INSURANCE INSTITUTE
FOR HIGHWAY SAFETY

July 2, 2001

The Honorable Julie Cirillo
Acting Deputy Director
Federal Motor Carrier Safety Administration
400 Seventh Street S.W.
Washington, D.C. 20590

Safety Monitoring System and Compliance Initiative for Mexican Motor Carriers Operating in the United States
Docket No. FMCSA 98-3298, 98-3299

Dear Ms. Cirillo:

The Insurance Institute for Highway Safety would like to express its concern about three recent proposals by the Federal Motor Carrier Safety Administration (FMCSA) regarding Mexican motor carriers operating in the United States. Although these proposals are well intended, they have deficiencies that could jeopardize the safety of the American public. The most serious flaw is that Mexican trucks would be permitted to operate in this country even though the safety inspection work force and inspection facilities are grossly inadequate at most border crossings (City of Laredo, 2001). Currently, less than 2 percent of trucks crossing Mexican borders receive comprehensive Level I safety inspections, although past surveys indicate Mexican-based trucks have higher rates of safety defects than U.S. trucks. An active inspection program is vital to large truck safety, and until a reasonable percentage of trucks can be inspected at reasonable intervals at busy border crossings, the United States should delay expansion of the Mexican cross-border truck traffic.

Equipment and driver violations pose hazards to truck drivers and to those with whom they share the road. In a controlled study of equipment defects in which large trucks in crashes were compared with those traveling the same routes that were not in crashes, defects in steering, brakes, and other equipment were important risk factors for crash involvement -- the relative crash risk for trucks with defective equipment was 1.6 times the risk for trucks without defects (Jones and Stein, 1989; paper is attached). Crash risk also increases as a result of the most common driver violation, too many hours on the road. Increased crash risks associated with long driving hours have been reported as twofold or higher (Institute comments of August 4, 2000 that describe research are attached). Increased enforcement of the hours-of-service regulations are needed for all drivers, and the mandating of onboard recorders would enhance the ability of state and federal inspectors to enforce those requirements.

Remedying the inadequate inspection resources is not a simple task, but California has managed to mount a successful safety oversight program that should be emulated in other states. California is able to inspect all trucks crossing the border with Mexico at intervals of about every 90 days and has an out-of-service violation rate for such trucks of 26 percent, similar to the 24 percent U.S. national average (Office of Inspector General, 2001). Out-of-service violation rates for Mexican trucks in the border states of Arizona and Texas are 40 percent (Office of Inspector General, 2001). Although facilities such as those in California cannot be built immediately, the current roadside inspection teams in other states can use portable inspection equipment along roads used by cross-border traffic. In addition, FMCSA and the states should consider whether to use technology that might permit faster testing of truck brakes than traditional brake inspections. Although “frequent roadside inspections” (66 FR 22419) are mentioned in the agency’s proposal, there needs to be a requirement that individual trucks receive a full, Level I inspection at least every 90-120 days.

The other deficiency in the proposals is in the “safety fitness oversight program” that must be conducted within 18 months of the carrier being issued a registration certificate. This compliance review can be conducted at the carrier’s place of business or at an alternative location in the United States; if the latter option is chosen, the carrier must provide “all records determined to be necessary to adequately evaluate the carrier’s compliance with the applicable regulations” (66 FR 22419). Although such a compliance review provides some oversight of Mexican motor carriers, it is not adequate to ensure the safety of Mexican trucks.

Mexican motor carriers have to comply with the same standards as U.S. carriers, but these standards are meaningless if they are not enforced. Both frequent inspections and comprehensive compliance reviews are necessary to deter violations of equipment and driver standards and achieve acceptable levels of truck safety. As is done in California, FMCSA should require that large trucks crossing the borders be thoroughly inspected every 90-120 days.

Sincerely,

Elisa R. Braver

Elisa R. Braver, Ph.D.
Senior Research Analyst

cc: Docket Clerk, Docket No. FMCSA 98-3299

Attachments: Insurance Institute for Highway Safety, 2000;
Jones and Stein, 1989

References

City of Laredo. 2001. Comment to the Federal Motor Carrier Safety Administration concerning revision of regulations and application form for Mexican-domiciled motor carriers to operate in U.S. municipalities and commercial zones on the U.S.-Mexico border. Docket Document No. FMCSA-1998-3299-98, June 26, 2001. Washington, DC: U.S. Department of Transportation.

Insurance Institute for Highway Safety. 2000. Comment to the Federal Motor Carrier Safety Administration concerning the hours-of-service notice of proposed rulemaking. Docket Document No. FMCSA-1997-2350-20062, August 4, 2000. Washington, DC: U.S. Department of Transportation.

Jones, I.S. and Stein, H.S. 1989. Defective equipment and tractor-trailer crash involvement. *Accident Analysis and Prevention* 21:469-81.

Office of Inspector General. 2001. Interim Report on Status of Implementing the North American Free Trade Agreement's Cross-Border Trucking Provision. Report No. MH-2001-059. Washington, DC: U.S. Department of Transportation.

INSURANCE INSTITUTE
FOR HIGHWAY SAFETY

August 4, 2000

The Honorable Clyde J. Hart, Jr.
Acting Deputy Administrator
Federal Motor Carrier Safety Administration
U.S. Department of Transportation
400 Seventh Street, S.W.
Washington, D.C. 20590

49 CFR Part 395
Hours of Service of Commercial Drivers
Docket No. FMCSA 97-2350

Dear Mr. Hart:

The Insurance Institute for Highway Safety strongly supports major provisions of the Federal Motor Carrier Safety Administration's (FMCSA) notice of proposed rulemaking concerning the hours of service of commercial drivers, but we oppose some aspects of the proposal. The Institute applauds the proposed requirement for tamper-resistant automated time record systems and the proposed minimum daily rest time of 12 hours. Implementing these two requirements would be a major safety advance for truck drivers and those who share the road with them. Notwithstanding our strong opposition to extending permissible driving time from 10 hours to 12 hours, which may increase large truck crash involvement rates, we expect that the net safety effects of the rule, as proposed, would be positive.

The Insurance Institute for Highway Safety (IIHS) is a nonprofit research and communications organization, sponsored by auto insurers, that identifies ways to reduce deaths, injuries, and property damage from motor vehicle crashes. We have published scientific research concerning the problem of fatigued commercial drivers in peer-reviewed journals (Braver et al., 1992; Hertz, 1991; Jones and Stein, 1987, 1989) and have submitted numerous reviews of the scientific evidence relating to fatigue and hours of service to the U.S. Department of Transportation (IIHS, 1992, 1995, 1997, 1998a, 1998b, 1998c, 1999a). Our positions and concerns are explained in more detail below.

Fatigue-Impaired Driving Contributes to Many Large Truck Crashes

Numerous scientific studies have observed an increased crash risk among drivers operating large trucks for more than 8-10 hours (Campbell, 1988; Frith, 1994; Harris, 1978; Jones and Stein, 1987, 1989; Kaneko and Jovanis, 1992; Lin et al., 1993, 1994; Mackie and Miller, 1978;

National Transportation Safety Board, 1995; Saccomanno et al., 1995, 1996; Summala and Mikkola, 1994), even after controlling for the effects of time of day (Frith, 1994; Jones and Stein, 1987, 1989; Lin et al., 1993, 1994; Saccomanno et al., 1995, 1996). Increased crash risks associated with long hours of driving have been reported as twofold or higher (Frith, 1994; Jones and Stein, 1987, 1989; Lin et al., 1993, 1994; Saccomanno et al., 1995, 1996).

FMCSA estimates that fatigue contributes to 15 percent of fatal and nonfatal injury crashes involving large trucks (65 FR 25546). The agency's estimate is reasonable, based on the increased crash risks cited above and the proportion of driving hours in excess of 8-10 hours (see Lilienfeld and Stolley, 1994, for the formula to estimate the proportion of an outcome attributable to a risk factor). In three surveys of driving hours, percentages of drivers reporting they routinely drove trucks for more than 10 hours at a stretch or for more than 70 hours during a week ranged from 20 to 25 percent (Braver et al., 1992; Campbell and Belzer, 2000; McCartt et al., 2000).

FMCSA states that "the number of fatigue-related PDO [property damage only] crashes is probably small" (65 FR 25547). No research is cited to support this statement. On the contrary, many studies that show a relationship between long driving hours and increased crash risk were based on police-reported large truck crashes, which primarily consist of property-damage-only crashes (Frith, 1994; Jones and Stein, 1987, 1989; Lin et al., 1993, 1994; Saccomanno et al., 1995, 1996). FMCSA has underestimated the benefits of preventing fatigue-related property-damage-only crashes.

Tamper-Resistant Automated Recording of Driving Hours Must Be Required
The Institute commends FMCSA for proposing to mandate tamper-resistant electronic recording devices on vehicles of commercial drivers who spend at least one night away from home during their trips. Any efforts to improve the hours-of-service rules would be meaningless in the absence of a requirement for tamper-resistant recorders.

A great deal of data points to the need for electronic recorders. The studies cited above show significantly increased crash risk among drivers who have driven more than 8-10 hours, and there is ample evidence that the current driving hour limits are widely flouted (Beilock, 1995; Beilock and Capelle, 1987; Belman et al., 1998; Braver et al., 1992; Hertz, 1991; McCartt et al., 1997; McKane, 1994; Ouellet, 1994). Attached is a study that reports crash reductions among commercial vehicles equipped with onboard recorders, including a bus fleet equipped with an electronic recorder designed to record driving hours (Wouter and Bos, 2000).

Logbooks, the principal means of enforcing current hours-of-service rules, are easy to falsify. According to a survey of truck drivers, fewer than 20 percent thought logbooks reflected the hours most drivers work (Braver et al., 1992). Unlike logbooks, electronic recorders are reliable indicators of when trucks are in motion. Drivers and motor carriers have strong economic incentives to operate trucks longer than is safe (Campbell and Belzer, 2000; Ouellet, 1994); electronic recorders can supply the necessary counterbalance to these incentives.

Much of the opposition to the overall proposal actually is opposition to the prospect of having to adhere to the driving hour limits. A driver criticizing the proposed rule said, “It’s not going to work because 80 percent of truckers don’t run their log books legal now. If they did, nothing would get delivered” (Kelley, 2000). Changing a system that relies upon routine violations of work hour limits and excessive work hours is justifiable.

Electronic recorders are economically feasible, with the simpler models costing less than $1,000 per truck (IIHS, 1995; Reynolds, 2000). At least one electronic device costs less than $300 as original equipment and $500-600 if it is retrofitted to existing vehicles (Reynolds, 2000). The cost-effectiveness of electronic devices also is demonstrated by motor carriers’ widespread adoption of onboard computers, wireless communication systems, and global positioning systems since the 1980s. Furthermore, most truck engines already contain electronic control modules that could be inexpensively modified to function as electronic logs (Vise, 1999).

A requirement for electronic recorders on commercial vehicles is long overdue. The Institute has repeatedly petitioned the U.S. Department of Transportation to require onboard recorders in large trucks to increase adherence to hours-of-service rules (IIHS, 1986, 1987, 1989, 1995). Other organizations have joined us in petitioning the Department of Transportation for electronic onboard recording devices: Advocates for Highway and Auto Safety, Parents Against Tired Truckers, Families Against Speeding Trucks, National Association of Governors’ Highway Safety Representatives, and Public Citizen. Starting in 1990, the National Transportation Safety Board also recommended automated tamper-resistant onboard recording devices to monitor driving hours of commercial truck drivers. Another organization calling for mandatory onboard monitoring is the National Sleep Foundation (2000), which recognizes the relationship between excessive driving hours and sleep loss. In addition, some trucking industry representatives have come forward to support the use of electronic monitoring devices in lieu of paper logs, including the California Trucking Association (Barnes, 2000), Arkansas Trucking Association (2000), Werner Enterprises (Abry, 1998), T.F. Boyle Transportation (Whitten, 2000), and the president of Kenan Transport Company (Barnes, 1999).

Throughout the world -- including the 15 countries belonging to the European Union, Chile, Israel, Japan, South Korea, Turkey, and Venezuela -- onboard recorders are required for large commercial vehicles (Lehmann, 1999). The United States should stop lagging behind other countries in enforcement technology. FMCSA must strengthen the ability of state and federal authorities to enforce hours-of-service rules by requiring tamper-resistant automated recording devices on commercial vehicles.

Commercial Drivers Need at Least 12 Hours of Off-Duty Time Each Day
Scientific literature consistently indicates that sleep deprivation adversely affects task performance, including driving performance (National Sleep Foundation, 2000; Federal Highway Administration, 1998). Truck drivers frequently drive at night, and sleep deficits are especially prevalent among night workers in all occupations (Gold et al., 1992; Rosa, 1991; Rosa and Bonnet, 1993). The longer the work shifts, the greater the sleep losses each day and over the course of the work week (Rosa et al., 1989). Reductions in total sleep time are severe among workers on 12-hour night shifts (Rosa, 1991; Rosa and Bonnet, 1993).

Another reason for needing at least 12 hours off duty is that research has shown measurable performance impairments among workers who had only 12 hours of off-duty time per day compared with those having 16 hours off per day (Baker et al., 1994; Rosa, 1991; Rosa and Bonnet, 1993; Rosa and Colligan, 1988; Rosa et al., 1989). Impaired performance was observed among workers on 12-hour day and 12-hour night shifts (Rosa, 1991; Rosa and Bonnet, 1993; Rosa et al., 1989). Long work hours contribute to performance decrements even after controlling for the amount of sleep obtained (Rosa et al., 1989).

FMCSA’s proposed 12 hours of off-duty time, including 10 consecutive hours of rest, is a sensible and reasonable compromise between the need for alert well-rested drivers and the productivity needs of the trucking industry. Employees at fixed work sites usually have a minimum of 15 hours off between the end of one work period and the beginning of the next. There is virtually universal consensus that the current 8-hour off-duty period for drivers is inadequate because it does not allow sufficient time for drivers to meet their personal needs and get enough sleep (American Trucking Associations, 1999; Federal Highway Administration, 1998; National Sleep Foundation, 2000).

The controversy seems to be how much additional rest time drivers need, with some advocating as little as 10 hours of off-duty time (American Trucking Associations, 1999; Detter, 2000). Both the National Sleep Foundation (2000) and the expert panel convened by the Federal Highway Administration (1998) recommended 12 hours of off-duty time. Optimally, drivers should sleep 8 hours. Having only 2 hours to attend to all other personal requirements is insufficient (Jaster, 2000). Truck drivers have the same needs as other human beings, and if they have no more than 10 hours of off-duty time per day, sleep inevitably will be shortchanged.

Driving More than 10 Hours Daily Increases Crash Risk

FMCSA has proposed to permit up to 12 hours of driving per day. Currently, truck drivers are allowed up to 10 hours of driving at a stretch. Driving a large truck safely for 10 hours is taxing, even under the best conditions. Driving 12 hours would place truck drivers and other road users at undue risk. About 85 percent of 1998 deaths in large truck crashes were among people sharing the road with large trucks (IIHS, 1999b). Driving should be recognized for what it is: a sedentary and often monotonous task requiring constant vigilance; momentary lapses of attention can have devastating consequences.

Current rules differentiate between driving and nondriving duties by limiting driving hours to 10 and specifying that no driving can occur after 15 total work hours. The proposal, however, sets an overall 12-hour work limit without making any distinction between driving and nondriving time. The rationale for eliminating the distinction between driving and nondriving duties is that “all on-duty time should be treated the same, as the effect on driver safety is similar” (65 FR 25561). It is true that all duties result in fatigue and that an overall work hour limit is appropriate, but it is not true that all duties have the same effect on driver safety. Deaths and serious injuries among truck occupants and other road users can occur only when the truck is in motion.

FMCSA has placed insufficient weight on studies of driving hours that observed increased large truck crash risk after 8-10 hours of driving, including studies that controlled for the effects of time of day (Frith, 1994; Jones and Stein, 1987, 1989; Lin et al., 1993, 1994; Saccomanno et al., 1995, 1996). Techniques used to control for the effects of time of day were matching cases and controls by time of the crash (Frith, 1994; Jones and Stein, 1987, 1989), multivariate analyses (Lin et al., 1993, 1994), and stratification of the study population by daytime and nighttime (Saccomanno et al., 1995, 1996). One strength of these studies relative to other analyses is that they used an objective definition of potential fatigue (driving more than 8-10 hours) rather than relying on subjective assessments made by investigating officers of whether a crash was related to fatigue.

Another strength is that these studies had comparison groups, enabling control of confounding effects from travel patterns and other variables.

FMCSA states there is uncertainty concerning the high odds ratio (OR=6.2) observed by Lin et al. (1994) for the 10th hour of driving. However, this does not negate the findings for previous driving hours. Controlling for time of day, the authors observed significant increases in the odds of crashing starting at the 5th hour of driving (OR=1.6) and continuing through the 9th hour (OR=2.5). These findings strongly suggest that driving more than 10 hours is unsafe.

Other studies have observed a relationship between long driving hours and falling asleep at the wheel of a large truck (Braver et al., 1992; IIHS, 1992; McCartt et al., 2000). Drivers reporting work hours longer than 60-70 per week or other hours-of-service violations were 1.8 times as likely to report falling asleep while driving during the month prior to their interview as drivers reporting fewer work hours (IIHS, 1992). McCartt et al. (2000) reported a significant correlation between driving more than 10 hours and having dozed while driving.

In addition, the research on crash risk and driving performance is consistent with findings in other work settings. Hanecke et al. (1998) observed an exponential increase in injuries beyond the 9th work hour for the German working population. Microsleeps in airline pilots "multiplied after 8 hours of flight time during the day-time operations" (Samel et al., 1997). Task performance is decreased among those working 12-hour shifts compared with 8-hour shifts (Baker et al., 1994), including studies that controlled for hour of day (Rosa, 1991; Rosa and Bonnet, 1993; Rosa and Colligan, 1988; Rosa et al., 1989). FMCSA cited three of the preceding studies (Rosa, 1991; Rosa and Bonnet, 1993; Rosa et al., 1989) as evidence that risk increases *after* the 12th hour of duty time (65 FR 25556); however, these studies indicated substantial decrements in skills *before* persons had worked a full 12 hours.

With regard to involvement in fatigue-related crashes, FMCSA reports relative risks of 1.6 for driving 8 hours, 1.9 for driving 9 hours, 3.4 for driving 10 hours, and even higher relative risks for driving more than 10 hours (Campbell and Belzer, 2000). Given the agency's analysis, together with other research, FMCSA's proposal to allow drivers to operate trucks for 12 hours is perplexing.

Perhaps FMCSA assumes that the proposed 12-hour off-duty period will make it safe for drivers to operate vehicles for more than 10 hours, but there is no sound evidence that this is the case. Existing driving simulator studies purporting to show this are limited by the small number of driver participants (Rogers, 1999) and serious questions about generalizing simulator results to real-world conditions and driver behavior (National Highway Traffic Safety Administration, 1997). Twelve-hour work shifts result in impaired performance, independently of the amount of sleep obtained (Rosa et al., 1989). Increasing the off-duty period should make it safer for drivers to operate vehicles during 10-hour driving shifts. Fatigue-related impairment can occur long before the current 10-hour limit is reached.

The best method of keeping overall duty time close to the 12-hour limit proposed by FMCSA is to maintain the 10-hour driving limit, enforced by electronic recording devices. Apart from the risk of driving more than 10 hours, another problem with allowing drivers to operate trucks for 12 hours is that, judging from current practices, many drivers will not comply with the proposed 12-hour duty-time limit. Because drivers usually are not paid for nondriving duties, they avoid recording these duty hours so as to maximize the hours available for paid work (Campbell and Belzer, 2000; Owner-Operator Independent Drivers Association, 1997). Nondriving duties are considerable, averaging 15-40 hours each week (Braver et al., 1992; Campbell and Belzer, 2000; Martin Labbe Associates, 1998, 1999; McCartt et al., 1997). Under the proposed rule, it is likely that many drivers will drive 12 hours and spend additional hours on nondriving tasks such as unloading cargo. Electronic recording devices do an excellent job of automatically recording driving hours but rely on drivers’ manual inputs of time spent on nondriving tasks, which can be falsified if the truck does not move during those tasks.

An alternative approach is to limit weekly cumulative driving hours to some quantity less than the proposed weekly maximum of 60 work hours. A limit of 50 driving hours for each 60 cumulative work hours would not guarantee adherence to the overall work hour limits, but it would decrease one of the most common types of time record falsification. Assuming that at least 10 hours of work time per week would be spent on nondriving tasks is conservative, based on the survey research cited above that reports nondriving tasks average 15-40 hours per week. An analogous policy has been adopted by safety inspectors: drivers operating trucks for distances greater than 550-600 miles during one driving shift, over roads where the maximum speed limit is 65 mph, are suspected of being in violation of either the speed limits or the 10-hour driving limit (Office of Safety Policy, 2000).

Will There Be More Trucks on the Road if the Proposal Is Implemented? Trucking executives have testified there will be more trucks on the road and thus more crashes if the proposal is implemented (American Trucking Associations, 2000). This assertion is overly simplistic because increased exposure to truck traffic will not necessarily occur if the amount of freight remains the same. The proposed increase in off-duty hours may affect a particular load in several possible ways: a driver may take longer to deliver it, may hand off the same load to another driver prior to taking required rest, or may team up with another driver. The same load of freight requiring a fixed number of driving hours to get from one place to another may or may not be divided among several drivers, but that load would not result in more exposure from multiple trucks traveling on the road at the same time. Depending on how motor carriers organize multiple pickups and deliveries, individual trips currently carried out by one truck driver may have the same, fewer, or more total hours of driving if additional drivers are utilized. The growing transportation logistics industry is developing networks of shippers and carriers to make more efficient use of drivers and trucks, which may reduce truck traffic (J.B. Hunt, 2000).

Another safety question raised by trucking industry executives is whether the proposed requirement for 2 nights off following 60 hours of work would lead to more trucks traveling during daylight hours (Birkhead, 2000). The proposal would allow drivers to start work at 7 a.m. if they have had at least 32 hours off spanning a period that would include 11 p.m. to 7 a.m. on 2 successive nights. Whether the proposed requirement for 2 nights off would result in more daytime truck traffic is questionable because current rules already require drivers to take several days off, including 3 nights, if they have reached maximum driving hour limits (60-70 hours over 7-8 days) within 5 days. Truck driver surveys indicate that many long-haul drivers currently reach maximum work hour limits before 5 days have elapsed and must take at least 3 days (and nights) off before they legally can drive again (Belman et al., 1998; IIHS, 1992).

FMCSA Should Clarify Some Aspects of the Hours-of-Service Proposal
Although the requirements of the proposal appear to be clear, questions have arisen at the public hearings concerning the proposed revision to the hours-of-service rules for commercial drivers (see Appendix for a list of questions). FMCSA must publish responses to these questions in the Federal Register and on its website to ensure that all interested parties understand the intended proposal. After this clarification is published, the Institute might have further comments on the proposal.

Summary
FMCSA has proposed a rule that should save lives and decrease injuries and property damage arising from large truck crashes. One provision of the proposal that may result in adverse safety consequences is the expansion of permissible driving shifts to 12 hours. The costs of the proposed rule are reasonable, given the proportion of crashes in which fatigue is a contributing factor and the estimated public health

benefits. Electronic recorders to monitor driving hours, which cost as little as $300-600, are essential to monitor compliance with hours-of-service limits; otherwise, the pattern of widespread violations of these limits will continue. Another provision critical to reducing fatigue-impaired driving among commercial drivers is the proposed increase in the daily mandatory rest period to 12 hours. If these two provisions are adopted, for the first time since the hours-of-service rules were promulgated more than 60 years ago, all drivers will be able to get a reasonable amount of rest on work days and will have to adhere to the driving hour limits.

Sincerely,

Elisa R. Braver

Elisa R. Braver, Ph.D.
Senior Epidemiologist

cc: The Honorable Rodney Slater
Docket Clerk, Docket No. FHWA-97-2350

Appendix

Attachment

Appendix
Questions About Hours-of-Service Proposal (65 FR 25540; May 2, 2000)

The Institute reads the proposed rule as unambiguously requiring that all the following requirements be met and that a motor carrier would not be in compliance with the proposed rule if Types 1-4 drivers were permitted to work longer than 60 hours over 7 days. Yet in public hearings the possibility was raised that compliance with the mandatory time-off requirements (32-56 hours that include 2 consecutive nights off) would relieve motor carriers of having to adhere to the maximum limit of 60 work hours over 7 days. FMCSA must respond to questions about the proposal that have arisen at the public hearings.

Requirements

- A maximum of 60 work hours over 7 days
- A daily maximum of 12 work hours within 14 consecutive hours
- A 7-day workweek that is fixed and recurs regularly
- An extended off-duty period of at least 32-56 consecutive hours that spans a minimum of two 11 p.m. to 7 a.m. periods before the beginning of a new workweek (hereafter referred to as a “weekend” although it may occur on weekdays)

Questions

1. Is the limitation of 60 work hours over 7 days absolute for drivers (Types 1-4) except for Type 1 drivers averaging work hours over 2 successive weeks? Or may a driver who has had the requisite “weekend” begin working again before the 7-day workweek has concluded?

   For example, suppose a driver with an assigned workweek of Monday-Sunday works 12 hours a day for 5 days starting on Monday and is released from work by 11 p.m. on Friday. Can that driver go back to work on Sunday at 7 a.m., or does that driver have to wait until Monday before starting work again?

2. May a driver take the extended off-duty period (“weekend”) in the middle of the 7-day workweek, rather than at the end of it, and then start working again on the first day of the next workweek?

   For example, may a driver with a regular Monday-Sunday workweek work 12 hours on Monday and 12 hours on Tuesday, go off duty at 11 p.m. Tuesday night until 7 a.m. Friday morning, work 12 hours each day on Friday, Saturday, and Sunday, and then start working again on the following Monday, the first day of the next workweek? Such a driver would have worked no more than 60 hours over 7 days and would have had a “weekend” in the middle of that workweek.

References

Abry, G. 1998. Satellite logs get trial run in FHWA plan. *Transport Topics* (April 13, 1998):1,28.

American Trucking Associations (Walter B. McCormick, Jr.). 2000. DOT's hours of service proposal is a 'recipe for disaster.' Alexandria, VA. Available at http://www.truckline.com/insideata/comments/070600_wbm_fmcsatest.html. Accessed July 7, 2000.

American Trucking Associations. 1999. Recommendations for future hours of service rules. Submitted to U.S. Department of Transportation and Office of Management and Budget. Alexandria, VA.

Arkansas Trucking Association. 2000. Arkansas Trucking Association adopts hours-of-service policy. Little Rock, AR. Available at http://www.arkansastrucking.com/news.html. Accessed June 2, 2000.

Baker, K.; Olson, J.; and Morisseau, D. 1994. Work practices, fatigue, and nuclear power plant safety performance. *Human Factors* 36:244-57.

Barnes, D. 1999. Shaffer embraces 'black boxes.' *Transport Topics* (November 8, 1999):1,27.

Barnes, D. 2000. California group backs recorders. *Transport Topics* (July 17, 2000):52.

Beilock, R. 1995. Schedule-induced hours-of-service and speed limit violations among tractor-trailer drivers. *Accident Analysis and Prevention* 27:33-42.

Beilock, R. and Capelle, R.B. 1987. Economic pressure, long distance trucking, and safety. *Journal of the Transportation Research Forum* 28:177-85.

Belman, D.L.; Monaco, K.A.; and Brooks, T.J. 1998. And Lord, let it be palletized: a portrait of truck drivers' work and life. Ann Arbor, MI: University of Michigan Trucking Industry Program.

Birkhead, P. 2000. Testimony regarding the Department of Transportation's proposed driver hours-of-service regulation before the House Transportation and Infrastructure Ground Transportation Subcommittee. Alexandria, VA: Snack Food Association.

Braver, E.R.; Preusser, C.W.; Preusser, D.F.; Baum, H.M.; Beilock, R.; and Ulmer, R. 1992. Long hours and fatigue: a survey of tractor-trailer drivers. *Journal of Public Health Policy* 13:341-66.

Campbell, K.L. 1988. Evidence of fatigue and the circadian rhythm. *Proceedings of Federal Highway Administration Symposium on Truck and Bus Driver Fatigue,* 20-38. Washington, DC: U.S. Department of Transportation.

Campbell, K.L. and Belzer, M.H. 2000. Hours of service regulatory evaluation analytical support. task 1: baseline risk estimates and carrier experience. Prepared for the Federal Motor Carrier Safety Administration (UMTRI-2000-11). Ann Arbor, MI: University of Michigan.

Detter, G.L. 2000. Testimony before the House Transportation and Infrastructure Committee, Ground Transportation Subcommittee. Available at http://www.truckline.com/legislative/testimony/062600_detter.html. Accessed July 7, 2000.

Federal Highway Administration. 1998. Potential Hours-of-Service Regulations for Commercial Drivers: Report of the Expert Panel on Review of the Federal Highway Administration Candidate Options for Hours of Service Regulations. Washington, DC: U.S. Department of Transportation.

Frith, W.J. 1994. A case-control study of heavy vehicle drivers' working time and safety. *Proceedings of the 17th Australian Road Research Board Conference* 17:17-30. Queensland, Australia: Australian Road Research Board.

Gold, D.R.; Rogacz, S.; Bock, N.; Tosteson, T.D.; Baum, T.M.; Speizer, F.E.; and Czeisler, C.A. 1992. Rotating shift work, sleep, and accidents related to sleepiness in hospital nurses. *American Journal of Public Health* 82:1011-14.

Hanecke, K.; Tiedemann, S.; Nachreiner, F.; and Grzech-Sukalo, H. 1998. Accident risk as a function of hour at work and time of day as determined from accident data and exposure models for the German working population. *Scandinavian Journal of Work, Environment, and Health* 24(suppl. 3):43-48.

Harris, W. 1978. Fatigue, circadian rhythm, and truck accidents. *Vigilance: Theory, Operational Performance, and Physiological Correlates* (ed. Mackie, R.), 133-46. New York, NY: Plenum Press.

Hertz, R.P. 1991. Hours of service violations among tractor-trailer drivers. *Accident Analysis and Prevention* 23:29-36.

Insurance Institute for Highway Safety. 1986. Petition to require automatic on-board recording devices for motor carriers. Submitted to the Bureau of Motor Carrier Safety (October 1, 1986). Washington, DC: U.S. Department of Transportation.

Insurance Institute for Highway Safety. 1987. Petition for reconsideration to require automatic on-board recording devices for motor carriers. Submitted to the Federal Highway Administration (February 25, 1987). Washington, DC: U.S. Department of Transportation.

Insurance Institute for Highway Safety. 1989. Petition to require automatic on-board recording devices for motor carriers transporting hazardous materials. Submitted to the Federal Highway Administration (December 20, 1989). Washington, DC: U.S. Department of Transportation.

Insurance Institute for Highway Safety. 1992. Comments submitted to the Federal Highway Administration. Docket No. MC-92-30 (November 4, 1992). Washington, DC: U.S. Department of Transportation.

Insurance Institute for Highway Safety. 1995. Petition to require electronic onboard recording devices for motor carriers. Submitted to the Federal Highway Administration (August 3, 1995). Washington, DC: U.S. Department of Transportation.

Insurance Institute for Highway Safety. 1997. Comments submitted to the Federal Highway Administration. Docket No. FHWA-97-2350 (June 30, 1997). Washington, DC: U.S. Department of Transportation.

Insurance Institute for Highway Safety. 1998a. Comments submitted to the Federal Highway Administration. Docket No. FHWA-97-2350 (January 27, 1998). Washington, DC: U.S. Department of Transportation.

Insurance Institute for Highway Safety. 1998b. Comments submitted to the Federal Highway Administration. Docket No. FHWA-97-3706 (June 19, 1998). Washington, DC: U.S. Department of Transportation.

Insurance Institute for Highway Safety. 1998c. Comments submitted to the Federal Highway Administration. Docket No. FHWA-97-2350 (August 27, 1998). Washington, DC: U.S. Department of Transportation.

Insurance Institute for Highway Safety. 1999a. Comments submitted to the Federal Highway Administration. Docket No. FHWA-97-2350 (July 30, 1999). Washington, D.C.: U.S. Department of Transportation.

Insurance Institute for Highway Safety. 1999b. Fatality facts: large trucks. Available at http://www.highwaysafety.org/safety_facts/fatality_facts/trucks.htm. Accessed July 20, 2000.

Jaster, W. 2000. Eight is not enough (letter to the editor). *RoadStar* 2:12.

J.B. Hunt, Inc. 2000. Six of the Nation's Largest Transportation Companies Merge Logistics Businesses in New Internet Venture, Transplace.com, to Maximize Marketing, Utilization, and Purchasing Efficiencies. Available at http://www.jbhunt.com/Newsroom/Transplace/transplace.html. Accessed August 3, 2000.

Jones, I.S. and Stein, H.S. 1987. Effect of driver hours of service on tractor-trailer crash involvement. Arlington, VA: Insurance Institute for Highway Safety.

Jones, I.S. and Stein, H.S. 1989. Defective equipment and tractor-trailer crash involvement. *Accident Analysis and Prevention* 21:469-81.

Kaneko, T. and Jovanis, P.P. 1992. Multiday driving patterns and motor carrier accident risk: a disaggregate analysis. *Accident Analysis and Prevention* 24:437-56.

Kelley, S. 2000. Industry bristles over hours reduction, on-board recorders. *Overdrive* 40:36-40.

Lehmann, G. 1999. Highway recording systems: a report on European and U.S. experiences. International Symposium on Transportation Recorders. Crystal City, VA: National Transportation Safety Board and International Transportation Safety Association.

Lin, T.D.; Jovanis, P.P.; and Yang, C.Z. 1993. Modeling the safety of truck driver service hours using time-dependent logistic regression. *Transportation Research Record* 1407:1-10. Washington, DC: Transportation Research Board.

Lin, T.D.; Jovanis, P.P.; and Yang, C.Z. 1994. Time of day models of motor carrier accident risk. *Transportation Research Record* 1467:1-8. Washington, DC: Transportation Research Board.

Lilienfeld, D.E. and Stolley, P.D. 1994. *Foundations of Epidemiology*, 3rd ed. New York, NY: Oxford University Press.

Mackie, R.R. and Miller, J.C. 1978. Effects of hours of service, regularity of schedules, and cargo loading on truck and bus driver fatigue (DOT HS-803-799). Washington, DC: National Highway Traffic Safety Administration.

Martin Labbe Associates. 1998. *National Refrigerated Driver Survey*. Ormond Beach, FL.

Martin Labbe Associates. 1999. *1999 Dry Van Drivers Survey*. Ormond Beach, FL.

McCartt, A.T.; Hammer, M.C.; and Fuller, S.Z. 1997. Work and sleep/rest factors associated with driving while drowsy experiences among long-distance truck drivers. *Proceedings of the 41st Annual Conference of the Association for the Advancement of Automotive Medicine*, 95-108. Des Plaines, IL: Association for the Advancement of Automotive Medicine.

McCartt, A.T.; Rohrbaugh, J.W.; Hammer, M.C.; and Fuller, S.Z. 2000. Factors associated with falling asleep at the wheel among long-distance truck drivers. *Accident Analysis and Prevention* 32:493-504.

McKane, D. 1994. Three-state effort enforces hours of service regulations. *The Guardian* 1:4-5.

National Highway Traffic Safety Administration. 1997. An investigation of the safety implications of wireless communications in vehicles (DOT HS-808-635). Washington, DC: U.S. Department of Transportation.

National Sleep Foundation. 2000. Position statement regarding hours-of-service rules for commercial drivers and fatigue interventions/ countermeasures. Washington, DC.

National Transportation Safety Board. 1990. Fatigue, alcohol, other drugs, and medical factors in fatal-to-the-driver heavy truck crashes (vol. I). NTSB/SS-90-01. Washington, DC: National Transportation Safety Board.

National Transportation Safety Board. 1995. Factors that affect fatigue in heavy truck accidents (vol. I). NTSB/SS-95-01. Washington, DC: National Transportation Safety Board.

Office of Safety Policy. 2000. Interpretation and guidance for compliance officers (unpublished information). Alexandria, VA: American Trucking Associations.

Ouellet, L.J. 1994. The work lives of truckers. *Pedal to the Metal*. Philadelphia, PA: Temple University Press.

Owner-Operator Independent Drivers Association. 1997. Comments in response to advance notice of proposed rulemaking concerning hours of service regulations. Submitted to Federal Highway Administration. Washington, DC.

Reynolds, T. 2000. Hours of service of drivers. Testimony before the Federal Motor Carrier Safety Administration. Winchester, VA: VDO North America.

Rogers, W.C. 1999. Effects of operating practices on commercial driver alertness. Presented at Traffic Safety of Two Continents, Malmo, Sweden. Alexandria, VA: ATA Foundation.

Rosa, R.R. 1991. Performance, alertness, and sleep after 3-5 years of 12 h shifts: a follow-up study. *Work and Stress* 5:107-16.

Rosa, R.R. and Bonnet, M.H. 1993. Performance and alertness on 8 and 12 h rotating shifts at a natural gas utility. *Ergonomics* 36:1177-93.

Rosa, R.R. and Colligan, M.J. 1988. Long workdays versus restdays: assessing fatigue and alertness with a portable performance battery. *Human Factors* 30:305-17.

Rosa, R.R.; Colligan, M.J.; and Lewis, P. 1989. Extended workdays: effects of 8-hour and 12-hour rotating shift schedules on performance, subjective alertness, sleep patterns, and psycho-social variables. *Work and Stress* 3:21-32.

Saccomanno, F.F.; Yu, M.; and Shortreed, J.H. 1995. Effect of driver fatigue on truck accident rates. *Urban Transport and the Environment for the 21st Century* (ed. Sucharov, L.J.), 439-46. Southampton, United Kingdom: Computational Mechanics Publications.

Saccomanno, F.F.; Shortreed, J.H.; and Yu, M. 1996. Effect of driver fatigue on commercial vehicle accidents. *Truck Safety: Perceptions and Reality*, 157-74. Waterloo, Canada: The Institute for Risk Research.

Samel, A.; Wegmann, H.M.; and Vejvoda, M. 1997. Aircrew fatigue in long-haul operations. *Accident Analysis and Prevention* 29:439-52.

Summala, H. and Mikkola, T. 1994. Fatal accidents among car and truck drivers: effects of fatigue, age, and alcohol consumption. *Human Factors* 36:315-26.

Vise, A. 1999. Big brother under your hood. *Trucking Co.* (December, 1999):7.

Whitten, D.L. 2000. Black boxes and the small carrier. *Transport Topics* (June 26, 2000):1,13-14.

Wouters, P.I.J. and Bos, J.M.J. 2000. Traffic accident reduction by monitoring driver behaviour with in-car data recorders. *Accident Analysis and Prevention* 32:643-50.

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DEFECTIVE EQUIPMENT AND TRACTOR-TRAILER CRASH INVOLVEMENT*

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Abstract—The role of defective equipment in large truck crashes on interstate highways in Washington State was investigated using a case-control study design. For each large truck involved in a crash, three trucks were randomly selected from the traffic stream at the same time and place as the crash, but one week later both crash and comparison trucks were inspected by Commercial Vehicle Enforcement officers of the Washington State Patrol. The effects of truck equipment condition, truck operating characteristics (carrier type, carrier operation, and truck load), and driver characteristics (driver age, hours of driving) on crash involvement were analyzed by comparing their relative frequency among crash-involved and comparison sample tractor-trailers. A logistic regression model was used to estimate the adjusted odds ratio for each factor. Overall, 77% of tractor-trailers in crashes and 66% of those not involved in crashes had defective equipment warranting a citation. Forty-one percent in crashes had defective equipment warranting taking the truck out of service, and 31% not in crashes had these defects. Brake defects were the most common type and were found in 56% of tractor-trailers in crashes; steering equipment defects were found in 21%. The relative risk of crash involvement for trucks with brake defects was about one and one-half times that for trucks without brake defects. For trucks with steering defects, the relative risk of crash involvement was at least twice that for trucks without defects, and the risk increased substantially for trucks with out-of-service steering defects.

INTRODUCTION

Large-truck crashes are a major highway safety problem [Insurance Institute for Highway Safety (IIHS) 1986]. The numbers of large trucks that operate with defective equipment is of growing concern. Data from truck inspections around the country indicate that substantial numbers of trucks operate with one or more safety-related defects [Office of Motor Carrier Safety (OMCS) 1985, 1987]. However, because trucks involved in crashes are rarely inspected for defects, it has been difficult to assess the extent to which safety-related defects are contributing to big-truck crash involvement [Transportation Research Board (TRB) 1981; [National Highway Traffic Safety Administration (NHTSA) 1987].

The most frequently cited source for statistics on the involvement of defective equipment in truck crashes is data from crash reports of interstate carriers compiled by the OMCS of the Federal Highway Administration (FHWA) (OMCS 1986). These data appear to indicate that defective equipment, most commonly brakes, is a factor in only 5% of all truck crashes; however, the data are self-reported by the carriers and are unlikely to be reliable. The Transportation Research Board concluded "carriers may not know some specifics about their trucks at the time of an accident and it is unlikely that safety violations are fully reported" (1981). Furthermore, many relevant crashes are not reported; the OMCS estimated that between 30% and 40% of all eligible crashes involving interstate trucks are not reported (Pierson 1983).

Other sources of truck crash data include state police reports, but these are also limited because investigating officers are not trained in truck equipment inspection techniques. Even in states with active truck inspection programs, trained inspectors are only called in for the more severe crashes or for crashes where defective equipment appears to be an obvious crash factor. Even more routine information about crash-involved

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trucks, such as configuration and load, is generally not recorded (McGee 1986); thus, assessing the influence of these factors on crash involvement is not possible.

Two previous studies that examined defective equipment in relation to truck crash involvement found that the estimate from the OMCS data is low (Eicher, Robertson, and Toth 1982; Oregon Public Utility Commission 1985). However, neither of these studies had detailed truck inspection data, and they relied on police reports and driver statements for assessing the condition of the truck's equipment. A recent review by the NHTSA concluded that, among the many causes of truck crashes, vehicle-related factors "play a critical, if somewhat unrecognized and underreported role" (1987). The study also states that, among all vehicle-related factors, truck brake systems should receive the highest priority because their analyses estimated that brake system performance could be involved as a contributing factor in as many as one third of all truck accidents.

The very question of what is defective equipment is complex; for example, until recently, OMCS permitted three-axle tractors or trucks to legally operate without brakes on the front steering axle. This regulation allowed these tractors to operate with the brakes removed, but they could *not* be plugged or simply disconnected. Thus, a truck without front brakes was considered legal and one with plugged brakes was considered defective.

Data on the prevalence or exposure of trucks with defective equipment are also limited. National data on truck mileage, such as the *Truck Inventory and Use Survey*, do not categorize trucks by condition of equipment or other relevant factors on a trip-by-trip basis (TRB 1981). Major sources of exposure data are the FHWA annual roadside inspections and the state truck inspections funded through the federal Motor Carrier Safety Assistance Program (MCSAP). These inspections typically place 30% to 40% of trucks out of service for defective equipment; the most common defects involve brake systems (OMCS 1985, 1987). These figure are also subject to bias because trucks chosen for inspection are not necessarily selected at random but are selected because the general condition of the truck suggests defective equipment is likely to be present. Two limited inspection programs where the trucks were selected randomly found somewhat lower percentages of trucks with out-of-service defects, although over 25% of trucks were still taken off the road (Davis 1986; Tyson 1987).

The most common defects found in the roadside inspections involve brakes and steering. Vehicle tests have demonstrated that truck stability and handling performance are affected by the condition of the brake and steering systems (NHTSA 1987). Improper brake adjustment or lack of front brakes significantly increases stopping distance, which is already considerably longer than that required for passenger cars. Also, poorly maintained brakes increase the chance of brake imbalance and the likelihood of wheel lockup with subsequent tractor-trailer jackknife. Defects in the steering system are likely to degrade a tractor-trailer's maneuverability, increasing the likelihood of rollover and exacerbating any adverse off-tracking characteristics (NHTSA 1987).

Although the effects of truck equipment condition on handling performance and stability can be demonstrated in test situations and are evident in some individual crash reports, previous studies have not been able to identify reliably the extent to which truck equipment condition contributes to crash involvement. The objective of the present study was to examine whether tractor-trailers with equipment defects are overinvolved in crashes. The frequency of equipment defects on crash-involved trucks was compared to that of a matched comparison sample of trucks traveling the same roadways under similar conditions. To document equipment condition in a uniform and consistent manner, detailed inspections were performed on both crash-involved and comparison sample trucks.

METHOD

Washington State has allowed a diversity of truck configurations including western doubles, Rocky Mountain doubles, and truck-trailers as well as tractor-trailers, tractors (bobtails), and single-unit trucks to operate on all its roads for more than 25 years. The state provides a wide variety of climate and terrain ranging from the temperate coastal region through the Cascade Mountains to the desert areas in the eastern part of the state. The study was conducted primarily on Interstate 5, which carries north–south traffic, and Interstate 90, which has east–west traffic. The data were collected over a two-year period from June 1984 through July 1986.

Truck data were collected by the Commercial Vehicle Enforcement Section (CVES) of the Washington State Patrol. Approximately 100 officers are responsible for the weight enforcement and inspection programs in the state, which includes weigh stations on interstates and other major routes, as well as port-of-entry weigh scales. The officers conduct detailed inspections of truck equipment including brakes, steering equipment, tires, and other major systems. They also provide assistance to the State Patrol in the investigation of truck crashes. Truck inspections followed the procedures detailed by the Commercial Vehicle Safety Alliance (CVSA) and the National Uniform Driver–Vehicle Inspection Manual (OMCS 1983).

Study design

In this application of the case-control study design, for each crash-involved truck three trucks were selected and inspected at the crash site at the same time of the day of the crash but one week later. Thus, a case sample of crash-involved trucks and a control (comparison) sample matched for roadway, time of day, and day of week were established. The study included all crashes involving trucks with gross vehicle weight rating greater than 10,000 pounds that occurred on the interstate highway system and involved property damage of at least $1,500 or personal injury. Each crash-involved truck was inspected by a CVES officer to check the condition of the major truck components including brakes, steering, and tires. Where possible, quantitative measures of performance were used; for example, brake adjustment was measured from pushrod travel. Other variables including truck weight, size, and configuration; driver age and experience; and the type of trip were also recorded.

One week after each crash, the CVES officers conducted a random roadside truck inspection at the crash location. For every crash-involved truck, three trucks were selected for the comparison sample: one approximately 30 minutes before the time of the crash, one at the time of the crash, and one 30 minutes later. The only criterion for selection of comparison sample trucks was that they have a gross vehicle weight rating of 10,000 pounds or greater. Because of safety and convenience considerations, the inspection site was usually at the next interchange, weigh scale, or rest area. Each comparison truck selected was inspected following the same procedures used for the crash-involved trucks. If the inspection was at the roadside, truck weights were obtained using portable scales or estimated from shipping papers. The inspection was typically completed within 30 minutes, which allowed the officers to select the next truck at the appropriate time.

This sampling procedure could not always be followed; some crash locations did not have sufficient area at the roadside to conduct an inspection or a convenient alternate site before the next interchange. In these cases, the inspection site was moved to an appropriate location as near the crash site as possible, and the inspecting officers confirmed that the selected truck had passed the crash location. Because of very severe weather or because the officers were investigating other crashes, a few of the comparison sample inspections were conducted two or three weeks after the original crash. In addition, a few comparison inspections were omitted because the crash had occurred in congested areas (e.g. downtown Seattle), where it was not possible to apply the sampling procedure satisfactorily. The study collected data for 676 crashes involving 734 large trucks that occurred between June 1984 and July 1986.

Data analysis

The analyses reported here examined the association between vehicle equipment defects and crash involvement for tractor-trailers. The Washington state truck study was set up to allow the relative involvement of different truck configurations to be compared;

thus, the control sample was constructed by sampling trucks irrespective of configuration. However, because it cannot be assumed that vehicle factors are independent of truck configuration, this report is limited to tractor-trailers, which comprised 60% of the crash-involved trucks. These analyses could have been repeated for the other main truck configurations (e.g. single-unit trucks, which were 23% of the control population, and twin-trailer trucks, which were 7%), but sample sizes were too small to provide meaningful results.

Limiting the analysis to crashes involving tractor-trailers meant that the control sample was also limited to tractor-trailers. Because trucks were randomly sampled, eliminating control cases that were not tractor-trailers did not bias the sample. For each case involving a tractor-trailer, the control sample was examined and controls that were not tractor-trailers were excluded. Individual cases could have one, two, or three control trucks depending on how many had to be discarded. Cases where all three controls were discarded were eliminated from the analysis.

There were a number of crash-involved trucks where inspection of equipment was not possible because of the damage sustained in the crash. Forty-one percent of tractor-trailers in single-vehicle crashes had complete inspections compared to 81% for multiple-vehicle crashes. Nineteen crash-involved trucks were eliminated from the analyses because none of their major equipment (i.e. brakes, steering, and tires) could be inspected. The number of matched cases that had complete information on brakes, steering, and tires are given in the tables as appropriate.

The variables used in the analyses included truck equipment condition, truck operating factors, and driver characteristics. If a variable of interest was unknown for a crash-involved truck, then both crash and comparison trucks were excluded from the particular analysis. If a variable was unknown for one of the comparison sample trucks, that truck was excluded from the analysis.

Truck equipment condition factors analyzed included defects that could result in a violation or place the truck out of service. The equipment inspection procedures followed those outlined by the OMCS in the *National Uniform Driver Inspection Manual* (1983). The criteria from this manual were also used for determining defect violations and out-of-service defects, with the exception of brake adjustment where the more stringent Washington State standard was used. With the OMCS criteria, a truck is placed out of service if more than 40% of its brakes are out of adjustment; in Washington, it is placed out of service if 25% are out of adjustment. Front brakes that were removed, which was legal at the time of the study, were not counted toward this percentage.

Equipment defects analyzed in this paper were limited to brake system components, brake adjustment, steering system components, and tires or wheels. Other defects involving the lights, frame, or suspension were not included because they were difficult to quantify. To provide an objective measure, brake performance was assessed by measuring the pushrod travel for each brake and noting whether each brake was in adjustment. Other types of brake defects such as defective low air warning devices and air leaks were not included. Steering condition was assessed by measuring the amount of play in the steering wheel, and tire condition was assessed by measuring the tire tread depth.

Truck operating factors included carrier type, which was separated into common, contract, and private carriers, carrier operation, and truck load. Private carriers (e.g. supermarket or department store delivery trucks) transport their own cargos as part of another nontrucking enterprise. For-hire carriers transport freight that belongs to others and are classified as common or contract carriers. Common carriers (e.g. Roadway and Consolidated Freightways) offer services to any shipper. Contract carriers (e.g. logging trucks and U.S. Mail trucks) are restricted to serving a shipper or limited number of shippers under specific contracts and may not offer services to the public at large.

Carrier operation delineates those trucks used in *interstate* commerce from those in *intrastate* commerce. Truck load was categorized as empty, partially loaded (less than 90% of permitted gross vehicle weight), and fully loaded.

Driver characteristics analyzed were driver age and hours of driving since the last eight-hour rest period.

The estimated relative risk of crash involvement for each of the study factors are given in the Results as crude odds ratios; 95% confidence intervals for the odds ratios are also presented. The odds *ratio* is the odds of crash involvement given a particular factor divided by the odds of crash involvement in the absence of that factor. The χ^2 test was used to test the null hypothesis that the odds ratio is unity (Schlesselman 1982). The crude odds ratio is a good approximation to the relative risk of crash involvement because the outcome—a crash—hypothetically associated with the risk factors—equipment defects—is rare and because there is little likelihood of bias due to the selection of control trucks based on the state of their equipment (Anderson et al. 1980).

To analyze the simultaneous effects of various study factors, a logistic regression model was used to estimate the adjusted odds ratio for each of the factors included in the model. To fit the regression model the logistic regression procedure MCSTRAT from the SAS Users Group International (SUGI) Supplemental Library was used (SAS 1986). This program facilitates running a logistic regression on a matched case-control data set with a variable (unbalanced) number of controls per case.

RESULTS

Truck equipment defects

Table 1 gives the distribution by crash configuration of crash-involved tractor-trailers that had defective equipment compared to the matched comparison sample of trucks. Equipment defects sufficient to constitute a violation are given separately from those that were more serious and sufficient to place the truck out of service; the two figures add to give the total number of defects. Overall, 77% of crash-involved tractor-trailers had at least one defect violation compared to 66% of the comparison sample trucks and the relative risk of crash involvement for trucks with defective equipment compared to trucks with no defects was 1.7. Forty-one percent of crash-involved tractor-trailers had at least one defect sufficient to put them out of service compared to 31% of the com-

Table 1. Percentage distribution of tractor-trailers with defective equipment in crash and comparison samples

Crash Type	Number*	Percent with Defective Equipment		Crude Odds Ratio**	95% Confidence Interval
		Crash Sample	Comparison Sample		
All Crashes	231				
Violation Defect		36	35	1.5	(0.96, 2.25)
Out-of-Service Defect		41	31	1.9	(1.28, 2.90)
All Defects		77	66	1.7	(1.17, 2.46)
Single Vehicle	51				
Violation Defect		43	29	2.3	(0.90, 5.88)
Out-of-Service Defect		31	37	1.2	(0.52, 2.83)
All Defects		74	66	1.6	(0.72, 3.34)
Multiple Vehicle	180				
Violation Defect		33	37	1.3	(0.82, 2.17)
Out-of-Service Defect		43	29	2.2	(1.39, 3.59)
All Defects		76	66	1.7	(1.14, 2.67)
Sideswipe	62				
Violation Defect		32	38	0.9	(0.39, 1.93)
Out-of-Service Defect		42	34	1.4	(0.65, 3.03)
All Defects		74	72	1.1	(0.56, 2.22)
Rear-End	36				
Violation Defect		33	42	2.4	(0.57, 10.10)
Out-of-Service Defect		53	20	8.8	(2.04, 38.28)
All Defects		86	62	4.9	(1.36, 17.55)

*Number of matched cases.
**Crude odds calculated using matched sets.
Note: Reference group is tractor-trailers without defects within each crash type.

parison tractor-trailers, and the relative risk of crash involvement for trucks with out-of-service defects was 1.9. As a general trend, the relative risk of crash involvement was higher for trucks with out-of-service defects than with less serious defects. The results were similar for both single-vehicle and multiple-vehicle crashes although out-of-service defects occurred more often in multiple-vehicle crashes where the relative risk of crash involvement for tractor-trailers with out-of-service defects was 2.2 times that of trucks without defects.

Multiple-vehicle crashes were further separated into crashes in which the trucks rear-ended or sideswiped other vehicles. Tractor-trailers with defective equipment were very much overinvolved in rear-end crashes. Fifty-three percent of tractor-trailers in rear-end crashes had out-of-service defects compared to 20% of those in the comparison sample so that the relative risk of involvement in this type of crash for tractor-trailers with defects compared to those with no defects was almost 9:1.

Tables 2–4 give distributions by crash type separately for brake adjustment, steering, and tire/wheel defects. Tractor-trailers with brake and steering defects were overinvolved in all types of crashes. For crash configurations in which trucks strike other vehicles (i.e. sideswipe and rear-end crashes), the involvement of defective brake and steering equipment increases. For example, nearly 50% of the tractor-trailers that rear-ended other vehicles had out-of-service brake defects and their relative risk of involvement in these crashes was 6.8.

Equipment defects may interact with driving hours because as drivers become fatigued they may be less able to compensate for equipment defects. Table 5 gives the percentage of tractor-trailers that had equipment defects (separated into brake, steering, and tires/wheels) by hours of driving at the time of the crash or inspection. For brake defects, the overinvolvement of tractor-trailers with defects increases with driving hours for both violation and out-of-service defects, although the latter effect was more pronounced. However, the interaction between driving hours and brake defects was not statistically significant. The overinvolvement of tractor-trailers with defects does not appear to increase with driving hours for either steering or tire defects.

Table 2. Percentage distribution of tractor-trailers with brake adjustment defects in crash and comparison samples

Crash Type	Number*	Percent with Brake Adjustment Defects		Crude Odds Ratio**	95% Confidence Interval
		Crash Sample	Comparison Sample		
All Crashes	260				
Violation Defect		26	22	1.5	(1.03, 2.20)
Out-of-Service Defect		30	22	1.7	(1.19, 2.46)
All Defects		56	44	1.6	(1.19, 2.18)
Single Vehicle	69				
Violation Defect		30	18	2.0	(0.96, 4.29)
Out-of-Service Defect		23	31	0.8	(0.42, 1.68)
All Defects		53	49	1.2	(0.69, 2.19)
Multiple Vehicle	191				
Violation Defect		25	23	1.3	(0.86, 2.10)
Out-of-Service		32	18	2.3	(1.50, 3.63)
All Defects		57	41	1.8	(1.25, 2.54)
Sideswipe	63				
Violation Defect		32	23	1.7	(0.81, 3.70)
Out-of-Service Defect		29	19	2.2	(1.03, 4.75)
All Defects		61	42	2.0	(1.05, 3.66)
Rear-End	39				
Violation Defect		13	29	0.6	(0.18, 2.26)
Out-of-Service Defect		49	12	6.8	(1.89, 24.34)
All Defects		62	41	2.2	(0.95, 5.32)

*Number of matched cases.

**Crude odds calculated using matched sets.

Note: Reference group is tractor-trailers without defects within each crash type.

Table 3. Percentage distribution of tractor-trailers with steering equipment defects in crash and comparison samples

Crash Type	Number*	Percent with Steering Equipment Defects		Crude Odds Ratio**	95% Confidence Interval
		Crash Sample	Comparison Sample		
All Crashes	242				
Violation Defect		14	8	2.0	(1.20, 3.42)
Out-of-Service Defect		7	4	1.9	(0.99, 3.80)
All Defects		21	12	2.0	(1.29, 3.07)
Single Vehicle	57				
Violation Defect		9	4	2.0	(0.55, 7.24)
Out-of-Service Defect		5	3	2.1	(0.41, 11.19)
All Defects		14	7	2.0	(0.69, 6.06)
Multiple Vehicle	185				
Violation Defect		15	9	2.0	(1.15, 3.61)
Out-of-Service		8	5	1.9	(0.90, 3.97)
All Defects		32	14	2.0	(1.24, 3.18)
Sideswipe	62				
Violation Defect		15	12	1.5	(0.59, 3.69)
Out-of-Service Defect		10	4	2.9	(0.80, 10.78)
All Defects		25	16	1.8	(0.85, 3.98)
Rear-End	37				
Violation Defect		19	10	2.9	(0.76, 10.97)
Out-of-Service Defect		11	5	2.8	(0.56, 13.67)
All Defects		30	15	2.8	(0.93, 8.68)

*Number of matched cases.
**Crude odds calculated using matched sets.
Note: Reference group is tractor-trailers without defects within each crash type.

Relative risk of crash involvement for various truck operating factors and equipment defects

Although trucks operating with equipment defects are overinvolved in crashes, other factors also affect truck crash involvement. An earlier analysis of the Washington State data that examined more general driver and truck factors identified driver age, driving

Table 4. Percentage distribution of tractor-trailers with tire/wheel equipment defects in crash and comparison samples

Crash Type	Number*	Percent with Tire/Wheel Equipment Defects		Crude Odds Ratio**	95% Confidence Interval
		Crash Sample	Comparison Sample		
All Crashes	310				
Violation Defect		14	11	1.2	(0.80, 1.86)
Out-of-Service Defect		2	5	0.5	(0.22, 1.21)
All Defects		16	16	1.0	(0.70, 1.53)
Single Vehicle	99				
Violation Defect		8	12	0.6	(0.27, 1.47)
Out-of-Service Defect		2	3	0.7	(0.14, 3.29)
All Defects		10	15	0.6	(0.29, 1.39)
Multiple Vehicle	211				
Violation Defect		17	10	1.6	(0.96, 2.63)
Out-of-Service		2	5	0.5	(0.17, 1.30)
All Defects		19	15	1.2	(0.78, 1.97)
Sideswipe	63				
Violation Defect		24	7	3.4	(1.33, 8.47)
Out-of-Service Defect		5	5	0.9	(0.22, 3.84)
All Defects		29	12	2.3	(1.07, 5.12)
Rear-End	43				
Violation Defect		26	15	2.3	(0.78, 6.79)
Out-of-Service Defect		5	3	2.4	(0.29, 20.21)
All Defects		31	18	2.3	(0.80, 6.65)

*Number of matched cases.
**Crude odds calculated using matched sets.
Note: Reference group is tractor-trailers without defects within each crash type.

Table 5. Percentage distribution of tractor-trailers in crash and comparison samples by equipment defects and hours of driving

Hours of Driving	Violation		Out-of-Service	
	Crash Sample	Comparison Sample	Crash Sample	Comparison Sample
		Brake Adjustment Defects		
0-2	8	8	10	7
>2-8	16	13	16	12
>8	2	1	4	1
	26	22	30	20
Sample Size	245	455	245	455
		Steering Defects		
0-2	3	4	2	2
>2-8	11	4	5	2
>8	0.4	0.5	0	0.5
	14.4	8.5	7	4.5
Sample Size	233	437	233	437
		Tire/Wheel Defects		
0-2	4	4	1	2
>2-8	11	7	0.4	2
>8	1	1	0.4	1
	16	12	1.8	5
Sample Size	282	534	282	534

Table 6. Crude and adjusted odds ratios of relative risk of crash involvement for tractor-trailers by equipment defects and other factors for all crashes

Variable	Crude Odds	95% Confidence Interval	Adjusted Odds**	95% Confidence Interval
Equipment Defects (N=231)				
Violation Defect	1.5	(0.96, 2.25)	1.6	(0.98, 2.46)
Out-of-Service	1.9	(1.28, 2.90)	2.0	(1.28, 3.11)
(None)*	(1.0)		(1.0)	
Hours Driving (N=300)				
(0-2)	(1.0)		(1.0)	
>2-8	1.1	(0.81, 1.58)	1.3	(0.83, 1.89)
>8	1.8	(1.03, 3.26)	1.7	(0.80, 3.45)
Driver Age (N=332)				
≤30	1.7	(1.20, 2.31)	1.3	(0.82, 1.99)
(>30)	(1.0)		(1.0)	
Carrier Operation (N=331)				
(Intrastate)	(1.0)		(1.0)	
Interstate	1.8	(1.23, 2.68)	1.8	(1.08, 2.9
Carrier Type (N=332)				
(Common)	(1.0)		(1.0)	
Private	0.6	(0.43, 0.89)	0.8	(0.52, 1.33)
Contract	1.3	(0.91, 1.80)	1.5	(0.93, 2.36)
Load (N=331)				
Empty	1.1	(0.73, 1.58)	1.1	(0.65, 1.76)
Partial	0.8	(0.54, 1.07)	0.9	(0.55, 1.36)
(Full)	(1.0)		(1.0)	
Power Steering (N=321)				
Yes	0.7	(0.52, 0.92)	0.8	(0.52, 1.10)
(No)	(1.0)		(1.0)	

*Reference groups for odds ratios are shown in parentheses; the odds ratios are computed within each factor.
**Matched logistic regression; 214 cases in the adjusted model.

hours, truck load, carrier type, and carrier operation as being significantly associated with crash involvement (Stein and Jones 1988). The combined effects of these factors and equipment defects were analyzed, and the crude and adjusted odds ratios for each factor are given in Table 6 for all crashes and all defects. Equipment defects sufficient to warrant a citation (violation defects) were analyzed separately from the more severe out-of-service defects.

Trucks with equipment defect violations were overinvolved in crashes (relative risk = 1.6, $p < 0.06$). For trucks with out-of-service equipment defects the relative risk of crash involvement was even higher (2.0) and statistically significant. The relative risk (1.8) for trucks with at least one defect was also statistically significant. Of the other driver and truck operating factors, young drivers, long driving hours, contract carriers, and interstate carriers were associated with increased crash risk although only the adjusted odds for the interstate carrier effect was significant.* Trucks equipped with power steering showed a reduced crash risk.

The adjusted odds ratios for the three categories of equipment defects (brakes, steering, and tires/wheels) were also analyzed as separate factors. Trucks with one type of defect were also likely to have other defects such that the three defect variables are to some extent correlated. This was particularly true for steering and tire defects. Because brake defects were so prevalent, trucks with steering or tire/wheel defects were also likely to have brake defects. However, *by separately* analyzing trucks that had only one type of defect, an assessment of the individual effects could be made. Table 7 gives the percentage distribution of trucks with defects, for the crash and comparison sample, separated into mutually exclusive groups. Preliminary analyses were made with each of these categories separated into violation and out-of-service defects; however, only steering defects showed any appreciable difference in relative risk between these groups. Thus, the categories were combined for brake and tire/wheel defects. The adjusted odds ratios in Table 7 were computed taking into account the confounding effects of driving hours, driver age, carrier operation, carrier type, load, and power steering. (Note for clarity the adjusted odds for these other factors are omitted but in general they had similiar values to those given in Table 6.)

The relative risk of trucks that had brake defects only (1.6) was slightly lower than for trucks with brake defects combined with either steering (2.8) or tire/wheel defects (3.1). For trucks with steering defects only, the relative risk for out-of-service defects appears higher (8.7) than for trucks with violation defects (3.6). For trucks with steering and brake defects, the relative risk (2.8) appears lower than either of the individual steering defect estimates. However, for this combined defect group, the steering defects were predominantly violation defects and the brake defects predominantly out-of-service defects so that this estimate would be expected to be closer to that for steering violation defects. Trucks with only tire/wheel defects had a relative risk of crash involvement that was not significantly different from trucks without these defects. Trucks that had both brake and tire/wheel defects had a higher relative risk than trucks with either individual effect. It should be noted that the confidence intervals for all of these estimates overlapped.

Although Table 7 gives the relative risk of the various disaggregated brake and steering defect categories, an aggregated relative risk cannot be computed for each type of defect from these data. To provide separate overall estimates of relative risk for trucks with brake defects and with steering defects, adjusted odds ratios were computed including each of these two defect categories irrespective of whether other types of defect were present (Table 8). Separate results are given for all crashes and multiple-vehicle crashes.

For all crashes, both defective brakes and defective steering were significantly associated with increased crash risk when adjusted for other factors. For brake defects, the relative risk of crash involvement was about the same for violation defects and for

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*In a previous analysis of truck factors based on a larger sample size and with equipment defects omitted, these factors were significant (Jones and Stein 1987).

Table 7. Relative risk of crash involvement for tractor-trailers with brake, steering, and tire/wheel defects adjusted for other factors

Type of Defect[**]	Percent with Defects		Adjusted Odds[***]	Confidence Interval
	Crash Sample	Comparison Sample		
Single Defects				
Brake Defects	32	30	1.6	(1.05, 2.48)
Steering Violation Defects	5	3	3.6	(1.38, 9.40)
Steering Out-of-Service Defects	3	1	8.7	(2.09, 36.20)
Tire/Wheel Defects	6	7	1.2	(0.51, 2.67)
Combined Defects				
Brake and Steering Defects	10	5	2.8	(1.38, 5.84)
Steering and Tire/Wheel Defects	1	2	1.9	(0.43, 8.52)
Brake and Tire/Wheel Defects	10	6	3.1	(1.48, 6.29)
Brake, Tire/Wheel, Steering Defects	2	2	2.6	(0.76, 9.05)
(No Defects)	31	44	(1.0)	—
	100	100		

[*] Factors adjusted for include hours driving, driver age, carrier operation, carrier type, load, and power steering. For simplicity these odds ratios are omitted from table.

[**] Defect categories are mutually exclusive; percentage distribution is from unmatched data.

[***] Matched logistic regression; 214 cases in the adjusted model; reference group for odds ratios is trucks with no defects (shown in parentheses) and is the same for each defect category.

out-of-service defects although the effect for defect violations was not statistically significant. For steering defects, trucks with violation defects had a lower overall relative risk than trucks with out-of-service defects. Both estimates suggested a lower overall relative risk than for trucks that had steering defects only (see Table 7), although the difference between the estimates was not statistically significant.

The pattern for multiple-vehicle crashes was generally similar to that for all crashes. Single-vehicle crashes were also analyzed separately but the estimates were not presented because the sample was limited by the number of trucks that could not be completely inspected.

The single-vehicle and multiple-vehicle crash analyses presented in Tables 2 and 3 suggested that specific defects were more strongly associated with certain crash types where the truck was the striking vehicle. The association between brake defects and rear-end crashes was further analyzed by computing the adjusted odds for equipment defects taking into account other factors in rear-end crashes. Tractor-trailers with out-of-service brake defects appeared to have a much higher relative risk (18.2) of involvement in rear-end crashes than in all multiple-vehicle crashes, and, although the effect was significant, the sample variance was large. The association between steering defects and sideswipe crashes was also further analysed by computing the adjusted odds for equipment defects and other factors in sideswipe crashes. Trucks with out-of-service steering defects were significantly overinvolved in sideswipe crashes (17.4) and the effect was larger than for multiple-vehicle crashes, although again the sample variance was large because of the small sample.

DISCUSSION

The results presented in this paper clearly show that defective brakes and steering equipment are significantly associated with increased risk of crash involvement for tractor-trailer trucks. The association between brake defects and crash risk increased when only rear-end crashes were considered; steering equipment defects were most highly associated with crases where trucks sideswiped other vehicles.

Each truck in this study, whether crash-involved or in the comparison sample, had a comprehensive equipment inspection. Most previous studies that have examined the role of defective equipment in crashes relied on OMCS data that is self-reported by the trucking companies. The results presented here show that the percentage of trucks with equipment defects involved in crashes is much higher than reported by studies using the

Table 8. Crude and adjusted odds ratios of relative risk of crash involvement for tractor-trailers with brake and steering defects and other factors for all crashes and multiple-vehicle crashes

Variables*	All Crashes		Multiple-Vehicle Crashes	
	Adjusted Odds**	95% Confidence Interval	Adjusted Odds**	95% Confidence Interval
Brake Defects (N=260)				
Violation	1.5	(0.93, 2.28)	1.3	(0.77, 2.14)
Out-of-Service	1.6	(1.02, 2.39)	2.0	(1.23, 3.35)
(None)	(1.0)		(1.0)	
Steering Defects (N=242)				
Violation	2.1	(1.19, 3.77)	2.5	(1.35, 4.79)
Out-of-Service	2.6	(1.17, 5.94)	2.5	(1.03, 5.95)
(None)	(1.0)		(1.0)	
Hours Driving (N=300)				
(0-2)	(1.0)		(1.0)	
>2-8	1.2	(0.80, 1.83)	1.6	(0.96, 2.60)
>8	1.6	(0.78, 3.43)	1.9	(0.83, 4.31)
Driver Age (N=332)				
≤30	1.3	(0.84, 2.08)	1.2	(0.72, 2.05)
(>30)	(1.0)		(1.0)	
Carrier Operation (N=331)				
(Intrastate)	(1.0)		(1.0)	
Interstate	2.1	(1.23, 3.57)	2.2	(1.18, 4.05)
Carrier Type (N=332)				
(Common)	(1.0)		(1.0)	
Private	0.9	(0.55, 1.41)	0.8	(0.45, 1.35)
Contract	1.5	(0.95, 2.44)	1.5	(0.85, 2.49)
Load (N=331)				
Empty	1.1	(0.66, 1.80)	0.8	(0.45, 1.45)
Partial	0.8	(0.51, 1.27)	0.7	(0.41, 1.16)
(Full)	(1.0)		(1.0)	
Power Steering (N=321)				
Yes	0.8	(0.52, 1.14)	0.8	(0.53, 1.30)
(No)	(1.0)		(1.0)	

*Reference groups for odds ratios are shown in parentheses; the odds ratios are computed within each factor.
**Matched logistic regression; 214 cases in the adjusted model.

OMCS data. The percentage of trucks with defective equipment in the comparison sample is consistent with reports from OMCS roadside truck inspections (OMCS 1985, 1987; Davis, 1986; Tyson 1987). Roadside inspections conducted in Washington State in 1985–1986 under MCSAP found that 48% of trucks had out-of-service equipment violations (Washington State Patrol 1986) compared to 30% in the present study. This figure is higher because additional defects (e.g. lights and frame) are included in the MCSAP program and because many of the trucks were selected for the MCSAP inspections because defects were suspected.

Previous studies have tried to establish an association between truck operating characteristics and crash involvement. OMCS data, reported by the involved truckers, indicate that defective equipment was a factor in only 5% of all truck crashes; other studies suggest figures that range from 5% to 24% (Eicher, Robertson, and Toth 1982; Oregon Public Utility Commission 1985; NHTSA 1987). A recent NHTSA study concluded that vehicle-related factors play a critical role and estimated brake system performance to be a contributing factor in up to one third of all truck accidents (1987). However, in all of these studies, the association between defects and crashes was established by making a subjective judgment about the role of a particular factor in causing a specific crash. The case-control method used in the present study provides a more objective way to quantify the effect of particular factors; it establishes the frequency with which the factor occurred in the comparison population and determines the relative risk of crash involvement for that factor by comparing its occurrence in the crash-involved and comparison populations.

In this study, the effects of truck equipment defects were considered simultaneously with other driver and truck operating characteristics. Although many of these factors also showed an increased relative risk of crash involvement (e.g. driving in excess of eight hours, drivers aged 30 or less, driving an empty truck, and operating as an interstate rather than intrastate carrier), the increased relative risk in operating a truck with defective equipment was typically the largest risk factor.

Brake defects were the most common type of equipment defect followed by steering and tire/wheel defects. However, this study of truck crashes on interstate highways did not appear to show an association with increased relative risk of crashes for tire/wheel defects. The increased relative risk for trucks with defective brakes remained relatively constant irrespective of whether the brake defects were violation or out-of-service defects. Steering defects were relatively infrequent compared to brake defects, but the estimates of relative risk for trucks with steering defects were substantially higher particularly when they were severe enough to put the truck out of service.

Sixty-six percent of tractor-trailers on the Washington interstate system sampled at the same time as crash-involved tractor-trailers had defective equipment warranting a citation, and 31% of tractor-trailers had defective equipment warranting placing the truck out of service. The relative risk of crash involvement for trucks with these types of defects was almost twice that of those in good condition. Quite clearly, truckers need to be made aware that operating with defective equipment is a serious safety hazard to themselves and other road users. Reducing the number of trucks with defective equipment would be likely to reduce truck crashes substantially. This might be achieved by requiring rigorous annual truck inspections, which would ensure that all trucks were in good condition at least once per year; frequent random inspections of truck equipment so that truckers operating defective equipment are less likely to go undetected; and more severe penalties for violators. The combination of a reasonable chance of being inspected plus significant fines for violators should convince many truckers that operating with defective equipment is not only unsafe but also uneconomic.

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REFERENCES

Anderson, S.; Auquier, S.; Hauck, A.; et al. Statistical methods for comparative studies. New York: Wiley and Sons; 1980.

Davis, B. Preliminary results of MCSAP random sample inspections at Kegonsa and Utica scales southeast of Madison on Interstate 90. Madison, WI: Wisconsin State Patrol; 1986.

Eicher, J. P.; Robertson, H. D.; Toth, G. R. Large truck accident causation. DOT HS-806300. Washington, DC: National Highway Traffic Safety Administration, U.S. Department of Transportation; 1982.

Insurance Institute for Highway Safety. In: Fleming, A., editor. Big trucks. Washington, DC; 1986.

Jones, I. S.; Stein, H. S. Effect of driver hours of service on truck crash involvement. Washington, DC: Insurance Institute for Highway Safety; 1987.

McGee, H. W. Accident data needs for truck safety issues. Transportation Research Record 1052. Washington, DC: Transportation Research Board, National Research Council; 1986.

National Highway Traffic Safety Administration. Heavy truck safety study. Washington, DC: U.S. Department of Transportation; 1987.

Office of Motor Carrier Safety. National uniform driver–vehicle inspection manual. Washington, DC: Federal Highway Administration; 1983.

Office of Motor Carrier Safety. BMCS annual roadside inspection 1983 and 1984. Washington, DC: Federal Highway Administration; 1985.

Office of Motor Carrier Safety. Accidents of motor carriers of property 1984. Washington, DC: Federal Highway Administration; 1986.

Office of Motor Carrier Safety. Motor carrier safety assistance program state activities for fiscal 1986. Washington, DC: Federal Highway Administration; 1987.

Oregon Public Utility Commission. 1984 truck inspections and truck accidents in Oregon. Salem, OR; 1985.

Pierson, K. L. Statement before a Subcommittee of the U.S. House Committee on Government Operations. Improving the effectiveness of the Bureau of Motor Carrier Safety and its enforcement of hazardous materials regulations. House Report 98-562. Washington, DC; 1983.

SAS Institute, Inc. SUGI supplemental library, user's guide, version 5. Cary, NC; 1986.

Schlesselman, J. J. Case control studies: Design, conduct analysis. New York: Oxford University Press; 1982.

Stein, H. S.; Jones, I. S. Crash involvement of large trucks by configuration: A case-control study. AJPH. 78:491–498; 1988.

Transportation Research Board. Truck-accident data systems: State-of-the-art report. Transportation Research Circular 231. Washington, DC: National Academy of Sciences; 1981.

Tyson, R. What 4 state truck inspections found. USA Today; March 24, 1987.

Washington State Patrol, Commercial Vehicle Enforcement Section. Washington State Motor Carrier Safety Assistance Program Final Report. Olympia, WA: Washington State Patrol; 1986.