Effect of Driver Hours of Service on Tractor-Trailer Crash Involvement

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ABSTRACT

Crashes involving large trucks are a major problem on U.S. highways. Large truck crashes on interstate highways in Washington State were 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 and inspected by Commercial Vehicle Enforcement officers of the Washington State Patrol. Driver factors (age of driver, hours of driving, and logbook violations) and truck operating characteristics (carrier type, carrier operation, truck load, and fleet size) that might affect crash involvement were analyzed for the study population of tractor-trailers. A logistic regression model was used to estimate the adjusted odds ratio for each factor. Driving in excess of eight hours, drivers who violate logbook regulations, young drivers, and interstate carrier operations were found to be associated with an increased risk of crash involvement. Trucks operated with equipment defects were also significantly overinvolved in crashes. The relative risk of crash involvement for drivers whose reported driving time exceeded eight hours was almost twice that for drivers who had driven fewer hours.

Large truck crashes account for 6 percent of all crashes nationwide and 12 percent of all fatal crashes.[1] Previous studies that have attempted to look at factors that contribute to large-truck crash involvement have been limited because traditional exposure, such as miles traveled or vehicles registered, cannot accomodate analyses of multiple factors. To identify the various factors contributing to large truck crashes, the Insurance Institute for Highway Safety conducted a case-control study in Washington State. The effect of factors, such as truck configuration, fleet size, load, weight, and road geometry, have been addressed in a previous paper.[2] The present paper focuses on truck driver characteristics, especially fatigue, and other factors that may affect truck involvement in crashes.[1,3,4]

Considerable research has been done on driver fatigue and the effect of hours of driving on performance.[1,5,6] Early studies concentrated on assessing how driver skills were degraded with increasing driving hours using both driving simulators and road test track experiments. However, studies that have endeavored to correlate the contribution of fatigue to crash involvement have been limited. Mackie and Miller[7] used a combination accident study, field experiment, and truck driver survey and reported that drivers on irregular schedules had an increased risk of accident after five to six hours of driving. Even on regular daytime schedules, adverse effects occurred after eight and one-half hours of driving. They also reported increased risks between midnight and 6 a.m. and earlier fatigue occurring among drivers using sleeper berths. Older drivers were reported to be more susceptible to fatigue than younger drivers.

The Mackie and Miller study emphasized the onset of fatigue, whereas a more recent study examined the role of driver fatigue when drivers had been driving for 15 or more consecutive hours.[8] Driving hours and mileage were retrospectively examined from bills of lading, fuel receipts, and weigh station and inspection tickets for 221 truck crashes in six western states during 1983-84. Only crashes where the truck had to be towed were included in the study, which biased the data toward single vehicle crashes. To establish the pattern of driving hours for trucks not in crashes, a limited driver survey was conducted at nine sites distributed across six western states. The study concluded that driving in excess of 15 hours was the probable cause in 41 percent of crashes and a contributing cause in a further 18 percent of crashes. However, the authors point out that, although excessive driving hours was a frequent factor in crash involvement, less than 7 percent of drivers drove over the 15-hour threshold. The driver survey, however, was not a representative sample and cannot be considered an adequate measure of exposure so the conclusion is somewhat misleading. It can be said that 41 percent of the drivers in accidents had been driving excessive hours compared to less than 7 percent of the truck drivers that were surveyed.

Although truck accident data may contain information on driver age, hours driven, equipment condition, and so forth, it is not possible to relate this to traditional measures of exposure such as truck miles traveled or numbers of trucks registered. Thus studies based on crashes per vehicle mile or registered vehicle cannot take into account the simultaneous effects of various truck operating factors. A research approach that permits assessment of the importance of different factors in exposure to crash risk is the case-control method commonly used in epidemiology. This method compares a case (crash) sample with a control (or comparison) sample that has the same or very similar exposure to risk as the case (crash) sample. In highway safety applications, the method typically involves returning to crash locations at the same time of day and day of week as the crash, but one week later, to collect comparison sample information. A two-year study comparing the vehicle and driver factors of large trucks involved in crashes with those of a comparison group on the interstate highway system in Washington State was conducted. Other analyses based on this study population have been reported elsewhere;[2] the present study examines the effect of driver's hours of driving on tractor-trailer crash involvement.

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 truck weight enforcement and inspection program 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, 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.[9]

Study Design

In this application of the case-control method, for each crash-involved truck, three trucks were selected and inspected at the crash site at the same time of the day as 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 and tire condition from the tread depth. Truck weight, size, configuration, and type of carrier were also recorded together with driver age and experience, hours of driving, and logbook violations. Hours of driving was recorded as the number of hours driven since the last eight hour rest period. This was established at the time of inspection by the CVES officer who used the driver's statement, logbook record, bill of lading, and current vehicle location to determine a credible estimate of driving hours. This estimate was also used to establish whether the logbook record was accurate; however, the most common logbook violations were either that it was missing or that it was not up to date.

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

*Although sampling one control for each crash-involved truck would have been sufficient, a larger control sample was used to increase the statistical power of the analyses.[10]

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 a congested area (e.g., downtown Seattle), where it was not possible to apply the sampling procedure satisfactorily. The study included 676 crashes involving 734 large trucks that occurred between June 1984 and July 1986.

Data Analysis

The analyses reported here emphasized the extent to which driver factors are involved in crashes. 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.[2] However, because it cannot be assumed that driver factors are independent of truck configuration, this analysis is limited to tractor-trailers, which comprised 60 percent of the crash sample. These analyses could have been repeated for the other main truck configurations (e.g., single unit trucks, which were 23 percent of the control population, and twin-trailer trucks, which were 7 percent), but sample sizes were too small to provide meaningful results.

Limiting the analysis to crashes involving tractor-trailers required that the control sample also be 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 tractor-trailers depending on how many had to be discarded. Cases where all three controls had to be discarded were also dropped from the analysis. The final subset represents 332 matched case-control data sets.

The estimated relative risk of crash involvement for each study factor was computed and is given in the results as crude odds ratios; 95 percent confidence intervals for the odds ratios are presented. The odds <u>ratio</u> is the odds of crash involvement given a particular factor divided by the odds of crash involvement in the absence of that factor.

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.[10] To fit the regression model the logistic regression procedure MCSTRAT from the SAS Users Group International (SUGI) Supplemental Library was used.[11] This program facilitates running a logistic regression on a matched case-control data set with a variable (unbalanced) number of controls per case. The program computes estimates of the regression coefficients, adjusted odds ratios, and confidence limits. The crude and adjusted odds ratios are estimates of the risk of crash involvement for the different levels of a factor relative to the reference group for that factor. Because each factor has a different reference group, the same relative risk for different factors does not imply the same absolute risk.

The variables used in this analysis include crash configuration, age of driver, hours of driving, logbook violations, carrier type, carrier operation (interstate, intrastate), truck load, and fleet size. Interaction between driver factors and defective truck equipment was also analyzed. If a variable of interest was unknown for a crash involved truck, then both crash and comparison trucks were excluded from the particular analysis. In the small number of cases where the value of a variable for one of the comparison trucks was unknown, the comparison truck was eliminated from the analyses.

For the crash configuration variable, crashes were separated into single vehicle and multiple vehicle crashes. Driver age was split into young drivers aged 30 years or less and others. Driving hours were divided into four categories: zero-two hours to represent the start of the current driving period, three-five hours representing the middle of the driving period, six-eight hours representing the end of the driving period, and greater than eight hours to include drivers who have driven sufficiently long that they are close to or have violated the 10-hour driving limit set by the Federal Motor Carrier Safety Regulations (49 CFR 395). Using a 10-hour cutoff would have been unrealistic because drivers whose driving hours exceed 10 hours, when stopped by the Commercial Vehicle Enforcement Officers, are unlikely to admit to a violation that would automatically put them out of service.

The Federal Motor Carrier Regulations (49 CFR 395.8) require that interstate truck drivers maintain a logbook in which the hours that are actually driven, the time and location of stops and rest periods, and other information is recorded. Washington State also requires common and contract intrastate carriers to maintain logbooks, although at the time of the study private carriers were not required to do so. The regulations allow a driver to drive for a maximum of 10 consecutive hours and then take a rest period of at least 8 hours. Logbook violations were separated into violations warranting citation and violations severe enough for the driver to be placed out of service. If the driver has driven more than the allowable hours, the truck is placed out of service until the driver has taken the required rest time. If the logbook is not up to date but less than 12 hours out of date, a violation is charged; if it is over 12 hours out of date, the truck is placed out of service. Because logbook violations and excessive driving hours were highly correlated variables, separate analyses were undertaken.

Carriers were distinguished as either common, contract, or private. Private carriers transport their own cargos as part of another nontrucking enterprise (e.g., supermarket or department store delivery trucks). For-hire carriers transport freight that belongs to others and are classified as either common carriers or contract carriers. Common carriers offer services to any shipper to transport goods between designated points (e.g., Roadway and Consolidated Freightway). Contract carriers are restricted to serving a single shipper or limited number of shippers under specific contracts (e.g., logging trucks and U.S. mail) and may not offer services to the general public.

Another important distinction is whether the carrier operates in interstate commerce. Interstate drivers are more likely to travel greater distances and consequently spend more hours on the road without the benefit of a return home to a definite rest period each day, thus it is possible that fatigue might be more pronounced with these drivers.

Truck load was categorized as empty, partial, or full by weight; thus a truck with a weight less than 90 percent of its permitted gross vehicle weight was classified as partially loaded. Truck fleet size was categorized as small (1-5 vehicles), medium (6-25 vehicles), and large (>25 vehicles). For the purposes of this analysis, truck equipment defects were separated into any defects sufficient for citation and defects sufficiently severe to place the truck out of service. Vehicle defects generally involved the brakes, steering, and tires ranked in that order of frequency.

RESULTS

Hours of Driving

Table 1 gives the distribution by hours of driving for the crash and comparison sample for all crashes and for single vehicle and multiple vehicle crashes. Ten percent of crash involved drivers had exceeded eight hours of driving compared to 6 percent of drivers in the comparison sample, so that the risk for drivers exceeding eight hours relative to drivers driving less than two hours was 1.8.* The effect was also significant for multiple vehicle crashes (2.6 relative risk) but not for single vehicle crashes indicating the effect of fatigue is more prevalent in multiple vehicle crashes. Drivers on the road six-eight hours were also overinvolved in multiple vehicle crashes but the effect was not significant.

Table 2 gives the proportion of drivers age 30 or less by crash configuration. Young drivers are overinvolved in all crashes, single vehicle crashes, and multiple vehicle crashes, and their risk relative to older drivers is the same (1.7) irrespective of crash type.

The results in Table 3 showing the possible interaction between driver age and driving hours suggest that young drivers and older drivers become overinvolved in crashes when they exceed eight hours driving. Both groups show overinvolvement for those driving in excess of eight hours, but it is greater for younger drivers. However, this interaction between driver age and driving hours was not statistically significant.

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* It is important to recognize that these results indicate the relative risk of crash involvement and not the absolute numbers of crashes. Thus, the finding that drivers who have been driving for more than eight hours have an elevated crash risk does not contradict other reports that most crashes occur after drivers have been driving only a few hours.

In addition to driving hours, time of day could also affect crash involvement. For example, a driver approaching the end of his allowable hours may experience more fatigue at night than during the day. Table 4 gives the distribution of driving hours by time of day in the crash and comparison samples. Time of day is separated into four periods: 12:01 a.m. to 6:00 a.m.; 6:01 a.m. to noon; 12:01 p.m.to 6:00 p.m.; and 6:01 p.m. to midnight. Drivers on the road for more than eight hours have a higher crash involvement irrespective of the time of day. However, their relative risk is higher in the 12:01 a.m. to 6:00 a.m. and 6:01 a.m. to noon periods than the other periods although the difference in risk is not statistically significant.

The preceding results have shown that the risk of involvement in a multiple vehicle crash is highest for those drivers who have spent more that eight hours behind the wheel. It is possible that the larger fleets have more efficient scheduling practices so that drivers are less likely to have to drive long hours to complete trips. However, there was no significant association between fleet size and crash risk. The increased risk of crash involvement for drivers with more than eight hours driving was about the same for small and large fleets.

Equipment defects may interact with driving hours. For example, 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 by hours of driving at the time of the crash or inspection. Overall, 76 percent of crash-involved tractor-trailers had defective equipment compared to 65 percent for the comparison sample. The corresponding figures for out-of-service equipment defects were 41 percent and 30 percent. Twenty-three percent of trucks were on the roadfor less than two hours and had defective equipment and 12 percent had defects sufficient to put them out of service. For drivers on the road for less than two hours, trucks with equipment defects did not appear to be overinvolved in crashes; however, as driving hours increased so did the involvement of trucks with defective equipment although the interaction was not statistically significant.

Logbook Violations

Table 6 gives the distribution of logbook violations and out-of-service logbook violations for tractor-trailers in the crash and comparison samples. Twenty-two percent of drivers of crash-involved trucks had a logbook violation and eight percent had a logbook violation severe enough to put the driver out of service; the corresponding figures for the comparison sample were 10 percent and 2 percent. The risk of crash involvement (unadjusted odds ratio) for trucks with logbook violations relative to those with no violations was 3.0, and, if the violation was severe enough to put the truck out of service, the risk increased to 4.2. The relative risk appeared to be consistent across crash configuration for any violations and for out-of-service violations.

Table 7 gives the percentage distribution for driver age as a function of logbook violations. Drivers with logbook violations are overinvolved in crashes, particularly young drivers, although the interaction between drivers with logbook violations and young drivers was not significant. Also no fleet size effect for logbook violations was found.

The interaction between logbook violations and equipment defects is given in Table 8. Trucks with equipment defects were overinvolved in crashes, and this effect was more pronounced when logbook violations were present. Thirteen percent of crash-involved trucks had both equipment defects and logbook violations, compared to 6 percent of the comparison sample trucks.

Relative Risk of Crash Involvement for Various Driver and Truck Factors

Table 9 gives the crude and adjusted odds ratios for the various driver and truck factors. The dominant effects are driving in excess of eight hours, driver age 30 years or less, and interstate carrier operations. Other factors that appear to increase the relative risk of crash involvement are empty trucks and trucks operating as contract carriers. Table 10 shows the adjusted odds for these factors together with truck equipment defects. Trucks with equipment defects were analyzed separately because adding this variable reduced the sample size particularly for single vehicle crashes. The same factors show increased relative risk although excessive driving hours and young driver effects are no longer statistically significant. Trucks with equipment defects show a pronounced and significant increase in relative risk.

Table 11 gives the adjusted odds ratios for the various driver and truck factors with driving hours replaced by logbook violations. Drivers with logbook violations, young drivers, and interstate trucks all show significant increased relative risk of crash involvement. Empty trucks and contract carriers show an increased risk but the effects are not significant. Table 12 gives adjusted odds for these factors and truck equipment defects. Trucks with equipment defects have a significantly higher relative risk although the driver age effect loses significance.

DISCUSSION

In this examination of factors likely to affect the crash involvement of tractor-trailers, driving in excess of eight hours, drivers who violate logbook regulations, young drivers, and interstate carrier operations were found to be associated with an increased relative risk of crash involvement. Tractor-trailers operated with equipment defects were also significantly overinvolved in crashes.

In 10 percent of crash-involved tractor-trailers, the drivers had exceeded eight hours behind the wheel. Because the data were collected by asking the driver how long he had been driving, these estimates of driving hours are probably very conservative. Six percent of drivers in the comparison sample, which represents a random sample of trucks taken at the same time of day as the crash-involved trucks, exceeded eight hours driving. However, although the number of drivers spending more than eight hours behind the wheel in these two samples may not appear large, it is important to remember that <u>none</u> of these drivers had reached their final destination. This means that the proportion of drivers who would eventually drive long hours is much greater. For example, a recent survey of long-haul tractor-trailer drivers reports that the majority of drivers believe that at least 70 percent of drivers regularly exceed the hours-of-service regulation.[12] What is important from this study is that the relative risk of crash involvement for drivers driving more than eight hours is almost twice that for drivers with fewer hours behind the wheel. This increase in relative risk confirms earlier work by Mackie and Miller,[8] which reported that risk of accident increased after five-six hours for drivers on irregular schedules and eight and one-half hours for drivers on regular schedules. They also reported that the risk for fatigued drivers increased between midnight and 6:00 a.m. The present results confirm this and show that the risk from driving long hours increases for drivers operating between 12:01 a.m. and 6:00 a.m. and 6:01 a.m. and noon.

The higher relative risk found for interstate carriers compared to intrastate carriers is likely to reflect driver fatigue. Because interstate truckers are less likely to schedule regular rest periods than intrastate truckers who are more likely to return home each evening, their level of rest is likely to be less and contributing to their fatigue problem.

Young drivers aged 30 years or less were overinvolved in crashes. They represent about 18 percent of the truck driver population and their risk of crash involvement is 1.6 greater than older drivers. The interaction between age and driving hours was not significant although there was some indication that young drivers driving longer hours were at greater risk than older drivers.

The association between driving hours and truck equipment defects was examined to see if trucks in poor condition were also being driven long hours. The proportion of trucks with equipment defects in the comparison sample did not significantly vary with driving hours. However, the crash involvement of trucks with equipment defects did increase when driving hours were greater than eight. Trucks with defective equipment had a 1.8 times higher risk of crash involvement relative to those in good condition. Also of concern is the 23 percent of trucks in the comparison sample with equipment violations that had been on the road for less than two hours and the 12 percent with out-of-service equipment defects. These trucks almost certainly started their trip with these equipment defects and they should have been detected in the pretrip inspection.

Ten percent of comparison sample tractor-trailers had logbook violations and the increased risk of crash involvement for these trucks was 3.0. It is reasonable to conclude that much of this increase in crash risk is associated with fatigue brought about by operating long hours. Comparing this increased risk with the 1.8 for drivers exceeding eight hours driving, it is clear that the effect for drivers with logbook violations is considerably higher. Also the 10 percent of drivers in the comparison sample with logbook violations must represent a low estimate. These drivers typically had no logbook or the entries were not current rather than falsified logbook entries. It is generally accepted that cheating on logbooks is a common occurrence, and these violations would not be included in the estimate unless sufficiently blatant for the inspection officer to detect them at the time of inspection.

The results of this study show clearly that truck drivers who have been driving long hours or have logbook violations have in increased risk of crash involvement. It is also evident that interstate drivers, who are likely to drive long hours, have higher crash risk compared to intrastate drivers. Both these problems could be addressed by requiring tachographs or on-board recorders in trucks. These devices monitor driving hours and rest schedules, which is advantageous to both drivers and fleet operators. Shippers and fleet managers would be less likely to set schedules that force drivers to drive excess hours to complete trips, because cheating on the hours-of-service regulations would be much easier to detect. Consequently, those drivers obeying the regulations would be much less likely to be at a competitive disadvantage as they are with the present system. Most importantly, many of the crashes involving fatigued drivers would be eliminated.

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Table 1

Percentage Distribution of Tractor-Trailers
in Crash and Comparison Samples
by Crash Configuration and Hours of Driving*

Crash Type	Hours of Driving	Crash Sample Percent	Comparison Sample Percent	Crude Odds Ratio	Confidence Interval
All	(0-2)	34	36	(1.0)	
N=300	>2-5	37	37	1.2	(0.82, 1.69)
	>5-8	19	21	1.0	(0.67, 1.61)
	>8	10	6	1.8	(1.01, 3.22)
Single Vehicle	(0-2)	46	38	(1.0)	
N=93	>2-5	30	35	0.7	(0.34, 1.23)
	>5-8	14	20	0.5	(0.22, 1.09)
	>8	10	7	1.0	(0.36, 2.96)
Multiple Vehicle	(0-2)	27	35	(1.0)	
N=207	>2-5	41	38	1.6	(1.05, 2.54)
	>5-8	21	21	1.5	(0.90, 2.62)
	>8	11	6	2.6	(1.25, 5.18)

*Percentage distribution from unmatched data; crude odds ratio calculated using matched sets.

Note: Reference group is 0-2 hours of driving; the odds ratios are computed within crash type.

Table 2

Percentage Distribution of Tractor-Trailers
in Crash and Comparison Samples
by Crash Configuration and Age of Driver*

Crash Type	Age	Crash Sample Percent	Comparison Sample Percent	Crude Odds Ratio	Confidence Interval
All	≤30	27	18	1.7	(1.20, 2.31)
N=332	(>30)	73	82	(1.0)	–
Single Vehicle	≤30	32	22	1.6	(0.97, 2.78)
N=109	(>30)	68	78	(1.0)	–
Multiple Vehicle	≤30	25	16	1.7	(1.10, 2.55)
N=223	(>30)	75	84	(1.0)	–

*Percentage distribution from unmatched data; crude odds ratio calculated using matched sets.

Note: Reference group is >30 age group; the odds ratios are computed within crash type.

Table 3

Percentage Distribution of Tractor-Trailers in
Crash and Comparison Samples by
Age of Driver and Driving Hours - All Crashes

Hours of Driving	Driver Age ≤ 30 Crash Sample	Driver Age ≤ 30 Comparison Sample	Driver Age >30 Crash Sample	Driver Age >30 Comparison Sample
0-2	30	45	35	34
>2-5	35	27	38	39
>5-8	20	21	18	21
>8	15	7	9	6
Total	100	100	100	100
N=	82	103	218	473

Table 4

Percentage Distribution of Tractor-Trailers
in Crash and Comparison Sample
by Driving Hours and Time of Day - All Crashes

Hours of Driving	Time of Day: 12:01 a.m.-6:00 a.m. Crash	12:01 a.m.-6:00 a.m. Comparison	6:01 a.m.-Noon Crash	6:01 a.m.-Noon Comparison	12:01 p.m.-6:00 p.m. Crash	12:01 p.m.-6:00 p.m. Comparison	6:01 p.m.-Midnight Crash	6:01 p.m.-Midnight Comparison
0-2	38	34	42	53	24	28	34	28
>2-5	31	39	38	34	39	37	38	40
>5-8	20	23	14	11	25	27	14	20
>8	11	4	6	2	12	8	14	12
Total	100	100	100	100	100	100	100	100
N=	45	93	98	175	106	196	42	97

Table 5

Percentage Distribution of Tractor-Trailers in Crash
and Comparison Sample by Hours Of Driving and Equipment Defects

Hours of Driving	Any Equipment Defects				Out-of-Service Equipment Defects			
	Crash		Comparison		Crash		Comparison	
	Yes	No	Yes	No	Yes	No	Yes	No
0-2	23	9	23	12	14	18	12	23
>2-5	31	8	23	15	14	25	9	29
>5-8	15	5	14	7	8	12	7	15
>8	7	3	5	2	5	5	2	4
All	76	25	65	36	41	60	30	71
N=	222		413		222		413	

Table 6

Percentage Distribution of Tractor-Trailers
In Crash and Comparison Sample by
Logbook Violations by Crash Configuration*

Crash Type	Violations	Crash Sample Percent	Comparison Sample Percent	Crude Odds Ratio	Confidence Interval
	Any				
All crashes (N=332)	No	78	90	(1.0)	
	Yes	22	10	3.0	(1.97, 4.41)
Single-Vehicle (N=109)	No	70	87	(1.0)	
	Yes	30	13	3.3	(1.74, 6.12)
Multiple-Vehicle (N=223)	No	83	92	(1.0)	
	Yes	17	8	2.8	(1.63, 4.64)
	Out-of-Service				
All Crashes (N=332)	No	92	98	(1.0)	
	Yes	8	2	4.2	(2.05, 8.70)
Single-Vehicle (N=109)	No	91	98	(1.0)	
	Yes	9	2	4.3	(1.31, 14.05)
Multiple-Vehicle (N=223)	No	93	98	(1.0)	
	Yes	7	2	4.2	(1.68, 10.41)

*Percentage distribution from unmatched data; crude odds ratios calculated using matched sets.

Note: Reference group is no logbook violation; odds ratios are computed within crash type.

Table 7

Percentage Distribution of Tractor-Trailers in
Crash and Comparison Samples by Logbook Violations by Driver Age

Logbook Violations	Driver Age ≤ 30 Crash Sample	Driver Age ≤ 30 Comparison Sample	Driver Age >30 Crash Sample	Driver Age >30 Comparison Sample	All Ages Crash Sample	All Ages Comparison Sample
No	20	16	59	75	79	91
Yes	8	2	14	7	22	9
All	28	18	73	82	100	100
N=	90	116	242	524	332	640

Table 8

Percentage Distribution of Tractor-Trailers
in Crash and Comparison Sample by
Logbook Violations and Equipment Defects

Logbook Violation	Any Equipment Defects				Out-of-Service Equipment Defects			
	Crash		Comparison		Crash		Comparison	
	Yes	No	Yes	No	Yes	No	Yes	No
No	63	19	59	32	33	49	29	62
Yes	13	4	6	3	8	10	2	8
All	76	23	65	35	41	59	31	70
N=	176	55	283	150	94	137	133	300

Table 9

Crude and Adjusted Odds Ratios of Relative Risk of
Crash Involvement of Tractor-Trailers by
Hours of Driving and Other Factors

Factor	Crude Odds Ratio	Confidence Interval	Adjusted Odds Ratio*	Confidence Interval
Driving Hours (N=300)				
(0-2)**	(1.0)		(1.0)	
>2-5	1.2	(0.82, 1.69)	1.2	(0.80 1.76)
>5-8	1.0	(0.67, 1.61)	1.2	(0.75 1.98)
>8	1.8	(1.01, 3.22)	1.8	(0.97 3.47)
Driver Age (N=332)				
≤30	1.7	(1.20, 2.31)	1.6	(1.09 2.37)
(>30)	(1.0)		(1.0)	
Fleet Size (N=278)				
1-5	0.9	(0.61, 1.31)	1.0	(0.64 1.51)
6-25	0.9	(0.64, 1.25)	1.0	(0.67 1.38)
(>25)	(1.0)		(1.0)	
Load (N=331)				
Empty	1.1	(0.73, 1.58)	1.3	(0.84 2.08)
Partial	0.8	(0.54, 1.07)	0.9	(0.57 1.29)
(Full)	(1.0)		(1.0)	
Carrier Operation (N=331)				
(Intrastate)	(1.0)		(1.0)	
Interstate	1.8	(1.23, 2.68)	1.7	(1.06 2.57)
Carrier Type (N=332)				
(Common)	(1.0)		(1.0)	
Contract	1.3	(0.91, 1.80)	1.3	(0.88 1.98)
Private	0.6	(0.43, 0.89)	0.7	(0.48 1.14)

*Matched logistic regression; 265 matched cases in adjusted model.
**Reference group is given in parentheses; the odds ratios are computed within each factor.

Table 10

Adjusted Odds Ratio for Relative Risk of Involvement for Tractor-Trailers by Hours of Driving, Equipment Defects, and Other Factors

Factor	Adjusted Odds Ratio*	Confidence Interval
Driving Hours		
(0-2)**	(1.0)	
>2-5	1.2	(0.77, 1.92)
>5-8	1.2	(0.68, 2.07)
>8	1.7	(0.81, 3.71)
Age		
≤30	1.1	(0.70, 1.78)
(≥30)	(1.0)	
Fleet Size		
1-5	0.9	(0.55, 1.51)
6-25	1.1	(0.72, 1.63)
(>25)	(1.0)	
Load		
Empty	1.1	(0.68, 1.92)
Partial	0.9	(0.54, 1.38)
(Full)	(1.0)	
Carrier Operation		
(Intrastate)	(1.0)	
Interstate	1.7	(1.00, 2.76)
Carrier		
(Common)	(1.0)	
Contract	1.6	(0.99, 2.61)
Private	0.9	(0.53, 1.40)
Equipment Defect		
Any	1.8	(1.10, 3.06)
(None)	(1.0)	

*Matched logistic regression; 200 matched cases in the adjusted model.
**Reference group for each factor is given in parentheses; the odds ratios are computed within each factor.

Table 11

Adjusted Odds Ratios of Relative Risk of Crash Involvement for Tractor-Trailers by Logbook Violations and Other Factors

Factor	Adjusted Odds Ratio*	Confidence Interval
Logbook Violation		
Any	2.6	(1.62, 4.01)
(None)**	(1.0)	
Age		
≤30	1.5	(1.01, 2.16)
(>30)	(1.0)	
Fleet Size		
1-5	0.9	(0.62, 1.44)
6-25	1.0	(0.69, 1.42)
(>25)	(1.0)	
Load		
Empty	1.3	(0.84, 2.07)
Partial	0.9	(0.59, 1.32)
(Full)	(1.0)	
Carrier Operation		
(Intrastate)	(1.0)	
Interstate	1.7	(1.11, 2.62)
Carrier		
(Common)	(1.0)	
Contract	1.3	(0.89, 1.99)
Private	0.8	(0.52, 1.23)

*Matched logistic regression; 277 matched cases in adjusted model.
**Reference group for each factor is given in parentheses; the odds ratios are computed within each factor.

Table 12

Adjusted Odds Ratios of Relative Risk of Crash Involvement for Tractor-Trailers by Logbook Violations, Equipment Defects, and Other Factors

Factor	Adjusted Odds Ratio*	Confidence Interval
Logbook Violation		
Any	2.3	(1.35, 4.05)
(None)**	(1.0)	
Age		
≤30	1.1	(0.71, 1.79)
(>30)	(1.0)	
Fleet Size		
1-5	0.9	(0.51, 1.40)
6-25	1.2	(0.76, 1.73)
(>25)	(1.0)	
Load		
Empty	1.2	(0.72, 2.03)
Partial	0.9	(0.57, 1.45)
(Full)	(1.0)	
Carrier Operation		
(Intrastate)	(1.0)	
Interstate	1.8	(1.08, 2.93)
Carrier		
(Common)	(1.0)	
Contract	1.6	(0.99, 2.57)
Private	1.0	(0.60, 1.59)
Equipment Defect		
Any	1.7	(1.11, 2.56)
(None)	(1.0)	

*Matched logistic regression; 203 matched cases in adjusted model.
**Reference group for each is given in parentheses; the odds ratios are computed within each factor.