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Exploring determinants of log truck accidents resulting in injury or fatality in the Northwest United States between 2015-2019 using Motor Carrier Management Information System data

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ABSTRACT
Log truck drivers represent a high-risk yet understudied worker population. Logging, more generally, is known to be one of the most dangerous industries in the country, but little is known about injury and fatality rates among log truck drivers specifically. Using data from the Motor Carrier Management Information System (MCMIS), this study aims to characterize log truck crashes in Washington, Oregon, Idaho, and Montana. Using multiple logistic regression, we estimated the odds of a crash resulting in an injury or fatality by environmental and structural conditions at the time of each crash. Results indicate that the presence of a positive median barrier is strongly associated with a decreased odds of injury or fatality for log truck crashes (odds ratio (OR) = 0.45, $p = 0.03$). An increased number of vehicles involved in the crash was significantly associated with an increased odds of injury or fatality (OR = 1.32, $p = 0.01$). Crashes occurring in Washington or Oregon had significantly decreased odds of resulting in an injury or fatality, in comparison to Idaho and Montana (OR = 0.14, $p < 0.001$; OR = 0.53, $p = 0.01$, respectively). These results indicate that the presence of highway safety measures and a state-approved OSHA plan may be beneficial in decreasing the odds of injury or fatality in log truck crashes.

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Logging safety; forestry transportation; truck safety; forestry operations

Introduction

The logging industry is seen as one of the most dangerous industries in the United States (US), with a fatality rate of more than 30 times the rate for all US workers (BLS 2018). The northwest US represents a particular geographic region of interest; not only is logging prevalent, but logging stakeholders have requested research that connects industry and academic partners across Federal Region X (Alaska, Oregon, Washington, Idaho) to better serve worker populations into the future (PNASH 2020). Log truck drivers are responsible for transporting logs from worksites to mills, driving off-road, loading and unloading logs, and transporting loads with a high center of gravity and overhang (Smidt et al. 2021). A survey of Washington state log truck drivers estimated that more than half (64%) of all log truck drivers are owner-operators, meaning they are not employees of a logging company (Mason et al. 2008). Log truck drivers are a small occupational group that are not counted as a separate Standard Occupational Classification (SOC) code but included in the occupational code for "Heavy and Tractor-Trailer Truck Drivers" (SOC 53–3032), making it challenging to quantify not only the number of log truck drivers in the US, but also the number of injuries and fatalities associated with this small but important occupational sub-group (BLS 2019). According to Bureau of Labor Statistics (BLS) data, there were 8,070 heavy and tractor-trailer truck drivers working in the logging industry in the US in 2020, which comprised approximately 20% of all logging employees (BLS 2023). Similarly, 18.5% of all US loggers operate in Washington (WA), Oregon (OR), Idaho (ID), and Montana (MT), which, when applied to the 8,070 total drivers, yields an estimated 1,493 log truck drivers in this region.

Previous research found that the number of fatal accidents involving log trucks increased 41% between 2011 and 2015 nationwide (Cole et al. 2019). Despite log truck drivers making up a relatively small number of workers, it is estimated that 27% of all logging fatalities between 2011 and 2019 were classified as transportation incidents (BLS 2022). Log truck crashes contribute to the national and regional burden of logging injuries and fatalities, representing an opportunity to identify potential determinants of fatal or injurious crashes as well as to inform future safety interventions.

Long-haul truck driving in general is known to require long working hours, with the National Institute for Occupational Safety and Health (NIOSH) reporting an average of 61.5 working hours per week in a survey of long-haul truck drivers (Chen et al. 2015). Log truck drivers similarly experience rigorous work schedules, including long shifts, working during nights, and taking few breaks (Nakata et al. 2022). Fatigue has been shown to be a contributing factor in large truck crashes, including in short-haul trucking, which is similar to log trucking (Gander et al. 2006). Research has shown that as truck drivers' pay rates increase, they work fewer hours, but are also safer overall, indicating that truck drivers may feel pressured to work longer hours in order to earn enough money, which in turn may increase risk for accidents (Kudo and Belzer 2019).

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Previous research has established that log truck crashes have been increasing over time, with long working hours and fatigue increasing the risk of accidents. However, there has yet to be a regional analysis of log truck crashes and potential risk factors for fatality or injury. Therefore, the objectives of this study are: (1) to characterize log truck crashes in WA, OR, ID, and MT, and (2) to estimate the odds of a crash resulting in any injury or fatality, comparing conditions at the time of the crash.

Materials and methods

We used data from the Motor Carrier Management Information System (FMCSA n.d.). MCMIS is a database maintained by the Federal Motor Carrier Safety Administration (FMCSA) to record safety-related incidents among commercial motor carriers and hazardous material shippers that are subject to Federal Motor Carrier Safety Regulations. FMCSA requires states to report a standard set of data from police crash records in which a motor carrier driver or vehicle was involved. MCMIS includes data on motor carrier registrations, inspections, crashes, investigations, and enforcement cases. MCMIS offers these data for both fatal and nonfatal crashes involving motor carriers, including log trucks, and is publicly available for a small fee.

To assess crashes involving log trucks, MCMIS data were obtained for a 5-year period from 2015–2019. This time period was chosen to account for 2014 FMCSA-imposed changes to MCMIS data that allow states to adjudicate citation data and have it reflected accurately in MCMIS (FMCSA 2014). The time period cutoff of 2019 was chosen to avoid the inclusion of any industry disruptions during the COVID-19 pandemic starting in 2020. Since raw data from MCMIS includes multiple single-year datasets for all 50 states in the US, the data were combined to create a single file including all years from 2015–2019 and narrowed to only include observations from ID, MT, OR, and WA (FMCSA). Initially, observations from Alaska were to be included in the analysis, but these were ultimately excluded due to very few observations. To isolate observations involving log trucks, the data field "Cargo Body Type" was used to filter the observations and only include those that indicated a log truck was involved in the crash.

Other variables retrieved from MCMIS for each of the observations included crash time and date, crash location, type of trafficway (i.e. one-way, not divided), road surface condition, weather condition, light condition (i.e. daylight), number of fatalities and injuries, and carrier name and location. Not all data elements retrieved were included in the model, as described below.

Data to estimate number of employees for the respective companies were manually extracted from the US Department of Transportation FMCSA Safety and Fitness Electronic Records System by looking up the company size using the USDOT number of the log truck that was in a crash. The number of employees was categorized as 1 employee, 2–10 employees, or more than 10 employees to match the common sizes of logging truck companies.

Each observation was individually reviewed for consistency. Irregular observations (i.e. a school bus erroneously coded as a log truck) and observations with missing data in fields that were included in the model were removed from the dataset.

Summary statistics and chi-squared statistics were generated for the dataset. The total number and proportion of each variable were calculated and categorized by whether the crash resulted in an injury or fatality or did not result in an injury or fatality. Summary statistics for categorical variables were calculated for the categories as they appeared in MCMIS; for continuous variables, such as number of employees and vehicles in accident, summary statistics were calculated by assigning the values to categories. In addition, chi-squared tests for independence were conducted for each of the variables with respect to the dependent variable of any injury/fatality or no injury/fatality.

The association of various characteristics with likelihood of injury and/or fatality of crashes involving log trucks, was assessed using multiple logistic regression. The dependent variable in the model was whether or not the crash resulted in any injury or fatality; the binary variable indicated a "0" for observations with no injury or fatality, or "1" for observations with any injury or fatality. The composite dependent variable was created from existing variables for number of injuries and number of fatalities in the MCMIS dataset. Certain categorical independent variables were converted into binary variables for the regression model; these included binary variables for weather condition (clear/not clear), light condition (daylight/not daylight), road condition (clear/not clear). Other variables included crash state (ID, MT, OR, WA), time of day crash occurred (3:01 am–9 am, 9:01 am–3 pm, 3:01 pm–9 pm, 9:01 pm - 3 am), trafficway (two-way undivided, two-way unprotect divided, two-way positive median barrier, one-way undivided), number of employees (continuous), and number of vehicles involved in the accident (continuous). For descriptive and regression analyses, a $p < 0.05$ was considered significant. Analyses were performed in RStudio 2021.09.0.

Results

Data Characteristics. The total number of log truck crashes reported in the final dataset was 647. The frequency and percent of crashes resulting in an injury or fatality, versus not resulting in an injury or fatality, by conditions at the time of the incident are shown in Table 1.

Two hundred and nineteen crashes (33.8%) resulted in either a fatality or injury, while 428 crashes (66.2%) resulted in neither a fatality nor injury. Overall, the frequency of crashes was highest for each covariate under the following circumstances: daylight (75.0%), no adverse weather (73.4%), dry roads (67.7%), nondivided two-way road (80.1%), between the hours of 3 pm and 9 pm (44.5%), OR state (60.9%), and company having between 2–10 employees (37.7%).

Chi-squared Test for Independence. The number of crashes that resulted in a fatality or injury versus crashes without fatality or injury differed significantly by weather condition ($\chi^2 = 19$, $p < 0.01$). There was also a significant relationship between road condition and crash outcomes ($\chi^2 = 14.2$, $p = 0.05$), as well as trafficway type and crash outcomes ($\chi^2 = 10.7$, $p = 0.01$). Crash outcome by crash state also differed significantly ($\chi^2 = 43.5$, $p < 0.001$).

Table 1. Number (percent) of crashes resulting in injury/fatality or no injury/fatality by crash conditions for n = 647 log truck crashes, MCMIS, 2015–2019.

	n (%)		
Variable	Injury/Fatality	No Injury/Fatality	*p* value
Total	219 (100)	428 (100)	
Light Condition			0.7
Daylight	162 (74.0)	323 (75.5)	
Dark – Not lighted	37 (16.9)	55 (12.6)	
Dark – Lighted	6 (2.70)	13 (3.00)	
Dark – Unknown Road Lighting	0 (0.00)	1 (0.20)	
Dawn	13 (5.90)	34 (7.90)	
Dusk	0 (0.00)	1 (0.20)	
Other	1 (0.50)	1 (0.20)	
Weather Condition			0.004**
No Adverse Condition	169 (77.2)	306 (71.5)	
Rain	18 (8.20)	47 (11.0)	
Sleet/Hail	0 (0.00)	4 (0.90)	
Snow	6 (2.70)	11 (2.60)	
Fog	2 (0.90)	16 (3.70)	
Other	7 (3.20)	31 (7.20)	
Unknown	17 (7.80)	13 (0.70)	
Road Condition			0.05*
Dry	146 (66.7)	292 (68.2)	
Wet	38 (17.4)	89 (20.8)	
Snow	3 (1.40)	13 (3.00)	
Slush	1 (0.50)	1 (0.20)	
Ice	12 (5.50)	17 (4.00)	
Sand	4 (1.80)	1 (0.20)	
Other	0 (0.00)	2 (0.50)	
Unknown	15 (6.80)	13 (3.00)	
Trafficway			0.01*
Two-way, not divided	178 (81.3)	340 (79.4)	
Two-way, divided	22 (10.0)	22 (5.10)	
Two-way, divided with barrier	12 (5.50)	48 (11.2)	
One-way, not divided	7 (3.20)	18 (4.20)	
Crash State			<0.001**
Idaho	47 (21.5)	44 (10.3)	
Montana	13 (5.90)	12 (2.8)	
Oregon	141 (64.4)	253 (5.9)	
Washington	18 (8.20)	119 (27.8)	
Time of Day			0.9
3:01 am–9 am	89 (40.6)	172 (40.2)	
9:01 am–3 pm	29 (13.2)	49 (11.4)	
3:01 pm–9 pm	94 (42.9)	194 (45.3)	
9:01 pm–3 am	7 (3.20)	13 (3.00)	
Season			0.8
Spring	93 (14.4)	43 (6.64)	
Summer	114 (17.6)	66 (10.2)	
Fall	105 (16.2)	55 (8.50)	
Winter	116 (17.9)	55 (8.50)	
Weekday			0.4
Monday	77 (11.9)	43 (6.60)	
Tuesday	92 (14.2)	33 (5.10)	
Wednesday	86 (13.3)	42 (6.50)	
Thursday	94 (14.5)	57 (8.80)	
Friday	75 (11.6)	39 (6.00)	
Saturday	2 (0.30)	3 (0.30)	
Sunday	2 (0.30)	2 (0.30)	
Year			0.6
2015	46 (14.5)	94 (7.10)	
2016	46 (14.9)	97 (7.10)	
2017	48 (16.5)	107 (7.40)	
2018	37 (10.5)	68 (5.70)	
2019	42 (9.60)	62 (6.50)	
Employees			0.3
1 Employee	55 (25.1)	129 (30.1)	
2–10 Employees	91 (41.6)	153 (35.7)	
More than 10 Employees	73 (33.3)	146 (34.1)	
Vehicles in Accident			0.009*
1 vehicle	184 (84.0)	397 (92.8)	
2 vehicles	27 (12.3)	22 (5.10)	
3 or more vehicles	8 (3.70)	9 (2.10)	

*Significance at the $p < 0.05$ level; **significance at the $p < 0.01$ level; p value calculated by chi-squared test.

Table 2. Multivariable logistic regression analysis of predictors of crashes resulting in injury or fatality, MCMIS 2015–2019.

	OR	*p* value	Lower 95%	Upper 95%
Intercept	0.68	0.38	0.29	1.6
Time of Day (ref: 3am-9am)				
9 am–3 pm	0.84	0.46	0.53	1.3
3 pm–9 pm	1.12	0.38	0.61	2.0
9 pm–3 am	0.96	0.94	0.32	2.7
Weather Condition: Adverse	0.85	0.48	0.53	1.2
Light Condition: Adverse	1.02	0.99	0.60	1.7
Trafficway (ref: two-way not divided)				
Two-way divided	1.48	0.27	0.73	3.0
Two-way barrier divided	0.45	0.03*	0.22	0.89
One-way nondivided	1.00	1.00	0.33	2.5
Crash State (ref: Idaho)				
Montana	1.16	0.76	0.43	3.0
Oregon	0.53	0.01*	0.33	0.88
Washington	0.14	<0.001***	0.07	0.27
Season (ref: Fall)				
Spring	1.02	0.94	0.60	1.7
Summer	1.12	0.64	0.69	1.8
Winter	0.92	0.76	0.55	1.5
Weekday (ref: Friday)				
Monday	1.16	0.60	0.66	2.1
Tuesday	0.70	0.23	0.39	1.3
Wednesday	0.99	0.98	0.56	1.8
Thursday	1.22	0.47	0.71	2.1
Saturday	3.48	0.22	0.48	31.0
Sunday	1.47	0.73	0.15	14.2
Year (ref: 2015)				
2016	1.17	0.58	0.68	2.0
2017	1.00	1.00	0.59	1.7
2018	1.02	0.95	0.58	1.8
2019	1.14	0.65	0.65	2.0
Vehicles in Accident	1.32	0.01*	1.1	1.6
Employees	1.00	0.98	1.0	1.0

*Significance at the $p < 0.05$ level; **significance at the $p < 0.01$ level; ***significance at the $p < 0.0001$ level; OR, odds ratio.

Factors Influencing Crash Outcomes. The results of the multivariable logistic regression model are presented in Table 2. The odds ratio tells us how much higher the odds of injury or fatality from a crash are when comparing groups. An odds ratio of 1.0 indicates that the odds of a crash causing a fatality or injury are the same between groups; an odds ratio >1.0 indicates increased likelihood of a crash causing a fatality or injury and odds <1.0 indicates decreased likelihood of a crash causing a fatality or injury.

As presented in Table 2, crashes occurring in the states of WA and OR had significantly decreased odds of fatality or injury relative to those in ID. The odds ratio of a fatality or injury occurring in a crash in WA compared to a crash in ID was 0.14 indicating that there is an estimated 86% decrease in the odds of a crash causing an injury or fatality in WA when compared to ID (95% CI: 0.07, 0.27, p<0.001). OR crashes also had significantly decreased odds of fatality or injury relative to those in ID, with the odds ratio equal to 0.53 (95% CI: 0.33, 0.88, p=0.01).

Additionally, crashes with more vehicles involved in the crash had higher odds of resulting in an injury or fatality than those with fewer vehicles, with an additional vehicle increasing the odds of an injury or fatality by 31% (odds ratio = 1.32, 95% CI: 1.1, 1.6, p = 0.01). Finally, crashes that occurred on a trafficway that was a divided two-way road with a barrier had significantly lower odds of resulting in a fatality or injury relative to crashes occurring on a trafficway that was two-way but not divided (odds ratio = 0.45, 95% CI: 0.22, 0.89, $p = 0.03$).

Discussion

The results of this study demonstrate a decreased odds of injury or fatality when a crash occurred in OR or WA, relative to ID, increased odds of injury or fatality for crashes that involved more vehicles, and decreased odds of injury or fatality for crashes that occurred on a divided two-way road with a positive median barrier relative to an undivided two-way road with no positive median barrier. No significant relationships with crashes involving injuries or fatalities were observed for time of day, light condition, weather condition, or number of employees.

In a meta-analysis of 37 studies from 1948 to 1989 evaluating the safety effects of public lighting, it was found that public lighting was estimated to reduce nighttime fatal accidents by 65% and a 30% reduction in nighttime injury accidents (Elvik 1995). Another study analyzing over 125,000 fatal crashes in the US found that the risk of fatal crashes increases approximately 34% during active precipitation (Stevens et al. 2019). While these studies included all types of vehicles and drivers, crashes involving log trucks like those examined in this study have some key differences that might explain the discrepancy between previous studies and the results herein: (1) log trucks are substantially different in size and weight than an average vehicle, and (2) log truck drivers possess specialized training and experience that may influence how they drive in inclement weather.

It is also of note that there was no significant relationship between the time of day when the crash occurred and injury or fatality occurrence. Fatigue is most likely to impact driving between 12 am and 6 am (American Association of Motor Vehicle Administrators 2005), when roads may otherwise have fewer vehicles on them. However, less is known about how fatigue may impact the risk of fatality or injury in a crash. The results of this study indicate that time of day was not significantly associated with the odds of a crash resulting in an injury or fatality. This does not mean that fatigue is not playing a role, but improved measures of fatigue may be required to elucidate the true relationship between fatigue and odds of injury or fatality in log truck crashes.

The observation of a significant decrease in odds of injury or fatality in crashes where there was positive median barrier is consistent with previous research findings. In studies not specific to log trucks, it is well-established that positive median barriers prevent cross-median crashes, thus decreasing risk for head-on collisions which tend to be significantly more severe than noncross-median crashes (Nystrom 1997; Miaou et al. 2005). In a 2020 report looking at all road accidents, the National Safety Council (NSC) found that when a crash involved more vehicles it was more likely to result in a fatality (National Safety Council n.d.). This is consistent with the results of this study which showed an increase in the odds of any injury or fatality for accidents involving more vehicles.

Interestingly, we found that there was a difference in odds of a log truck crash resulting in a fatality or injury by state. Using the estimated number of log truck drivers in each state and the frequency of crashes from Table 1, ID represents approximately 7.7% of the log truck driver population in the region under study but accounts for 14.1% of the observed crashes. Similarly, the results of the logistic regression model indicate that the risk of injury or fatality in crashes which occurred in OR or WA was significantly less relative to ID. This observation could be related to the adoption of OSHA-approved State Plans that have been implemented in both OR and WA. State Plans are required to be at least as effective as the federal OSHA program and are often more stringent and/or address hazards that are not covered by the federal OSHA program (OSHA 2023). Both OR and WA state plans have unique standards in place for log trucks specifically (Oregon OSHA 2014; Washington State Department of Labor and Industries 2017). These standards are far more detailed and stringent than the federal OSHA program requirements regarding log transportation (OSHA 2023b). These results indicate that the presence of an OSHA-approved State Plan may reduce the risk of injury or fatality in accidents involving log trucks. However, additional research is warranted to better understand the specific aspects of WA and OR OSHA-approved State Plans that may be contributing to the observed reduction in the odds of injury or fatality in log truck crashes.

There are specific characteristics of the logging industry in the Northwest which add context to the results of this analysis and could uniquely impact the risk of log-truck crashes, injuries, and fatalities in this region. The Northwest allows higher gross vehicle weights on interstates and state highways than many other parts of the country, which means log trucks can generally operate on interstate and state highways when hauling logs (US Department of Transportation 2019). Research in the Southeast region of the US found that when log trucks are able to operate on interstate and state highways the routes are safer for log truck drivers due to fewer intersections, stop signals, and school zones (Conrad 2020). Interstates are also more likely to have positive median barriers which our study found to reduce the odds of injury or fatality. Previous research using Fatality Analysis Reporting System data (FARS) found that log truck drivers and log trucks themselves tend to be older in the Western US compared to other parts of the US, but fatalities from log truck crashes (number of fatalities per cubic feet of wood produced) were lower in the Western states than in the Northeast or Southeast (Cole et al. 2019).

In a 2008 survey and analysis of the WA Log Trucking Industry, top industry concerns related to extended hours of service, an aging workforce, poor driver recruitment, increasingly congested roadways, and an increase in out-of-state trucks, all which could impact risk of log truck crash but were not able to be characterized in this study (Mason et al. 2008). The survey found that the WA log truck fleet tended to be a six-axle long logger truck, and logs are hauled around 12 h/day for 5 days/week, with the average log truck driver working 69 h/week. The average log truck driver traveled close to 70 miles for each trip, from point of loading to point of delivery. While most of the travel is on pavement, 17% of miles traveled were reported to be on gravel.

The Northwest is known for its steep terrain and more extreme weather events due to the Cascade and Rocky Mountains cutting through these states, the high snowfall that can accumulate in these mountains, and the annual wildfires in this region. Terrain and weather could increase risks of crashes, and wildfire season can suspend operation of logging in affected areas for weeks or months, making log truck driving and crash risks in this region unique compared to other parts of the country with less extreme terrain and different weather events.

There are several limitations to note in this study. First, the data obtained from MCMIS only provided information on environmental and roadway factors of a crash and did not include data on driver characteristics, vehicle characteristics, or other crash variables, such as speed. The data available only reflects crashes which have been reported to police; therefore, the dataset may be lacking crashes that occurred on private or logging roads unless there was a police response. Another limitation is the lack of readily available research on crash characteristics of log trucks specifically, as there are limited results with which to compare the results of this study. Understandably, log trucks make up a very small number of all motor carriers, but log hauling and transportation comes with its own set of specific hazards that require more targeted research. The results of this study are also limited to the states of OR, WA, ID, and MT, so the results are not generalizable to the rest of the US or other countries.

In the future, the methodology employed in this study may be easily applied to an analysis of log truck crashes nationwide or other logging regions, such as the Southeast, with regional considerations for how the log truck industry operates also being explored and included.

Conclusions

This study aimed to characterize log truck crashes in the northwestern states of WA, OR, ID, and MT, and to estimate the odds of a crash resulting in any injury or fatality with respect to various conditions reported at the time of the crash. The results of the logistic regression analysis herein demonstrate that several factors are associated with injury or fatality in log truck crashes, including presence of a positive median barrier decreasing odds of an injury or fatality, number of vehicles involved in the crash increasing the odds of an injury or fatality, as well as the odds of injury or fatality varying by the state in which the crash occurred. This is the first study to utilize MCMIS data to examine risk factors for injury or fatality in log truck crashes. However, limitations of the data and study must be acknowledged, including the MCMIS data not including information on all factors known to influence risk of injury or fatality in a crash (e.g. driver characteristics, vehicle characteristics, or speed), the MCMIS database not being complete as it only summarizes crashes to which there was a police response, and lack of generalizability outside of the four northwest states (ID, MT, OR, WA) covered by this analysis.

The results of this study are consistent with prior research done on both log truck crashes and other motor vehicle crashes more generally. Since there are so few studies that have specifically examined log truck crashes, especially with regard to risk factors for injury or fatality, the results of this study are important to both identify gaps in the existing data as well as provide a basis for future studies on log truck crashes. The methodology described herein could be applied to a nationwide or another regional analysis, which may yield additional insights. The results of this study will be used to provide informative feedback to logging stakeholders in the northwestern US and will be built upon by ongoing survey and interview data with logging workers in the region.

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Disclosure statement

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