3
Intersection related	14.0	13.0	15.9	13.8
Straight	43.2	49.2	39.0	44.2
Curved	2.9	3.5	3.6	3.1
Parking	2.7	2.4	2.5	2.6
Other	2.1	1.8	4.1	2.1
Non-traffic area	0.2	0.4	1.1	0.5
Unknown	0.0	0.0	0.0	0.0
Total	100.0	100.0	100.0	100.0

Incidentally, it should be noted that the roadway area variable (from which Table 6 and Table 7 are taken) is the only place in the Michigan data where it is possible to identify the alignment (straight or curved) of the roadway on which the crash occurred. Roadway curvature is often a factor in crashes, especially for large, heavy vehicles with a high center of gravity such as CMVs. Crashes on curves cannot be identified on freeways other than on ramps, and it would have to be inferred that the ramp is curved. With such a large share of CMV crashes occurring on freeways, this is a significant limitation.

So far, we have compared the conditions and circumstances of CMV crash involvements with those of the two other primary vehicle types, automobiles and pickups. The purpose is to provide the reader with a perspective on relative magnitude of the traffic safety problem associated with CMVs and other vehicle types and the overall associations with environmental factors such as weather, time of day and day of week, and road type. CMVs are involved in substantially fewer crashes than automobiles and pickups, but their crashes are much more likely to be serious, because of their greater mass and stiffness. The comparisons also showed the operational differences between the vehicle types and how heavily crash patterns for CMVs are influenced by the fact that they are working vehicles. Compared with automobiles and pickups, crashes involving CMVs are much more likely to occur during the normal working hours and during the work week. During the day, CMV crash involvements are more uniformly from 8 a.m. to 3 p.m.

because they are working, while the passenger vehicle types show distinct rush hour peaks. There were no significant differences in terms of weather at the time of the crash, but large differences in the types of roads on which the crashes occur, again, reflecting operational differences. CMV crash involvements occur more frequently on major road types such as freeways, as they operate to transport people and property over long distances.

In the next sections, we drop the comparisons with passenger vehicles and focus more narrowly on the types of crashes, driver actions, and driver condition that contribute to CMV crash involvements.

3.5 Crash Types

A method of classifying crashes into meaningful types was developed that uses several variables. The primary variable used is the crash type variable as it is recorded on the UD-10 (Michigan Department of State, 2004). This variable has ten levels that essentially capture the vectors of movement of the vehicles at the first impact. The instruction manual for the UD-10 states "Crash Type is based on the intended direction of travel, regardless of point(s) of impact or direction vehicles ultimately face after crash."[3] As coded by the police officer on the UD-10, crash type captures the relative movement of the vehicles without regard to their orientation. This is a reasonable approach but the variable must be used with some care because certain crash types, though they appear on the surface to be simple actually combine certain subtypes that should be separated for analysis purposes. For example, head-on crashes are defined as crashes in which the intended direction of travel of both vehicles is toward each other. This crash type includes not just crashes in which vehicles are traveling in opposite directions and collide front-to-front but also some backing crashes, when a vehicle backs into another vehicle intending to go straight ahead.

It is desirable to capture backing crashes as a separate category in classifying CMV crashes because backing poses a different challenge to CMV drivers than to drivers of other vehicle types, specifically passenger vehicles. It is much more difficult for a CMV driver to see where he or she is backing, and in some cases impossible, because of the design of trucks and buses. In addition, backing crashes are typically very low speed, and occur in specific circumstances that are quite different from other crashes that the UD-10 system combines them with. For clarity in evaluating countermeasures, it was deemed appropriate to separate backing crashes as a separate category, rather than leave them included with head-on, angle, or rear-end crashes.

Accordingly, a system of classifying crashes was developed that assigns backing crashes to their own category. This also has the effect of cleaning up the other categories, so that the types of crashes they contain are more homogenous. Thus the head-on crashes in the crash type

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[3] Michigan Department of State, *UD-10 Traffic Crash Report Instruction Manual 2004 Edition*, p 17.

classification that was developed for this project does not include cases where one of the vehicles was backing, but instead captures crashes in which vehicles moving forward on the roadway collide essentially front-to-front. The same is true of the other crash types. The crash type variable developed largely follows the crash types from the UD-10, except backing crashes are separately identified. Pre-crash maneuver and hazardous action were used to identify backing crashes.

An initial attempt was made to use the UD-10 crash data to develop a classification that would provide even more information. For example, in the case of rear-end collisions, it would be useful to identify which vehicle was striking and which was struck, particularly from the standpoint of developing countermeasures. Similarly, in the case of head-on collisions, identifying the vehicle that crossed the centerline would be valuable in determining which vehicle primarily contributed to the crash and therefore the direction in which to explore countermeasures. But the police-reported data is not complete or detailed enough to support such a classification. First impact could not be used to sort out certain crash types—e.g., to distinguish the striking from the struck vehicle in a rear-end crash by identifying front or rear damage—because the variable is not coded in approximately two-thirds of the records for CMVs. Hazardous action could not be used to systematically identify the vehicle that crossed the centerline because in addition to “drove left of center”, other hazardous actions such as “speeding” or “reckless driving” could have been used.

Table 8 shows the distribution of crash types for all CMVs involved in a traffic crash, 2001 through 2005. The categories are similar to the UD-10 crash type, but we have identified backing crashes separately (extracting them mainly from rear-end, angle, and head-on crash types) and combined rear-end with rear-end lead vehicle turning left and rear-end lead vehicle turning right. Rear-end and sideswipes in which both vehicles were traveling in the same direction are the most common types. These crash configurations are similar in that both vehicles are traveling in the same direction. Note that the crash type does not indicate which vehicle moved into or struck the other. Angle collisions are the next most common. These crash involvements most commonly occur at intersections. Single-vehicle crashes are the other primary crash type, with 12.5 percent of all CMV crash involvements. Head-on crashes account for less than three percent of CMV crash involvements, while backing crashes account for almost eight percent. Note that the crash types do not identify specific roles for any of the vehicles in the crash, so the CMV in a backing crash may either be the vehicle backing or the one backed into.

Table 8 Crash Type, All CMVs and All Crash Severities, Michigan 2001-2005

Crash type	N	%
Single vehicle	10,799	12.5
Head-on	1,319	1.5
Head-on left turn	976	1.1
Angle	13,332	15.4
Rear-end	19,281	22.3
Sideswipe same direction	21,516	24.8
Sideswipe opposite direction	4,813	5.6
Backing	6,869	7.9
Other/unknown	7,733	8.9
Total	86,638	100.0

Crash types differ significantly in their severity and thus in their contribution to the overall problem of CMV safety. Table 9 shows the distribution of CMV involvements by crash type and crash severity. All five years of data are used in order to better reflect the underlying pattern. In the top section of the table are the frequencies. The bottom half of the table shows the distribution by crash severity of each crash type. Head-on crash involvements are the most likely to be severe. Over eleven percent of head-on involvements resulted in a fatality, compared with only 0.7 percent of all CMV involvements. An additional 42.2 percent of CMV head-on involvements resulted in at least one injury, also the highest rate for any crash type. Head-on crashes typically have the highest relative velocity because the colliding vehicles are moving towards each other. On the other hand, head-on involvements also have the lowest frequency (along with head-on left turn). So while they are very severe, they are also relatively uncommon.

Table 9 CMV Involvements by Crash Type and Crash Severity, Michigan 2001-2005

Crash type	Crash Severity			Total
	Fatal	Injury	PDO	
Single vehicle	56	1,378	9,365	10,799
Head-on	148	556	615	1,319
Head-on left turn	18	393	565	976
Angle	185	3,927	9,220	13,332
Rear-end	140	5,444	13,697	19,281
Sideswipe same direction	16	2,077	19,423	21,516
Sideswipe opposite direction	28	566	4,219	4,813
Backing	11	371	6,487	6,869
Other/unknown	40	1,127	6,566	7,733
Total	642	15,839	70,157	86,638
	Percentage by crash severity			
Single vehicle	0.5	12.8	86.7	100.0
Head-on	11.2	42.2	46.6	100.0
Head-on left turn	1.8	40.3	57.9	100.0
Angle	1.4	29.5	69.2	100.0
Rear-end	0.7	28.2	71.0	100.0
Sideswipe same direction	0.1	9.7	90.3	100.0
Sideswipe opposite direction	0.6	11.8	87.7	100.0
Backing	0.2	5.4	94.4	100.0
Other/unknown	0.5	14.6	84.9	100.0
Total	0.7	18.3	81.0	100.0

After the head-on crash types, angle collisions are the next most severe type. Angle collisions typically occur where traffic streams intersect, such as at intersections or driveways. While angle collisions are typically not as severe as head-on collisions, they are much more frequent, with about ten times more than pure head-on crashes and about six times more if head-on left turn crash involvements are combined. The most common crash types are rear-end and same direction sideswipes. In both of these types, the vehicles are both going in the same direction. Rear-end crashes are somewhat more severe than same direction sideswipes, likely because the differences in velocity in rear-ends can be greater. Same direction sideswipes are typically lane change or merge crashes in which the differences in speed are small, therefore the impact is not as severe, and this is reflected in the distribution of crash severity. Only 0.1 percent of same direction sideswipes resulted in a fatality; 90.3 percent resulted in no injury. In opposite direction sideswipe crashes, closing speeds can be great, but since they are sideswipes, the impact is not direct, but rather is a more glancing blow and so the severity is much lower than a head-on crash.

Table 9 illustrates the great differences in *frequency* and *severity* between the crash types. The most frequent crash types are often the least severe, while the most severe types are the least frequent. To identify crash types for countermeasures, it is useful to develop a metric that takes into account both frequency and severity. This will allow the crash types that produce the most harm to be determined so that countermeasures can be targeted most efficiently. Crash costs are a metric that is used to estimate the total social harm. The costs include, as described in section 2.3, direct costs in terms of medical care, emergency services, and property damage, but also the long term social costs from loss of life, diminished quality of life, and reduced productivity. Though expressed in dollar terms, they give the greatest weight to loss of life and lost quality of life. Thus, using crash costs to determine the total harm can give a picture of the effect of the crash types that is in some sense “truer.”

Using crash costs as a weight, angle and rear-end crashes account for the greatest total costs. Of the five-year total of $3,311 million in crash costs, angle collisions accounted for $881.6 million and rear-end crashes $787.2 million. (Table 10) Head-on crashes, though the least frequent of the crash types (including left turn) accounted for the next-highest crash costs with over $580 millions in costs ($497.4 million + $86.2 million). The table also shows that fatal crashes account for the greatest share of the costs (or harm) related to CMV traffic accidents. Though only 642 of the 86,638 crash involvements over the five-year period included a fatality, those crash involvements accounted for $1,800.7 million of the total $3,311.6 million.

Table 10 Total Crash Costs by Crash Type and Crash Severity
CMV Crashes in Michigan, 2001-2005

	Crash severity			
Crash type	Fatal	Injury	PDO	Total
Single vehicle	155.5	69.0	42.5	267.0
Head-on	447.0	45.0	5.4	497.4
Head-on left turn	54.4	26.4	5.4	86.2
Angle	543.5	252.9	85.2	881.6
Rear-end	354.8	306.1	126.3	787.2
Sideswipe same direction	40.9	102.7	172.7	316.3
Sideswipe opposite direction	74.3	33.4	37.0	144.7
Backing	32.2	19.8	56.4	108.5
Other/unknown	98.1	66.8	57.8	222.8
Total	1,800.7	922.1	588.7	3,311.6

Table 11 shows directly the share of crash costs for each crash type and severity. Note that the table sums to 100 percent. Fatal angle collisions, such as occur at an intersection, account for the highest percentage of crash costs, with 16.4 percent. Fatal head-on crashes account for 13.5 percent of the total costs of CMV traffic accidents, the next highest combination of type and severity. The table also shows that fatal CMV involvements account for over half, 54.4 percent of the total harm, as expressed by costs. Considering all crash severities, angle collisions and rear-ends are the top two crash types. Angle collisions account for 26.6 percent of costs and rear-ends account for 23.8 percent. Countermeasures, including training and other actions, targeted at these types, can have a substantial impact.

Table 11 Distribution of Crash Costs by Type and Severity of Crash, Michigan 2001-2005

Crash type	Crash severity			Total
	Fatal	Injury	PDO	
Single vehicle	4.7	2.1	1.3	8.1
Head-on	13.5	1.4	0.2	15.0
Head-on left turn	1.6	0.8	0.2	2.6
Angle	16.4	7.6	2.6	26.6
Rear-end	10.7	9.2	3.8	23.8
Sideswipe same direction	1.2	3.1	5.2	9.6
Sideswipe opposite direction	2.2	1.0	1.1	4.4
Backing	1.0	0.6	1.7	3.3
Other/unknown	3.0	2.0	1.7	6.7
Total	54.4	27.8	17.8	100.0

3.6 Hazardous Actions

Hazardous actions record the investigating officer's judgment of actions that contributed to the crash. The officers record the most significant action, if any, for each operator in the crash. Note that officers can record a hazardous action, regardless of whether a violation was charged. Officers can exercise judgment as to whether charging a violation is appropriate in the given circumstances, so not all chargeable violations are in fact charged. In contrast, the hazardous action variable records the most significant hazardous action, if any, of an operator, and thus provides a more complete record of the types of actions that contribute to crashes.

Figure 12 shows the distribution of hazardous actions in single-vehicle, CMV only crashes, and in two-vehicle crashes involving a CMV and another vehicle. Single- and two-vehicle crashes account for 93.3 percent of all CMV crash involvements. In single vehicle CMV crashes, which involve only one motor vehicle, the CMV, (though a pedestrian or other nonmotorist may be involved), 50.7 percent of CMV drivers were coded with a hazardous action, and 41.4 percent were not. Hazardous action was left unknown in 7.9 percent of involvements.

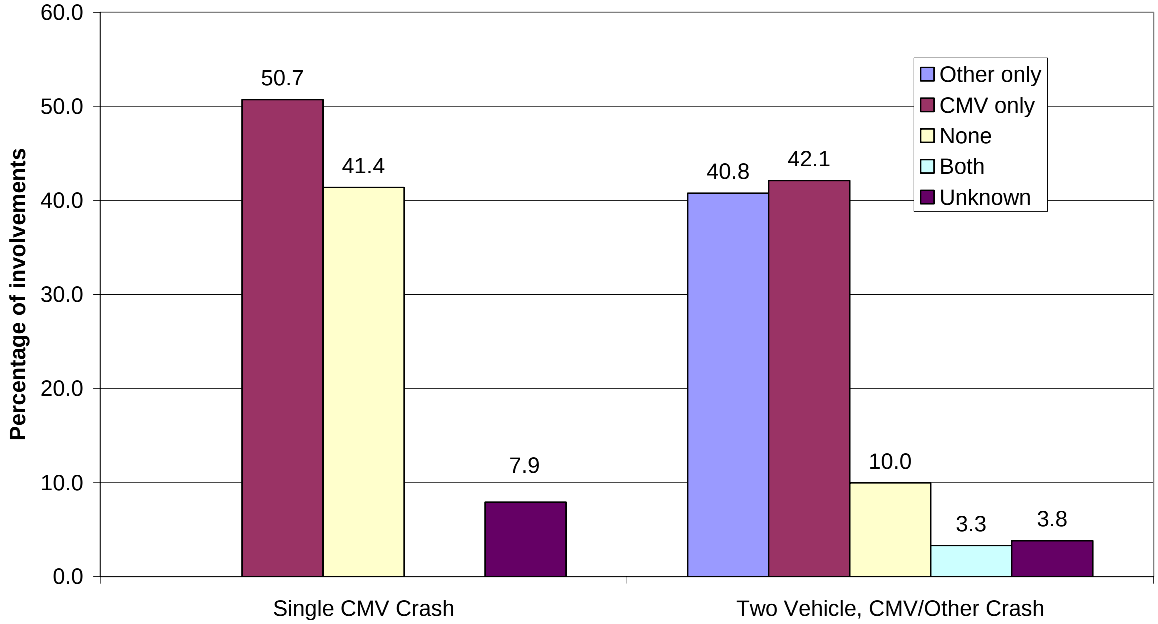

Figure 12 Distribution of Hazardous Actions
Single Vehicle CMV Crashes and Two Vehicle, CMV/Other Crashes, Michigan 2001-2005

The right side of the figure shows the distribution of hazardous actions in two vehicle crashes in which one of the vehicles was a CMV. In this crash type, CMV drivers are recorded with a hazardous action slightly more often than the other vehicle in the crash, typically a passenger car or other light vehicle. CMV drivers are recorded with a hazardous action in 42.1 percent of the involvements, the other driver in 40.8 percent, and both were assigned a hazardous action in 3.3 percent. The difference is statistically significant, but not practically significant. That is, the CMV driver is slightly more likely to have a hazardous action recorded, but the difference is small. (To avoid an excessive number of cases unknown, only cases in which hazardous action is unknown for both vehicles is treated as unknown in Figure 12. If, for example, a CMV is coded with a hazardous action, but hazardous action is left unknown for the other vehicle, that is counted as a hazardous action for the CMV only. The same procedure was used if the other vehicle was coded with a hazardous action, but hazardous action was left unknown for the CMV.)

Table 12 shows the specific hazardous actions recorded for CMVs and other vehicles in two-vehicle crashes involving a CMV and one other vehicle. (The percentage of involvements coded “none” is slightly different from the number implied in Figure 12 because of the method adopted to handle cases left unknown in determining the joint distribution of hazardous actions.) The table also shows the distribution of hazardous actions for non CMVs in crashes that do not involve a CMV. This column is included to show the differences in similarities in the hazardous actions of non CMV drivers in crashes with CMVs and with other vehicles.

Table 12 Percentage Distribution of Hazardous Action Coded for CMVs and Other Vehicles in Two Vehicle Crashes, and for Non CMVs in All Other Crashes

Hazardous action	Two vehicle, CMV/Other vehicle crash		Non CMV in crash not involving CMV
	CMV	Other vehicle	
None	45.0	46.2	48.9
Speed too fast	1.1	5.1	5.9
Speed too slow	0.1	0.2	0.2
Failed to yield	6.2	8.5	8.7
Disregard traffic control	1.3	2.1	2.2
Drove wrong way	0.1	0.1	0.1
Drove left of center	0.7	1.0	0.5
Improper passing	0.8	2.5	0.6
Improper lane use	6.1	4.7	1.9
Improper turn	4.3	1.3	1.0
Improper/no signal	0.2	0.2	0.1
Improper backing	5.8	0.9	1.7
Unable to stop	9.1	9.6	13.3
Reckless driving	0.1	0.3	0.5
Careless/negligent	1.2	2.4	2.1
Other	8.2	5.2	3.5
Unknown	9.6	9.7	8.9

In two-vehicle, CMV/other vehicle crashes, the types of hazardous actions by CMV drivers is very different from the hazardous actions of non CMV drivers. (Compare the first two columns of Table 12.) The other vehicle is much more likely to be coded with speed too fast, failure to yield, improper passing, and reckless or careless/negligent driving. Other drivers are almost five times more likely to coded with speeding, and three times more likely with improper passing. CMV drivers are more likely to be coded with improper lane use, improper turn, and improper backing. Each of the actions noted for CMV drivers may be related to the CMV driver's vision around the vehicle. This is clearest in the case of improper backing, but improper lane use may represent cases in which the CMV driver attempted to change lanes but failed to detect a vehicle in the blind zones.

In addition, it appears that the types of errors and actions non CMV drivers make that contribute to crashes with CMVs are similar to the actions that contribute to crashes with other non CMVs. That is, the types of mistakes non CMV drivers make around CMVs are reasonably similar to those they make around other vehicle types. Compare the distributions in the right-most two columns. The distributions are quite similar, with comparable percentages for speeding, failure to yield, disregard of traffic control, and several other actions. Note, however, that improper passing and improper lane use are much more likely in crashes with CMV drivers, and unable to stop (failure to maintain assured clear distance), is much more likely in crashes with other non CMVs. The remainder of this section focuses on just CMV hazardous actions in all crashes.

Hazardous actions vary with the severity of the crash. Certain types of hazardous actions are associated strongly with more severe crashes, while others more often occur in less severe crashes. Table 13 shows the percentages of coded hazardous action by crash severity. Crash severity is shown for each level of injury severity, rather than aggregated into a single "injury" category. The most common hazardous action is shown here as assured clear distance, the complete label for which is "unable to stop in assured clear distance." This code identifies situations in which the driver was following too close to be able to respond to unexpected events. Following too close is common both in severe crashes and overall. Speed too fast is a common hazardous action in serious crashes and also in the less serious crashes. On the other hand, certain hazardous actions are associated with serious crashes primarily and others mainly with less serious crashes. Disregard of traffic control was coded for 10.8 percent of fatal crash involvements but only 5.7 percent of C-injury involvements and 1.9 percent of PDO involvements. Failure to yield was coded for only 3.8 percent of fatal involvements but a much higher percentage of injury and PDO involvements. The relationship is stronger for improper lane use, which is coded in same direction sideswipes. These crashes generally have low closing speeds because both vehicles are going in the same direction, so improper lane use is relatively rare in fatal involvements (2.3 percent) but much more common in C-injury and PDO involvements (7.1 and 12.1 percent respectively).

Table 13 Percentage Distribution of CMV Hazardous Actions by Crash Severity

Hazardous action	Fatal	A-injury	B-injury	C-injury	PDO	Total
Speed too fast	13.8	12.3	15.6	9.1	5.5	6.4
Speed too slow	0.8	0.6	0.3	0.4	0.3	0.3
Failed to yield	3.8	18.6	19.8	14.0	10.3	11.2
Disregard traffic control	10.8	9.0	8.2	5.7	1.9	2.7
Drove wrong way	0.0	0.1	0.1	0.1	0.2	0.1
Drove left of center	7.7	2.1	1.0	0.5	1.4	1.3
Improper passing	0.0	1.3	1.1	0.8	1.6	1.5
Improper lane use	2.3	4.1	5.9	7.1	12.1	11.2
Improper turn	1.5	2.6	2.9	4.5	10.3	9.2
Improper/no signal	0.0	0.1	0.1	0.2	0.5	0.4
Improper backing	2.3	1.6	2.0	2.8	12.6	10.9
Assured clear distance	22.3	22.3	18.8	39.9	17.0	19.8
Reckless driving	1.5	0.6	0.1	0.3	0.2	0.2
Careless/negligent	13.8	9.5	10.2	4.6	3.8	4.3
Other	19.2	15.0	13.7	10.0	22.4	20.5
Total	100.0	100.0	100.0	100.0	100.0	100.0

Note also the high proportion of "careless/negligent," particularly in comparison with "reckless driving." Reckless driving is clearly aggressive driving, e.g., driving without regard for the safety of others. The percentage of reckless CMV drivers is quite small. The "careless/negligent" category encompasses distracted driving or inadequate attention, i.e., failing to take sufficient care. Careless driving is more strongly associated with serious crashes than less serious crashes. Note also the high percentage of “other” hazardous actions.

Hazardous actions also vary by the type of crash that they lead to. The next set of tables shows the primary hazardous actions that lead to the different crash types defined above. The tables show the most important hazardous actions in each crash type, along with the percentage of CMVs in the crashes coded with the hazardous actions. The percentages seem low for some crashes because of the relatively high percentage of some crash types in which no hazardous action was noted for the CMV driver. For each crash type, the primary actions coded are reasonably consistent and logically associated with the crash type.

In single-vehicle crashes, the primary hazardous action noted for the CMV driver is excessive speed. Single-vehicle crashes include cases in which a driver drove off the road, went into a curve too fast and lost control, but may also involve an animal or a non-motorist such as a pedestrian or bicyclist. The primary specific hazardous action for the CMV driver that led to single-vehicle crashes was travel speeds too high for the conditions, followed by careless or negligent actions. (Table 14a) These latter could be drifting off the road due to inattention or distraction. Note, however, that the officer chose “other” in 17.7 percent of involvements, meaning that the officer did not find the appropriate code on the list. In the large majority of head-on crashes (Table 14b), the officer did not code any hazardous action for the CMV driver, but where the CMV driver was considered to have contributed to the crash, the primary actions were drove left of center, speeding, and failure to yield. Failure to yield was the primary hazardous action in head-on, left turn, crashes (Table 14c), followed by improper turn and disregard of traffic control. Those were also the primary hazardous actions by the CMV driver in angle crashes (Table 14d).

Table 14a Single-vehicle Crashes

Hazardous action	%
None	43.4
Speed too fast	14.6
Careless/negligent	6.6
Improper turn	5.2
Assured clear distance	2.4
Improper lane use	1.0
Other	17.7

Table 14b Head-on Crashes

Hazardous action	%
None	71.6
Drove left of center	3.3
Speed too fast	2.8
Failed to yield	2.4
Assured clear distance	1.7
Careless/negligent	1.4
Improper lane use	1.1
Other	5.4

Table 14c
Head-on Left Turn Crashes

Hazardous action	%
None	49.0
Failed to yield	23.8
Improper turn	7.9
Disregard traffic control	4.3
Improper lane use	1.7
Assured clear distance	1.3
Other	2.9

Table 14d
Angle Crashes

Hazardous action	%
None	56.0
Failed to yield	15.9
Disregard traffic control	5.7
Improper turn	4.8
Improper lane use	2.2
Assured clear distance	1.5
Speed too fast	1.3
Other	3.6

Table 14e
Rear-end Crashes

Hazardous action	%
None	48.3
Assured clear distance	35.3
Speed too fast	1.7
Careless/negligent	1.3
Failed to yield	0.9
Improper lane use	0.8
Other	3.6

Table 14f
Sideswipe, Same Direction Crashes

Hazardous action	%
None	44.8
Improper lane use	14.8
Improper turn	6.6
Failed to yield	5.7
Improper passing	1.7
Careless/negligent	1.6
Assured clear distance	1.3
Other	8.9

Table 14g
Sideswipe, Opposite Direction Crashes

Hazardous action	%
None	46.6
Improper turn	10.1
Improper lane use	9.2
Drove left of center	5.2
Failed to yield	4.4
Improper passing	1.8
Speed too fast	1.7
Careless/negligent	1.5
Assured clear distance	1.4
Other	10.7

Table 14h Backing Crashes

Hazardous action	%
None	19.2
Improper backing	65.1
Failed to yield	2.3
Assured clear distance	1.3
Improper lane use	0.9
Other	6.1

Following too close was the primary action in rear-end involvements, with failure to maintain an assured clear distance to stop coded in over 35 percent of cases, as shown in Table 14e above. No other action accounted for even as much as 2 percent of rear-end crashes. In sideswipes in which both vehicles were going the same way, the primary hazardous action selected is improper lane use, which likely means merging or changing lanes into a lane that is already occupied. (Table 14f) Almost 15 percent of cases were coded improper lane use. Improper turn and failure to yield were the next most common actions at 6.6 and 5.7 percent respectively. In opposite direction sideswipes, some of the same hazardous actions were also the most important, but in a different order. Improper turn accounted for 10.1 percent, improper lane use for 9.2 percent, and drove left of center for 5.2 percent. (Table 14g) It appears that some of these crashes occurred while the CMV was attempting to turn, but in others the CMV moved across the centerline into the opposing lane of traffic, either unintentionally or while attempting a maneuver. Finally, improper backing by the CMV driver was coded in most backing crash involvements (Table 14h). Note that backing is the one crash type in which the CMV driver was overwhelmingly cited as contributing to the crash, with improper backing noted in 65.1 percent of cases and no hazardous action by the CMV driver indicated in less than 20 percent of the involvements. We believe this is related to the difficulty of the backing maneuver when driving a truck or other CMV. Restrictions on the driver's vision to the rear, from the cargo body and the sheer size of the vehicle, and the inadequacy of mirrors make backing a CMV a challenge.

So far this section has demonstrated that the driving errors made by CMV drivers are highly associated with the severity of the crash that results as well as the type of crash. In addition, we know from the previous section that most of the crash costs in CMV traffic accidents accrue in fatal crashes and that certain crash types (such as head-on crashes) are much more likely to be severe or even fatal than other crash types (such as backing or same-direction sideswipes). The association between hazardous actions and crash types, and crash types with serious injuries and costs, leads quite naturally to evaluating the contribution of different hazardous actions to crash costs, as well as to identify those hazardous actions that contribute disproportionately to crashes, the severity of crashes, and therefore crash costs.

Table 15 shows the costs of the crashes by the type of hazardous action coded to the CMV driver. The second column shows the ranking of each hazardous action in terms of the total crash costs associated with that hazardous action. "Assured clear distance," basically following too close to be able to stop safely, is the hazardous action that accounts for the greatest dollar amount of crash costs, followed by the miscellany of "other" and "failed to yield." "Speed too fast" ranks fourth with "careless/negligent" fifth and "disregard of traffic control" sixth. These top six categories account for about 80 percent of crash costs associated with CMV driver hazardous actions. In terms of the cost of CMV driver hazardous actions, those six factors are the primary driving errors to address.

Table 15 Crash Costs by CMV Hazardous Action

Hazardous action	Crash costs (millions)	Rank in terms of costs	Relative contribution to crash costs	Rank in terms of contribution
Speed too fast	$104.1	4	1.57	5
Speed too slow	$2.2	13	0.73	9
Failed to yield	$107.4	3	0.93	7
Disregard traffic control	$74.1	6	2.67	3
Drove wrong way	$1.0	15	0.68	10
Drove left of center	$38.0	10	2.86	2
Improper passing	$8.3	11	0.54	12
Improper lane use	$65.9	7	0.57	11
Improper turn	$46.2	9	0.49	14
Improper/no signal	$2.0	14	0.49	15
Improper backing	$55.3	8	0.49	13
Assured clear distance	$258.3	1	1.27	6
Reckless driving	$7.8	12	3.30	1
Careless/negligent	$89.2	5	2.03	4
Other	$168.3	2	0.80	8

Table 15 also rates the hazardous actions in terms of their relative contribution to crash costs. The third column shows the relative contribution of each hazardous action type to crash costs. This measure essentially rates each hazardous action in terms of crash costs, compared with all crash costs in which the CMV driver was coded with a hazardous action. The rates are normalized to one, so hazardous action rates over one contribute relatively more to crash costs, and values under one contribute relatively less. Relative contribution is calculated using the following equation:

$$RelativeContribution = C/I$$

Where: C = the proportion of costs associated with a hazardous action
I = the proportion of involvements associated with a hazardous action

For example, crashes in which the hazardous action was reckless driving by the CMV incur costs 3.30 times more than the average crash, while crashes in which improper backing was coded as a hazardous were only half as costly (0.49) as the average crash. This measure provides insight into the relative benefit of incremental reductions to each hazardous action. It could be used to prioritize the CMV hazardous action countermeasures.

3.7 Driver Age

We were unable to obtain the driving history files in time to include that analysis in the report. This section focuses on the contribution of driver age.

Table 16 shows the distribution of CMV driver age in the Michigan crash data. Note that driver age is unknown for about 18 percent of the drivers. About three-quarters of the drivers for whom driver age is unknown are from out of state. Although driver age is captured on the UD-10, it is missing in the coded crash data for only about 0.5 percent of drivers with Michigan licenses, but missing for 65.7 percent of other drivers. The column for the adjusted percentage distribution of driver age takes into account the fact that age is unknown at a much higher rate for out-of-state drivers than in-state drivers.

The driver age categories shown were selected to capture known differences by age. Among passenger car drivers, crash rates by age describe a U-shaped curve. Massie, et al. (1997) showed that rates are elevated up to the early 20s, at which point they reach a low and remain fairly constant to the 50s. Crash rates rise starting around age 60 and approach those of drivers in their teens and early 20s. There has been less work on crash rates by age for truck drivers, but the pattern is comparable. Campbell (1991), working with fatal crashes only, showed much higher rates for truck drivers under 25 than drivers older than that. Rates remained steady, with only a slight increase over the age of 60.

Table 16 Crash Involvements by CMV Driver Age

Driver age	N	%	%, adjusted for unknowns
18-20	820	0.9	1.0
21-25	4,497	5.2	6.1
26-60	61,599	71.1	87.0
60+	4,088	4.7	5.9
Unknown	15,634	18.0	
Total	86,638	100.0	100.0

Table 17 shows the distribution of crash types for several categories of driver age. The group 18 to 20 is shown separately because those drivers are not eligible for a Commercial Driver License (CDL). The lower half of the table shows percentage distributions by crash type for each age group. Overall, the distributions by crash type are roughly similar across the age groups. However, the two younger driver age categories tend to show higher proportions of involvements in rear-end crashes, and slightly higher involvement in single-vehicle crashes. In addition, the younger drivers also have a significantly higher proportion of backing crashes. Note that the driver role in rear-end and backing crashes is not identified here, but there is a suggestion of a greater involvement in crashes in which inexperience may play a role. The table showing hazardous actions will show this more clearly, where younger drivers tend more often to be identified as speeding, following too close to be able to stop, and improper backing.

Table 17 CMV Driver Age by Crash Type
Michigan 2001-2005

	Driver Age					
Crash type	18-20	21-25	26-60	60+	Unknown	Total
Single vehicle	114	610	7,788	566	1,721	10,799
Head-on	11	67	983	63	195	1,319
Head-on left turn	8	64	768	57	79	976
Angle	134	731	10,144	695	1,628	13,332
Rear-end	210	1,090	14,075	851	3,055	19,281
Sideswipe same direction	143	924	14,471	980	4,998	21,516
Sideswipe opposite direction	36	208	3,383	230	956	4,813
Backing	102	468	4,976	346	977	6,869
Other/unknown	62	335	5,011	300	2,025	7,733
Total	820	4,497	61,599	4088	15,634	86,638
	Percentage by Crash type					
Single vehicle	13.9	13.6	12.6	13.8	11.0	12.5
Head-on	1.3	1.5	1.6	1.5	1.2	1.5
Head-on left turn	1.0	1.4	1.2	1.4	0.5	1.1
Angle	16.3	16.3	16.5	17.0	10.4	15.4
Rear-end	25.6	24.2	22.8	20.8	19.5	22.3
Sideswipe same direction	17.4	20.5	23.5	24.0	32.0	24.8
Sideswipe opposite direction	4.4	4.6	5.5	5.6	6.1	5.6
Backing	12.4	10.4	8.1	8.5	6.2	7.9
Other/unknown	7.6	7.4	8.1	7.3	13.0	8.9
Total	100.0	100.0	100.0	100.0	100.0	100.0

Figure 13 compares the four age groups in terms of the proportion of crash involvements in which the reporting police officer noted a hazardous action. The two younger driver groups are clearly coded at a much higher rate than the other two. A hazardous action was coded for almost 70 percent of the drivers in the youngest group, and for almost 60 percent of the 21-25 age group. The broad middle group, running from 26 through 60, was coded with a hazardous action in only 48 percent of involvements. CMV drivers over 60 were cited in 54 percent of crash involvements. It is not possible to calculate crash rates by driver age because the necessary travel data do not exist, but the rate at which younger drivers are identified as having committed a hazardous action suggests that they contribute disproportionately to crashes. Moreover, while it cannot be determined if police officers are more likely to identify a hazardous action for a younger driver, it should be noted that this evidence is consistent with the work by others that suggests that younger drivers may have a safety problem.

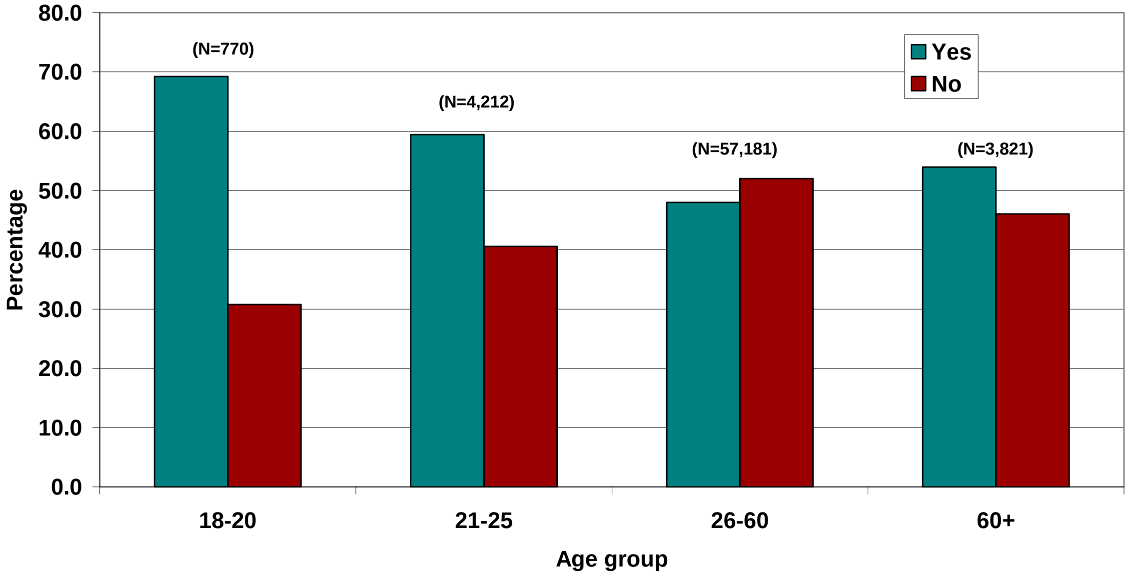

Figure 13 Hazardous Action Coded by CMV Driver Age Group Michigan Crash Data, 2001-2005

Figure 14 shows the percentages of drivers by age group coded with the detailed hazardous actions. It graphically shows that the different age groups are associated with different hazardous actions. Backing and unable to stop, that is, following too closely to safely stop if necessary, were the most common hazardous actions for the two younger driver groups. Younger drivers had much higher rates of coded backing and unable to stop actions than the older driver groups. Both hazardous actions are related to the special problems of handling a CMV. Given sight restrictions around a CMV, backing is clearly a challenging maneuver. CMVs also typically have longer stopping distances than other motor vehicles. With experience, it appears that older drivers substantially reduce the incidence of these two problems. In addition, younger drivers were also more likely to be identified as going too fast than either the broad middle group or the drivers in the 60+ age group.

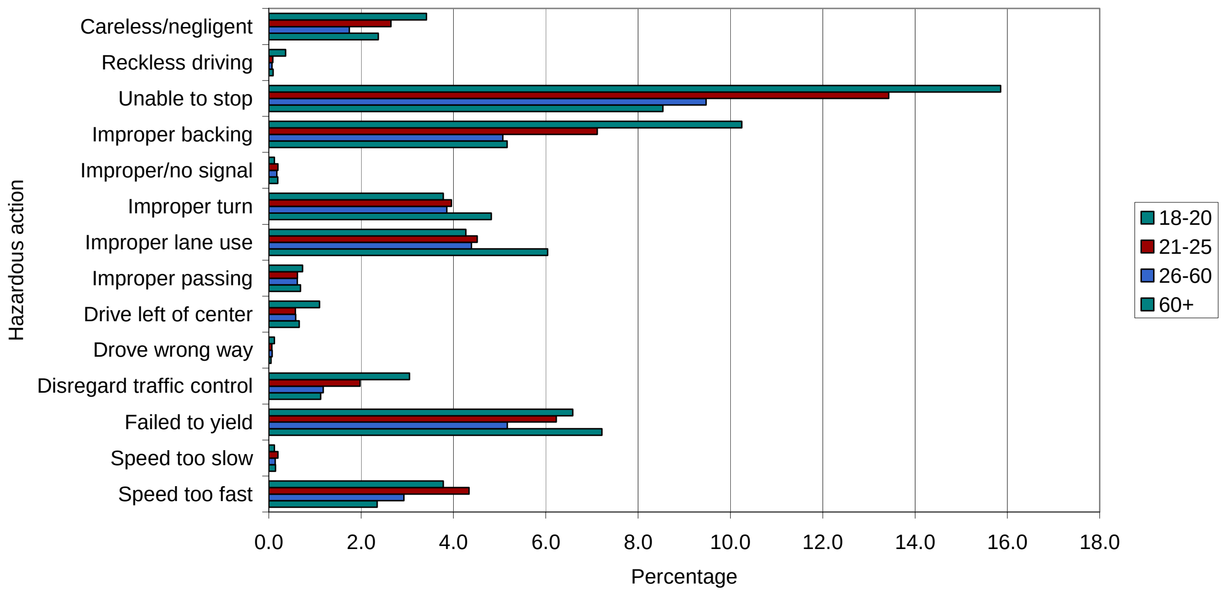

Figure 14 Specific Hazardous Actions by CMV Driver Age Group

Table 18 tabulates the percentages graphed in Figure 14. The table repeats the information in the figure because the number of action types and the age categories make it difficult to read the percentages for specific actions and age groups. The figure graphically represents the scale of difference between the groups and makes it easy to visually identify the major items, but the table provides the precise details. Overall, the most common hazardous actions are unable to stop in an assured clear distance (following too close), failure to yield right of way, improper lane use (unsafe merge or drifting out of lane) and improper backing. Speed too fast was only coded in about 3 percent of cases, though the hazardous actions represented here cover all crash severities, most of which are relatively minor.

Table 18 Percentage Distribution of Hazardous Actions by CMV Driver Age
Michigan Crash Data, 2001-2005

Hazardous action	Driver age					Total
	18-20	21-25	26-60	60+	Unknown	
None	28.9	38.0	48.3	43.0	35.4	45.0
Speed too fast	3.8	4.3	2.9	2.3	2.8	3.0
Speed too slow	0.1	0.2	0.1	0.1	0.1	0.1
Failed to yield	6.6	6.2	5.2	7.2	4.0	5.1
Disregard traffic control	3.0	2.0	1.2	1.1	1.2	1.2
Drove wrong way	0.1	0.1	0.1	0.0	0.0	0.1
Drive left of center	1.1	0.6	0.6	0.7	0.6	0.6
Improper passing	0.7	0.6	0.6	0.7	0.9	0.7
Improper lane use	4.3	4.5	4.4	6.0	7.9	5.1
Improper turn	3.8	4.0	3.9	4.8	5.5	4.2
Improper/no signal	0.1	0.2	0.2	0.2	0.2	0.2
Improper backing	10.2	7.1	5.1	5.2	3.7	5.0
Assured clear distance	15.9	13.4	9.5	8.5	6.0	9.1
Reckless driving	0.4	0.1	0.1	0.1	0.2	0.1
Careless/negligent	3.4	2.6	1.7	2.4	2.4	2.0
Other	11.5	9.7	9.1	11.0	10.0	9.4
Unknown	6.1	6.3	7.2	6.5	18.9	9.2
Total	100.0	100.0	100.0	100.0	100.0	100.0

3.8 Fatigue

Driver condition is recorded on the UD-10 for all drivers. Reporting officers may record driver conditions such as drinking, illegal drug use, illness, fatigue, asleep, reactions to medication, distracted driving, and the use of a cell phone. Table 19 shows the distribution of conditions selected for CMV drivers in Michigan crashes. More than one condition can be chosen for any particular driver so the sum of the conditions is more than the total of the drivers. The count of CMV drivers is used to calculate the percentages, so the percentages denote the percentage of CMV drivers coded with a given condition. Note that 84 percent of the drivers were coded “appeared normal” and another 15.0 percent were either coded “unknown” (4.2 percent) or left as missing data (10.8 percent). Only 1.2 percent of the conditions recorded for CMV drivers were something other than “normal” or unknown. Only 0.16 percent (rounded to 0.2 in the table) were coded fatigued and 0.16 percent were coded asleep.

Accurately discerning driver condition can be very challenging for an officer completing a UD-10, especially for “conditions” that do not have a physical marker. There are tests for drugs and alcohol, but there is no similar test to detect, after a crash, that the driver was fatigued or asleep. Officers must make inferences from witnesses, the events of the crash, time of day, or more rarely, from statements by the driver him/herself. It is likely that only the most obvious cases are identified, such as cases where the driver fell asleep and was seen to drift off the road. Accordingly, it is virtually certain that fatigue/asleep is not completely reported. In the five years of crash data used for this report, only 275 CMV drivers were identified as either fatigued or asleep.

Table 19 CMV Driver Condition
Michigan Crash Data, 2001-2005

Driver condition	Frequency	%
Normal	72,733	84.0
Had been drinking	269	0.3
Illegal drug use	33	0.0
Sick	76	0.1
Fatigue	136	0.2
Asleep	139	0.2
Medication	21	0.0
Driver distracted	322	0.4
Driver using cell phone	44	0.1
Unknown	3,665	4.2
Missing	9,373	10.8
Total	86,638	100.0

Because there are so few drivers identified as fatigued/asleep, detailed analysis of the data using multiple variables is not possible. However, this section will provide a general description of the primary ways that fatigued/asleep CMV drivers in crashes differ from other CMV drivers that were in traffic accidents. In the following tables, drivers coded either fatigued or asleep are counted as “fatigued” and will be referred to as fatigued.

Fatigued CMV drivers are much more likely to be involved in single vehicle crashes than other drivers. Over half of the 275 CMV drivers recorded as fatigued were involved in single-vehicle crashes, compared with 14.1 percent of other CMV drivers (Table 20). Fewer than 40 percent were in crashes with one other vehicle and only 4.7 percent in crashes with three or more vehicles. This is likely because in fatigue-related crashes, the typical mechanism is that the driver becomes less engaged in actively controlling his vehicle, allowing the vehicle to drift out of lane and the driver is not alert to steer it back. Whether another vehicle is involved is a matter of the chance that another vehicle is present when the vehicle goes out of the lane, or is in the lane in front of the fatigued driver but going more slowly. But note also that an officer may be more likely to conclude that the driver was fatigued if the evidence at the scene indicates the vehicle simply ran off the road and crashed. Without an independent marker for fatigue, it is difficult to determine whether the driver was fatigued, ill, or distracted.

Table 20 CMV Driver Fatigued/Asleep by Number of Vehicles in Crash

Number of vehicles	Other		Fatigued/asleep		Total	
	N	%	N	%	N	%
Single	12,205	14.1	154	56.0	12,359	14.3
Two	68,336	79.1	108	39.3	68,444	79.0
Thee or more	5,822	6.7	13	4.7	5,835	6.7
Total	86,363	100.0	275	100.0	86,638	100.0

Table 21 compares the distribution of crash types for fatigued CMV drivers and for other CMV drivers. Again, as in Table 20, there is a strong overrepresentation of fatigued drivers in single-vehicle crashes. But note also that the proportion of rear-end crashes is almost the same as for other drivers. In this classification of crash types, all rear-end crashes are combined, both striking and struck. It would be desirable to distinguish cases where the CMV was the striking vehicle from those in which the CMV was struck. But that is not possible given the data problems with the police-reported crash data, as noted above on page 24 in the discussion of the development of a crash type classification. However, it is tempting to think that the types of rear-end crashes—as the striking vehicle or the struck—differ between fatigued and other drivers. One would expect that in most of the rear-end crashes involving fatigued CMV drivers, the CMV struck the other vehicle in the rear, rather than the other way around. But this hypothesis could not be verified because of limitations in the UD-10 data. Note also that angle collisions account for a lower percentage of fatigued involvements than other CMV involvements. Over 15 percent of the involvements of other CMV drivers were in angle collisions, which typically take place at intersections. In contrast, only 3.6 percent of the involvements of fatigued drivers were in angle collisions. Bearing in mind that fatigue is likely substantially underreported, it appears that fatigued drivers are involved in different types of crashes, mainly crashes of omission, if one can put it that way, i.e., where the driver, because of his fatigue, essentially failed to control his vehicle, and either went off the road or failed to note other vehicles moving more slowly or stopped in front.

Table 21 CMV Driver Fatigued/Asleep by Crash Type

Crash type	Other		Fatigued/asleep		Total	
	N	%	N	%	N	%
Single vehicle	10,648	12.3	151	54.9	10,799	12.5
Head-on	1,318	1.5	1	0.4	1,319	1.5
Head-on left turn	976	1.1	0	0.0	976	1.1
Angle	13,322	15.4	10	3.6	13,332	15.4
Rear-end	19,220	22.3	61	22.2	19,281	22.3
Sideswipe same direction	21,483	24.9	33	12.0	21,516	24.8
Sideswipe opposite direction	4,810	5.6	3	1.1	4,813	5.6
Backing	6,863	7.9	6	2.2	6,869	7.9
Other/unknown	7,723	8.9	10	3.6	7,733	8.9
Total	86,363	100.0	275	100.0	86,638	100.0

Fatigue-related crashes tend to be more severe than other crashes, at least among CMVs. Table 22 shows the distribution of crash severity for crashes in which the CMV driver was coded as fatigued/asleep and other CMV crash involvements. The difference in proportion of fatal crash involvements is not statistically significant because of the small number of cases, but the difference in the proportion of injury crashes is highly statistically significant. Over 41 percent of crash involvements in which the CMV driver was coded fatigued or asleep resulted in an injury or a fatality, compared with only 18.9 percent of other CMV involvements. Again, this difference is likely because of the environment in which the crashes occur and their mechanism. Many fatigue-related involvements are run-off the road crashes, in which the CMV goes off the road and either overturns or strikes a fixed object, both of which are associated with a much higher risk of severe injury. Or if the CMV strikes another vehicle, the fact that the CMV driver is fatigued likely means that the driver either is slow to make an evasive maneuver or fails altogether. Also, fatigue-related crashes tend to occur on high-speed roads, so the higher vehicle speed also contributes heavily to the severity of the crashes.

Table 22 CMV Driver Fatigued by Crash Severity

Crash severity	Other		Fatigued/asleep		Total	
	N	%	N	%	N	%
Fatal	637	0.7	5	1.8	642	0.7
Injury	15,730	18.2	109	39.6	15,839	18.3
PDO	69,996	81.0	161	58.5	70,157	81.0
Total	86,363	100.0	275	100.0	86,638	100.0

Table 23 shows that fatigue-related crash involvements are much more likely to occur on high-speed roads than other crash types. Almost half (47.3 percent) of fatigue-related CMV involvements occurred on Interstate roads, compared with only 20.1 percent of all other CMV involvements. In addition, 17.1 percent occurred on US routes and another 13.8 percent on M routes, for a total of 78.2 percent on high-speed roads. Only 48.6 percent of other CMV involvements occurred on those three road types. This difference is highly significant. Fatigue-related CMV involvements are associated with high-speed roads, indeed, in light of the overrepresentation of Interstate highways, the highest-quality roads in the system. This is likely related to the context in which the fatigue-related crashes occur. Fatigue-related involvements are much more likely to occur at night than other involvements (Figure 15 below). At night and in the early morning hours, CMVs are in transit to destinations rather than making deliveries, and so are more likely on the Interstates or other high speed, long haul roads. In addition, considering Interstates specifically, the driving task on Interstate roads is the least challenging, given the wide lanes and sweeping, predictable curves.

Table 23 CMV Driver Fatigue by Highway Class

Highway class	Other		Fatigued/asleep		Total	
	N	%	N	%	N	%
Interstate	17,342	20.1	130	47.3	17,472	20.2
US Route	8,330	9.6	47	17.1	8,377	9.7
M Route	16,362	18.9	38	13.8	16,400	18.9
Other business route/connector	2,572	3.0	4	1.5	2,576	3.0
Other road, city street	39,046	45.2	41	14.9	39,087	45.1
Unknown/missing data	2,711	3.1	15	5.5	2,726	3.1
Total	86,363	100.0	275	100.0	86,638	100.0

Most fatigue-related CMV crash involvements occur between midnight and 8 a.m., while most non-fatigue-related involvements occur during the day (although it should be noted that officers may be more likely to suspect fatigue at night). Figure 15 shows the distributions of fatigue-related and other CMV involvements by time of day. Over 57 percent of involvements in which the CMV driver was coded as fatigued or asleep occurred between midnight and 8 a.m., compared with 16.2 percent of other CMV involvements. The frequency declines during daylight hours and only starts to increase again after 10 p.m. CMV involvements not coded as fatigue-related show a quite different pattern, being low over night, increasing after 8 a.m., and then remaining at a plateau until 4 p.m., after which the proportion declines to a low rate between 8 p.m. and 10 p.m. There appears to be a slight rise in the proportion of fatigued involvements in the period between 2 p.m. and 4 p.m. but the number of cases is too few for this observation to be reliable. It should be noted, however, that studies of human circadian rhythm show an increase in fatigue in the early afternoon. But, again, the amount of data available here is not sufficient to be able to detect that.

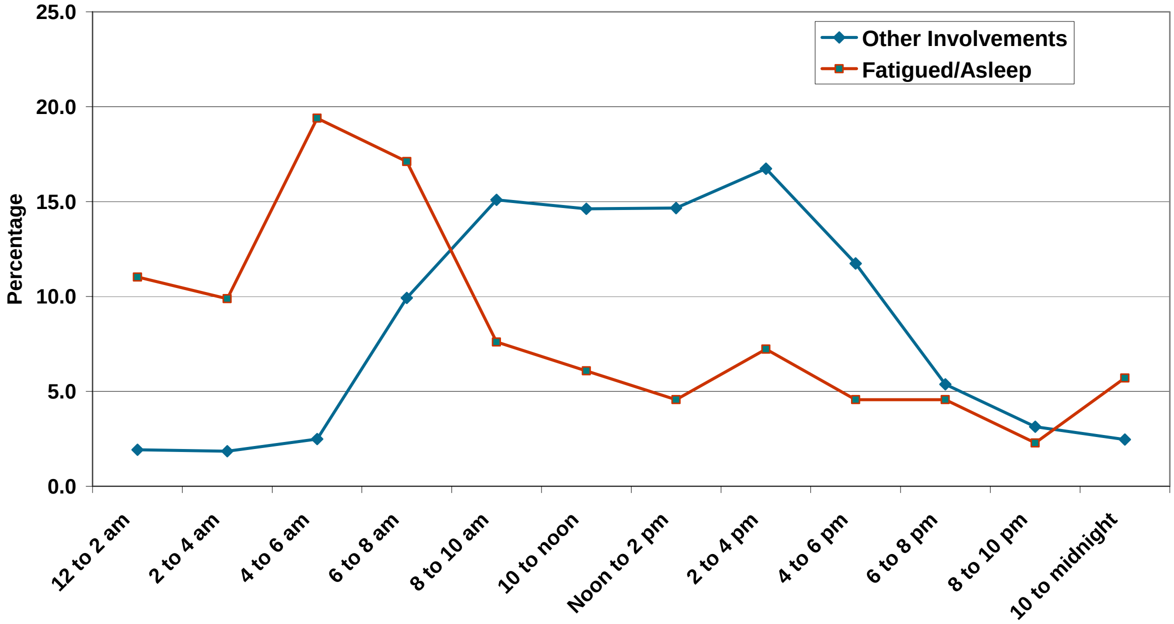

Figure 15 CMV Driver Fatigue by Time of Day

Figure 16 shows a different way of evaluating the impact of fatigue in CMV crash involvements. It shows the proportion of all CMV involvements that are fatigue-related by time of day in two-hour increments. The rate is high between midnight and 6 a.m., with between 1.8 and 2.4 percent of CMV involvements associated with driver fatigue. The rate decreases sharply after 6 a.m., and remains quite low until after 10 p.m. Looking at fatigue in terms of the percent of involvements related to fatigue is a more direct measure of the close coupling of fatigue and time of day than looking at the distribution of fatigued involvements over the whole day, as in Figure 15. That is because the proportion of all fatigued involvements in any particular time window is the product of the number of involvements and the percentage that are fatigue-related. The high percentage of fatigued-involvements between 6 and 8 a.m. in Figure 15 is mostly due to the fact that there are more involvements at that time of day. However, the rate of involvements in that time period is much lower than the overnight rate, and much closer to the daytime rate.

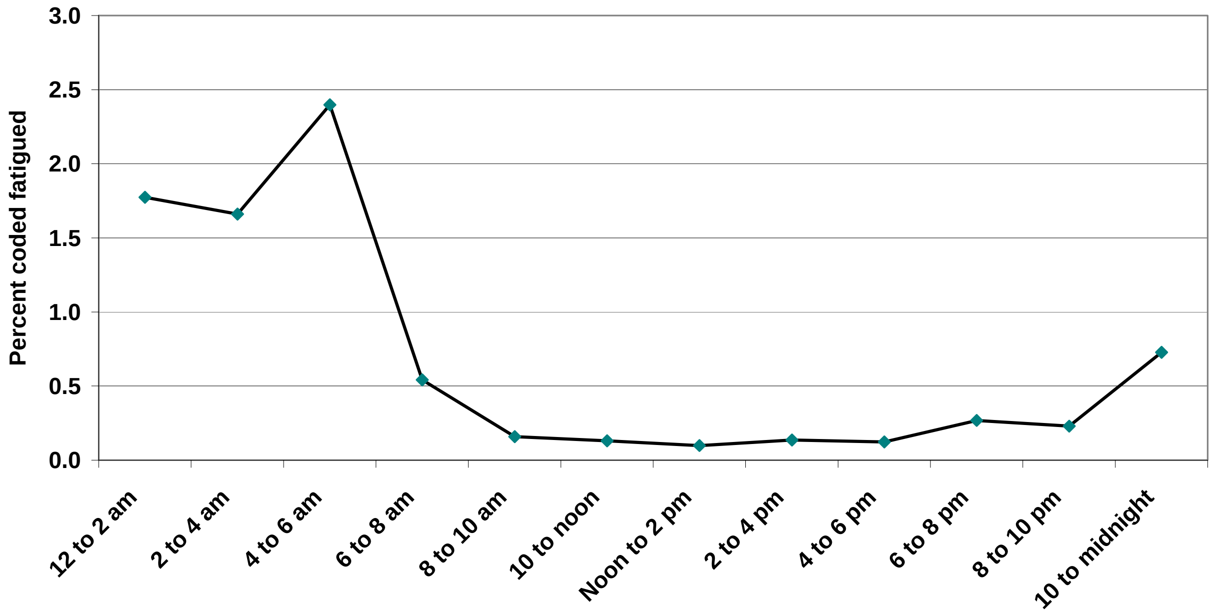

Figure 16 Fatigued/Asleep Rate for CMV Crash Involvements

Fatigue-related CMV involvements also show intriguing patterns by the configuration of the vehicle. The vehicle-type variable on the main UD-10 does not provide any information about the configuration of CMVs, even a simple distinction between trucks and buses. But in the CMV supplemental data, which is required if the crash meets certain thresholds, there is an elaborate classification of CMVs. The classification there combines several dimensions, including the CDL type required for the vehicle, the specific endorsements required, whether the vehicle is a combination, and so on. In Table 24, the vehicles are combined into a more accessible classification. Note that tractors cannot be identified separately, so the truck-trailer combination vehicles include both tractors and straight trucks pulling trailers. The CMV supplemental information is not collected on all CMVs in crashes, so the number of vehicles is less than the total of CMVs in the main police reported data.

Table 24 CMV Driver Fatigue by CMV Configuration

	Other		Fatigued/asleep		Total	
CMV configuration	N	%	N	%	N	%
Truck-one trailer	35,900	48.2	175	70.0	36,075	48.3
Truck-two trailers	2,860	3.8	13	5.2	2,873	3.8
Large SUT*	12,708	17.1	21	8.4	12,729	17.0
Medium SUT*	584	0.8	0	0.0	584	0.8
Large Bus	5,438	7.3	2	0.8	5,440	7.3
Small Bus	1,995	2.7	3	1.2	1,998	2.7
Other	3,948	5.3	17	6.8	3,965	5.3
Unknown	11,058	14.8	19	7.6	11,077	14.8
Total	74,491	100.0	250	100.0	74,741	100.0

* SUT denotes a single unit truck or a tractor with no trailers. Bobtails may be included here.

The overrepresentation of trucks with one trailer among CMV drivers coded fatigued/asleep is striking. Seventy-percent of CMVs whose drivers were determined to be fatigued or asleep were trucks with a single trailer, compared with 48.2 percent of other CMVs involved in crashes. Two-trailer combinations were also higher among the fatigue-related involvements though that difference is not significant statistically. In contrast, the proportion of large single unit trucks (SUT) among the non-fatigued involvements is almost twice as great. Large SUTs are used more in local operations such as construction and heavy delivery, while single and double trailer combinations are used more in long-haul operations. This is suggestive only, however, given the prevalence of the big eleven-axle doubles, with two dump trailers that are also used heavily in construction and other local heavy hauling operations. Also, note that fatigue is virtually undetected among buses, with only five total cases coded fatigued.

Finally, the CMV supplemental data classifies vehicle by the type of motor carrier operating the CMV, specifically whether the carrier operates in interstate commerce or is an intrastate carrier. Table 25 shows that over two-thirds of CMV drivers coded as fatigued or asleep were driving for interstate carriers at the time of the crash, in comparison with only about 40 percent of the CMV drivers not coded fatigued. Note, however, the high proportion of cases for which carrier type was not determined. Over 17 percent of the cases were left unknown, with a higher proportion for non-fatigue-related crashes than for fatigue-related crashes. However, if the unknown cases are excluded and the proportions recalculated, the difference remains large and statistically significant. A table for these results is not shown here, but, excluding the cases left unknown, about 75 percent of the fatigued CMV drivers were driving for interstate carriers, which accounted for only about 48 percent of the CMV drivers not coded fatigued.

Table 25 CMV Driver Fatigue by Carrier Type

	Other		Fatigued/asleep		Total	
Carrier type	N	%	N	%	N	%
Interstate	29,748	39.9	168	67.2	29,916	40.0
Intrastate	31,757	42.6	54	21.6	31,811	42.6
Unknown	12,986	17.4	28	11.2	13,014	17.4
Total	74,491	100.0	250	100.0	74,741	100.0

What is the cost of fatigue-related CMV crash involvements? Using the crash cost estimates developed above, it may be calculated that an average fatigue-related CMV crash costs $78,000, compared with $38,000 for a non-fatigue-related CMV crash. The higher costs of fatigue-related CMV crashes are because such crashes are much more likely to be severe than other crashes. Fatigue-related crashes cost about twice as much as other CMV crashes because such crashes are about twice as likely to result in a fatality or injury as non-fatigue-related crashes.

As indicated above, detecting fatigue is very difficult and it is quite likely that the number of CMV involvements with fatigued drivers is underestimated. Accordingly, the total costs of fatigue-related CMV crashes is likely to be higher than estimated from the per crash cost and the number of involvements identified. A research note from the Federal Highway Administration (FHWA) Office of Motor Carrier and Highway Safety[4] (1999) provides a useful metric for scaling police-reported estimates of driver fatigue to a more-realistic estimate of fatigue in the crash population. The research note reviewed a variety of estimates of driver fatigue developed using different methodologies and data sources. The note recommends a correction factor of 1.4 to 3.1 times the incidence of fatigue in police-reported data to determine a more accurate estimate of the true incidence of fatigue in truck crashes. Given the uncertainty and difficulty of identifying driver fatigue, a range, rather than a point estimate, is probably the most defensible.

Applying the correction factors of 1.4 and 3.1 results in a new estimate of the number of fatigued CMV involvements, ranging from 385 to 853 over the period 2001-2005, or from 77 to 171 annually. Table 26 also shows that the application of the correction range changes the range of the fraction of all CMV involvements related to fatigue to 0.4 percent to 1.0 percent. This range is consistent with the estimated police-reported incidence of fatigue in the research note of 0.5 to 1.1 percent. The corrected estimate for the Michigan data fits very well with the overall estimate in the research note. Finally, the corrected estimate of the number of fatigued involvements also results in a new estimated range of associated costs, from $30.04 million to $66.51 million (though of course the per-crash costs do not change). Thus, it is estimated that crash costs associated with fatigued CMV drivers account for 0.9 percent to 2.0 percent of all CMV crash costs. Though not one of the primary drivers of CMV crash costs in Michigan, reducing fatigue will disproportionately contribute to reducing crashes and the associated costs in deaths, injuries, and property damage.

Table 26 Actual and Estimated Incidence of CMV Driver Fatigue in Crashes

		Estimated Range	
	Actual	Low end	High end
Number of involvements	275	385	853
Percent of all involvements	0.3%	0.4%	1.0%
Total costs (millions)	$21.46	$30.04	$66.51
Percent of all costs	0.6%	0.9%	2.0%

While the amount of data available is limited, taken together the above analysis presents a picture that captures the main outlines of the driver fatigue problem in Michigan. As might be expected, most fatigue-related CMV involvements occur at night, between midnight and 6 a.m. The probability of a fatigue-related crash is increased by 5 to 8 times at night. During the day,

[4] Now the Federal Motor Carrier Safety Administration, FMCSA

rates are much lower, with only about 0.1 to 0.5 percent of crash involvements resulting from CMV driver fatigue. Fatigue-related involvements occur disproportionately on Interstate-quality roads, and involve tractor-semitrailers or doubles operated by interstate carriers. The picture suggests carriers in long-haul operations, on long trips on high-speed roads. And the crashes themselves are more likely to be severe, single-vehicle crashes in which the CMV runs off the road, or is involved in a rear-end crash. The UD-10 data are not detailed and reliable enough to provide more details, but it is likely that a common scenario for fatigued CMV involvements is the vehicle either drifting off the road and colliding with a fixed object or overturning, or colliding with slower moving traffic on the roadway that the driver fails to detect and avoid.

Obviously this picture does not reflect all the varieties of fatigue-related crashes. They also occur on low speed roads, and sometimes involve intrastate carriers, straight trucks, and daylight hours. But the main lines are clear, given the underlying uncertainty of the data and the very high probability of underreporting. However, one also notes that in these data, even using the high end of the correction range, fatigue-related CMV crashes are estimated to account for two percent of all CMV crashes. On the other hand, drawing the boundaries around behaviors and actions that are defined as fatigue-related is very difficult and essentially not yet attempted in the crash literature. For the purposes of this section, fatigue is effectively defined as those cases in which the driver’s responsiveness, alertness, and control over the vehicle is seriously and obviously impaired, e.g., fell asleep. Yet there are also more subtle effects in which the driver’s judgment was impaired, reactions slowed, alertness and awareness of the driving situation degraded, that may contribute to crash risk. The effects of fatigue at that level cannot be evaluated currently with available data and understanding of how crashes occur.

3.9 Carrier Type and Gross Combination Weight in Fatal Crashes

UMTRI’s Trucks Involved in Fatal Accidents file includes only fatal truck involvements but it provides unique information on the vehicles and the carriers that operate them, allowing the population of trucks involved in fatal crashes in Michigan to be compared with trucks in fatal crashes in other states. At the time this report was prepared, the 2005 data year had not yet been completed, so it was not available for analysis. However, earlier years were available. Accordingly, we prepared a data file that covered the six years from 1999-2004. In this section we compare Michigan trucks in fatal crashes with the national population of trucks in fatal crashes, to highlight differences in the physical configuration of the vehicles and the types of carriers operating them.

The Michigan truck fatal crash population tends to have higher proportions of private carriers and of intrastate carriers. These differences may be related to Michigan’s unique weight laws, which have permitted the development of a population of very large trucks that are restricted from operating in other states. Table 27 shows that almost 44 percent of trucks in fatal crashes in Michigan are operated by private carriers, in comparison with about 36.1 percent in other states.

Table 28 shows that a much higher percentage of trucks in fatal crashes in Michigan are operated by intrastate carriers, in comparison with other states. Almost 35 percent of the Michigan trucks were intrastate only, while in all other states, the intrastate-only trucks amounted to less than 25 percent of all trucks in fatal crashes. Trucks in fatal crashes in Michigan tend to be operated more often by private carriers and much more often by intrastate-only carriers.

Table 27 Trucks in Fatal Accidents by Operating Authority
Michigan and All Other States, TIFA 1999-2004

	Michigan		All other states	
Operating Authority	N	%	N	%
Private	353	43.6	10,905	36.1
For Hire	418	51.7	16,955	56.1
Government-owned	19	2.3	531	1.8
Daily rental	8	1.0	260	0.9
Unknown	11	1.4	1,556	5.2
Total	809	100.0	30,207	100.0

Table 28 Trucks in Fatal Accidents by Area of Operation
Michigan and All Other States, TIFA 1999-2004

	Michigan		All other states	
Area of Operation	N	%	N	%
Interstate	481	59.5	19,715	65.3
Intrastate	281	34.7	7,295	24.2
Government-owned	19	2.3	531	1.8
Daily rental	8	1.0	260	0.9
Unknown	20	2.5	2,406	8.0
Total	809	100.0	30,207	100.0

The unique population of trucks in Michigan is readily identified in terms of gross combination weight (GCW). Michigan does not limit truck weights directly, but rather regulates axle weight and limits the number and spacing of the axles. Truck combinations may have up to eleven axles, if properly spaced. As a result, trucks in Michigan may operate at weights up to 164,000 pounds without special permits. Table 29 compares the configuration and GCW of trucks involved in fatal crashes in Michigan and all other states. Overall, the distributions of truck configuration are similar, though Michigan has slightly higher percentages of straight trucks, both with and without trailers, and tractors with two trailers, and a compensating lower percentage of tractor-semitrailers. In other states, almost 60 percent of trucks involved in fatal accidents are tractor-semitrailers, but only about 52 percent of those in Michigan.

Table 29 Trucks in Fatal Accidents, Frequency and Gross Combination Weight Michigan and All Other States, TIFA 1999-2004

Configuration	Michigan			All other states		
	N	%	GCW	N	%	GCW
Straight truck	262	32.4	22,907	8,639	28.6	24,308
Straight truck /1 trailer	50	6.2	59,338	1,229	4.1	34,015
Bobtail	14	1.7	16,400	642	2.1	17,346
Tractor /1 semitrailer	418	51.7	53,922	17,961	59.5	54,973
Tractor /2 trailers	56	6.9	90,871	890	2.9	60,257
Other combinations	6	0.7	42,067	216	0.7	44,863
Unknown	3	0.4	unknown	630	2.1	105,010
Total	809	100.0	46,172	30,207	100.0	44,718

The higher percentage of trucks with two cargo bodies than in other states is doubtless a consequence of Michigan's weight laws. By allowing very heavy combination weights, carriers operate more efficiently by carrying more cargo in a single vehicle. This is readily apparent by comparing the GCW columns in Table 29. There is no practical or significant difference between the GCWs of straight trucks, bobtails (a tractor with no trailer), tractor-semitrailers, or other combinations. The respective GCWs of these combinations are about the same in other states as they are in Michigan. Michigan straight trucks in a fatal crash average about 23,000 pounds, and they average about 24,000 in other states. Bobtails in the TIFA data weigh about the same in other states as they do in Michigan. And tractor-semitrailers average about 54,000-55,000 pounds GCW both in Michigan and elsewhere in the US. Taking all trucks together, the average GCW of a truck involved in a fatal crash in Michigan is very similar to that in all other states.

The differences are significant when trucks with two cargo bodies are compared. These vehicles are most able to exploit Michigan's weight laws, and the results are obvious. In Michigan, straight trucks with one trailer had a GCW of about 59,000 pounds on average at the time of a fatal crash, compared with only about 34,000 pounds in other states. The Michigan combination averaged about 74 percent more than the national average. Similarly, Michigan doubles in a fatal crash averaged almost 91,000 pounds, compared with only about 60,000 in other states. These two truck combinations—straight truck with one trailer (typically a full trailer) and a tractor with two trailers—frequently have the full eleven axles permitted by law and are configured to carry the maximum allowable cargo.

Figure 17 further illustrates the point. The chart includes only trucks that were found to be carrying any amount of cargo. We calculated the average gross combination weight for the different combination types shown. The average GCWs are very similar for straight trucks, tractor-semitrailers, and other truck combinations. But the special Michigan combinations averaged almost twice their counterparts in other states. Michigan straight trucks with one trailer had a mean GCW of over 72,000 pounds at the time of the crash, compared with about 39,000 pounds in other states. Michigan tractors with two trailers averaged almost 140,000 pounds, compared with only about 70,600 in other states.

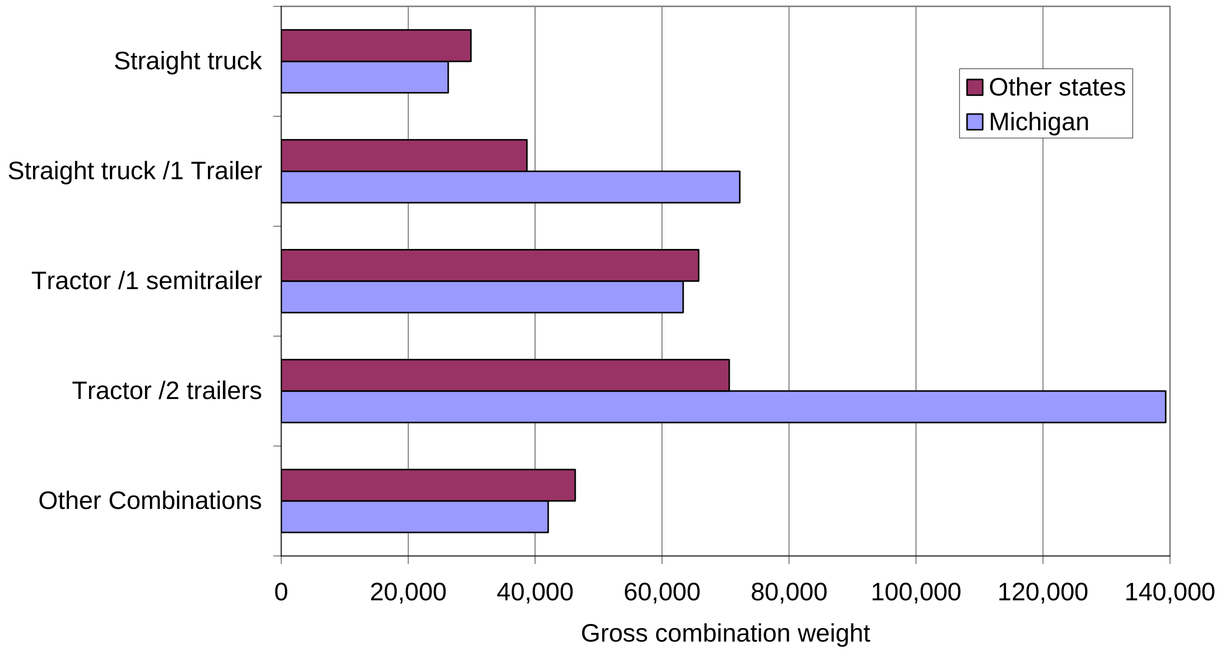

Figure 17 Average Gross Combination Weight, Loaded Trucks Only, Michigan and All Other States TIFA 1999-2004

Intrastate trucks in Michigan tend to be much heavier than intrastate trucks in other states at the time of a fatal crash. Loaded intrastate trucks in Michigan averaged 50,315 pounds, compared with 45,435 for trucks operated by intrastate carriers in other states. Michigan's intrastate trucks also had significantly higher empty weights than the trucks operated by intrastate carriers in other states. In Michigan, the average empty weight was 28,328, compared with 21,616 in all other states. On the other hand, there was no significant difference between trucks in fatal crashes in Michigan and in other states where the carrier had interstate operating authority. For both groups, the trucks had an average GCW of about 61,000 pounds.

While we were unable to carry the analysis further in the TIFA file, it may be pointed out that one result of the analysis of vehicle inspection data (presented in section 3.11) was to show higher rates of driver and vehicle out-of-service violations and higher average number of violations for vehicles operated by intrastate carriers.

3.10 Vehicle Condition

From August 1996 to July 2001 the Michigan State Police Motor Carrier Enforcement Division (MSP MCED) conducted a study of all fatal truck crashes in Michigan. As part of this program the Fatal Accident Complaint Team (FACT) conducted investigations of trucks involved in fatal accidents in Michigan. The goal of the FACT team was to investigate every traffic accident in Michigan that involved a commercial vehicle and at least one fatality. Only truck crashes were investigated, so these data do not include any buses. In practice, the ability of FACT investigators to cover every fatal truck accident was dependent on notification by local authorities. As a result, the FACT team investigated about 80 percent of fatal truck accident involvements in Michigan.

The FACT program was in many ways a forerunner of the FMCSA Large Truck Crash Causation Study (LTCCS) project. The data collected by the FACT investigators included an extensive physical description of each truck involved, information about the driver and motor carrier, scene and roadway description, and a detailed description of the sequence of events in the crash, including the role of the truck. In addition, each truck was subject to a complete inspection to determine the compliance of the vehicle and driver with motor carrier regulations prior to the crash. All pre-crash defects were noted, regardless of whether the defect was thought to contribute to the accident.

The analysis here uses two essential elements of the FACT program: the detailed description of the physical events of the accident and the data on the physical condition of the trucks. The data include the movement of the truck prior to the crash, the event or action that immediately precipitated the collision, a determination of which vehicle had the right-of-way, the sequence of events for the truck, and the relative position and movement of the vehicles in single or two-vehicle accidents (about 80 percent of all fatal truck accident involvements). Using these data, it is possible to identify most accident scenarios in sufficient detail to isolate physical mechanisms that may lead to crashes. For example, in the case of head-on or sideswipe collisions, the vehicle that crossed the lane line can be identified.

The FACT data also provides information about the physical condition of the vehicle that is much more complete and reliable than is available in other accident data files. Each truck involved, regardless of whether vehicle condition was thought to contribute to the crash, was subject to an extensive inspection by a specially-trained officer. The standards to which trucks must conform are detailed in 49 Code of Federal Regulations, Part 393. The inspection protocol is specified in the *North American Uniform Out-Of-Service Criteria*, developed by the Commercial Vehicle Safety Alliance (CVSA)(2000), a non-profit organization of federal, state, and provincial government agencies and representatives from private industry in the United States, Canada and Mexico. This is the standard inspection protocol for most commercial vehicle inspections. FACT investigators were all CVSA-certified inspectors or had access to one. The inspectors recorded the compliance of the truck prior to the accident with the regulations. In some cases, damage from the crash no doubt masked pre-existing violations. Thus, the results of the inspections probably understate the incidence of violations by an unknown amount. Nevertheless, the vehicle condition data in the FACT file are much more reliable than in any other mass accident data file prior to the LTCCS.

In order to detect the effect of vehicle condition on crash risk, we consider the association between the truck's role in the crash and its mechanical condition. Vehicle defects are hypothesized to increase the risk of accident involvement. But specific defects should not increase accident risk across all accident types. Particular vehicle defects are more likely to be found in some accident types than in others. "Accident complements" can be defined that pair accident types where the defect being investigated could explain the truck's role with the complementary accident type where the defect would be irrelevant to the truck's role. For example, the truck's brakes play a crucial role in rear-end collisions in which the truck is the striking vehicle, but not when the truck is the struck vehicle in a rear-end.

The approach here tests if certain vehicle conditions are over-represented in certain crash types as compared to their complements. Since the way the accident physically occurred is known, statistical tests can show if a particular "risk increasing factor," focusing on vehicle condition here, was over involved in the kind of crash where the physical mechanism could be expressed. By providing detailed information about the physical events of a crash, the FACT data establishes the necessary link between the statistical association and the physical mechanism that explains the association.

The FACT file includes records on 503 trucks involved in a fatal crash. Of the 503 trucks, the results of a North American Standard (NAS) Level 1 inspection are available on 407, or 80.1 percent of the trucks. The NAS Level 1 inspection includes all regulated mechanical systems as well as compliance with driver licensing, medical certification, hours of service and duty status, cargo securement, and certain other requirements. Not all of the trucks could be inspected, primarily because they were not available to the inspectors. In a handful of cases, accident damage was so extensive that meaningful inspection was impossible. Statistical tests were performed to see if there was selection bias in the trucks that were inspected. There was almost no difference as to right-of-way between the trucks that were inspected and those that were not. There was some difference in the type of accidents the trucks were involved in, but the difference was primarily that a higher proportion of trucks not inspected were involved in ran-off-the-road crashes than inspected trucks. It is likely that the severity of vehicle damage contributed to the decision not to inspect. See Table 32 and discussion for accident types.

Table 30 shows the aggregated results for all inspected trucks in the FACT file. The inspection covers 91 items related to the vehicle, driver, and certain paperwork requirements. In the table, inspection items are aggregated into general categories. The table shows the number of trucks with violations in each general category. Safety belt records compliance with the requirement that safety belts designed to a certain standard be available. "Driver log" includes all items related to the possession, completeness, and accuracy of the logs. "Hours of service" combines compliance with the various rules governing driving and duty hours. The "other driver" category records compliance with medical certification, age, qualification, licensing, and other driver regulations. "Cab" items include heater, speedometer, emergency equipment, wipers, mirrors, fuel tank, and other items connected with the truck's cab. The "coupling devices" category covers the condition and use of fifth wheels and other coupling devices. "Miscellaneous trailer" violations combines compliance with trailer header board, mud flaps, wiring, and rear-end protection requirements. The "brake" category includes all items related to the functioning of the brakes, including slack adjustment, brake shoes, air hoses, and other items. "Lights/signals" includes headlamps, tail lamps, stop and turn signals, and identification lights. "Tires/wheels" records compliance with all tire, wheel, or rim requirements. The "steering" category covers steering component requirements. The "suspension" category includes frame and suspension requirements; "cargo securement" covers both tarping and cargo loading requirements. Finally, the "other" category includes a variety of licensing, permitting, registration, and document requirements.

Table 30 Trucks with Violations by Violation Type
FACT Data, 1996-2001

Violation type	N	%
Safety belt	15	3.7
Driver log	50	12.3
Hours of service	9	2.2
Other driver reg.	58	14.3
Cab	59	14.5
Coupling devices	14	3.4
Misc. trailer	10	2.5
Brake	142	34.9
Lights/signals	94	23.1
Tires/wheels	59	14.5
Steering	21	5.2
Suspension	39	9.6
Cargo securement	22	5.4
Other	117	28.7

Brakes and the lighting system were the two most common areas of vehicle defects. Over 34 percent of the trucks inspected had at least one brake violation. Over 23 percent of the trucks had some violation of lighting requirements. Other systems had significantly lower rates of violations. Log, driver, cab, tires/wheels, and suspension violations were found on between nine percent and 15 percent of the trucks or drivers. Most of the log violations were for false logs or for logs that were not current; driver violations primarily had to do with medical certification; and the cab violations were predominantly the failure to have required emergency equipment such as a fire extinguisher or various warning devices. Note that only 9 drivers, representing 2.2 percent of the inspected trucks, had an hours of service (HOS) violation. The HOS violations primarily were driving more than 10 hours after 8 hours off duty, or driving after being on duty more than 15 hours since the last 8 hour off-duty period, which were violations of HOS regulations at that time.

A violation was found for either the truck or the driver in 66.1 percent of the trucks inspected (Table 31). Over half of those, 35.1 percent, had at least one out-of-service (OOS) condition, which means that, had the truck or driver been inspected prior to the accident, it would have been parked until the condition was corrected. Considering just the mechanical condition of the truck itself, almost 56 percent of the vehicles recorded at least one violation and 29.5 percent had at least one OOS condition.

Table 31 Aggregate Inspection Results, Michigan FACT Data, 1996-2001

Violation/OOS	N	%
Truck or driver OOS	143	35.1
Truck or driver violation	269	66.1
Truck OOS	120	29.5
Truck violations	227	55.8

The FACT data provides extensive detail on the events of the accident so that fairly detailed accident typologies may be developed. For this study, a typology was developed showing standard accident types (head-on, rear-end, sideswipe, etc.) as well as the relative movement of the vehicles in the accident. Thus, there are two head-on collision accident types, one in which the truck crossed the center line and the other for cases in which the other vehicle crossed the center line into the truck's lane. Rear-end collisions distinguish events in which the truck was struck from those in which the truck was the striking vehicle. Information about right-of-way was not incorporated into this typology (though available in the FACT data) because the focus is on the physical configuration of the accident. Crash in which the truck became involved after the crash was initiated between other vehicles are included in the "other" crash type category.

Table 32 Crash Type,
Michigan FACT Data, 1996-2001

Crash type	N	%
Truck ran off road	15	3.7
Truck hit object in road	22	5.4
Rear-end, truck striking	32	7.9
Rear-end, truck struck	37	9.1
Sideswipe same direction, truck encroached	1	0.2
Sideswipe same direction, other encroached	4	1.0
Head-on, truck encroached	8	2.0
Head-on, other encroached	66	16.2
Sideswipe opposite direction, truck encroached	7	1.7
Sideswipe opposite direction, other encroached	18	4.4
Truck turned across other path	15	3.7
Other vehicle turned across truck path	41	10.1
Intersecting paths, truck into other vehicle	45	11.1
Intersecting paths, other into truck	28	6.9
Truck backed into other	2	0.5
Other backed into truck	1	0.2
Untripped rollover	1	0.2
Other	64	15.7
Total	407	100.0

Table 32 shows the distribution of trucks involved in FACT cases by accident type. Only involvements with completed inspections are included in the table. About nine percent of the involvements were single vehicle, precipitated either by running off the road or by striking a nonfixed object (primarily a pedestrian or bicyclist) in the roadway. Rear-end collisions account for 69 (17.0 percent) of the 407 FACT involvements represented—in 37 the truck was struck in the rear by the other vehicle while in 32 the truck struck the other vehicle. About 18.2 percent of the trucks were involved in head-on collisions. In 66 of the 74 head-on accidents, the other vehicle crossed the center line into the truck's lane. Opposite direction sideswipes are like head-on collisions, in that the vehicles are moving in opposite directions on the same roadway, but the impact is with the side of at least one of the vehicles rather than engaging their fronts, as in a head-on collision. The other vehicle moving into the truck's lane is similarly overrepresented in opposite direction sideswipes, with the other vehicle classified as encroaching in 18 cases, and the truck encroaching in seven.

Overall, the FACT data do not show a strong relationship between the truck's condition, as measured by *violations* recorded in the truck inspection, and the truck's role in the accident. It might be hypothesized that if vehicle condition contributes to accidents, one would expect trucks that violated the right-of-way in the crash would have higher rates of inspection violations than trucks that had the right-of-way prior to the collision. However, taking all accidents together, 70.0 percent of the trucks that violated the right-of-way had one or more violations, compared with 64.9 percent of trucks with the right-of-way. This difference is both practically and statistically insignificant.

However, there is a strong relationship for OOS condition (see Table 32). Where the other vehicle had the right-of-way in the crash, 47.8 percent of the trucks had at least one OOS condition, compared with a 31.4 percent OOS rate for trucks that had the right-of-way. The OOS rate was almost 50 percent higher for trucks that violated the right-of-way than for trucks with the right-of-way in the FACT crashes. Violations are so prevalent across all the inspection items that they do not distinguish between the truck's role in the accident. But OOS items apparently are significant enough to show a safety effect. Clearly the OOS rate is high for all trucks in these data. But the rate is significantly higher among trucks that violated the right-of-way in the accident.

Table 33 Truck/Driver Out-of-service and Right-of-Way
FACT data, 1996-2001

Truck/driver OOS condition	Right-of-way: Truck	Right-of-way: Other vehicle	Total
No OOS condition	205	47	252
1 or more OOS item	94	43	137
Total	299	99	389
	Proportion Out-of-Service		
No OOS condition	68.6	52.2	64.8
1 or more OOS item	31.4	47.8	35.2
Total	100.0	100.0	100.0

chi=8.09, p=0.004

The previous analysis shows that truck OOS is associated with a higher probability that the truck violated the right-of-way in FACT-reported crashes. The detailed information available in the FACT protocol describing the events of the crash can be used to link specific vehicle defects and accident involvement. Defects in certain truck systems are more likely to be expressed in some accident types than others. To illustrate this, the relationship of the mechanical condition of the truck and the truck's role in rear-end collisions will be explored.

In rear-end collisions, braking is the most obvious system to play a role in the crash. But the importance of the brake system depends on the role of the truck in the crash. In rear-end traffic accidents in which the truck is struck in the rear by another vehicle, the condition of the truck's brakes is irrelevant, essentially. Whether the truck has adequate braking or not has no affect on the crash. In those crashes, it is the braking system of the other vehicle that is critical, to the extent that vehicle condition plays a role at all in the generation of the crash. However, when the truck is the striking vehicle in a rear-end accident, the truck's brakes play the critical role, since brake application is the primary collision-avoidance mechanism in that situation.

There are 69 trucks involved in a rear-end collision with a truck inspection in the FACT data. Table 33 shows braking system inspection results. Overall, 28 of the 69 trucks (40.6 percent) had at least one brake violation. This is close to the 34.9 percent brake defect rate for all FACT trucks. But the rate of brake violations is strongly associated with the truck's role in the accident. Only 29.7 percent of trucks that were struck in the rear had a brake violation, compared with 53.1 percent of trucks that were the striking vehicle. In other words, the proportion of rear-end striking trucks with brake violations was almost twice that of rear-end struck trucks. Chi-square test for independence was significant at the 0.05 level.

Table 34 Brake Inspection Results by Truck Role in Rear-End Collisions Fact Data, 1996-2001

Brake inspection results	Rear-end type: Truck striking	Rear-end type: Truck struck	Total
0 violations	15	26	41
1 or more violation	17	11	28
Total	32	37	69
	Proportion with Violations		
0 violations	46.9	70.3	59.4
1 or more violation	53.1	29.7	40.6
Total	100.0	100.0	100.0

chi=3.89, p=0.05

All of the other inspection categories listed in Table 30 were tested for association with the truck's role in rear-end traffic accidents, on the hypothesis that the association of brake defects with the truck's role was just a marker for poor vehicle and driver condition in general. However, there was no relation between any of the other inspection categories and rear-end collisions, with one significant exception, the lighting system. The inspection categories examined include log violations, hours-of-service violations, and other driver violations, all of which might be expected to be associated with rear-end collisions in which the truck was the striking vehicle. But there was no statistically significant association with any of those factors.

Taking all inspection items together, striking-vehicle trucks had a somewhat higher rate of violations than the comparison group, 76.9% to 66.7%, but the difference is relatively small and not statistically significant. Similarly, trucks/drivers of striking trucks were not significantly more likely to have had a pre-existing out-of-service condition than trucks that were struck in rear-end accidents. Striking-vehicle trucks or drivers had a higher rate, 53.8% to 42.4%, but the difference was not significant. Violation and OOS rates are virtually identical if brake items are excluded. Brake defects and lighting defects were the only vehicle categories that reliably differentiated striking and struck trucks in rear-end collisions.

Table 35 shows the inspection results for lighting-related items in the truck inspection regime. These items include head-lights, turn signals, stop or brake lights, marker, and tail lights. The table compares the incidence of light violations when the truck was the striking vehicle in a rear-end collision with trucks that were the struck vehicle in such accidents. Truck lighting violations are strongly associated with whether the truck was the striking or struck vehicle in rear-end collisions. Almost 38 percent of the struck trucks had one or more lighting violations, compared with only 12.5 percent of striking trucks. Lighting violations were three times as likely when the truck is struck than when it is the striking vehicle. Note that the inspection records only defects that existed prior to the accident. Accident-induced damage is excluded. It is possible that some lighting violations are masked by accident damage, though the inspectors have techniques to minimize such bias.

Table 35 Lighting Violations
by Truck Role in Rear-end Collisions
FACT Data, 1996-2001

Inspection results	Rear-end type		Total
	Truck striking	Truck struck	
0 violations	28	23	51
1 or more violations	4	14	18
Total	32	37	69
	Proportion of lighting violations		
0 violations	87.5	62.2	73.9
1 or more violations	12.5	37.8	26.1
Total	100.0	100.0	100.0

chi=5.71, p=0.02

The over-representation of lighting violations in rear-end struck trucks suggests that the conspicuity of the truck plays a role in these collisions. When the truck's lights do not function properly, it is less visible or conspicuous to the drivers of other vehicles, increasing the risk of rear-end collisions. This hypothesis can be tested further by focusing just on lights visible from the rear. The previous table includes all lighting violations. Lighting violations considered in Table 36 are limited to just those lights visible from the rear of the truck. Basically, headlight and front turn signals are excluded. Again, rear-lighting violations are strongly associated with rear-end truck-struck collisions. A truck that is rear-ended in a fatal collision is over three times more likely than a striking truck to have at least one violation of the requirements for the lighting systems on the rear of the vehicle. This finding strongly suggests that lack of conspicuity contributes to crashes where the truck is struck in the rear.

Table 36 Rear-end Lighting Violations on Rear of Truck by Truck Role in Rear-end Collisions FACT Data, 1996-2001

Inspection results	Rear-end type: Truck striking	Rear-end type: Truck struck	Total
0 violations	29	24	53
1 or more violations	3	13	16
Total	32	37	69
	Proportion of rear lighting violations		
0 violations	90.6	64.9	76.8
1 or more violations	9.4	35.1	23.2
Total	100.0	100.0	100.0

chi=6.39, p=0.01

Some other accident types were examined for the relationship between the truck's role in the collision and truck or driver condition. These are opposite-direction collisions, crossing-paths collisions at an intersection in which both vehicles were going straight, and collisions in which one of the vehicles turned across the other's path.

Opposite-direction collisions include both head-on accidents in which the fronts of the two vehicles are engaged as well as opposite direction sideswipes, which involve the side of one or both vehicles. Opposite direction sideswipe crashes are included on the grounds that the mechanisms that lead to them are probably the same as true head-on crashes, except that an avoidance maneuver was at least partially successful. Combining head-on collisions with opposite direction sideswipes also increases sample size. Note in Table 32 that in only eight of the 74 true head-on crashes did the truck cross the center line. Adding the 25 opposite direction sideswipes increases the number of truck encroachments to 15.

As in the previous example, the various categories of inspection items were compared with the truck's role in the collision. In this case, trucks were separated into those that crossed the centerline into the other vehicle, and trucks involved in head-on crashes in which the other vehicle crossed into the truck's lane. Only two of the inspection categories showed any relationship to the truck's role in the crash, brake defects and steering defects. Almost half, 46.7 percent, of encroaching trucks had at least one brake defect, compared with only 21.4 percent of trucks that were encroached upon. The association was statistically significant. Also, one-third of encroaching trucks had an OOS brake condition, compared with only 11.9 percent of trucks that were encroached upon. Steering defects were also associated with truck encroachment in opposite direction crashes. Pre-existing steering defects were found in 26.7 percent of encroaching trucks and only 2.4 percent of trucks involved in an opposite direction crash in which the other vehicle crossed the center line. Overall, encroaching trucks were no more likely to have an inspection defect than trucks that were encroached upon. Encroaching trucks, however, were significantly more likely to have an OOS condition, though this difference is accounted for by the braking and steering equipment defects already identified.

In intersecting-paths crashes, both vehicles were going straight on intersecting paths prior to the crash. In this crash configuration, right-of-way may be used to discriminate the truck's role. Where the other vehicle had the right-of-way, the truck or driver condition may play a critical role in avoiding the collision. For example, it might be expected that brakes would be crucial. There were 73 intersecting paths crash involvements (Table 32), of which the truck had the right-of-way in 57 (78.1 percent) and the other vehicle had the right-of-way in 16 (21.9 percent).

None of the inspection items showed a statistically significant association with the truck's role in intersecting-paths crashes, except log violations. But no item related to the mechanical condition of the truck showed any association. In the case of log violations, the truck driver was found with a violation in 1.8 percent of the cases in which the truck had the right-of-way, while 18.8 percent of truck drivers who violated the right-of-way had one or more log violations (usually a false or not current log). This difference was significant, both statistically and practically. The interpretation of this finding may be that such drivers were probably in a hurry or under pressure and consequently more likely to run a stop sign or red light.

Right-of-way was also used to discriminate the truck's role in turn-across-path collisions. In these crashes, either the truck or the other vehicle attempted to execute a turn while the other vehicle went straight ahead. The physical configuration of the crash does not suggest the location of the failure in this crash type, so right-of-way is used. There were 55 such involvements. (Table 32 shows 56 involvements but right-of-way could not be determined in one case.) In these crashes, the other vehicle had the right-of-way in 14 (25.5 percent) and the truck was determined to have the right-of-way in 41 (74.6 percent).

Only brake defects showed a statistically or practically significant association with truck role. Almost two-thirds of the trucks that violated the right-of-way had one or more brake defects, compared with 34.2 percent of the trucks that were imposed upon. A chi-square test of the association was significant at the 0.05 level. No other inspection category, either for driver or vehicle, showed a significant association. Overall, trucks that violated the right-of-way were not significantly more likely to have a violation or OOS condition than trucks that had the right-of-way in these crashes.

Truck defects contribute significantly to the involvement of trucks in fatal crashes. The primary defects found by this analysis were in the braking system, lighting, and steering components. Overall, both roadside inspections and the inspections of trucks in fatal crashes show that mechanical defects are common. About two-thirds of the fatal-crash-involved trucks or drivers had at least one violation and around one-third had at least one out-of-service condition. The role of other factors in producing crashes, including other vehicles and drivers on the road, should not be underestimated—note that in most rear-end crashes, the truck is struck in the rear, and in over 80 percent of collisions in which the vehicles were going in opposite directions, the other vehicle crossed over into the truck. Nevertheless, this analysis has shown that brake, lighting, and steering components defects contribute substantially to truck crashes.

3.11 Inspection Data

The MCMIS Inspection file is relevant here because it provides data about the mechanical condition of CMVs and the compliance of their drivers with the hours of service and other regulations that govern their operations. The previous section demonstrated that the mechanical condition of the CMV (trucks, specifically) has a safety effect. Trucks with poorly adjusted brakes or lights violations tended to be over involved in certain crash types; in fact, precisely the crash types where their action is most relevant. In this section, we examine the results of CMV inspections to identify factors relating to the carrier that are associated with the mechanical condition and regulatory compliance of CMVs.

The Motor Carrier Management Information System (MCMIS) Inspection file has records of approximately 156,000 inspections of CMVs that took place in Michigan from 2001 to 2005. Table 37 shows that the inspections were evenly divided between carriers based in Michigan and carriers based in some other state or nation (chiefly Canada with some from Mexico). The inspection file contains records of five different levels of inspection. The inspections are conducted under a protocol developed by the CVSA and adopted by the states and Federal government. The most thorough inspection is the full inspection, also called a North American Standard Level 1 inspection. The Level 1 inspection includes all regulated mechanical systems as well as compliance with driver licensing, medical certification, hours of service and duty status, cargo securement, and certain other requirements. There were about 31,000 Level 1 inspections in Michigan over the period. The material presented in this section focuses on the results of the Level 1 inspections because they are the most thorough and are performed to a uniform standard.

Table 37 CMV Inspections in Michigan, 2001-2005

	Carrier base		
Inspection level	Michigan	Other	Total
Full	19,468	11,541	31,009
Walk around	30,592	30,636	61,228
Driver only	22,328	35,920	58,248
Special	643	865	1,508
Terminal	3,854	384	4,238
Total	76,885	79,346	156,231

In this section, we discuss the effect of two carrier-related factors—fleet size and carrier type—on the incidence of violations in the population of trucks inspected. Fleet size is categorized into four groups, intended to sort the carriers roughly by size. Carrier type is dichotomized as either private or for-hire. A private carrier is one that operates a CMV as part of a business other than freight hauling or passenger transport. For example, a construction company that uses a flatbed to move construction materials around is considered a private carrier. A business that operates a bus to transport employees or customers as part of its primary business (e.g., a shuttle at a nursing home) is considered a private carrier. A for-hire carrier is one whose primary business is to transport persons or cargo. Examples include package delivery companies and truckload carriers.

Fleet size and carrier type information are only available in another MCMIS file, the “carrier” file. This file contains records of all carriers that are registered with the US DOT and issued a DOT number. Registered carriers report the number of vehicles in various classes in their fleet as well as the type of operations for which they are seeking authority, number of drivers in different class, types of cargo, and a few other descriptive details. Since this information is only available in the MCMIS Carrier file, not in the inspection file, fleet size and carrier type can only be determined for vehicles whose operator is registered with the US DOT. Of the approximately 156,000 CMV inspections, carriers could be matched for 126,000. Table 38 shows the distribution of fleet size for inspected vehicles matched with the carrier file. About a quarter of the vehicles inspected were operated by small carriers (one to eight power units[5]), about 30 percent by small-to-moderate carriers (nine to 55 power units), about 35 percent by moderate to large carriers, and 10 percent by very large carriers. This distribution provides enough cases in each group to permit valid comparisons.

Table 38 Fleet Size of CMVs Inspected

Fleet size (power units)	N	%
1 to 8	31,818	25.2
9 to 55	37,192	29.4
56 to 999	43,655	34.5
1000+	12,760	10.1
Unknown	1,011	0.8
Total	126,436	100.0

The private/for-hire distinction is not cleanly determined in the MCMIS Carrier file. Carriers may select any or all of eleven different types of operations, including authorized carrier, exempt, private passenger, state government, and so on. There is nothing to prevent a carrier from choosing both a type of for-hire authority and a type of private authority. In fact, some do, because they may operate primarily as a private carrier but desire for-hire authority (to transport other’s goods) to keep their vehicles productively employed. For example, a retail company may

[5] A “power unit” is a vehicle with an engine and that is self-propelled. A straight truck, tractor, or bus are examples of power units. A trailer is not a power unit, because it requires another unit—a tractor or straight truck—to pull it.

want for-hire authority so that it could carry a paying load and avoid empty miles on the return trip from a delivery to its own stores. To distinguish private from for-hire carriers, we assigned carriers that selected only one (or more) of the for-hire authority types as for-hire, only private as private, and carriers that chose both were classified as "other." Some carriers selected no authority type and were left "unknown." Table 39 shows the resulting distribution. Note that the "other" category accounts for less than 10 percent of the vehicles inspected. In the discussion of the effect of carrier type, only private and for-hire carriers are included.

Table 39 Carrier Type of CMVs Inspected

Carrier type	N	%
For-hire	92,530	73.2
Private	21,416	16.9
Other	12,321	9.7
Unknown	169	0.1
Total	126,436	100.0

Matching the inspection records against the MCMIS Carrier file also allows another useful distinction to be made. Inspections records that find a match in the Carrier file identify vehicles that fall under the regulatory domain of the FMCSA, for the most part. Actually, any carrier can register, whether they intend to operate in interstate commerce or not. Some states are requiring their strictly intrastate carriers to register with the US DOT, and Michigan is currently in the process of establishing that requirement. But during the time period covered by the inspection data used here, carriers that are not registered in the MCMIS Carrier file primarily identify carriers that are strictly intrastate, i.e., carriers not regulated by the FMCSA. Following the discussion of the effect of fleet size and carrier type on the incidence of violations, we will present comparable information on the intrastate-only carriers.

A set of charts are presented showing that fleet size is associated with differences in the rate of violations detected and vehicle or drivers put out of service because of the violations. One caution that should be noted before the discussion is that the inspections should not be treated as a random sample of the CMV population on the roads. The rates of violations detected are so high because the inspections are targeted in some respects. That is, it appears that inspectors select vehicles to inspect that, based on their experience, are more likely to have violations. The documentation for the MCMIS Inspection file gives no indication of the basis on which vehicles are chosen for Level 1 inspections, and the CVSA description of Level 1 inspections describes them in passing as random. However, we have more confidence in the differences found in the levels of violations between carrier types than in the absolute level of violations.

CMVs operated by smaller carriers tend to have more average vehicle violations, driver violations, and all violations than vehicles that are part of larger fleets. The differences are statistically as well as practically significant; that is, CMVs operated by the smallest fleets have above twice as many violations as those operated by the largest fleets. Figure 18 shows that CMVs in fleets with only one to eight power units average 4.63 violations per inspection, compared with 2.40 violations for vehicles in fleets with 1,000 or more vehicles. CMVs from small-to-moderate fleets (9 to 55) had 4.32 violations and moderate to large fleets (56 to 999) 3.41 violations. The trend is similarly linear for vehicle violations and driver violations. Vehicles from the largest fleets have the fewest violations while those from smaller fleets have more. The ratio of smallest to largest is consistently about two to one.

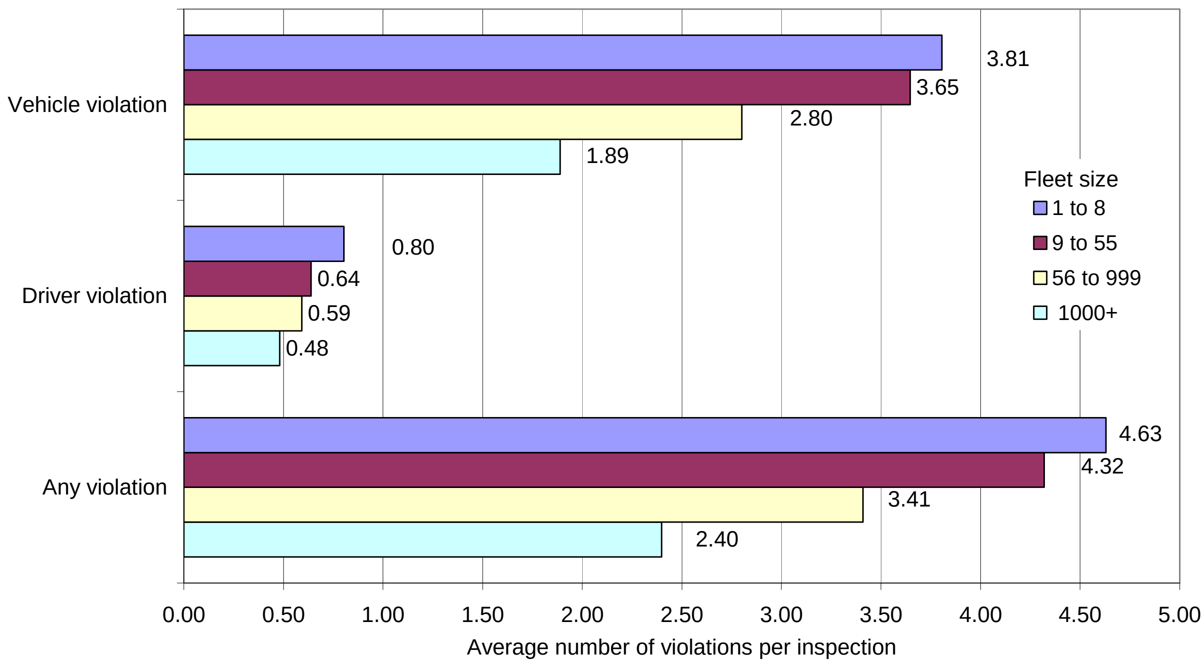

Figure 18 Fleet Size and Mean Number of Violations

Fleet size is also associated with the percentage of vehicles with violations, and in the same way, although the differences are not as great as with mean violations. Figure 19 shows the percentage of vehicles inspected with one or more violations by the different categories of fleet size. About 89 percent of CMVs from the smallest fleet size category had one or more violation of any type, compared with 82.2 percent of vehicles from the largest fleets. Violations were detected for about half of the drivers from the smallest fleets, but only 34.8 percent of the largest fleets. About 71 percent of vehicles from the largest fleets had one or more violations, compared with 80 percent of the smallest fleets. Note that for vehicle violations, the two categories of smaller fleets are virtually the same and that for any violation, only the largest category is significantly different. The largest spread is observed with driver violations, where the proportion for the largest fleets is about two-thirds of that of the smallest. Driver violations are typically related to hours of service, medical certification, and log books. It appears that the largest fleets are able to comply with these regulations more effectively.

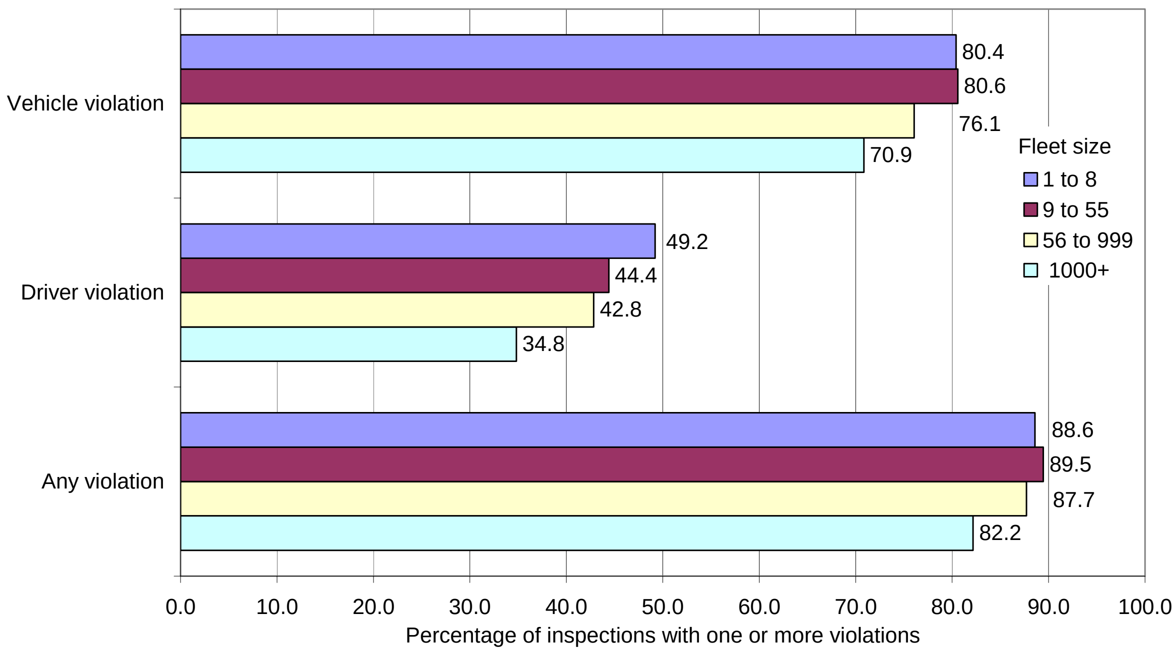

Figure 19 Fleet Size and the Percentage of Vehicles Inspected with Violations

Fleet size also appears to be strongly related to the incidence of OOS violations (see Figure 19). Vehicles and drivers can be put out-of-service—that is, prohibited from operating until the condition is corrected—if certain conditions are met. For example, drivers are put OOS if the hours of service permitted are exceeded. More than 20 percent of brakes out of adjustment qualifies as an OOS condition for trucks. For each of the three measures—any OOS, driver OOS, and vehicle OOS—vehicles/drivers from small fleets have the highest rates and those from the largest fleets have the lowest. Drivers from small fleets are put OOS at more than twice the rate of drivers from the largest fleets, though at about the same rate as moderate to large fleets. Similarly, CMVs from small and small-to-moderate fleets have an OOS condition significantly higher than moderate to large fleets and almost twice as high as the largest fleets. Differences in management controls and resources to maintain vehicles may account for these differences.

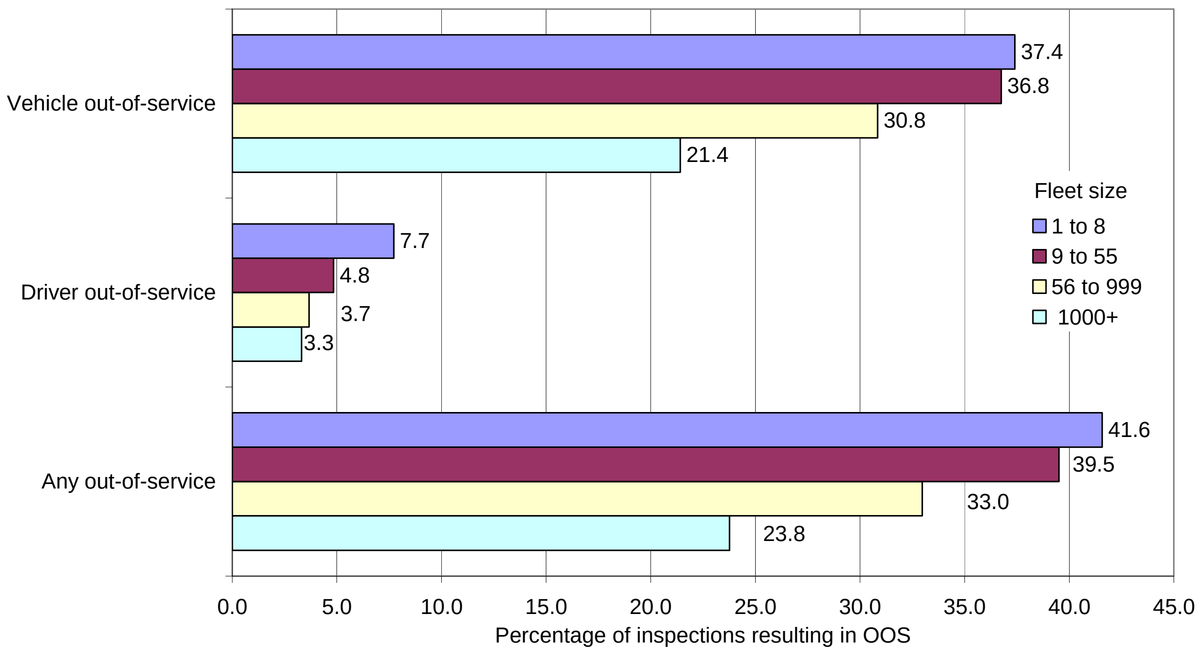

Figure 20 Fleet Size and Vehicles/Drivers Out-of-Service

We also examined differences in the rates of certain specific inspection items by fleet size. Violations related to specific items were aggregated to determine if a violation existed for any part of a given system. Thus, in the figure below, any type of brake violation is included under brakes, a violation to any part of the lighting system—headlights, marker lights, turn signals, and brake lights—is counted as a lighting violation. For this figure, we selected the systems with the greatest number of violations, that is, the systems most often found with violations of regulatory standards.

The relatively high rate of violations in lighting and braking systems is notable (see Figure 21.) Defects in those two systems, regardless of fleet size, are detected at a much higher rate than in any of the other shown, and are roughly comparable in incidence, though the brake systems have a somewhat higher rate of detected violations. The second point is that, for each system, the ranking of fleet size is the same. CMVs from small fleets tend to have higher rates of violations detected in each of the systems, and vehicles from larger fleets tend to have lower rates. The one notable exception is that CMVs from small-to-moderate fleets had at least one brake violation at a somewhat higher rate than the smallest firms. It should also be pointed out that CMVs from the largest fleets have significantly lower rates of brake violations than those from any of the other fleet sizes. This same pattern holds true for log violations (typically, not up to date, more than one log book, or false entry). Drivers from the largest fleets had the lowest rates, while those from all other fleet sizes had similar rates. Note the relatively low rates of hours of service (HOS) violations detected for all fleet sizes (though the rank ordering remains).

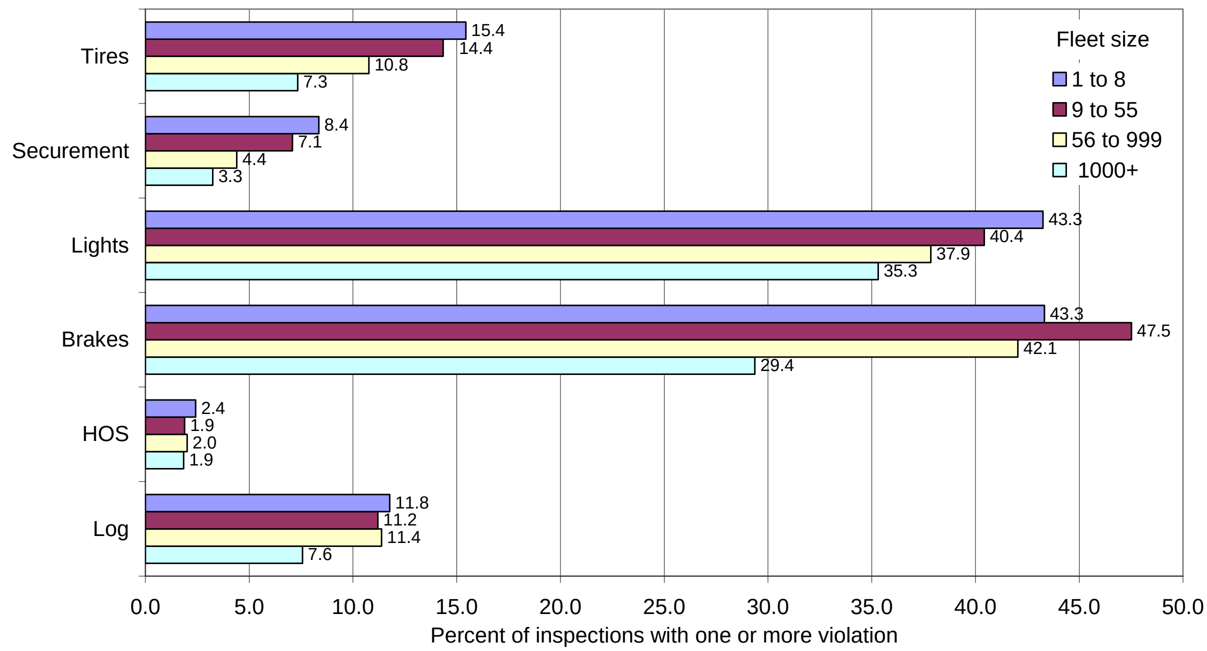

Figure 21 Fleet Size and Specific Violation Types

Carrier type, at least in terms of the private/for-hire distinction, proved less powerful in discriminating carriers. The differences found in terms of the overall level of violations between private and for-hire carriers were slight and not meaningful. Figure 22 shows that the average number of violations detected in CMVs was about the same for vehicles operated by private firms and by for-hire firms. In terms of the overall level of violations, both vehicle and driver, carrier type made no difference.

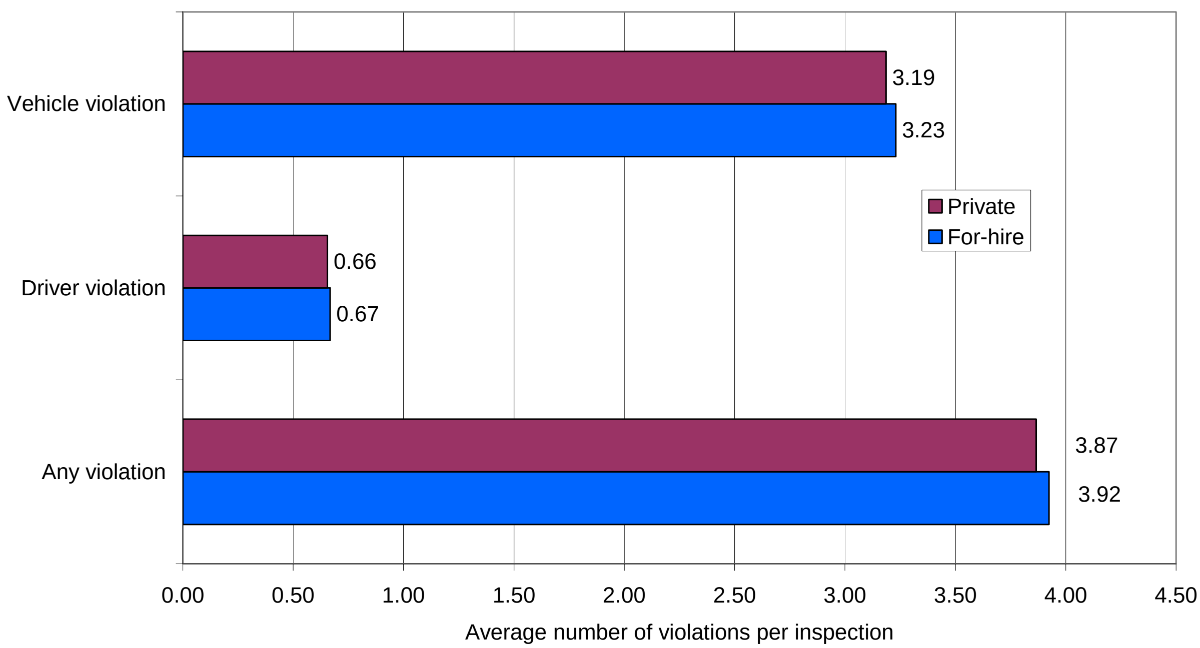

Figure 22 Carrier Type and Mean Violations

However, there were some differences in specific items inspected, probably related to the types of operations in which private and for-hire carriers engage. Figure 23 shows that CMVs operated by for-hire carriers tend to have higher rates of brake, tire, light, HOS, and log violations, while private firms have higher rates of cargo securement violations. The largest relative differences are in log, HOS, and brake violations, which may relate to differences in operations. For-hire carriers likely tend to have longer and less predictable hauls than private carriers moving their own goods among their own properties. More drivers in for-hire firms have to keep log books, while the operations of some private firms may allow the drivers to substitute hourly work records for log books. Similarly, private operations may be more conducive, generally, to regular hours and so less likely to run afoul of the HOS regulations. On the other hand, cargo securement is more often an issue only for certain load types, such as solids in bulk in a dump, or large objects such as lumber and steel coils, which may be hauled more often as part of a private operations business than as a for-hire haul.

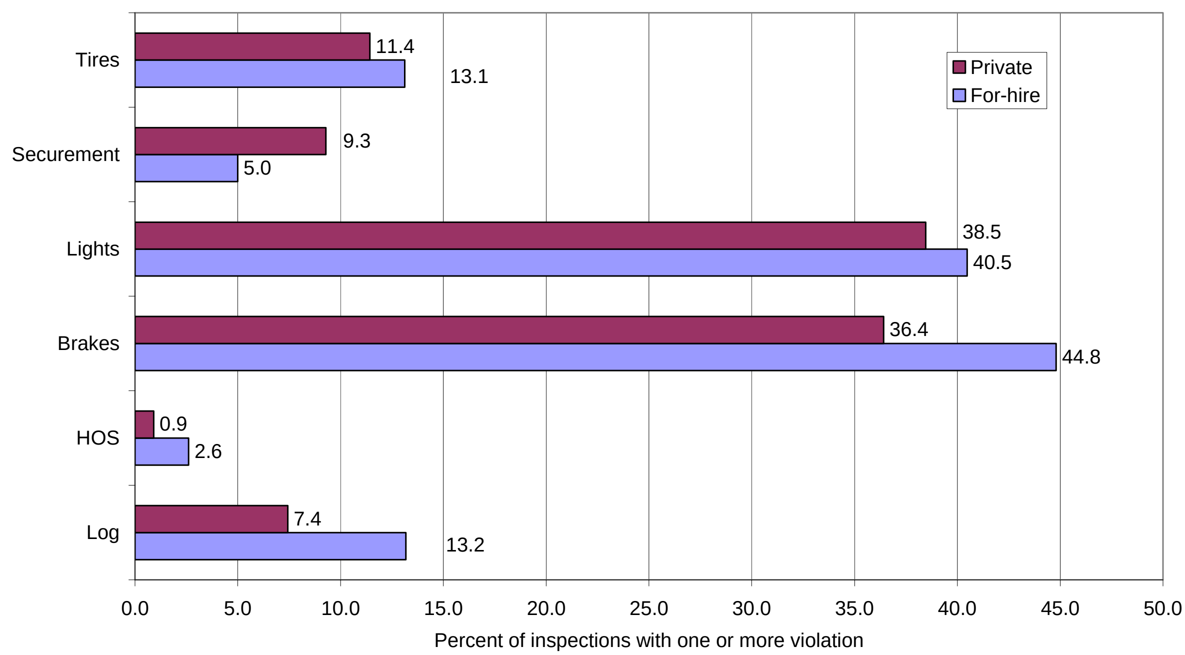

Figure 23 Carrier Type and Specific Violations Types

As noted above, the process of joining the inspection records to the MCMIS Carrier file, to add information about characteristics of the carrier operating the CMV, also discriminated the vehicles between those operated by a US DOT registered carrier and those that were not. The CMVs not registered with the US DOT generally fall within the regulatory domain, with respect to operations, of the state of Michigan rather than the Federal government. Of course, regulations as to vehicle condition and certain of the driver regulations cover both groups. Accordingly, we compared the inspection results for the two groups.

In general, about the same percentage of vehicles were detected with violations and OOS conditions for vehicles operated by both the US DOT registered carriers and those that were not. However, the intrastate-only group (not registered) consistently had higher rates of violations and OOS conditions, regardless of the measure. (Please see Figure 24.) Only when any violation was considered did the CMVs operated by US DOT registered carriers have a slightly higher rate. In terms of the incidence of violations, the rates were similar. However, rates of OOS conditions were significantly higher for the intrastate only group as compared with the US DOT registered group. Intrastate only vehicles were put OOS at a rate about seven percentage points higher than the other group; the driver OOS rate was about 3.5 percentage points higher, and the rate of OOS for any reason was about eight percentage points higher. In terms of the most serious violations, the intrastate only group tends to have higher rates than carriers registered with the US DOT.

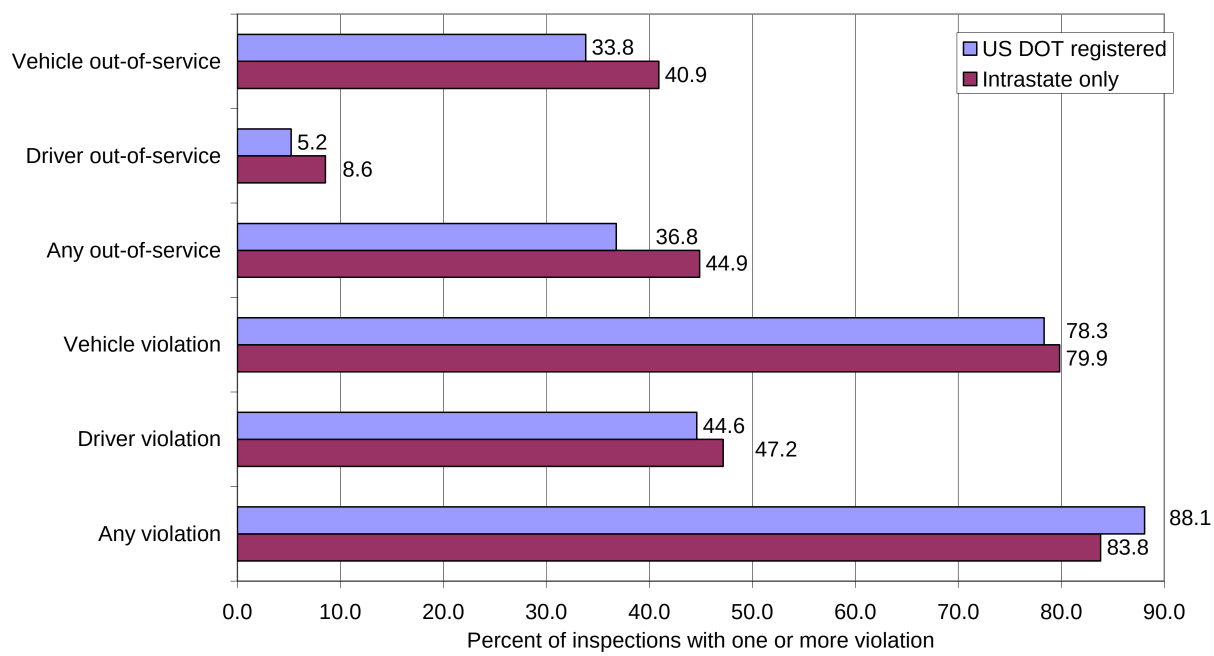

Figure 24 Violations by US DOT Registration

The results are the same in terms of average violations per vehicle (Figure 25). Intrastate CMVs have a higher average number of vehicle, driver, and any violations, and the results are highly significant for vehicle and any violations. It appears that while both groups have about the same level of violations, the number and severity of violations are higher for the intrastate only group.

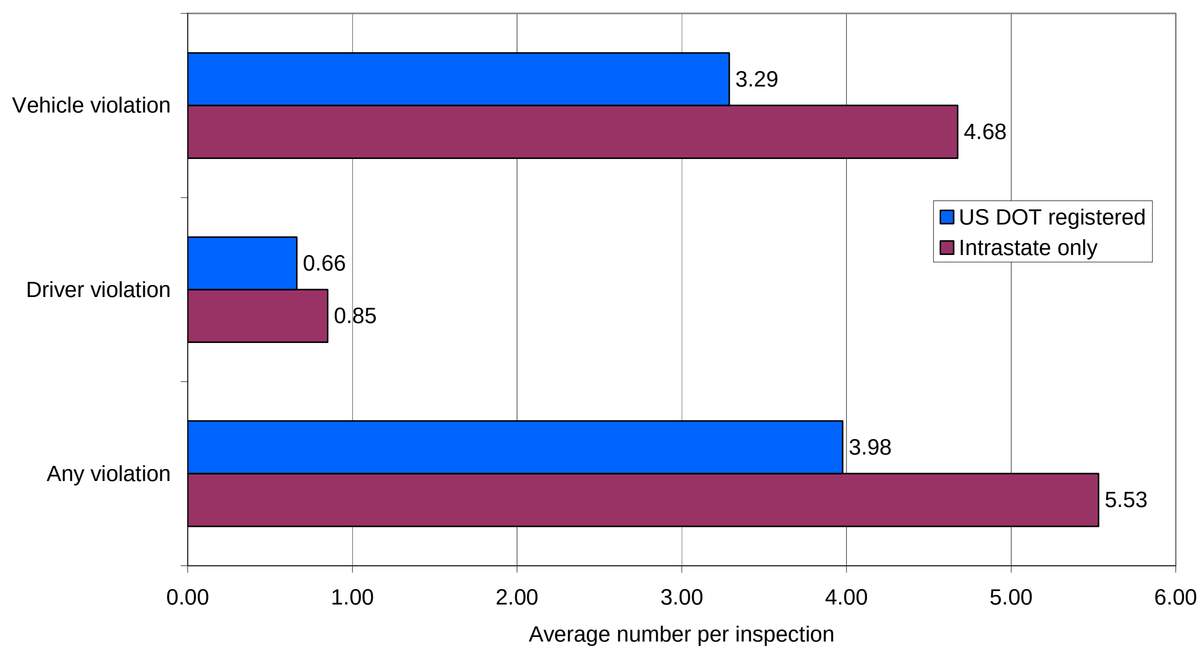

Figure 25 Average Violations by US DOT Registration

3.12 Geographic Distribution

The Michigan crash data includes the latitude and longitude for each crash, which can be used to locate the crashes on a map and study the geographic distribution of the crashes. One purpose of geolocating crashes is to search for clusters of crashes that may indicate areas of increased risk or of high-use. Even if the relative risk of a location or stretch of road is not elevated, that is, the reason for the concentration of crashes may be explained by the amount of travel through the area, it may be useful to deploy enforcement tools such as patrols and vehicle inspections in such areas.

Of the approximately 87,000 CMVs involved in a crash over the period of data used for this report, a valid latitude and longitude was available for all but about 2,700, or 3.1 percent. In other words, all but about 3 percent of the crashes could be located on a map. The experience of the present authors is that the accuracy of crash location is entirely adequate for the purposes here. It was beyond the scope of the present project to validate crash locations. But in a previous project of one of the authors, crash locations relative to a base map were quite consistent within a few tens of meters.

Figure 26 shows the location of all serious CMV crashes—those resulting in a fatality, an A-injury or a B-injury—in Michigan from 2001 to 2005. At this scale, one can see the general distribution of the crashes. The largest cluster is in the Detroit area, which is a major industrial area, the largest center of population in the state, and a primary point of entry for international trade into Michigan. Other clusters are observable in the Flint and Lansing areas, Grand Rapids and environs, and the Kalamazoo/Battle Creek area. Note also that the crashes delineate the primary CMV (truck) routes in Michigan. Most of the crashes occur along the main roads and highways, and in fact those roads are readily identifiable even at this scale. Relatively few of the most serious crashes occur off the main arteries of travel.

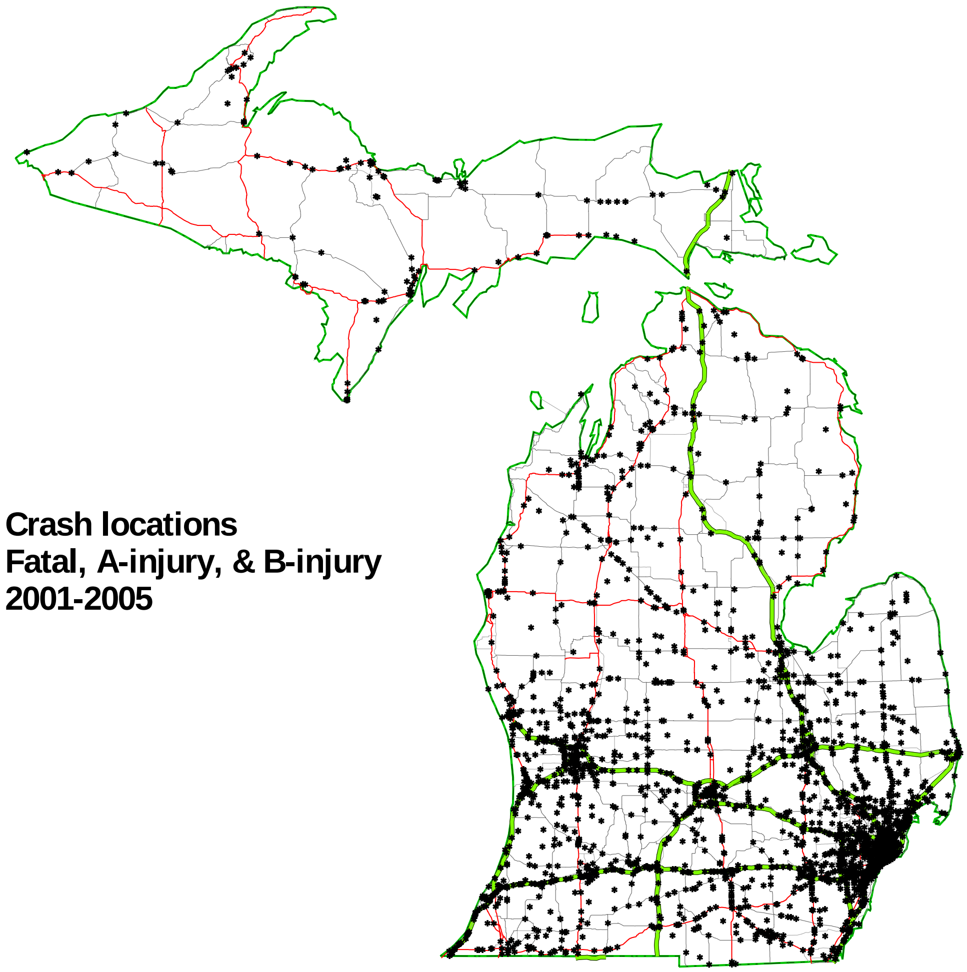

Figure 26 Serious CMV Crashes in Michigan, 2001-2005

Figure 27 provides a detailed view of serious CMV crashes in southeastern Michigan. In the Detroit area, crashes occur not just on the major roads, the Interstates and main US and Michigan routes, but throughout the city. But outside of Detroit, the crashes tend to follow the major routes in Michigan. There is a string of CMV crashes that delineate M 24 and M 53 north of the Detroit area into Macomb County. There is also a string of crashes on US 127 south from Jackson, as well as a large number on US 223 between US 12 and US 23. This stretch of road apparently is used as a connector by CMVs between I 94 and US 23 and points south, avoiding traffic in the Ann Arbor and Detroit areas. In addition, there is a string of serious CMV crashes on US 12 from I 94 near Ann Arbor to I 69 at Coldwater, and the parallel route to the north of M 60 from Jackson all the way to Three Rivers and beyond to the Indiana border at South Bend.

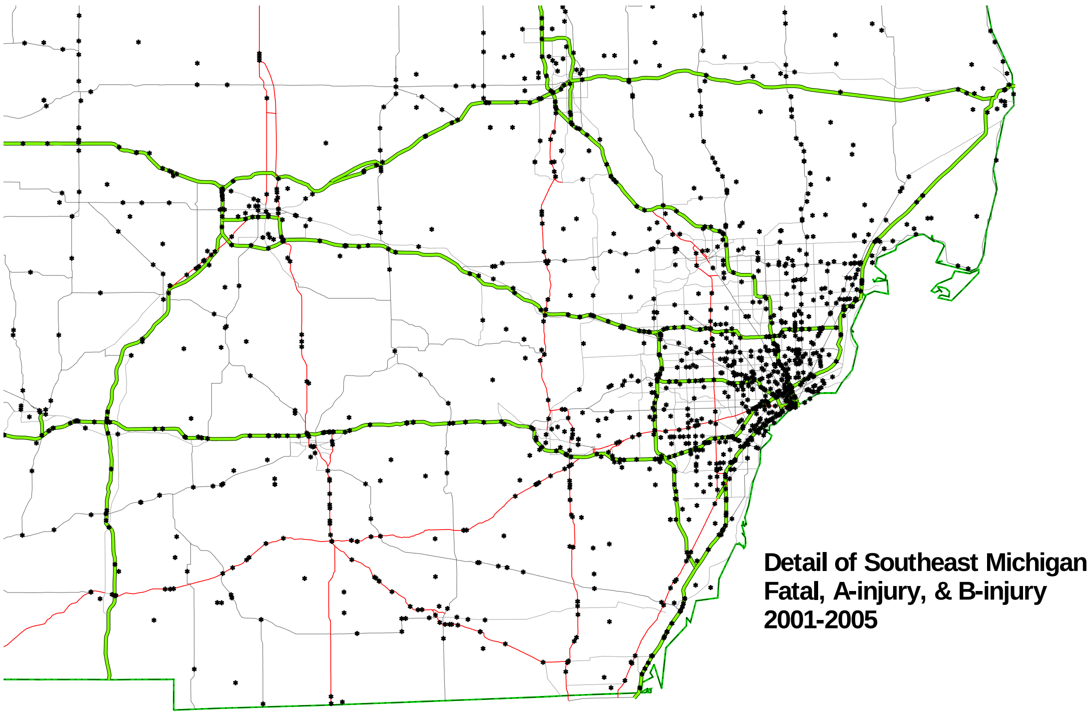

Figure 27 Serious CMV Crashes in Southeast Michigan, 2001-2005

Figure 28 shows the detail of CMV crashes in southern and western Michigan, from the cluster in Kent and Ottawa Counties down to the Indiana border. In Berrien County, the concentration of crashes along I 94 is striking. The elevated number of serious CMV crashes on I 94 extends to the Kalamazoo/Battle Creek area. There is also a number of crashes off the Interstates, but closer inspection shows that the crash involvements primarily occurred on major routes, such as US 131, M 60, US 12, and US 31 up to the Muskegon area.

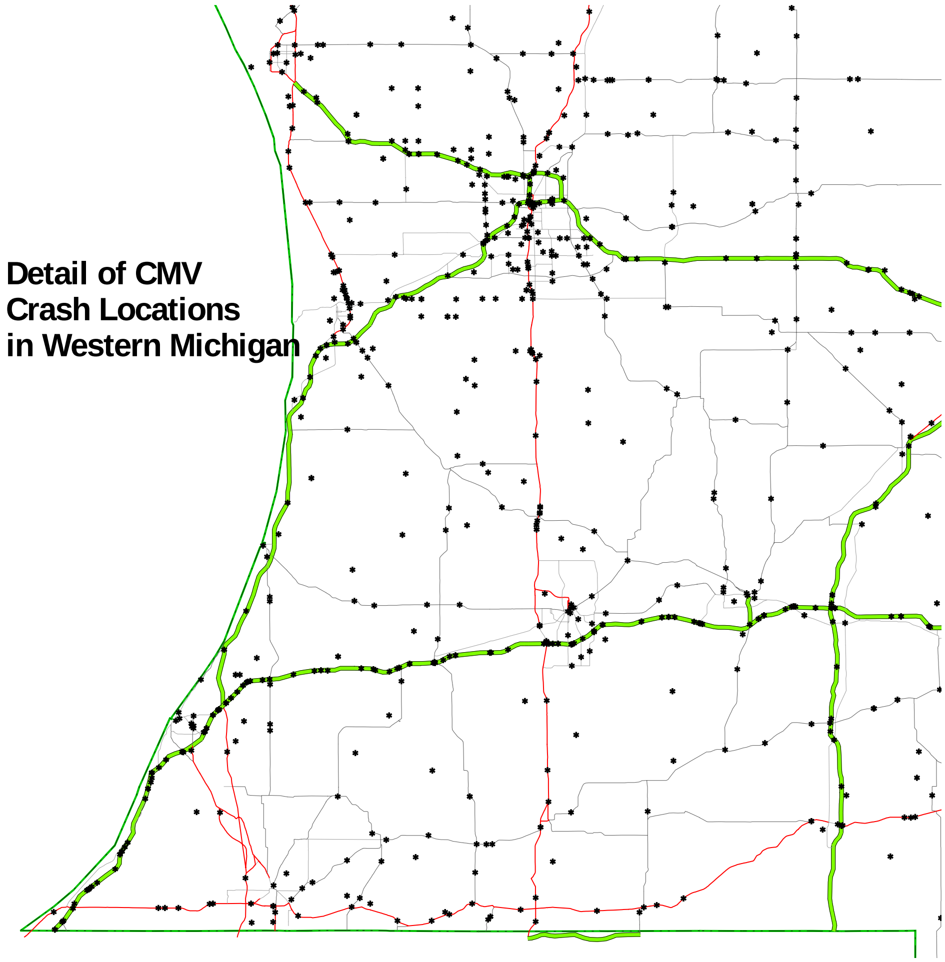

Figure 28 Serious CMV Crashes in Southwestern Michigan, 2001-2005

Using the estimates of crash costs by crash severity and the locations of crashes, it is reasonable to estimate the geographic distribution of the burden of CMV crashes. This work identifies the areas where the crash costs are incurred, and thus the areas where countermeasures such as enforcement of traffic and other CMV regulations may have the most impact. Figure 29 shows the distribution of CMV crash costs by county. Annual costs ranged from a low of about $47,000 in annual costs in Keweenaw County in the upper peninsula to a high of over $125 million in Wayne County. The range of crash costs is so great, the scale used in Figure 29 to display the data is geometric, that is, the crash cost range doubles with each step up the scale. Most of the impact of CMV crashes is felt in the southern half of the lower peninsula. Wayne County accounts for the highest proportion of CMV crash costs, with about 19.2 percent of the total. Oakland, Macomb, and Kent Counties form the next tier, with annual crash costs ranging from $35 million to $55 million. The top eight counties in terms of crash costs—Wayne, Oakland, Kent, Macomb, Berrien, Washtenaw, Genesee, and Ottawa—combined account for just over half of all annual CMV crash costs.

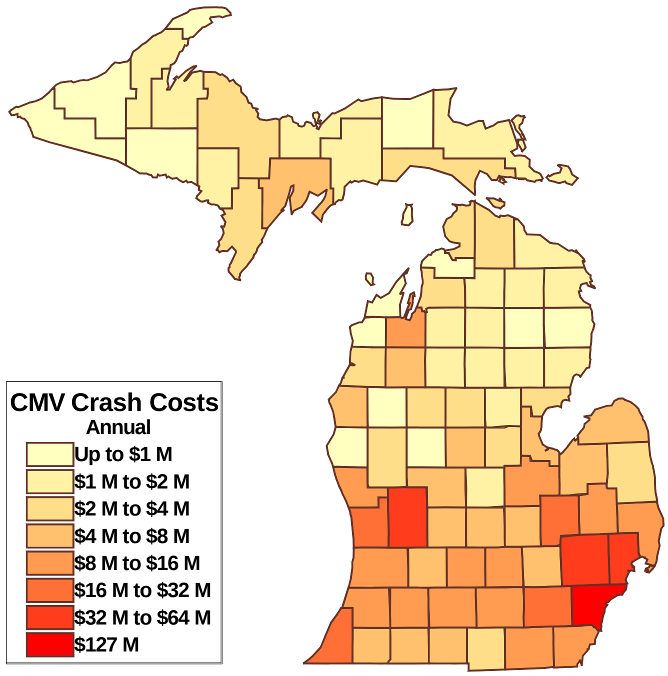

Figure 29 Annual Crash Costs by County

Figure 30 reduces the levels of crash costs to just three in order to show the concentration of CMV crash costs. Eight counties account for over half—52 percent—of the annual costs associated with CMV crashes. Again, in the figure the scale is not linear, but geometric, reflecting the very large disparities from the top to the bottom counties. The 76 other counties that account for just under half of the CMV crash costs have annual costs that range up to about $16 million. In the next tier are the seven counties with costs that range from $16 million to about $64 million. Wayne County is alone at the top with annual costs of about $127 million.

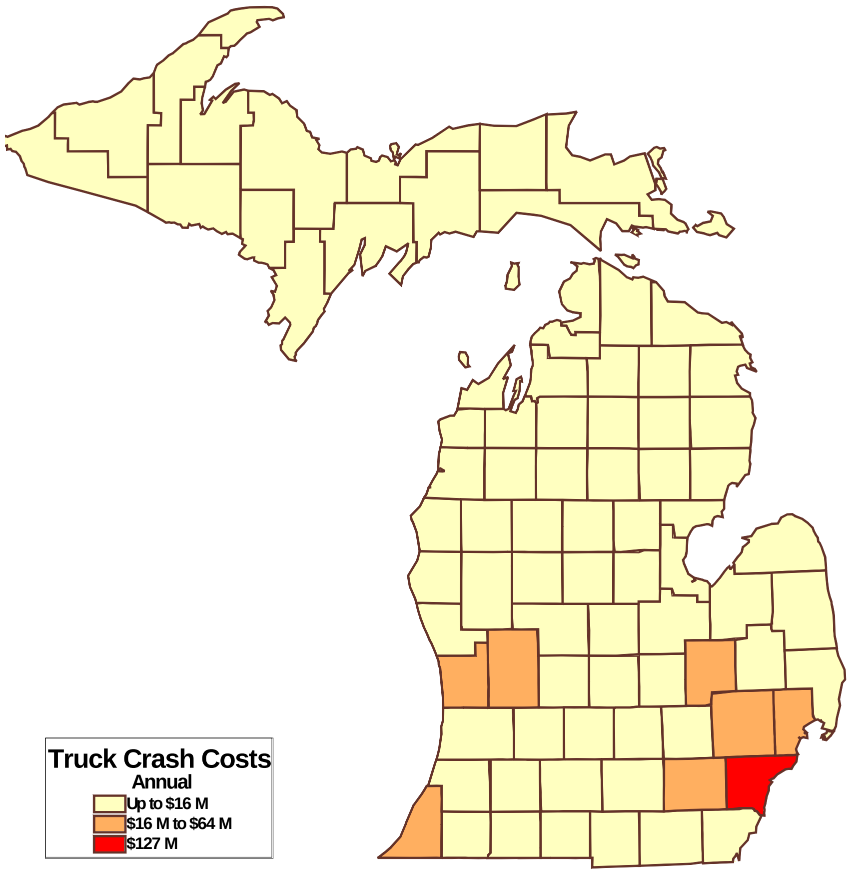

Figure 30 Counties Accounting for Most CMV Crash Costs

Section 3.10 above on vehicle condition showed that the mechanical condition of the CMV (in this case just trucks) is related to the risk of crash involvement in certain roles. The clearest results were for rear-end crashes, in which it was shown that CMVs with poorly adjusted brakes are much more likely to be involved in rear-end crashes as the striking vehicles, while CMVs with problems with the light system, particularly on the rear of the vehicle, are much more likely to be involved as the struck vehicle. If it is generally true, which seems reasonable, that vehicles in poor mechanical condition are more likely to be involved in crashes, then one countermeasure to crashes is to ensure that the vehicles are in good condition, and one tool is the CMV inspection program that Michigan operates under the auspices of the Motor Carrier Safety Assistance Program (MCSAP).

Figure 31 shows the distribution of Level 1 inspections over the five-year period from 2001 to 2005. Only Level 1 inspections are included because they are the most thorough. Again, the scale on the figure is geometric because the range from the highest to the lowest is great and the distribution across counties is uneven. The fewest Level 1 inspections over the five years were recorded in Mason and Iosco Counties, with ten each, while the most inspections occurred in Monroe and Berrien Counties with 3,871 and 3,244 respectively. Comparing Figure 31 with

Figure 29 and especially Figure 30 shows how well the distribution of Level 1 inspections matches the distribution of the CMV safety problem. In southeastern and southwestern Michigan, especially Berrien County, the match is quite good. Both Monroe and Berrien Counties have the highest number of Level 1 inspections, which is reasonable because they are located at the primary entry points of CMVs into Michigan: I 94 from the Chicago area and I 75 from the Toledo area. Inspections are also concentrated in Jackson, Oakland, Genesee, and Wayne Counties. On the other hand, Kent and Ottawa Counties were identified as areas that ranked high in terms of CMV safety problems, as measured by crash costs. Both counties are among those with relatively few Level 1 inspections.

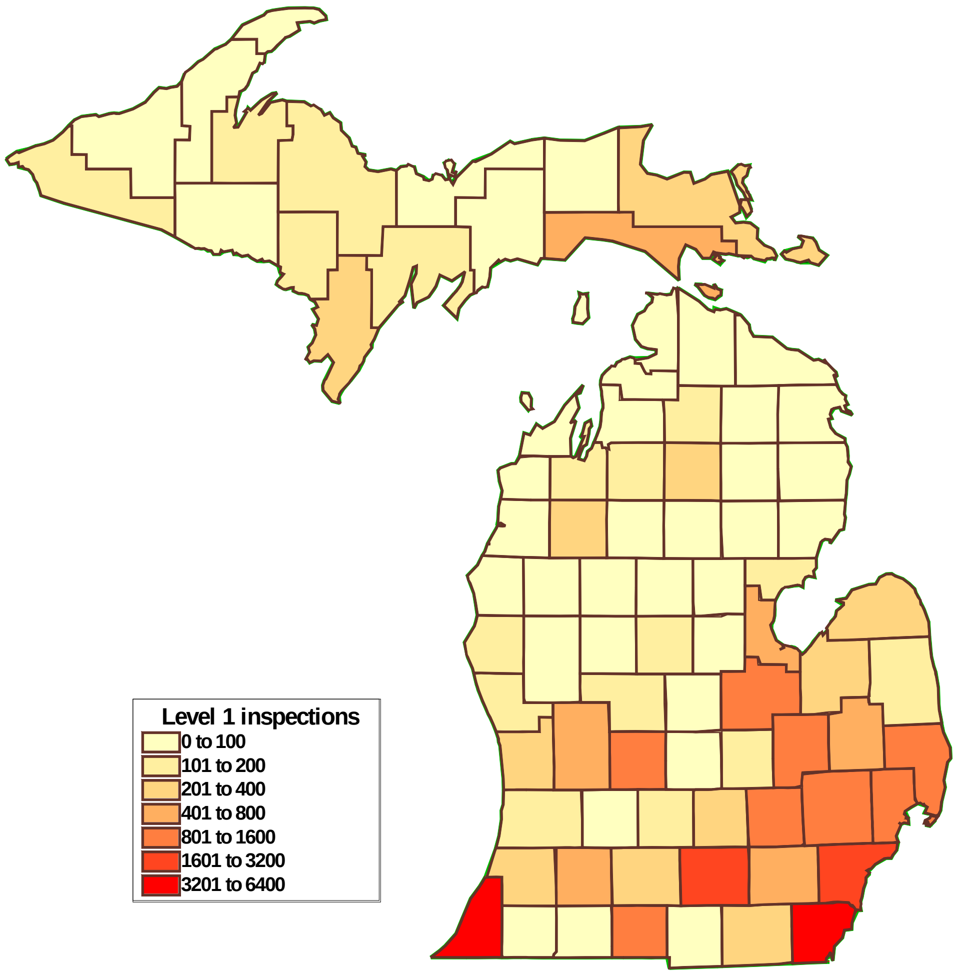

Figure 31 Level 1 Inspections by County

Table 40 shows the top counties in terms of crash counties and their overall ranking in terms of the number of Level 1 inspections. Most of the top counties also rank high in inspections, but Macomb County north of the Detroit area is fourth in costs, but only eleventh in inspections. Washtenaw County is sixth in costs, but thirteenth in inspections. Kent and Ottawa Counties rank 18th and 27th in inspections, respectively.

Table 40 Top Counties in Crash Costs and Number of Level 1 Inspections, Michigan 2001-2005

County	Rank in costs	5-year costs	Rank in inspections	5-year Inspections
Wayne	1	$636,626,257	3	2,038
Oakland	2	$275,356,616	5	1,453
Kent	3	$206,701,149	18	408
Macomb	4	$176,034,551	11	1,010
Berrien	5	$119,925,272	2	3,244
Washtenaw	6	$115,848,950	13	719
Genesee	7	$107,450,474	6	1,424
Ottawa	8	$87,567,589	27	240

It is not argued here that there should be a one-to-one correspondence between the distribution of crashes and the allocation of enforcement resources, especially vehicle inspections. CMVs of course travel far from their bases, and inspections can occur anywhere, including the home base. But the allocation of enforcement resources in the areas where the bulk of the safety problems occur may reduce their incidence. Particularly in light of the relationship between vehicle condition and crash risk, it is important to insure that the CMVs' mechanical condition at a minimum meets the required standards. While a wide range of factors contribute to CMV crashes, including actions of the driver, other vehicles on the road, and road conditions, a fundamental principle should be that the vehicle and its systems be in sound working order. The driving task places the primary responsibility on the driver to avoid crashes. It seems reasonable that the vehicle meet the minimum requirements.

4 Summary of CMV Safety Issues

In Michigan in 2005 there were 16,553 CMV crashes resulting in 120 deaths and 2,857 injuries. While this is an eleven percent decrease in crashes, and a nine percent decrease in fatalities from 2001, paralleling the downward trend in all vehicle crashes in Michigan, CMVs were still disproportionately involved in serious crashes. Three percent of all vehicles involved in crashes between 2001 and 2005 were CMVs, but CMVs accounted for nearly seven percent of vehicles involved in crashes in which at least on person was killed.

A metric of harm developed from medical costs, emergency services, property damage, lost productivity to injured person and monetized quality-adjusted life years lost, but not including lost productivity due to congestion delays, was used to compare different types of CMV crashes and circumstances of CMV crashes. Using this measure, the annual cost of CMV crashes in Michigan from 2001 through 2005 was estimated at $662.3 million. Of this amount, 54 percent was attributed to fatal crashes. Only 18 percent of the total cost was due to property-damage-only crashes.

4.1 Time and Location

CMVs are working vehicles, and 80 percent of their crash involvements occur between 8 a.m. and 8 p.m. The severity of CMV crashes that occur at night tends to be higher. However, there are fewer of them. Approximately 70 percent of the CMV crash costs, and therefore harm, are associated with the time period from 8 a.m. to 8 p.m. Ninety percent of CMV crash involvements occur on weekdays (i.e., Monday through Friday). The highest number of CMV crashes occur in the month of January (ten percent of total) and the month of fewest CMV crashes is April (seven percent of total).

Almost one-half of CMV crash involvements occurred on local roads and streets and accounted for 40 percent of the harm as measured by crash costs. Ten percent of CMV involvements occurred on US routes, 19 percent on M routes, and 20 percent on Interstates, accounting for 13 percent, 28 percent, and 19 percent of the CMV crash harm respectively. Of CMV crashes that occurred on freeways, 22 percent were on ramps. Of CMV involvements that are not on freeways, one-half occurred at or near intersections, and four percent occurred on curves.

4.2 Crash Types

The most frequent CMV crash types were rear-end and same-direction sideswipe crashes, accounting for 22 percent and 25 percent of all CMV crash involvements. The next most frequent crash types were angle crashes that accounted for 15 percent of CMV involvements, and single vehicle crashes that accounted for 13 percent of CMV involvements. Backing up crashes accounted for 8 percent, and head on crashes accounted for 3 percent of CMV crash involvements.

The most severe CMV crashes were head-on crashes. Eleven percent of head-on involvements resulted in at least one fatality and 42 percent resulted in at least one injury. Angle crashes were the next most severe, with 1.4 percent resulting in a fatality and 30 percent in an injury.

When frequency and severity of a crash type were considered together, the most harmful crash type was the angle crash, which accounted for 27 percent of all CMV crash costs. Rear-end crashes accounted for 24 percent of CMV crash costs, followed by head-on crashes at 15 percent, same-direction sideswipes at 10 percent, and single vehicle crashes at 8 percent of total CMV crash costs. Fatal angle collisions (such as those that occur at intersections), accounted for 16 percent of all CMV crash costs, and fatal head-on collisions accounted for 14 percent of all CMV crash costs.

4.3 Hazardous Actions

The most common hazardous action for CMV drivers, present in 20 percent of crashes in which a hazardous action was coded for the CMV driver was “unable to stop in assured distance.” The next most frequent were, “failure to yield,” “improper lane use,” and “improper backing” (each at 11 percent of CMV hazardous actions), and “speed too fast” (six percent of CMV hazardous actions).

A different pattern emerges for CMV driver hazardous actions in serious (fatal and A-injury) crashes. “Unable to stop in assured distance” was still the most frequent CMV driver hazardous action, accounting for 22 percent of CMV hazardous actions. The next most frequent was “speed too fast” recorded for 14 percent of fatal crashes and 12 percent of A-injury crashes. This was followed by “careless/negligent” at 14 percent of fatal and 10 percent of A-injury crashes in which a CMV driver hazardous action was recorded.

Certain CMV driver hazardous actions are associated with specific crash types. “Speed too fast” was noted in 15 percent of single-vehicle involvements. “Failed to yield” was the primary CMV driver hazardous action in 24 percent of head-on left turn crashes and 16 percent of angle crash involvements. “Unable to stop in assured distance” was the primary CMV driver hazardous action in 35 percent of rear-end crashes, and “improper lane use” was noted in 15 percent of same-direction side swipes and nine percent of opposite-direction side swipes. In addition, “improper turn” was noted in ten percent of opposite-direction side swipes. “Improper backing” was the primary CMV hazardous action in backing crashes. For head-on crashes, no hazardous action was noted for the CMV driver in 72 percent of the crashes. The most frequent CMV driver hazardous action for head-on crashes was “drove left of center,” present only in three percent of the cases.

The CMV driver hazardous actions that contribute most to total CMV crash costs and therefore, harm are: “unable to stop in assured distance” (i.e., following too closely and being unable to stop safely), “failed to yield”, “speed too fast”, “careless/negligent”, and “disregard for traffic control.”

If the crash cost of a hazardous action is compared to the cost of all crashes costs in which the CMV driver was coded with a hazardous action, the relative contribution of the specific hazardous action can be measured. This measure indicates how harmful a particular hazardous action is compared to an average hazardous action. The most harmful individual CMV driver hazardous actions are: “reckless driving,” “drove left of center,” “disregard of traffic control,” “careless/negligent,” “speed too fast,” and “unable to stop in assured distance.”

4.4 Driver Age

As noted before, CMVs are working vehicles, and the majority of their crashes involve drivers of working-force age; 87 percent of CMV-crash involved drivers (where age was known) are age 26-60 years, 5 percent are age 21-25 years, and 5 percent are over the age of 60 years.

Approximately 1 percent of crash-involved CMV drivers was 18-20 years of age, and not eligible for a commercial driver license (CDL).

CMV drivers under age 25 are more likely than older drivers to be involved in backing-up crashes. Eleven percent of crash involvements of CMV drivers under 25 were backing-up crashes compared to eight percent for drivers over age 25.

Rear-end crash involvements decreased with driver age. The youngest CMV drivers had higher rear-end crash involvements than older drivers. The proportions of rear-end crashes for drivers age 18-20, 21-25, 26-60, and over 60 years were 26 percent, 24 percent, 23 percent, and 21 percent, respectively.

Drivers under age 25 and over age 60 were slightly more likely to be involved in single vehicle crashes than drivers age 25-60. Fourteen percent of CMV crashes for drivers under age 25 and over age 60 were single-vehicle crashes compared to 13 percent for drivers age 26-60.

Younger crash-involved CMV drivers were more likely to be coded with a hazardous action than other CMV drivers. CMV drivers under age 21 and between 21 and 25 years were coded with a hazardous action for 70 percent and 60 percent of their crash involvements, respectively. CMV drivers age 26-60 were coded with hazardous actions for 48 percent, and those over age 60 were coded with hazardous actions in 54 percent of their crash involvements.

“Improper backing” and “unable to stop in assured distance” (i.e., following too closely to stop safely) were the most common hazardous actions for drivers under age 25. Drivers under age 25 were also more likely than other CMV drivers to be identified as “going too fast.”

4.5 Fatigue

There were 275 CMV crashes coded with driver condition as “fatigued” or “asleep” in the CMV crash data from 2001 to 2005. These crash types were most likely underreported because it is very challenging for police officers to accurately discern driver condition when filling out the crash report. Using correction factors based on national data, the number of fatigued CMV crash involvements for Michigan was estimated in this report to range from 77 to 171 incidents annually.

Most CMV fatigued driver crashes occurred at night, between midnight and 6a.m. Chances that a crash was fatigue-related increased by 5 to 8 times at night compared to the day. Fatigue-related crashes were more likely to occur on Interstate roads and to involve tractor-semitrailers or doubles operated by interstate carriers. The crashes tended to be severe, single-vehicle crashes in which the CMV ran off the road, or rear-end crashes. An average crash cost for a fatigued-driver CMV crash was $78,000 compared to $38,000 for a non-fatigued-driver crash. Thus, the harm from a fatigue-related CMV crash is about twice that of an average CMV crash. The range of annual costs of fatigued-driver CMV crashes in Michigan based on the corrected number of these crashes is from $30.0 million to $65.5 million. Based on this estimate, fatigued driver crashes account for 1 to 2 percent of all CMV crash costs.

4.6 Vehicle Condition

NAS Level 1 inspections of 407 CMVs that had been involved in fatal crashes between 1996 and 2001 showed a high level of violations of standards (49 Code of Federal Regulations, part 393) which CMVs are legally required to meet. A violation, either for the vehicle or for the driver was found for 66 percent of the CMVs inspected. Of these inspections, 35 percent had at least one out-of-service (OOS) condition. Brakes and lighting system violations were the most common areas of defects. Over 34 percent of the vehicles had a brake defect, and over 23 percent had a lighting system defect. Log, driver, tires/wheels, and suspension violations were found for between nine to 15 percent of the CMV vehicles or drivers.

Of CMVs involved in rear-end collisions, brake defects were found for 53 percent of the trucks that were the striking vehicle, compared to 30 percent of trucks that were struck in the rear. Of the CMVs struck in the rear, 38 percent had one or more lighting violations, compared to 12 percent of the striking CMVs.

Brake and steering defects were found to be associated with opposite-direction collisions (head-ons and opposite direction side swipes). Of trucks that encroached into the opposite lane, 47 percent had at least one brake defect, over 30 percent had an OOS brake violation, and 27 percent had a pre-existing steering defect. Of trucks that were encroached upon, 12 percent had a brake defect, and two percent had a steering defect.

Brake defects were also associated with intersecting path crashes. Almost two-thirds of trucks that violated the right-of-way had at least one brake defect, compared with just over one-third of trucks that were imposed upon.

4.7 Inspections

Examination of 156,231 NAS inspections records of all levels carried out on CMVs traveling on Michigan roads from 2001 to 2005 indicated that approximately one-half of the vehicles inspected were of Michigan-based carriers. The others were from carriers based in other states, Canada, or Mexico. Of the inspected vehicles that were registered with the US DOT, 25 percent were from fleets with fewer than eight power units, 29 percent from fleets of 9-55 power units, 36 percent from fleets of 10-999 power units, and ten percent from fleets with 1,000 or more power units. About three-quarters of the inspected vehicles came from for-hire carriers, and about 17 percent were from private carriers.

Records of 31,009 NAS Level 1 inspections show that CMVs operated by smaller carriers tend to have a higher average number of vehicle and driver violations than vehicles from larger fleets. CMVs from fleets with fewer than nine power units, and those from fleets of 9-55 power units averaged 4.6 and 4.2 violations per inspection respectively, compared to 3.4 and 2.4 violations per inspection for CMVs from fleets of 56-999 and 1,000 or more power units. Fleet size appears to be strongly related to the incidence of OOS violations, such that CMVs from the largest fleets are the least likely to have an OOS condition. Only 24 percent of CMVs from fleets with more than 1000 power units were placed OOS, compared to 42 percent of vehicles from fleets with one to eight power units, 39 percent of vehicles from fleets with nine to 55 power units, and 33 percent of vehicles from fleets with 56 to 999 power units.

CMVs from small fleets also had higher rates of violations for each specific inspection item than the larger fleets, and the rank ordering by fleet size remained basically the same for each inspection item. Violations in lighting and braking systems were the highest for each fleet size category.

Comparison by carrier type shows that CMVs operated by for-hire carriers had higher rates of brake, tire, light, driver hours-of-service, and log violations, while private carriers had higher rates of cargo securement violations. These differences may reflect the different types of operations. Comparison of inspection results of CMVs from intrastate and interstate carriers shows that intrastate CMVs had higher numbers and severity of violations than interstate CMVs.

4.8 Geographic Distribution

Examination of the location of serious CMV crashes (fatal, A-injury, and B-injury) shows that the largest cluster of CMV involvements is located in the Detroit area. Other clusters are observable in the Flint and Lansing areas, Grand Rapids and environs, and the area around Kalamazoo and Battle Creek. When the geographic burden of CMV crashes was estimated by allocating the crash costs to the counties in which they occurred, eight counties accounted for just over one-half of all annual CMV costs, and therefore, harm. These counties are: Wayne, Oakland, Kent, Macomb, Berrien, Washtenaw, Genesee, and Ottawa. Wayne County alone accounted for 19 percent of the total CMV crash cost.

Comparing the proportion of CMV inspections performed in counties against the proportions of total CMV crash costs for the counties shows that four of the eight counties with the highest CMV crash costs are not among the eight counties with the highest proportion of CMV inspections. Kent County was 18th, Macomb 11th, Washtenaw 13th and Ottawa 27th with respect to the number of CMV inspections performed in the state.

4.9 Summary

Analyses of crash data, post fatal-crash inspections, and MCMIS inspection and carrier records together with a weighting based on crash harm is summarized as follows:

1. The most costly CMV crashes and therefore, most harmful to society, are fatal crashes with angle crashes, head-on crashes, and rear-end crashes contributing most to overall CMV crash costs.
2. When crashes of all severity levels are considered, angle crashes, rear-end crashes, head-on crashes, same-direction sideswipe, and single-vehicle crashes contribute most to overall CMV crash costs, in the order presented.
3. Brake system defects have been associated with rear-end crashes, opposite direction crashes (head-on, opposite direction sideswipes), and intersecting path crashes (including angle collisions).
4. Lighting defects have been associated with rear-end collisions, where the CMV was the vehicle struck.
5. Steering defects have been associated with opposite-direction collisions in which CMV was the encroaching vehicle.
6. Brake and lighting system violations are the most frequent violations in CMV inspections.
7. Violation rates in inspections are highest for CMVs from small fleets.
8. CMVs from intrastate carrier’s fleets have higher rates and more serious violations in inspections than CMVs from interstate carrier fleets.
9. The CMV driver hazardous actions that contribute most to overall CMV crash costs are, “unable to stop in assured distance” (i.e., following too closely), “failed to yield,” “speed too fast,” “careless/negligent,” and “disregard for traffic control.”
10. The most costly individual CMV driver hazardous actions (compared to the average hazardous action) are: “reckless driving,” “drove left of center,” “disregard of traffic control,” “careless/negligent,” “speed too fast,” “unable to stop in assured distance,”(i.e., following too closely).
11. Younger crash-involved CMV drivers are more likely to be with coded with hazardous actions, particularly “unable to stop in assured distance,” (i.e., following too closely), and “speed too fast,” (i.e., speeding).
12. Younger CMV drivers are more likely to be involved in backing-up crashes than older drivers.
13. In approximately one-half of CMV crashes, a hazardous action is coded for the driver of the other vehicle.
14. Fatigue-related CMV crashes tended to be severe single-vehicle crashes in which the CMV ran off the road, or rear-end crashes. Most CMV fatigued driver crashes occurred at night, between midnight and 6 a.m. on Interstate roads, and involved tractor-semitrailers or doubles operated by interstate carriers. Fatigue-related crashes account for two to three percent of total CMV crash costs in Michigan.
15. Eight counties (Wayne, Oakland, Kent, Macomb, Berrien, Washtenaw, Genesee, and Ottawa) accounted for almost one-half of Michigan’s annual CMV crash costs. Wayne County alone accounted for 19 percent of the costs.

16. Four of the above eight counties were not among the top eight counties when CMV inspections were considered.

5 Countermeasures and Strategies

There is no single strategy that can address the problems identified above. The problems are interrelated and the system is complex. Strategies to increase safety will have to work on many fronts, including programs to improve the performance and condition of CMVs, CMV drivers, the safety culture of carriers, and other drivers on the road.

5.1 Improve Maintenance of CMV

A major problem identified above is that of the mechanical condition of CMVs. Vehicle condition affects crash risk. Brakes defects are associated with the costliest and most severe crashes, and brake defects are very common. This is compounded by the fact that the inability to stop in the assured distance is the top hazardous action in CMV crashes. Operating a CMV in traffic is sufficiently challenging for drivers, without having to compensate for defects in the mechanical condition of the vehicle. It should be a given that the vehicles are in good operating condition, and it appears that this is not the case, especially for braking systems.

Maintenance is critical for safe management of CMV fleets. As noted above, vehicle defects in brake and lighting systems as well as in steering systems have been found in CMV vehicles involved in crashes which contribute significantly to the overall CMV crash cost in Michigan. Furthermore, the brake and light systems violations are the most frequent violations in CMV inspections, although the frequency of all violations is high. Carriers with small fleets and intrastate carriers appear to have more problems with vehicle maintenance than large fleets. Approaches for improving CMV maintenance may include targeted enforcement, mandating preventive maintenance programs, and improving fleet safety management.

5.1.1 Targeted Enforcement

Given the relationship between vehicle condition and crash risk, it is important that CMVs mechanical conditions at minimum meet the required standards. Enforcement is necessary for regulatory compliance by motor carriers and drivers. However, enforcement resources are limited and should be optimized for maximum effect. Thus, allocating resources to areas with the most safety problems is a reasonable strategy. The eight counties that account for close to one-half of all CMV crash costs should get special consideration when enforcement and inspection resources are allocated in the state.

5.1.2 Mandating Preventive Maintenance Programs

Regularly scheduled vehicle inspections and maintenance are part of safety programs practiced by many fleets. However, not all motor carriers voluntarily implement strong fleet maintenance programs. Strategies to get carriers to develop and sustain good preventive maintenance practices should be considered.

The state of Maryland has a program that in addition to meeting the FMCSS regulations requires that carriers conduct and document an ongoing preventive maintenance program for their vehicles. Enforcement officers in the state of Maryland can enter the premises of any motor carrier at any time during regular business hours to inspect equipment and also to review and copy records relating to the carrier's preventive maintenance program. The program has resulted in improved vehicle inspection performance both for vehicle inspections conducted at carrier sites and those conducted at the roadside. (Knipling et al., 2004).

While the program has some appeal, there are several impediments to implementing this approach in Michigan. The first is that it requires new legislation. The program in Maryland is mandated by legislation specified in the Code of Maryland Regulations Title 23 (Vehicle Laws) Subtitle 3 (Preventive maintenance program) and Title 11 (DOT) Subtitle 22 (Motor Vehicle Administration-Preventive Maintenance Program). Thus, this idea would have to be accepted by the legislature and governor. The second challenge is that it would require enforcement resources from an already limited source, thus either new sources of funds would have to be found, or taken from current enforcement activity.

5.1.3 Proactive Approach to Avoiding Safety and Compliance Problems

The state of New York was the first to use the "compliance letter" approach for safety compliance. Instead of issuing a citation to carriers or conducting a full compliance review, the state may simply require that problem carriers write a letter to the state, stating that they are aware of the regulation(s) in question and current deficiencies in their operations and describe their plans to get into full compliance. Otherwise, these fleets receive no punishment at this stage. The state has found that this non punitive approach often gets the attention of the fleet managers and motivates them to improve their safety and compliance practices, prior to experiencing any major fines or other sanctions.

The Tennessee Department of Safety has an **Alternative Commercial Enforcement Strategies** (ACES) program that provides compliance-related information to fleets in a non threatening way. Specially trained officers visit fleets using an advisory rather than enforcement approach. The officers provide as much information as possible to help fleets become more proactive in avoiding safety and compliance problems. Training services provided range from demonstrating vehicle inspection procedures to reviewing compliance paperwork requirements to training new drivers. Later visits may be enforcement-oriented, but the initial visit is advisory and permits fleet operators to improve their practices. The ACES program is based on the concept of community-oriented policing where the "community" is the commercial vehicle industry of the state.

5.1.4 Educational, Training, and Consultation Programs

Educational, training, and consultation programs can also help carriers manage their safety compliance and safety programs. However, these programs are voluntary and do not have the weight of enforcement behind them.

Colorado has a **Circuit Rider** program. It is an industry-based initiative to provide free consultation to fleets on their safety compliance and management practices. Veteran carrier safety managers visit motor carriers that have requested a consultation. The program does not result in punitive actions to the carrier. Consultation might include: review of carrier operations, staffing levels, equipment, driver files, and insurance; review of fleet's approach to compliance with key FMCSA regulations; advice on building a stronger safety program for the fleet. In addition the program offers safety workshops for motor carrier managers, drivers, and dispatchers.

FMCSA provides educational and outreach programs to the motor carrier industry. Educational material targeted for small motor carriers covers the full range of safety practices that fleet owners can implement to reduce crashes and stresses the high costs of crash involvement and the benefits of crash prevention.

Michigan has a training and consultation program in the **Michigan Center for Truck Safety** (MCTS). The MCTS provides free and low-cost training and consultation to truck drivers and carrier safety managers. Training includes driver coaching, "decision" driving courses (conducted on skid pad to teach drivers dynamic safety maneuvers such as pulling out of a jackknife) defensive driving, fatigue management, inspection training, load securement, and safety manager training. There is also an Annual Truck Exposition and Safety Forum.

A training need was identified through our analysis of crashes. Younger CMV drivers were more likely than others to be involved in back-up crashes. Though these crashes are not severe, and are not the top contributors to the cost of CMV crashes in the state, it seems that additional training could reduce these crashes, given that a training facility and programs already exist.

Another role for the MCTS could be in helping develop preventive maintenance programs for carriers through workshops, consultations, and site visits.

5.2 Deployment of Truck Safety Technologies

All new trucks must meet the Federal Motor Carrier Safety Standards (FMCSS), but beyond compliance with these standards, buyers have considerable options in the safety features they select for their vehicles. Improved braking systems including electronic braking systems, higher performance tires, conspicuity lighting, and convex and fender-mounted side mirrors are among these safety-related features. In addition to these safety-related components, various advanced technology systems are now available for trucks. These include radar-based collision avoidance systems, adaptive cruise control, back-up camera systems, side-object detection, driver monitoring systems, electronic vehicle speed regulation, vehicle and cargo tracking systems, roll-stability advisors and controllers, on-board-recorders for driver hours-of-service verification, and lane-departure warning systems. Other advanced technology systems are on the horizon.

Forward collision avoidance systems and adaptive cruise control can decrease rear-end collisions in which the CMV is the striking vehicle. Back-up cameras can help drivers with backing the vehicle. Driver monitoring systems can alert the drowsy driver from falling asleep or careless/negligent driving. Other driver monitoring systems can reduce the incidence of speeding and reckless driving. Rollover advisors and controllers can help reduce single-vehicle rollover crashes. Side-object detection can counter the "blind spot" problem. Lane departure warning can help reduce crashes in which the CMV crosses the centerline or runs of the road.

While truck safety vehicle technology promises to increase safety, it does add to the cost of the vehicle, will require active maintenance, and driver safety management. There is often resistance to new technology. It may take some time for fleet managers to routinely buy this equipment for their new vehicles, and for drivers to accept them. Tax incentives would be a way of getting fleet managers to use and consider some of the advanced systems. FMCSA has an active program to promote some of these advanced technologies. The advances in technology show promise in reducing CMV crash involvements. However, it is important that they be tested and evaluated through pilot studies before they are widely deployed.

5.3 Increase Knowledge on Sharing the Road

There is a need for a broad-based public understanding of the hazards associated with driving too close to large trucks. Public information and education (PIE) campaigns and driver manuals and handbooks as well as CDL licensure are ways of increasing this understanding. The "No Zone" was an earlier PIE campaign and "Share the Road" is the current one. Both contain clear messages about behaviors that create hazardous car-truck interactions. However, experience gained from PIE campaigns for using safety-belts and on drinking and driving, indicates that it will take some time for the message of sharing the road safely with trucks to get through to the public. The MCTS manages the Share the Road PIE program in Michigan. It should continue to do so, and take advantage of all the resources provided by FMCSA and NHTSA.

Incorporating how to drive safely near CMVs into light vehicle driving courses and the licensing process is a way of reaching the next generation of drivers. The organization of traffic safety educators (ADSTEA) has a model curriculum for novice drivers that includes topics on truck driver fatigue, truck wide right turns, side blind areas and safe passing, other No-Zone areas, and being able to see the driver in the truck's mirrors.

Another strategy is to promulgate "Share the Road" information through print and electronic media. This means finding a way to involve and interest the media on a regular basis in reporting on the dangers of hazardous maneuvers in the vicinity of trucks when reporting on car/truck crashes. The media did this for safety belts, by reporting whether or not a person involved in a crash was using a safety belt.

Through persistent PIE messages and campaigns, public awareness through newspaper stories as well as education of novice drivers, the public should become more and more aware of how to drive around large trucks. This should be accompanied by a reduction in crashes caused by light vehicle engaging in hazardous driving behaviors in the vicinity of trucks.

5.4 Strengthen CDL Program

We did not analyze the CDL status of crash-involved drivers because the crash data do not have reliable information about the CDL status of drivers, and we could not obtain the Michigan Driver history records in time to analyze them for this project. However, common sense indicates that making sure that the CDL program runs effectively is a good strategy for CMV safety. There is strong federal legislation mandating CDL requirements, but the literature notes that there still are problems with the program (Federal Highway Administration, 2000). Not all states comply with all of the provisions of the CDL, especially the interstate reporting of infractions. Another concern is the fraudulent issuing of licenses. Because a CDL is a license to hold a job, both drivers and carriers may resort to extreme measures.

Strategies identified for strengthening the CDL program include improving the administration of the knowledge test to minimize the opportunity to "cheat" either by copying or by getting access to questions before hand, and by increasing fraud detection among third party testers and state examiners.

Use of computer software and hardware for the knowledge test portion of the CDL exam will decrease opportunities for cheating. Electronic test forms make it easy to randomly order the questions so that tests differ from one another and over time. This also makes it difficult for anyone to commit the test questions to memory, and minimizes the chances that printed copies fall into the hands of potential applicants.

A system of regular reviews and audits of examiners is essential for reducing fraud in the CDL exams. Fraud can be discouraged by overt surveillance and detected by covert surveillance of how driving tests are conducted, and through statistical analysis of test scores and failure rates of individual examiners. Furthermore, candidate examiners should be thoroughly evaluated, including a criminal check and driver history check, and should be recertified annually.

5.5 Improve Crash Data

Reliable, clean, and unambiguous data are essential for identifying CMV safety problems systematically. The crash data extracted from the UD-10 served as the primary resource in preparing this report. Accordingly, we spent many weeks exploring the data and testing different hypotheses. In the process, we were able to identify both strengths and weaknesses in the data. A few brief examples of problems that we encountered are discussed below.

It is clear that an active data file of this size—with about 400,000 crashes, 600,000 vehicle, and 800,000 person records per year—is an enormous undertaking, and reasonable allowance must be made for incomplete data. Generally, we found the data to be well-documented and well-prepared. There are few “orphan” records (e.g., a person record with no crash record), and the files were easy to manipulate to link desired information. The types of information provided are comprehensive. One item of particular utility to safety research is the approach to identifying hazardous actions. Some crash data only record charged violations, which is useful for some purposes but less desirable for safety research since officers properly exercise discretion in charging violations.

However, we also encountered some problems that posed special challenges for CMV research. In the following, we identify a selection of the most serious obstacles encountered. We recognize the inherent problems posed by traffic accidents. Both authors are experienced data collectors and analysts, and appreciate the unique contribution of police officers in filling out crash reports in addition to their primary duty to preserve life and protect property. The following examples are offered in an effort to identify problems in a way that might contribute to implementing remedies that simplify the officer’s task and provide more comprehensive and complete data to support safety research.

- The initial problem encountered in preparing the data for this report was simply to distinguish trucks from buses in the crash data. The vehicle type variable on the UD-10 combines trucks and buses into a single code level. There is no other information that can be used to discriminate between the two. There is a “special use” variable that might be used to identify buses, but it is not coded in almost 60 percent of cases. Data from the CMV supplemental area of the UD-10 has the potential to be used to distinguish trucks from buses, but the supplemental area is supposed to be filled out only for crashes meeting certain severity thresholds, not all crashes, and that variable has problems of its own. The decision to make the combined truck/bus code was likely tied to the CMV supplemental data area, but the result is not tenable. A simple change in the vehicle type variable on the main page of the UD-10 would improve the situation.

- The vehicle type variable in the CMV supplemental data is very complicated and in fact combines several distinct dimensions. It is constructed based on the type of CDL, if any, required. CMVs are classified by the type of CDL required (A, B, or C) and the type of endorsements required (hazmat, tank, doubles, hazardous tank, passenger). Because of the variety of information embedded, certain features of the vehicle can be inferred. But also, because the variable is directly tied to the requirements of the CDL, important characteristics of the vehicle cannot be recovered. For example, a group A vehicle should be pulling a trailer, but tractor-semitrailers cannot be distinguished from straight trucks pulling a trailer. Moreover, all detail about trucks or buses that do not require a CDL is lost. A simpler approach that breaks out the different dimensions of information collected into separate variables would be easier for the reporting officer to complete accurately and also provide more detailed descriptive information. One method for achieving this would be to have separate variables for vehicle configuration, cargo body, hazardous materials, and GVWR. A good practice in data collection is to capture only one type of information per variable. This makes collecting the information by the officer easier and provides a richer, more flexible data source for safety research.

- The CMV supplemental data section of the UD-10 also includes variables to record the unit type (tractor, trailer, etc.) and number of axles for each unit in a combination. If completed accurately and comprehensively, this information could be used in combination with the vehicle type variable to solve some of the identification problems, such as to distinguish tractors from straight trucks, and to identify the multi-axle combinations that are important in Michigan. However, the information entered into the variables is incomplete and inconsistent. The variable for the first unit is missing data for over half the vehicles. There are also many “wild” codes, that is, information that does not belong. A variable with so much missing and unintelligible data cannot contribute to any analysis. A variable that so many officers are unable to complete correctly likely should be reformed.

- Missing and inconsistent data is a frequent problem. An example is the data on driver licensing. An attempt was made to compare the type of CDL and endorsements to the type of vehicle operated, to identify drivers correctly licensed, those licensed for the right CDL group but without required endorsements, and so on. Missing and inconsistent data frustrated the goal. In about 26 percent of the cases, missing data on either the type of vehicle or the type of license made it impossible to determine if the driver had the correct license for the vehicle. And where there did appear to be enough information, about a third of the drivers apparently did not have the right license or endorsements for the vehicle. This result was not considered reliable, so it was not presented in the body of the report. But the fundamental problem is that the information on driver licensing is not consistently or comprehensively recorded. A different approach, such as automated data collection using bar coded licenses and readers, could reliably capture such details and allow the reporting officer to focus on areas that require judgment.

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