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Analysis of Risk Factors in Severity of Rural Truck Crashes

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Analysis of Risk Factors in Severity of Rural Truck Crashes

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ABSTRACT

Trucks are a vital part of the logistics system in North Dakota. Recent energy developments have generated exponential growth in the demand for truck services. With increased density of trucks in the traffic mix, it is reasonable to expect some increase in the number of crashes. Analysis shows however, that the crash-injury risk associated with trucks cannot be explained solely with the traffic growth. Recent crash data has been analyzed to better understand characteristics and contributing factors in truck-involved crash events. Comparisons of truck-involved crashes to those not involving trucks show aspects of the crashes differ. In addition, multivariate models of three driver groups were defined, including truck drivers in multiple-vehicle crashes, other vehicle drivers in multiple-vehicle crashes, and truck drivers in single-vehicle crashes. Results reveal several predictors significantly associated with an increased likelihood for severe driver injury outcomes. Seat belt use was a significant predictor for severe injury likelihood in all models. Failure to stop or yield, rollover event, multiple truck involvement, curves and intersections were associated with increased likelihood for severe injury to truck drivers. Severe injury to other drivers in truck-involved crashes was associated with alcohol or drug involvement, head-on and sideswipe collisions, rollover event, weather and distracted driving. Findings largely were consistent with previous findings indicating some differences among driver group injury predictors. Understanding factors associated with increased likelihood for severe injury by driver group can encourage targeted interventions and countermeasures, which will them improve safety by reducing incidence of severe injury crashes involving trucks. Insight into truck crashes may allow drivers and businesses to identify areas for safety performance improvement.

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1. INTRODUCTION

Trucks are critical to economic connectivity in rural states like North Dakota. They are a flexible alternative to rail and pipeline in sourcing and delivering goods. Trucks also serve a vital role in local rural economies. Trucks enable natural resource-based industries, such as agriculture and oil, to consolidate products for longer distance shipment in rail and barge where they can gain economies in larger shipment sizes. Trucks also are a primary mode for many local processes in gathering inputs and distributing products. Therefore, truck traffic is heavily influenced by local economic activity and larger national economic trends. Unusual increases in truck traffic, such as that related to economic change or natural disaster, may create unintended crash risk. As changes in traffic volumes and patterns are recognized, levels and effects of increased safety for truck heavy corridors and truck related traffic must be monitored.

Nationally, trucks are involved in about 285,000 crashes annually. About 1 in 100 crashes resulted in fatal injury between 2010 and 2012 (Federal Motor Carrier Safety Administration 2014). The median for the 48 contiguous states was 0.14 fatalities per 100 million VMT. States with rates in the upper quartiles for crash-incidence rate are shown in the orange and red categories in Figure 1.1. State-level crash incidence shows geographic disparity, ranging from 0.46 per 100 million vehicle miles traveled (VMT) in North Dakota to 0.03 fatalities per 100 million VMT in Rhode Island (Federal Highway Administration 2014; National Highway Traffic Safety Administration 2014). Figure 1.1 also shows that many states in the central region experience relatively high truck crash incidence.

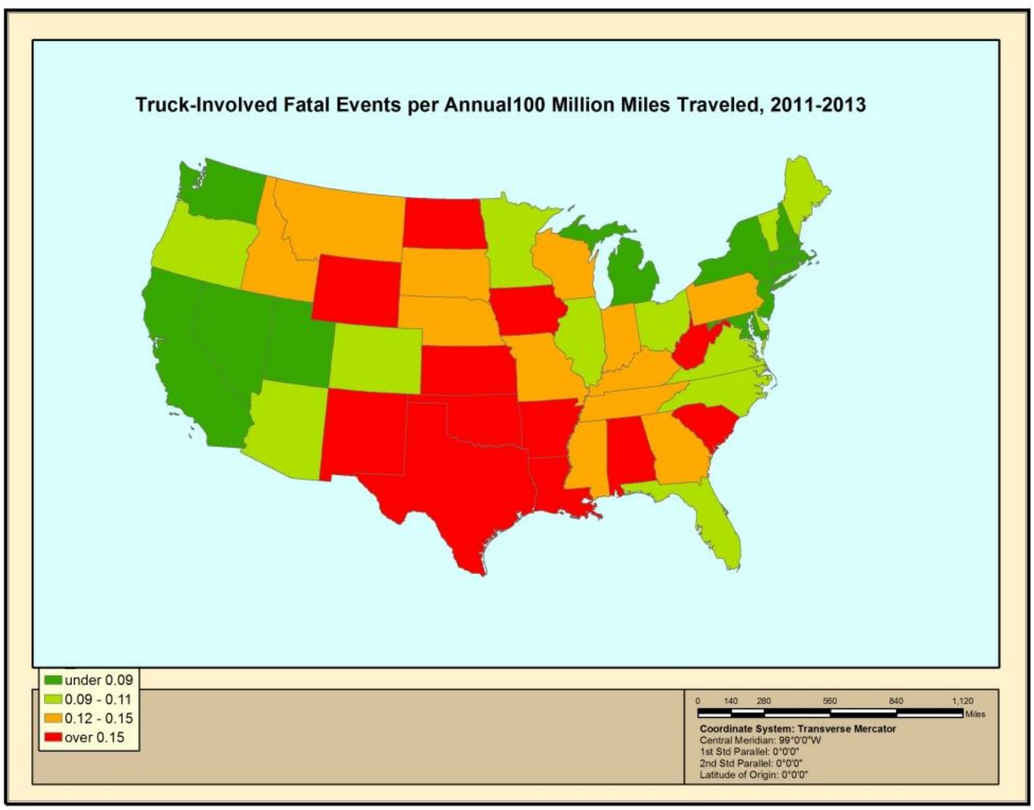
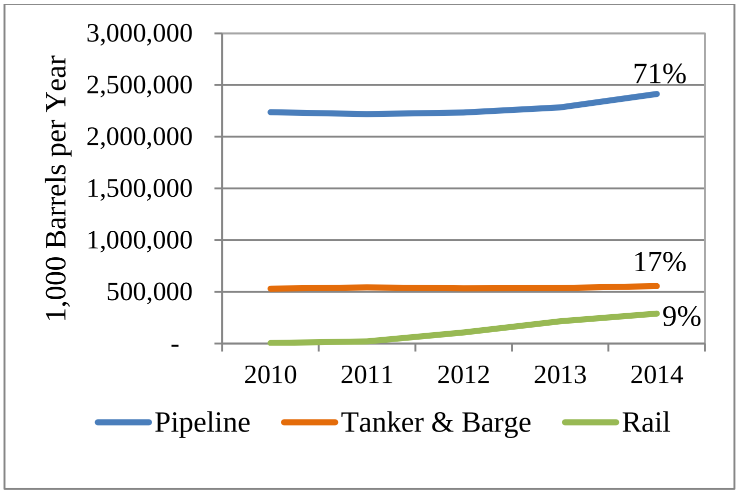


Figure 1.1 Truck-Involved Fatal Crash Incidence

When reviewing annual crash event figures, it is evident that large truck-involved crashes have become increasingly prominent in North Dakota. Oil exploration and development in the western region of the state has been the nexus for exponential growth in truck traffic. Trucks are used extensively in drilling and production phases. While trucks are commonly used in the drilling phase, the heavy reliance on trucks in oil-movement-to-rail-transfer facilities and pipeline facilities is atypical, considering the traditional industry supply chains. The majority of U.S. oil production is transported by pipeline from production point to consumption facilities (Figure 1.2). Nationally, about 9% of crude oil and petroleum products were moved by rail in 2014 compared to about 60% by rail in North Dakota (U.S. Energy Information Administration [EIA], ND Pipeline Authority 2015). Market maps published for 2012 and 2013 show transitions from rail to pipeline transport at wellhead (ND Pipeline Authority 2015). In addition, some local gathering pipeline-to-rail facility transport has been added, but a substantial reliance on truck-to-rail facilities continues to bereported in local traffic.



Source: EIA, U.S. Department of Energy

Figure 1.2 U.S. Oil and Petroleum Product Transport from Production Basin to Petroleum Administration for Defense District (PADD)

Most likely, the increased truck density will be a sustained traffic environment in the oil region for many years. Therefore, it is an opportune time to draw knowledge from crash events over recent years to more effectively address this critical safety issue. This study emphasizes injury crashes. Injury crashes, which include fatal injury crashes, were selected as the unit of study because of the more serious nature of these crashes. While property-damage-only crashes also may provide insight, previous experience has shown that injury crashes perform well in profiling and understanding a smaller number of serious crash events that end in disabling and fatal injury outcomes.

Injury crash trends in North Dakota show a pronounced increase in truck involvement (Figure 1.3). In comparison, the number of injury crash events for other vehicles also have trended upward, but at a slower rate. Overall, injury crash events involving trucks increased about 300% from 2004 to 2014. Other injury crashes increased only about 3% during the same period.

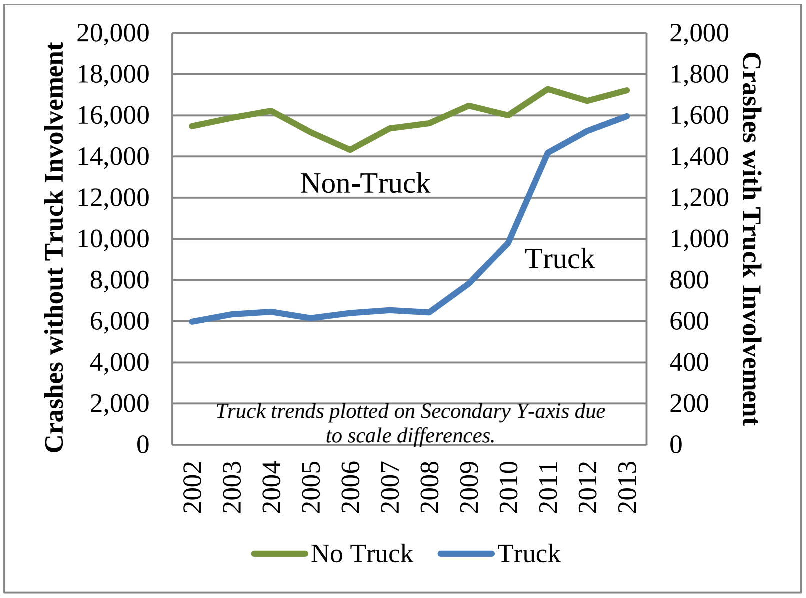


Figure 1.3 All Crash Events, by Vehicle Type

A larger increase in truck crash events can be expected given the differences in the rate of increase for the traffic, but figures show a disproportionately large increase in crashes relative to the traffic increase (ND Department of Transportation 2015). This dissimilarity in crash rates is consistent with findings in Europe that show the crash fatality rate increased as truck fleet density increased, while the same effect was not found for the car fleet (Castillo-Manzno et. al 2015). The higher crash rates in proximity to drilling activity also is consistent with experiences in Pennsylvania where heavily drilled counties experienced fatal and injury crash rates about 46% greater than non-drilling counties (Graham et. al 2015).

The trends in incidence rates for injury crashes involving trucks and those not involving trucks, as vehicle type reported in the law enforcement crash form, were graphed (Figure 1.4). North Dakota requires that traffic crashes are reported to law enforcement if injury results and/or damage exceeds $1,000. Although property-damage-only crashes may be under-reported, it is reasonable to assume that law enforcement-reported injury crashes closely represent the population, due to the more serious nature of the crashes.

Trucks retain lower overall injury crash incidence rates than other vehicles. Given that commercial truck drivers have specialized driver training and adhere to federal standards in their driving practices, this lower crash rate is expected for the professional driver group. A significant difference was found in the crash incidence associated with trucks compared to other traffic crashes in this measure over time (Chi-Sq.=461.54, df=10, p=<0.001). When standardized by VMT, the trend for other injury traffic crashes shows a decline, while the truck-involved crashes trends upward until 2012. The trends do appear to have leveled in recent years.

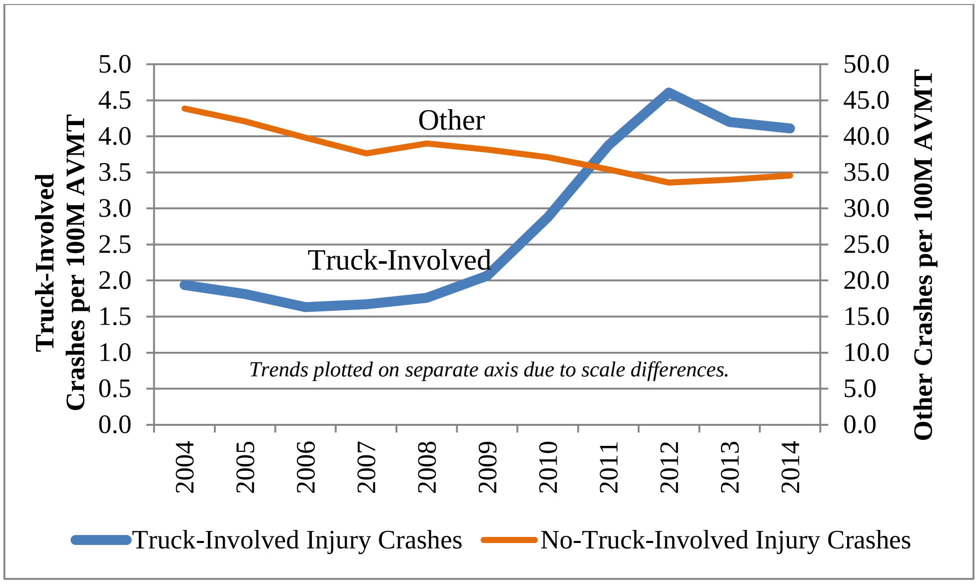


Figure 1.4 Injury Traffic Crashes (Includes Fatal Injuries), by Vehicle Type

Based on regression analysis of the limited data set covering the number of crash events and miles traveled annually between 2002 and 2014, a 10% increase in VMT on state highways results in a 15% increase in truck injury crash involvement. The VMT explained 98% of the variation in the crash event involvement, with significance at the 99th percentile. With the other vehicle crash events, the VMT had much lower explanatory value and the coefficient was not significant at the 99th percentile. This significant relationship supports the premise that crash risk is positively associated with truck traffic density.

The relative risk for truck crash risk has increased most rapidly in the northwest quadrant of the state. This area is the epicenter of oil and gas development. Seventeen counties in western North Dakota define the oil region, considering well locations and transportation, as illustrated in Figure 1.5.

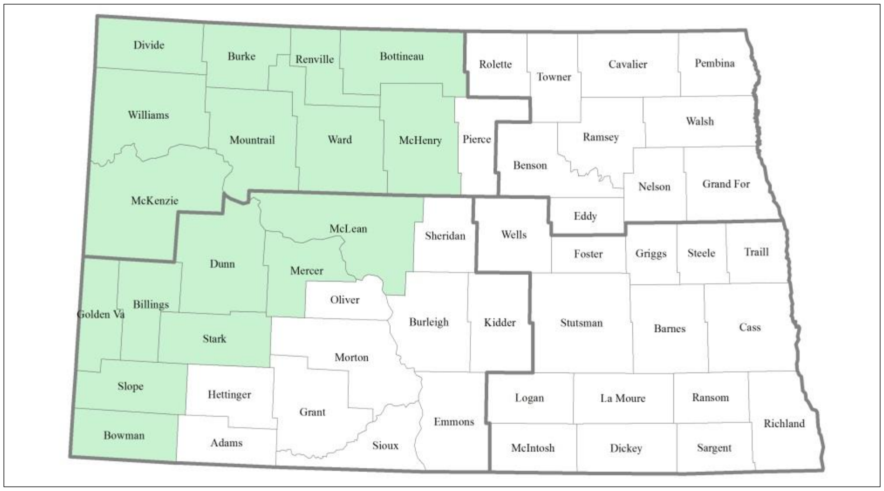


Figure 1.5 Oil Region Counties

Three counties heavily active in the oil production are McKenzie, Mountrail, and Williams. This trio of counties, located in the northwest quadrant, accounts for about 72% of the state's current oil production (Department of Mineral Resources, Oil and Gas Division 2015). Figure 1.6 shows how heavily truck safety in this area impacts the statewide truck crash trend depicted in the previous illustrations. Exponential growth in truck crash incidence in the northwest seems to have peaked in 2012. It will take several years to determine whether safety improvement, shown in the declining trend, can be sustained. It is reasonable to expect that changes in infrastructure, education, and enforcement that address the truck-involved crashes in the region will have a positive impact. More recently, lower oil prices also appear to be stemming truck traffic growth. The southwest region includes Dunn County, which is among the four largest oil-producing counties. This regionhas experienced higher truck-involved crash incidence compared to 2009, but not nearly the same magnitude in increase. The eastern regions truck-involved crash trend lines are relatively stable.

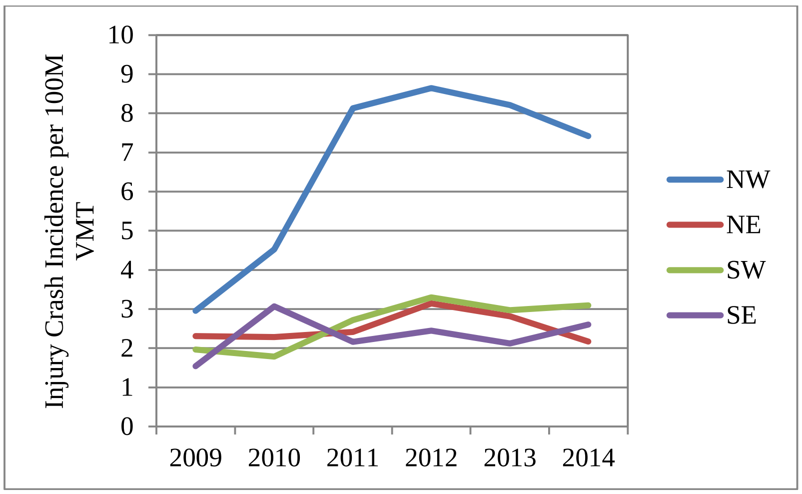


Figure 1.6 Truck-Involved Injury Crash Incidence by Region

As noted, in a comparison of truck crashes to other vehicle crashes, trucks are involved in a relatively small share. The significant differences found in crash incidence and severity likelihood, suggests that attention to the issue may be especially beneficial in improving traffic safety. There were about 106,000 crashes on North Dakota roadways between 2009 and 2014, with 7% involving trucks as at least one of the vehicles in the crash. Trucks were involved in 10% of the 22,000 injury crashes during this five-year period. Truck crashes are associated with a greater share of the more serious injury outcomes than crashes not involving trucks. In regard to severe injury crashes, which includes fatal and disabling injuries, trucks were involved in 20% of the reported crash events in the state.

An investigation into reported-injury crashes in North Dakota involving trucks was conducted. Findings offered insight into truck crashes as a traffic safety issue, since it is likely trucks will continue to attribute a larger proportion of vehicle type, especially in certain traffic corridors seasons. The following literature review provides a brief overview of current knowledge about truck crash risk factors. Descriptive analysis is used to relay basic facts about truck crash event from multiple sources. Section four describes the method and data used to model crash severity risk factors. Model results and discussion are provided in the final sections of the paper.

2. LITERATURE REVIEW

Previous work has substantiated that truck crashes are complex, as confounding factors in driver, roadway, environment and vehicle can all contribute to crashes. A Large Truck Crash Causation Report study, which included 967 crashes in 17 states, reported that in 87.2% of cases, critical issue in a crash was driver related (FMCSA 2005). Among the top driver critical factors were prescription drug use, traveling too fast for conditions, and unfamiliarity with the roadway. In comparison, vehicle and environment were the critical factors in 10.1% and 2.3%, respectively. While this national study proved enlightening, several studies at the state level offer additional insight.

Chen and Chen (2011) show that single- and multi-vehicle crashes on rural highways have different attributes, in regard to injury outcomes, in a study of truck-involved crashes in Illinois. Factors determined to lead to more severe injuries included: driver extraction, driver sleeping, driver fatigue, hazardous material load, wide line, wide median, truck overturn, improper lane usage, overtaking, and skidding. The disaggregation of the truck-involved crashes show substantial differences in the explanatory variable list and mixed effects for single- and multi-vehicle crashes.

Truck-involved crashes in California between 1997 and 2000 showed significant differences in driver injury outcomes on rural and urban roads (Khorashadi et al. 2005). An array of human, environmental, road geometry and traffic, and vehicle factors were considered in 6,300 crashes studied. Alcohol or drug use was the prominent causal factor in 4% of accident events where it involved for the rural road crashes, and probability for severe/fatal injury increased 246%. Intersections were identified as a rural road risk location with a 725% increase in likelihood of severe/fatal driver injury for the truck-involved crashes. Driver fault also was significant in the injury outcome with crashes caused by passenger vehicle drivers in truck-involved crashes having a 108% increase in probability of visible injury. Inconsistent with previous findings, tractor-trailer combinations resulted in decreased injury severity compared to single-unit large trucks. The increased probability for severe/fatal driver injury was 257% with a single-unit truck involvement and 671% with a truck-trailer unit.

Another study considered stratification across road group and vehicle involvement. The study of at-fault large truck crashes considered injury risk factors in Alabama crashes. Islam et al. (2014) support the premise that distinct differences are associated with urban and rural road groups for single- and multiple-vehicle crash events (Lee and Mannering 2002; National Highway Traffic Safety Administration 2014). Regarding driver factors, greater injury risk in rural crashes was attributed to male drivers and fatigue, but not in urban crashes. Larger trucks are associated with significantly greater injury risk on urban roads, but not on the rural roads. The single road geometry variable significant in risk was curve, for singlevehicle rural truck crashes. This is consistent with Daniel and Chien (2003). In a study of New Jersey truck crashes, they found that single-vehicle truck crashes are more likely than multi-vehicle truck crashes to occur on a curve or grade.

In addition to driving environment and vehicle involvement, specific driver-related risks have been studied at a national level. Knipling and Wang (1994) evaluated 182 fatal large truck crashes and reported that 31% of the crashes were related to fatigue. The authors also cited results from the NHTSA, which indicated that a driver being inattentive, drowsy, or asleep was the major factor in 31.5% of combination- unit and single-unit truck crashes that were single-vehicle road departure crashes. They estimate that when exposure is considered, combination-unit truck drivers were 4.5 times more likely to be involved in a drowsy driver crash than passenger vehicle drivers, and the fatality-to-crash ratio is 1.7 times greater for combination truck drivers than for passenger vehicle drivers.

Agent and Pigman (2002), in their study of Interstate crashes, found that truck drivers were more likely than all vehicles to be involved in a crash involving failure to yield and misjudging clearance. A lower percentage of trucks had a contributing factor of following too close, speeding, or alcohol compared to other vehicles. Truck-involved crashes were more likely to involve driver inattention and weaving in traffic as a contributing factor.

Hanowski et al. (2005) evaluated critical driving events of trucks. The main objective was to use a naturalistic approach to study driver distraction. The study used two tractors equipped to videotape and record essential data. Forty-one long-haul truck drivers used the tractors for a total of 140,000 miles and experienced a total of 2,737 critical incidents. Judgment error was the most common cause, contributing to 77% of all events. Other vehicles were deemed responsible for 9.7% of events; and 6.5% of events were attributed to driver distraction. Single drivers were more likely (64.6%) to be distracted than team drivers.

Haworth et al. (1989) also found fatigue to be a problem, in a study of truck crashes in Australia. Researchers evaluated coroner reports in fatal crashes to determine the degree to which fatigue was involved in fatal crashes involving a large truck. The coroner indicated fatigue was a contributing factor in 9.1% of the crashes evaluated. Fatigue was prevalent in 5.4% of crashes for car drivers and 3.7% for truck drivers.

Spainhour et al. (2005) evaluated 600 crashes in Florida that involved large trucks. Inattention was listed as a contributing factor (primary or other) in over 50% of crashes where a large truck was at fault. Decision errors were the primary contributing factor (12%) of crashes, followed by speed (9%). Alcohol and fatigue also were common contributing factors. Chang and Chien (2013) found driving under the influence and seat belt use were key factors in injury outcomes in a study of truck-involved crashes involving injury in Taiwan.

Massie et al. (1997) evaluated short-haul truck crashes in the United States. The authors created a definition of short-haul trucks and examined prevalence of driver fatigue, as it relates to short-haul trucking, using three data sources: travel data from the 1992 Truck Inventory and Use Survey, crash statistics from the 1991 to 1993 Trucks Involved in Fatal Accidents File, and 1995 SafetyNet data. The authors found that fatigue was coded as a factor in 1.9% of fatal truck crashes and in 1.3% of personal injury or tow-away crashes. Seventy-one percent of fatal fatigue-related crashes were single-vehicle crashes. Roll-over and fixed-object crashes were common in fatigue-related fatal crashes. The authors found a peak in fatal crash involvements from 4 a.m. to 7 a.m., and a peak from 3 a.m. to 7 a.m. for less severe involvements. The authors also found that medium- and large-duty trucks were equally involved in fatigue-related crashes. They found that driver fatigue was indicated as a factor for only 0.4% of truck crashes when the trip was 50 miles or less, and for 3.0% of truck crashes when the trip was greater than 50 miles.

Khattak and Schneider (2002) combined vehicle, roadway and driver factors in crashes to understand injury risk in rollover and non-rollover crashes. Descriptive analysis and regression models show that certain truck manufacturers, driver behaviors (including reckless, speed and passing violations), curves and newer trucks were associated with higher-crash risk. The hazardous material loads were especially problematic in rollover crashes, with associated ignition- and fire-risk following the rollover event. Results of this study should be used with caution, since occupant restraint is not among injury risk factors. This potential specification error means bias is likely in the independent variable coefficients, since effects are used from the omitted-occupant protection variable.

Weather as a role in crashes was considered by Agent and Pigman (2002) and Maze et al. (2006). Agent and Pigman found that the percent of truck crashes on a wet or snowy surface was lower than it was for all crashes in their interstate crash study. The authors reported that trucks were slightly more likely to be involved in a crash at night, when no roadway lighting was present, and that fatal truck crashes were less likely on a wet or snowy surface. Maze et al. (2006) found about 26% of all crashes during the winter in Iowa involved weather. In both urban and rural areas, higher design standard facilities (interstates and freeways) experience higher percentages of crashes (36% and 45%, respectively) and higher percentages of fatal- and major-injury crashes during winter weather than two-lane facilities. Although the actual reasons for this are unknown, authors speculate that higher design standard facilities and less congested facilities (rural roads) provide drivers more opportunity to drive at speeds that are unsafe for the conditions.

Time of day is found to be a significant environmental factor in a handful of studies. When this variable is added to road type, Stieff (1990) found nighttime driving on non-limited access highways in rural areas has the highest crash rate. Daniel and Chien (2003), in their evaluation of truck crashes from 1998 to 2000 in New Jersey, found that most truck crashes occur in daylight conditions. Agent and Pigman (2002) found that trucks were slightly more likely than all traffic to be involved in a crash at night when no roadway lighting was present on interstates.

In regard to vehicle characteristics, long-combination (LCV) truck safety was studied by Lemp et al. (2011) Data from the FMCSA LCCTS supported previous findings that longer vehicles are associated with more severe crash injury outcomes. Findings show, however, that these LCV may be safer if exposure is considered, since the crash rates are lower. Authors posit that lower crash rates for the LCV may be attributed to state restrictions on LCVs during inclement weather and LVC-driver qualifications that require more experience and enhanced training.

This study considers the large body of research related to truck crashes. It draws on established driver crash risk factors and effects of the driving environment, roadway and other event characteristics. Considering available crash data, a model was defined to acknowledge previous research, while intertwining some localized risk factors, to better understand risk factors in these complex crash injury events.

3. TRUCK CRASH CHARACTERISTICS

Literature review provided a multitude of potential factors to consider in analyzing contributing factors for truck-involved crashes in North Dakota. It is important to investigate the North Dakota crashes to better understand these events and common factors. In addition, the local market environment factors, such as limited urban truck traffic and recent traffic growth, were considered in defining queries to describe truck-involved crashes and drivers in those events. Crash data was collected from the ND Department of Transportation Safety Division and the Federal Motor Carrier Safety Administration. Traffic data was collected from the ND Department of Transportation.

Crashes can be described generally in terms of location and driving environment. Truck involvement in injury crashes in the west region is significantly higher than in the east, 13% compared to 6% in the east (χ^2=271.811 ρ<.001, n=19,161). Location effect was even more pronounced for the 17-county oil region, where 19% of injury crashes involved trucks, compared to 6% in other areas of the state χ^2=868.112 ρ<.001, n=19,161). Serious injury crashes were most commonly located in the northwest region of the state. This region accounted for 41% of all serious injury crash events between 2010 and 2014. The northwest region is heavily represented in regard to location for serious crashes involving trucks and accounts for 58% of the serious injury crash events over five years

When considering truck crash incidence, 28% of the serious injury crashes in the northwest region of the state involved trucks, compared to a low of 11% in the northeast region. Trucks were involved in 16% and 14% of the serious injury crash events in the southeast and southwest regions, respectively, during the same time period. Considering traffic in standardization of crash comparison in events, and based on exposure per 100 million VMT, the northwest region had the highest incidence at 9.56 serious injury crash events involving trucks. The incidence for serious injury truck-involved crashes was lowest in the southeast at 3.79 per 100 million VMT. The incidence rate for crashes not involving trucks also was highest in the northwest region at 4.81 per 100 million VMT; but the range was narrower, with the lowest rate in the southeast at 3.19 per 100 million VMT.

In terms of road functional class, driving environment also provides information about the truck-involved crash events. Lane miles in the state road system are categorized among the functional classes, generally related to ownership and traffic levels. Crash event counts were standardized by annual VMT estimates to determine truck-involved serious crash incidences among the functional classes. Subgroups for the urban functional classes were collapsed into a single urban category due to low counts for the serious injury truck-involved crashes. The highest incidence rate is for the local roads at 2.77 crashes per 100 million VMT, and the lowest was for the urban group at 0.38 crashes per 100 million VMT (Figure 3.1).

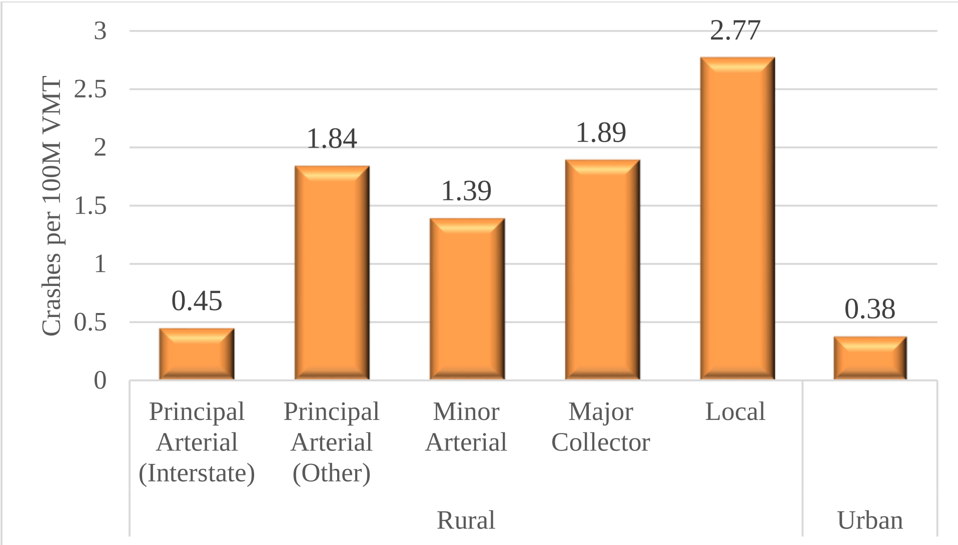


Figure 3.1 Serious Crash Incidence 2010-2014, Truck-Involved

While the five-year incidence rate does provide insight regarding functional classes, an understanding of the year-to-year trends in these crash counts also is useful. Ttruck-involved crash counts generally were around or under 10 for serious injury outcomes on the principal arterial interstates, minor arterials, minor collectors, and urban roads. The count on other principle arterials (not interstate) spiked in 2011 and trended upward after the decline in 2012. Events on local roads peaked in 2012 and have trended downward in the most recent two years.

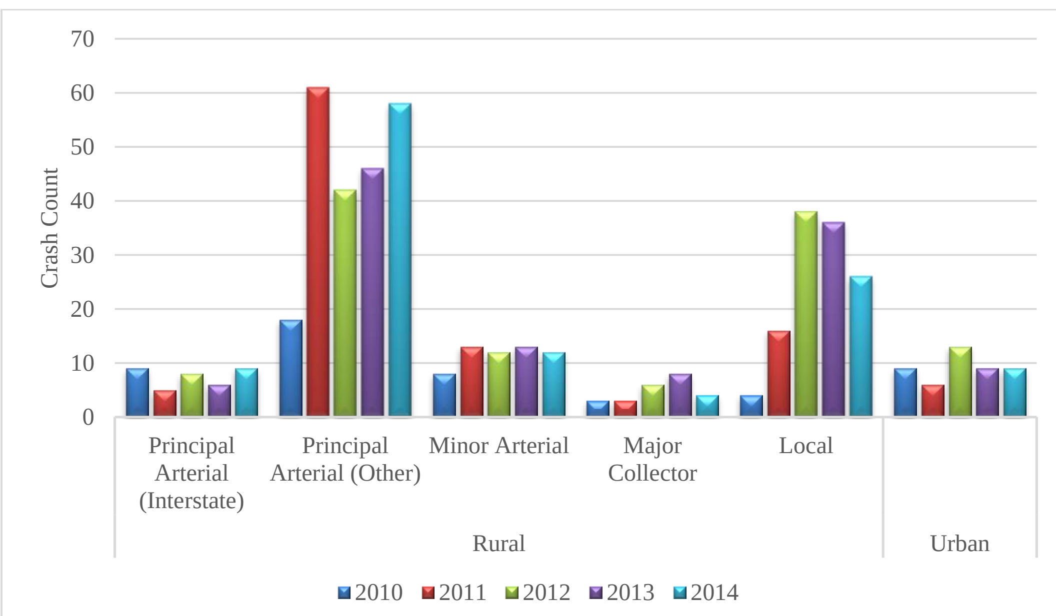


Figure 3.2 Annual Count of Truck-Involved Serious Injury Crash Events

Time effects also may be considered in the nature of truck crashes. Figure 3.3 shows that truck-involved crashes are more common in the September to December time period compared to shares during the other periods. Increased truck activity associated with harvest season may contribute to distribution across the time periods. The share of weekend and weekday crashes varies for truck-involved and no truck-involved crashes, with truck-involved more common during weekdays from Monday through Friday. Between 2010 and 2014, 1 in 5 truck-involved injury crashes occured on the weekend compared to 1 in 4 injury no-truck-involved crashes.

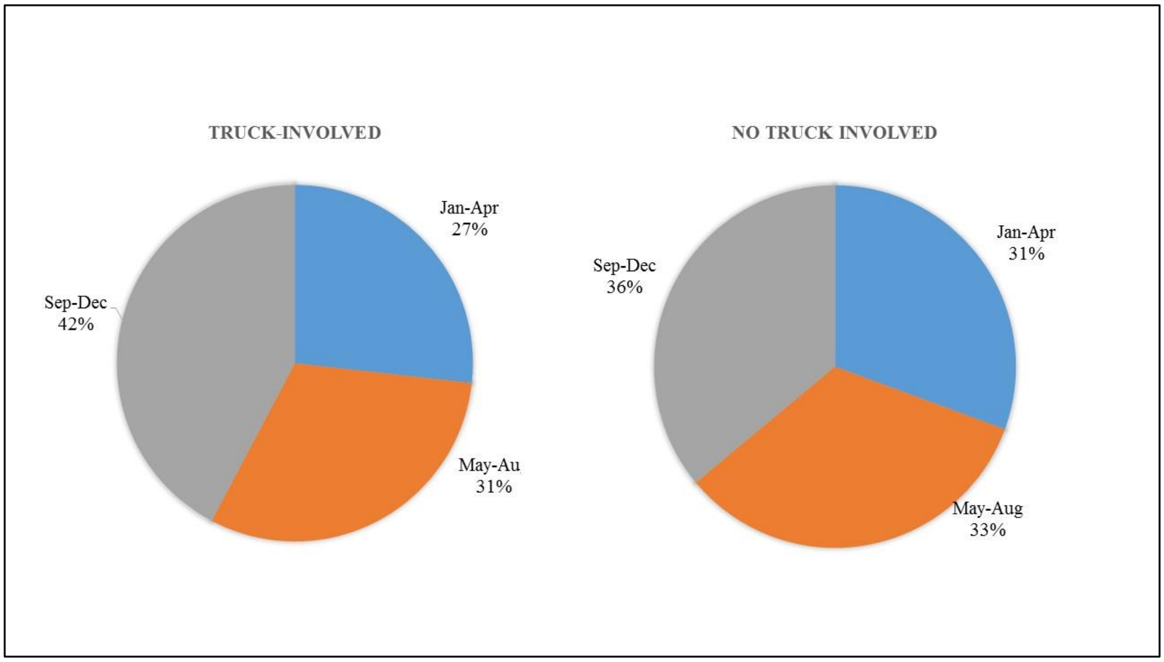


Figure 3.3 Injury Crash Events by Time Period

Truck body type also is a characteristic that may be useful in understanding the nature of truck-involved crashes. In order of total frequency for injury-crash involvement between 2010 and 2014, the liquid bulk cargo tank accounted for 31% of the reported truck body. Van/enclosed box and flatbed/platform were named in 16% and 15% of cases. Dump, hopper and dry bulk cargo tank were attributed in 12%, 9% and 7% of the units. Other truck body types were involved in 2% as units in the truck-involved injury crashes. About 71% and 70% of serious injury crashes involving trucks with liquid bulk cargo tank and flatbed/platform body types were single-vehicle events. The hopper and dump configurations were reported to be single-vehicle events in 59% and 64% of serious injury cases of truck-involved crashes. These figures would be especially useful if exposure data could be collected in the future.

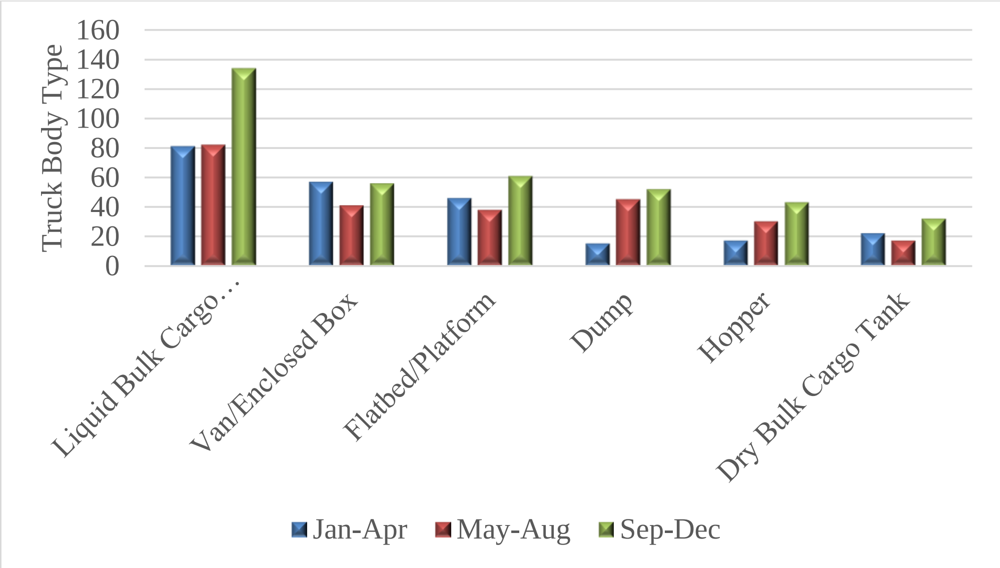


Figure 3.4 Truck Body Type in Injury Crashes, 2010 to 2014

When nature of the collision in multiple-vehicle crashes is reported, it shows that angle impact was most common in truck-involved and other serious crash events (Figure 3.5). Damage reported in these angle impact crashes shows damage to the truck and to the other vehicle in nearly all cases. Front area impact is the most commonly damaged area – in 54% of the truck cases and 39% of the other vehicle cases. The rear-end impact is second among collision types for truck-involved crashes. Front area damage is reported in 28% of the truck and 55% of other vehicle crashes, respectively. Head-on impact is reported in 15% of the events and sideswipe in about 10% of the truck-involved serious injury crash events. In head-on impact damage, 88% of trucks and 80% of other vehicles have front area damage.

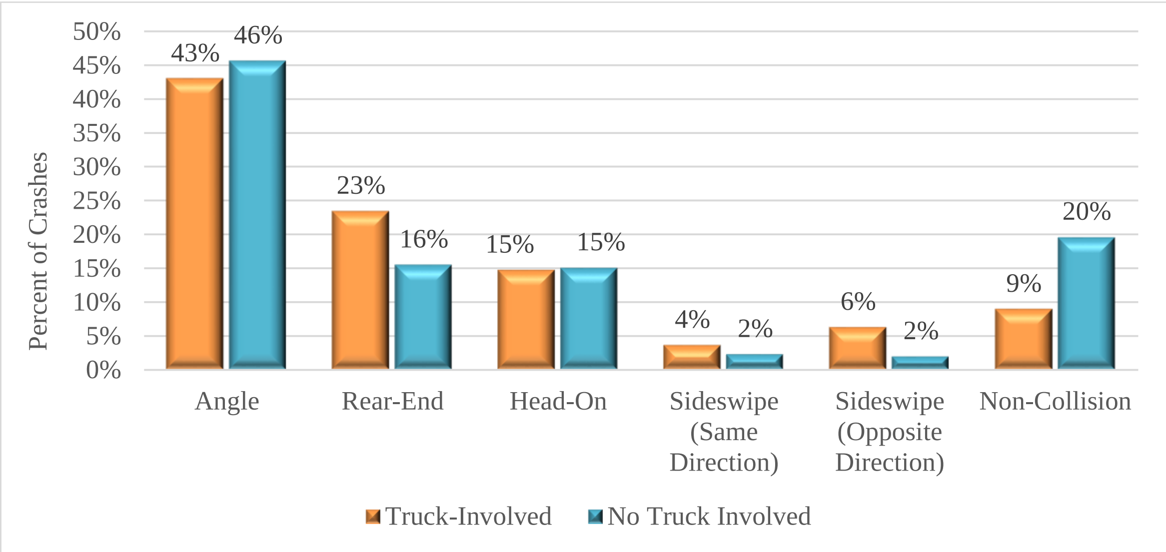


Figure 3.5 Collison Type for Serious Injury Multiple Vehicle Crash Events, 2010-2014

Traffic control devices are important factors in safe and efficient traffic flows. Traffic control present during serious-injury crash events for trucks and other vehicles offers insight for potential education and enforcement opportunities. A majority of serious injury crashes occurred in environments with no traffic control reported (Table 3.1). Among potential devices, the stop sign was the most often reported traffic control devise present for other vehicles in a serious injury crash event involving a truck. The stop sign and railroad crossbucks/pavement markings were most commonly reported for the truck in these crashes.

Table 3.1 Serious Injury Crash Units, Traffic Control

	Truck	Other Vehicle
None	*82%*	*78%*
Stop Sign	5%	14%
No Passing Zone	2%	4%
Flashing Beacon	1%	1%
RR Signals With Gates	1%	0%
RR Signals Only	1%	0%
RR Crossbucks/Pavement Marking	5%	0%
Officer/Flag person	1%	1%
Traffic Signal	0%	2%
Yield Sign	1%	1%
Warning Signs	1%	0%
	147	337

Vehicle movement in serious injury crash events provides additional insight about driver decisions in regard to crash events. In the most commonly reported collision – angle, left turns are the most problematic maneuver in regard to potential for angle impact. The left turn maneuver also is prominent for the truck in rear-end, head-on and sideswipe-same direction collisions. Not surprisingly, passing is an oft-reported maneuver for the other vehicle in the head-on and sideswipe-same direction collisions. Stopping, slowing and waiting were problematic maneuvers for both vehicles in rear-end collisions. Although smaller in terms of unit total, curve negotiation and traveling on the wrong side of the road were common themes in the side-swipe opposite direction collisions. The manner of collision, such as the left turn, offers a potential focus for education or enforcement efforts related to truck traffic safety for truck and passenger vehicle drivers.

Table 3.2 Serious Injury Crash Units, 2010-2014

Vehicle Movement	Manner of Collision									
	Angle		Rear-End		Head-On		Sideswipe (Same Direction)		Sideswipe (Opposite Direction)	
	Other Vehicle	Truck	Other Vehicle	Truck	Other Vehicle	Truck	Other Vehicle	Truck	Other Vehicle	Truck
Going Straight	*64%*	*69%*	*79%*	*61%*	*47%*	*85%*	*7%*	*39%*	*52%*	*81%*
Turning Left	11%	14%	3%	9%	0%	6%	14%	44%		
Turning Right			0%	5%						
Passing	3%	1%			17%	0%	57%	6%		
Wrong Side of Road					24%	0%			19%	0%
Negotiating Curve					3%	4%			15%	11%
Slowing/ Stopping			3%	8%						
Stopped	7%	3%	6%	8%						
Waiting to Turn Left			1%	3%						
Waiting for Traffic Signal			5%	2%						
Total Units	199	198	110	110	70	67	14	18	27	27

Other occupant actions also may factor into crash events and injury outcomes. Regarding traffic crash injury outcomes, seat belt use is a fundamental aspect in vehicle safety systems. Past research has shown proper occupant protection can reduce fatal injuries by about half (Robertson 1976, Evans 1986, Kabane 2000). Observation data from all traffic crashes in North Dakota between 2010 and 2014 show that 80 % of truck occupants were using seat belts, or other appropriate occupant protection, compared to 76% of occupants in other vehicles in truck-involved crashes. Crashes without truck involvement had occupant restraint reported at 74%, the lowest among occupant groups. The difference in use-by-truck driver-involved crashes was significantly higher at 79%, compared to 72% for other drivers at the 99th percentile (□□=145.889 ρ<.001, n=188,620). In addition to greater proclivity of truck drivers to use seat belts, Table 3.3 **Table**shows a generally positive relationship between seat belt use rates and reduced injury outcomes for crash occupants. For instance, only 21% of the truck occupants fatally injured in crashes were wearing seat belts. In comparison, 80% of the truck occupants not injured were wearing seat belts.

Table 3.3 Seat Belt Use in Crashes, by Occupant Type

	Injury Reported					
Crash Group, Occupant	Fatal	Disabl-ing	Non-Disabling	Possible/ Claimed	None	Total
Not Truck Involved, All	21%	39%	58%	75%	74%	174,482
Truck-Involved, Other	35%	53%	66%	77%	76%	5,843
Truck-Involved, Truck	21%	53%	70%	75%	80%	8,295
Source: NDDOT Crash Data 2010-2014						

Impaired driving is another occupant-related factor that has been shown to be influential in traffic crashes. North Dakota has among the highest rates in the nation for alcohol involvement in fatal crashes (NHTSA 2014). Nationally, 31% of fatal crashes involve a driver with blood alcohol content above 0.07% in 2013 compared to 42% of the fatal crashes in North Dakota during that year. Truck-involved crashes had significantly lower alcohol/drug involvement at 9% of cases compared to 14% of other injury crashes (□□=26.449 ρ<.001, n=19,161). Considering the population of drivers involved in reported-injury crashes, drivers of other vehicles in the truck-involved crashes had the highest rate for alcohol or drug involvement at 16.6%. Drivers in non-truck involved injury crashes were reported with alcohol or drug involvement in 12.5% of the cases. Truck drivers had the lowest share for alcohol or drug involvement at 1.3% of cases. This low rate for the truck drivers is expected, given the professional nature of their driving activitites.

Although the seat belt and impaired driving factors are useful in crash injury discussion, information about citations and contributing factors also provides insight regarding driver actions and other crash elements. Crash records do not include a field to indicating whether a driver is at-fault in a crash event, so a moving violation is a proxy for discussion related to driver decisions. Moving violation citations were issued to truck drivers in 24% of the multiple vehicle crashes involving trucks, compared to 41% of the other drivers in these crashes (Table 3.4). The citation rate for other drivers is higher in the truck-involved crashes than in crashes not involving trucks at 37%. The most common citation in the truck-involved crashes is care required. A slightly higher share of the tickets is issued for failure to yield when a truck is not involved in the crash. Citations were issued to truck drivers in 45% of the single vehicle crashes. The most common citation for single-vehicle truck crashes is care required.

Table 3.4 Citations in Injury Crashes, 2010-2014

	Single Vehicle	Multiple Vehicle		
		Truck-Involved		No Truck Involved
Citation	Truck	Other Vehicle	Truck	Other Vehicle
None Indicated	*55%*	*59%*	*76%*	*63%*
Care Required	35%	14%	7%	8%
Failed to Yield	1%	5%	5%	9%
Other Offense	0%	4%	4%	5%
Following to Close	0%	2%	3%	4%
DUI (Alcohol)	2%	7%	0%	2%
Failed to Stop	1%	1%	1%	3%
Improper Turning	0%	1%	2%	1%
Overtaking	0%	2%	1%	0%
Careless Driving	1%	1%	1%	0%
Driver's License	1%	1%	0%	1%
Left Accident Scene	1%	0%	0%	0%
No Insurance	0%	1%	0%	1%
Other Offense	3%	4%	4%	5%
Total	579	1,427	1,497	24,834

Contributing factors were indicated in 53% of cases for trucks and 67% of cases for other vehicles considering truck-involved injury crashes. Contributing factors for crashes not involving trucks were indicated as a rate similar to the trucks in the truck-involved crashes. The prominence of factors varied by event type and vehicle group. Weather was most frequently reported as a contributing factor for trucks and other vehicles in the truck-involved events at 16% and 15%, respectively. Speed was a contributing factor 10% of the time in truck-involved events, with failure to yield frequency, slightly higher for the other vehicle in truck-involved crashes. Failure to yield was third in rate of occurrence for trucks and other vehicles in the truck-involved crashes. At 16%, it was the most commonly reported contributing factor in crashes not involving trucks. Improper evasive action was the fourth leading contributing factor for trucks, in terms of frequency. It was less important for other vehicles in crashes, regardless of truck involvement. Too fast for conditions, which is typically weather-related, is among the top five contributing factors across vehicles and event types. The contributing factors for other vehicles in the truck-involved events share similar factors as those with no-truck-involved, but the greater occurrence of driving left of center and improper overtaking are concerning in regard to driver decisions when interacting with trucks. While these descriptive statistics offer insight, a multivariate approach to understanding crashes may be useful in better identifying influential factors, given the complex of elements in crash events.

Table 3.5 Contributing Factors Indicated in Injury Crashes, 2010 to 2014

	Truck-Involved Event		No Truck-Involved Event
Contributing Factor	Truck	Other Vehicle	Other Vehicle
None Indicated	*47%*	*33%*	*46%*
Weather	**16%**	**15%**	**8%**
Speed	**10%**	**10%**	**11%**
Failed to Yield	**8%**	**11%**	**16%**
Improper Evasive Action	**7%**	3%	5%
Too Fast for Conditions	**6%**	**9%**	**7%**
Failed to Keep Proper Lane	5%	4%	3%
Following Too Close	5%	**6%**	**8%**
Vision Obstructed	5%	5%	5%
Attention Distracted-Inside	4%	3%	4%
Over-Correcting	4%	1%	2%
Improper Turn	4%	2%	2%
Vehicle Mechanical Failure	3%	0%	1%
Drove Left of Center	2%	**6%**	1%
Defective Equipment	2%	0%	1%
Disregard Traffic Signs	2%	2%	2%
Attention Distracted-Outside	2%	1%	2%
Vehicle Operation Erratic	1%	4%	4%
Improper Overtaking	1%	4%	1%
Ran Red Light	1%	1%	3%
Animal in Roadway	1%	0%	1%
Improper Lane Change	0%	1%	1%
Physical Obstruction	0%	1%	0%
Attention Distracted-Cell	0%	1%	1%
Wrong Way	0%	1%	0%
Other (not specified)	11%	7%	10%
Total Units	2,076	1,427	30,446
Total Citations	1,656	1,494	24,390
Note: Up to three contributing factors may be indicated for each vehicle.			

4. METHOD AND DATA

Truck crashes have been studied from prediction- and factor-influence perspectives. The prediction work relies heavily on event counts or incidence to forecast future events. Factorial analysis, the approach researched here, is the study of crash factors in relation to injury outcomes using a generalized linear model form. Logistic regression analysis is applied in a binary model of risk factors associated with driver injury crash outcomes (Allison1999; Hosmer et al. 2013). With logistic regression, binary values are transformed into logit functions, which take on an infinite value range. The method relies on maximum likelihood estimation, which relaxes normal distribution and equal variance requirements of linear regression analysis.

This model provides measures for predictor variables, while recognizing effects of interactions among terms in relation to the response variable. The resulting log-odds ratios provide an understanding of the role of driver behavior and other factors more likely to result in serious injuries to drivers in truck-involved crashes. This methodology has been applied in other systematic traffic safety assessments and provides valuable quantitative information that may be used in prioritizing activities and designing policies to improve public safety (Kim et al. 1995, Al-Ghamdi 2002, Gonzales et al. 2005, Chandraratna et al. 2006).

The relative likelihood of serious injury in a crash, which is an injury resulting in driver death or disabling injury, is the dependent factor. Driver behavior factors are regressed while controlling for known road, vehicle, and environmental characteristics. Logistic regression is conducted to understand the relationship between predictor driver behavior factors and crash outcomes. The initial step in model development is to define a broad model to capture potentially significant predictor variables, considering previous research and subject matter expert input. Individual parameters are tested to confirm significant relation to the outcome variable. A combination of Stepwise Selection and subject knowledge are then used to define potential models so goodness of fit tests can be used to compare models to a base model, which is intercept-only, and alternative multivariate predictors variations. The goal is to define a parsimonious model that is well fit, considering predictor power.

The observed values of this response variable are compared to the predicted variable obtained in the models with and without the variable in question, based on a log-likelihood function. The logistic model generally is defined as follows:

$$P_n = \frac{e^{g(x)}}{1+e^{g(x)}} \text{, so} \qquad \text{Equation 1}$$

$$P_s = 1 - P_n = 1 - \pi(x) = \frac{1}{1+e^{g(x)}} \qquad \text{Equation 2}$$

P_n = probability of non-severe driver injury in crash, and
P_s = probability of severe or fatal driver injury in crash,
where g(x) includes a set of independent variables related to driver, vehicle, road, and environment in

$$g(x) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n \qquad \text{Equation 3}$$

The dichotomous-dependent variable is defined as driver-serious or non-serious injury. The fatal and disabling crashes are considered serious crashes in this analysis of North Dakota crash data. Driver observations for police-reported injury crashes with truck involvement, between 2009 and 2014, were collected for analysis. The file includes 3,074 drivers, with 82% reportedly multiple-vehicle crashes. The crash events include 593 trucks in single-vehicle crashes, 1,319 trucks in multiple-vehicle crashes and 1,162 other vehicles in the multiple-vehicle crash events.

As mentioned in previous sections, these crash records include information about the driver, environment, vehicle, and roadway. Driver characteristics and behavior related to crash severity outcome are a focus in the model. Design variables are included to account for effects of the environment, vehicle, and roadway characteristics. In addition to crash form records, probabilistic matching was used to assess correlation between the previous three years of traffic citations, impaired driving incidents and crash events as potential predictor variables from the driver record. The driver record information is limited to North Dakota drivers in the crash unit population. None of the driver record variables are retained in the final models.

5. MODEL FITTING AND RESULTS

A descriptive summary in crash severity is the dependent variable. Serious injury outcome is modeled as crashes resulting in fatal and disabling injury to the driver versus a non-disabling injury to the driver. Based on the review of truck crash research and information reported in the state crash form, predictor variables considered for the model are described in Table 5.2.

Table 5.1 shows potential predictor variable frequencies in truck-involved injury crashes. Cells with few observations would be concerning when assessing data available for the models. The only cells with few observations are truck driver alcohol/drug involved in the multiple- and single-vehicle crashes. Alcohol or drug involvement is reported for only 2 of the 1,319 truck drivers in multiple-vehicle crashes and 15 of the 593 single-vehicle truck crash drivers. Generalizations about the population cannot be derived from a model including such few cases. It seems likely the small number of cases is representative of the population, since the truck drivers are well-trained professionals who face serious penalties and loss of employment consequences for alcohol-impaired driving. Therefore, it is not expected that any model bias would be expected with omission of this potential predictor for the truck driver models. In the group of other drivers, the number of cases is sufficient, as indicated by the share of crashes, with 157 cases reporting alcohol- or driver-involved.

Crash severity is the dependent variable. Serious injury outcome is modeled for crashes resulting in fatal and disabling injury to the driver versus a non-disabling injury to the driver. Based on the review of truck crash research and information reported in the state crash form, predictor variables considered for the model are described in Table 5.2.

Table 5.1 ND Truck-Involved Driver Injuries, Rural Injury Crashes

	Driver Type		
	Multiple Vehicle		Single Vehicle
Driver Group	Truck	Other Drivers	Truck Drivers
N	1,319	1,162	593
Driver Serious Injury	4%	28%	12%
Potential Predictor	Share of Driver Injuries		
Driver Age Group			
Under 24 Years	5%	21%	8%
24 to 61 Years	86%	65%	83%
Over 61 Years	10%	14%	9%
No Restraint	12%	30%	36%
Alcohol/Drugs Involved	<1%	14%	3%
Head-On	8%	9%	NA
Sideswipe	17%	14%	NA
Rollover	5%	5%	76%
Distracted	6%	18%	14%
Failure to Yield/Stop	8%	14%	4%
Following too Close	6%	7%	NA
Winter Weather	36%	34%	9%
Intersection	11%	9%	14%
Horizontal Curve	16%	19%	23%
Vertical Curve			
Multiple Trucks in Crash	25%	7%	NA
Oil Region	68%	66%	62%
Truck Body Type			
Dump	13%	NA	13%
Liquid Bulk	32%	NA	43%
Platform	19%	NA	18%
Van Enclosed	19%	NA	12%
Other	16%	NA	14%
Functional Class			
Rural Interstate	12%	14%	6%
Rural Principle Art.	49%	50%	20%
Rural Other State	16%	14%	14%
Rural Local	23%	23%	59%

NA: Not Applicable

Table 5.2 Variable Definitions and Univariate Analysis

Predictor Variable	**Wald P-value[1]**			**Definition from Crash Reporting Form Fields**
	Model 1	Model 2	Model 3	
Driver Age Group	0.147	0.1339	<.0001	23 Years or Younger, 24 to 61 Years, and 62 Years or Older
Safety Restraint	<.0001	<.0001	<.0001	Driver Safety Restraint Yes (=1) or No/Not Used or Improperly Used (=0)
Alcohol or Drugs	0.9898	<.0001	0.2539	Alcohol and/or Other Drugs Present or Citation (=1) or No/Unknown (=0)
Head-On	0.346	0.346	NA	Manner of Collision Head On (=1) or Other
Sideswipe	0.031	0.031	NA	Manner of Collision Sideswipe Same or Opposite Direction (=1) or Other (=0)
Rollover	<.0001	<.0001	0.6946	Crash Events include Rollover(=1) or
Distracted	0.9858	<.0001	0.4565	Distracted Citation Yes (=1) or No (=0)
Speeding or Too Fast for Conditions	0.356	0.5898	0.4113	Exceeding Speed Limit or Driving Too Fast for Conditions Citation and/or Contributing Factor Yes (=1) or No (=0)
Failure to Yield or Stop	0.001	0.0518	0.001	Failure to Yield or Stop Citation and/or Contributing Factor (=1) or No (=0)
Too Close	0.5511	0.4676	NA	Following Too Close Citation and/or Contributing Factor (=1) or No (=0)
Winter Weather	0.0372	<.0001	0.8135	Snow, Blowing Snow, Sleet, Hail, Freezing
Intersection	0.1772	0.9829	0.0066	Yes, Relation to Junction reported at Intersection, Intersection related (=1) or No
Horizontal Curve	0.3297	0.2186	0.0196	Yes, Road Geometrics reported as Curve on
Vertical Curve (Hill)	0.7341	0.8489	0.8356	Road Geometrics reported as Straight on Grade, Curve on Grade or Hill Crest (=1) or
Vehicle Year	0.0101	0.008	0.4212	Vehicle Year for Unit in the Crash Report
Truck Body Type	0.5322	NA	0.3257	Dump, Liquid Bulk Cargo Tank, Flatbed/Platform, Van/Enclosed Box Van, and Other
Two or More Trucks in Crash	<.0001	<.0001	NA	Two or More Large Trucks Involved in the Crash (=1) or One Large Truck Involved (=0)
Oil Region	0.8873	0.0017	0.0833	Crash Occurred in Oil Region (=1) or No
Road Group	0.533	<.0010	0.1251	Functional Class Levels: Rural Interstate Roads, Rural Principal Arterial State Roads, Other Rural State and Rural Local Roads
Traffic Density	0.4385	0.4777	0.6053	County Rural Annual Vehicle Miles Traveled, Standardized by County Area in

[1]P-value is the outcome from univariate logistic regression analysis with each of the potential predictor variables. Variables with a minimum p-value 0.35 are entered into the initial multivariate analysis for

Based on exploratory analysis and discussions with law enforcement, three models were developed to explain factors of multiple- and single-vehicle truck crashes. The multiple-vehicle crash events were parsed to distinguish factors for the trucks from factors for other vehicles. A combined model was tested, but it performed poorly in regard to identifying significant factors. Three models were fitted in the logistic multiple regression analysis to define the most parsimonious model for each crash group: Model 1) other vehicles in multiple-vehicle crashes, Model, 2) trucks in multiple-vehicle crashes and Model, 3) single-vehicle truck crashes. The initial models were defined to include variables based on significant level of entry of 0.35 for the Wald Chi-Square as a univariate predictor for the crash severity outcome (Table 5.2). Predictor variables were examined for multicollinearity in simple pairwise Pearson correlation. No correlations were above 0.70. In addition, predictor variables retained in the final models had Variance Inflation Factors close to 1, indicating no linear relationship between the independent variables that would cause model instability.

Subsequently, the least significant variables that did not meet statistical significance criterion of 0.05 were removed, based on results from several iterations of each model. Individual predictor significance and overall model effectiveness were considered in each iteration to assess the effects, if the least significant variable was removed. The final models, presented in the following section, are the resulting parsimonious models. The models for each of the three crash groups include variables and definitions that best explained likelihood for serious driver injury in truck-involved crashes.

The log likelihood ratio (Likelihood Ratio) global test for parameter significance rejects the null hypotheses that all predictor coefficients are equal to zero for each model (add ref table). In iterations for each model, the parameter-inclusive models were compared to the intercept-only model to gauge predictive efficiency of the model. In addition, a larger generalized R-squared was considered positive in comparing model parameter compositions. The negative twice the log likelihood (-2 Log L) and Swarz Criterion (SC) have substantial reduction across all fitted models when comparing the models with predictor variables to that of the intercept-only models. Specifically, the negative twice the log likelihood (-2 LL) had reductions in Model 1 (null -2LL=450.888, final -2LL=376.60, χ^2=80.23, ρ <.0001), (null -2LL=1374.83, final -2LL=1207.93, χ^2=159.85, ρ <.0001), and Model 3 (null -2LL=407.22, final -2LL=365.30, χ^2=41.92, ρ <.0001). The large number of observations should mitigate potential undue influence for any single observation, however, Standardized Pearson residuals were examined to identify potential outliers and no cases fell outside the -3 to +3 range.

The model is validated in each case with good predictive power indicated in the measures of association. Model 1, the predicted outcome is concordant with the observed event in 73.7% of the cases. The neutral value for this statistic is 50%, where the result would be similar to the flip of a coin. Models 2 and 3 have concordance in 70.8% and 66.5%, respectively. The c-statistic, which accounts for tied results in the predicted probabilities, also was considered to assess the model predictive efficacy. Considering the receiver operating curve (ROC), the predictive power for each model increased substantially compared to the intercept-only model. Increases in the area under the ROC were considered favorable to defining the final models for each crash unit group. The predictive power of Model 1 is the greatest with a ROC=0.7935. The ROC for Model 2 and 3 are ROC=0.7267 and ROC=0.7176, respectively.

Table 5.3 Rural Truck Crash Model Results

	Multiple Vehicle				Single Vehicle	
	Truck Drivers		Other Drivers		Truck Drivers	
	Estimate	SE	Estimate	SE	Estimate	SE
Intercept	-5.7054	0.5089**	-1.7014	0.1640**	-2.4586	0.2783**
No Restraint	1.5664	0.3116**	0.8986	0.1519**	1.0244	0.2680**
Alcohol/Drugs Involved			0.5572	0.2022**		
Head-On	0.8686	0.4852	1.3110	0.2313**		
Sideswipe			-0.4577	0.2272*		
Rollover	1.6337	0.3932**	1.0496	0.2902**		
Distracted			0.3765	0.1904*		
Failure to Yield/Stop	1.0908	0.3906**	0.3558	0.2012	1.4206	0.5887*
Following too Close			0.3648	0.2637		
Weather	-0.9265	0.6142	-0.5132	0.2177*		
Intersection					-1.6587	0.6221**
Curve					0.8126	0.2938**
Multiple Trucks in Crash	1.3552	0.2997**				
Oil Region			0.1653	0.159	0.3653	0.2922
Global Likelihood Ratio	80.2883**		159.8498**		41.9189**	
Swartz Criterion	420.892		1285.563		402.137	
-2 Log L	370.600		1207.926		365.298	
ROC	0.7935		0.7267		0.7176	
***p=0.01* **p=0.05*						

Seat belt use is the single crash factor that is a significant risk factor for all vehicles in the rural truck crashes. The relative risk for serious crash injury is heavily influenced by seat belt use for the single-vehicle truck driver and passenger vehicles in the multiple-vehicle crashes. Truck drivers in single-vehicle crashes without proper restraint are 2.3 times more likely to incur serious injuries than in injury crashes where restraint is used (OR=2.786, 95% CI 1.647, 4.710). Passenger vehicle drivers are 2.2 times more likely to be seriously injured in these crashes when they fail to use proper restraint (OR=2.456, 95% CI 1.824, 3.308). In the multiple-vehicle crashes, truck drivers who fail to use proper restraint are 5.2 times more likely to suffer serious injury than drivers who are properly restrained (OR=4.789, 95% CI 2.600, 8.821). The 95% confidence interval is the range of values that has a 95% certainty to contain the true mean of the population.

Although crash events included only 54 multivehicle events where the truck driver sustained serious injury, driver decisions and vehicle involvement are identified as key factors. Truck driver failure to yield or stop in a multiple-vehicle event is associated with a three-fold increase in likelihood for serious injury compared to events where drivers comply with these traffic rules (OR=2.977, 95% CI 1.384, 6.401. Vehicle composition in these crashes also is relevant to predicting crash outcomes. Trucks involved in multiple vehicle crashes that include other trucks are 3.7 times more likely to incur serious injury compared to crashes involving only a single truck and one or more passenger vehicles (OR=3.877, 95% CI 2.155, 6.976). Truck driver injuries in multiple-vehicle crashes are five times more likely to be serious if a rollover event occurs (OR=5.123, 95% CI 2.370, 11.072). The head-on events and winter weather environment 95% confidence levels include 1.0 so the adjusted odds ratios are not statistically different from 1, but do contribute to the overall model fit.

Passenger vehicles involved in truck crashes had several other significant factors in regard to predicting severity of crash injury considering driver behavior, environmental elements and road features. It is not surprising that with driver distraction reported, the relative risk for serious injury increases 1.7 times (OR=1.457, 95% CI 1.003, 2.116). For crashes where alcohol or drugs are involved, the serious injury outcome is twice as likely for the passenger vehicle (OR=1.746, 95% CI 1.175, 2.5956). Crashes involving a head-on manner of collision had a 3.7 times greater likelihood for serious injury than for crashes involving other collision angles (OR=3.710, 95% CI 2.358, 5.837). Sideswipe collisions have a lower relative risk for serious injury than in other events with other manners of collision. The odds of drivers in sideswipe collisions experiencing serious injury is 0.663 that of the other drivers (OR=0.6330, 95% CI 0.405, 0.988). While the failure to yield/stop, following too close, and oil region location adjusted odds ratios are not statistically different from 1 in the final model, these factors were retained based on their contribution to overall model fit.

Single-vehicle truck crashes shared some significant predictors with the trucks involved in multiple-vehicle crashes. Along with failure to use proper restraint, road crash locations are influential predictors in regard to driver injury. Crashes on a curve have a relative risk 1.7 times greater than the risk on other road locations (OR=2.254, 95% CI 1.267, 4.009). Single-vehicle truck crash events at intersections or intersection-related junctures are 0.19 times less likely to result in serious injury to the driver than crashes at other types of road junctures. The adjusted odds ratio for serious injury risk for oil region crash location is not statistically different from 1 in the final model, but it is retained due to its contribution in overall model fit.

Table 5.4 Rural Truck Crash Log Odds Ratios

	Multiple Vehicle				Single Vehicle	
	Truck		Passenger Vehicle		Truck	
	Log Odds	95% CI	Log Odds	95% CI	Log Odds	95% CI
No Restraint	4.789	2.600-8.821	2.456	1.824-3.308	2.786	1.647-4.710
Alcohol/Drugs Inv.			1.746	1.175-2.595		
Head-On	2.384	0.921-6.169	3.710	2.358-5.837		
Sideswipe			0.633	0.405-0.988		
Rollover	5.123	2.370-11.072	2.857	1.617-5.045		
Distracted			1.457	1.003-2.116		
Failure to Yield/Stop	2.977	1.384-6.401	1.427	0.962-2.117	4.140	1.306-13.124
Following too Close			1.440	0.859-2.415		
Intersection					0.190	0.056-0.644
Curve					2.254	1.267-4.009
Weather	0.396	0.119-1.320	0.599	0.391-0.917		
Multiple Trucks	3.877	2.155-6.976	1.180	0.864-1.611		
Oil Region					1.441	0.813-2.555

6. CONCLUSION

Logistic regression was applied to identify influential factors in the severity of truck-involved crashes on rural roads in North Dakota. Driver records for six years of state crash data were collected for analysis. Refined factor identification was generated in defining models separately for truck drivers in multiple-vehicle crashes, other vehicle drivers in multiple-vehicle crashes, and truck drivers in single-vehicle crashes. Results identify three to seven statistically significant risk factors from among 13 selected for the models. These included: seat belt use, alcohol/drug involvement, head-on collision impact, rollover event, failure to yield/stop, weather, intersection, curve, and multiple-truck involvement.

Seat belt use was the single factor that was statistically significant across all driver groups in regard to increased likelihood for severe driver injury in the truck-involved crashes. Additional research to better characterize these drivers and predict seat beat belt use would be beneficial in a more targeted approach to increasing driver safety. Regarding truck drivers in multiple-vehicle crashes, analysis related to the rollover events and driver decisions in failure to yield/stop would provide additional insight in preventative measures that may be useful in reducing future severe injury incidence.

Other drivers are an important group in this study of truck-involved crashes. These drivers incur severe injury at a greater rate than truck drivers in the truck-involved crashes. Analysis to gain a more granular understanding of the head-on and rollover events show the greatest potential for reducing likelihood for severe injury outcomes to these drivers. Alcohol/drug involvement also is a potential factor for reducing severe injury incidence for other drivers, with driver distraction and failure to yield/stop also statistically significant factors in the increased likelihood for severe injury.

Few variables were statistically significant in predicting likelihood for severe injury to truck drivers in single-vehicle crashes. The limited number of observations and diversity of events produced few viable factors for targeted intervention to reduce likelihood for severe driver injury. In addition to efforts to increase seat belt use, additional study of the failure to yield/stop may produce more information about locations, road features or driver characteristics, which can then be used in a more clinical approach to improve driver adherence to traffic rules. An increased understanding of the increased likelihood for severe injury to drivers in the single-vehicle crashes associated with the curves also may be beneficial in identifying effective intervention or countermeasures.

The oil region location was not a statistically significant factor in any of the final models, but it did improve performance of the models for other drivers and truck drivers in single-vehicle traffic. A more refined metric, in terms of traffic volumes and/or mix not within the bounds of this study, may be useful in measuring risk for this factor.

Identification of factors associated with greater likelihood for severe injury outcomes in truck-involved crashes is important for prioritizing and mobilizing toward improved traffic safety. A sustained increase in statewide traffic and truck traffic likely is compared to flows prior to the late 2000s. Therefore, the truck-centric traffic safety interventions for truck drivers, and drivers who interact with trucks on the state’s roads, is critical to reducing severe driver injuries in the future.

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