Investigation of Gender Differences in Large-Truck Crash Injury Severity in Missouri

Final Report
June 2018

Sponsored by
Midwest Transportation Center
U.S. Department of Transportation
Office of the Assistant Secretary for
Research and Technology

IOWA STATE UNIVERSITY
Institute for Transportation

About MTC

The Midwest Transportation Center (MTC) is a regional University Transportation Center (UTC) sponsored by the U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology (USDOT/OST-R). The mission of the UTC program is to advance U.S. technology and expertise in the many disciplines comprising transportation through the mechanisms of education, research, and technology transfer at university-based centers of excellence. Iowa State University, through its Institute for Transportation (InTrans), is the MTC lead institution.

About InTrans

The mission of the Institute for Transportation (InTrans) at Iowa State University is to develop and implement innovative methods, materials, and technologies for improving transportation efficiency, safety, reliability, and sustainability while improving the learning environment of students, faculty, and staff in transportation-related fields.

ISU Non-Discrimination Statement

Iowa State University does not discriminate on the basis of race, color, age, ethnicity, religion, national origin, pregnancy, sexual orientation, gender identity, genetic information, sex, marital status, disability, or status as a U.S. veteran. Inquiries regarding non-discrimination policies may be directed to Office of Equal Opportunity, 3410 Beardshear Hall, 515 Morrill Road, Ames, Iowa 50011, Tel. 515-294-7612, Hotline: 515-294-1222, email eooffice@iastate.edu.

Notice

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. The opinions, findings and conclusions expressed in this publication are those of the authors and not necessarily those of the sponsors.

This document is disseminated under the sponsorship of the U.S. DOT UTC program in the interest of information exchange. The U.S. Government assumes no liability for the use of the information contained in this document. This report does not constitute a standard, specification, or regulation.

The U.S. Government does not endorse products or manufacturers. If trademarks or manufacturers' names appear in this report, it is only because they are considered essential to the objective of the document.

Quality Assurance Statement

The Federal Highway Administration (FHWA) provides high-quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. The FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle	5. Report Date
Investigation of Gender Differences in Large-Truck Crash Injury Severity in Missouri	June 2018
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Jill M. Bernard Bracy and Christopher Mondy	

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Center for Transportation Studies University of Missouri–St. Louis 240 JCPN, One University Boulevard St. Louis, MO 63121-4400	**11. Contract or Grant No.** DTRT13-G-UTC37

12. Sponsoring Organization Name and Address		13. Type of Report and Period Covered
Midwest Transportation Center 2711 S. Loop Drive, Suite 4700 Ames, IA 50010-8664 University of Missouri –St. Louis One University Boulevard St. Louis, MO 63121-4400	U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology 1200 New Jersey Avenue, SE Washington, DC 20590	Final Report **14. Sponsoring Agency Code**

15. Supplementary Notes

Visit www.intrans.iastate.edu for color pdfs of this and other research reports.

16. Abstract

Large-truck transport is vital for freight shipping in the United States, but it is also a dangerous mode of transportation. From 2002 to 2012, 91,145 crashes involving large trucks occurred in Missouri, resulting in 1,156 fatalities and 18,457 injuries. Many factors contribute to large-truck crash severity, and the authors theorize that these factors and their effect on severity vary as a function of gender. This study uses Missouri crash data from 2002 to 2012 to analyze circumstances that increase the probability of severity, given that a large-truck crash occurs.

The authors developed chi-squared automatic interaction detection (CHAID) decision tree models for each gender to better understand predictor importance and to uncover interactions among contributing factors. Results suggest that the major predictors of severity for female Missouri drivers with a commercial driver's license (CDL) are following too closely, physical impairment, and improper passing, while results suggest that the major predictors of severity for male Missouri CDL drivers are driving too fast for conditions, failing to yield, and physical impairment. Additionally, results do not suggest that environmental factors are significant predictors of severity for female CDL drivers, and road and lighting conditions play a tertiary role in the prediction of severity for male CDL drivers.

As a result, this study recommends that truck driver training programs focus educational efforts on gender-specific behaviors that affect crash injury severity in order to enhance road safety measures.

17. Key Words	18. Distribution Statement
driver gender differences—environmental factors—large-truck crash severity—truck analysis	No restrictions.

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified.	Unclassified.	28	NA

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

INVESTIGATION OF GENDER DIFFERENCES IN LARGE-TRUCK CRASH INJURY SEVERITY IN MISSOURI

Final Report
June 2018

Principal Investigator
Jill M. Bernard Bracy, Assistant Teaching Professor, Marketing
Assistant Director for Program Development, Center for Transportation Studies,
College of Business, University of Missouri–St. Louis

Research Assistant
Christopher Mondy

Authors
Jill M. Bernard Bracy and Christopher Mondy

Sponsored by
University of Missouri–St. Louis,
the Midwest Transportation Center, and
the U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology

A report from
Institute for Transportation
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
Phone: 515-294-8103 / Fax: 515-294-0467
www.intrans.iastate.edu

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

The authors would like to thank the University of Missouri–St. Louis, Midwest Transportation Center, and U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology for sponsoring this research.

INTRODUCTION

Large-truck transport is a vital medium for freight in the United States; however, it is also a dangerous mode of transportation. In a 10-year time span, approximately 400,000 crashes involving large trucks occurred in the US, resulting in more than 4,000 fatalities and 100,000 injuries each year (Javers and Schlesinger 2014). Many factors contribute to large-truck crash severity, and the authors theorize that these factors and their effect on severity vary as a function of gender. Responding to the push to recruit and train new truck drivers to alleviate the current driver shortage, the recognition of gender-specific factors that affect crash severity provides an opportunity for the enhancement of new truck driver training programs.

PRIOR RESEARCH

Much research has been conducted as a result of the devastating effects caused by collisions with large trucks (Zhu and Srinivasan 2011, Islam and Hernandez 2012, Islam and Hernandez 2013, Bunn et al. 2013, Choi et al. 2014, Kin et al. 2014, Islam and Hernandez 2014). For example, Zhu and Srinivasan (2011) developed ordered probit regression models to describe the likelihood of crash severity using data derived from a large-truck crash causation study. Considering human, vehicle, crash, and environmental characteristics, the authors concluded that the greatest dangers in truck crashes resulted from opposing traffic situations and lack of drivers' familiarity with their vehicles (Zhu and Srinivasan 2011). The authors proposed that increased driver training and vehicle familiarization would mitigate injury severity of large-truck crashes. Islam and Hernandez (2013) also employed ordered probit models to classify injury severity of large-truck crashes and found interaction effects between human-factor and vehicle-factor variables. Likewise, the authors suggested that additional research is needed to improve truck driver training.

Focusing on gender differences for truck drivers, Cantor et al. (2010) tested the effect of various factors on the likelihood of future crash involvement using data derived from the Federal Motor Carrier Safety Administration. Results indicated that the likelihood of a crash was significantly different for male and female truck drivers. More recently, Guest et al. (2014) analyzed the effects of gender differences on the crash rate of professional drivers using a negative binomial regression model. Results suggested that seatbelt use, airbag deployment, and driver conditions affect injury severity differently for each gender. The authors concluded that customization of safety features should apply to gender and that additional research in this area should be conducted.

Research using decision tree methodologies has also been undertaken to examine motor vehicle crash severity (Stewart 1996, Bayam et al. 2005, Chang and Wang 2006). For example, Stewart (1996) used classification tree models to predict severe injuries and fatalities in road crashes and concluded that decision trees are a useful tool for such evaluation. Bayam et al. (2005) developed classification and regression tree models to predict the likelihood of a crash based on driver information and environmental circumstances. The authors concluded that the small sample size in their study hindered the predictive power of the model and called for a similar study with a larger sample size. Cheng and Wang (2006) also examined the efficacy of using classification tree models to evaluate traffic crash severity and called for the future use of decision tree models to compare the effectiveness of such models against other forms of statistical models, such as regression and ordered probit models.

This study responds to the call for additional research in large-truck crash severity, gender-specific truck driver training, and the use of decision trees in crash severity analysis by examining differing circumstances that increase the probability of injuries and fatalities for male and female drivers holding a commercial driver's license (CDL) in Missouri.

DATA

The state of Missouri has stringent expectations for its commercial drivers, as outlined in the *Missouri Commercial Driver's License Handbook* and the *Commercial Driver's License Rules of the Road* (Missouri Department of Revenue 2015). After review of the aforementioned guides, drivers undergo a written test specific to the class of license sought. Upon successful completion, a road test that examines vehicle operation capabilities under varying conditions and driving situations, including parking, backing, merging into Interstate traffic, driving through intersections, crossing railroad grades, stopping and starting, and driving in traffic in both rural and urban areas, is required (Missouri Department of Revenue 2015). Ideally, drivers who successfully pass the examination process are proficient at safely operating their vehicles on Missouri roadways.

To assess the proficiency of Missouri CDL drivers on Missouri roadways, this study uses large-truck crash data from 2002 to 2012, obtained from the Missouri State Highway Patrol STARS database, which includes driver characteristics, road conditions, weather conditions, temporal factors, contributing circumstances, and crash injury severity. The Missouri State Highway Patrol reports injury severity using a three-class system—(1) fatality, (2) injury, and (3) property damage only—and determines the class of crash severity by the most severely injured victim of the crash occurrence (Missouri STARS Committee 2012).

Examination of the data indicated that from 2002 to 2012, 91,145 crashes involving at least one CDL driver of a large truck (single-unit truck with two or more axles, truck tractors, and other heavy trucks) occurred in Missouri. Missouri CDL drivers were involved in 61.5% of these crashes and were found to have contributed to 30,904 of these crashes by the reporting patrol officer. Considering only crashes to which a Missouri licensed CDL driver contributed, the frequency of injury severity occurrences by driver gender is provided in Table 1.

Table 1. Occurrences of crash severity by CDL driver gender

	Crash Severity			
Gender	**Fatality**	**Injury**	**Property Damage**	**Total**
Male	207	5,930	23,609	29,746
Female	11	310	762	1,803
Unknown	0	3	72	75
Total	218	6,243	24,443	30,904

In 2014, male drivers held 233,248 or 90% of Missouri CDLs, and female drivers held 25,679 or 10% of Missouri CDLs (Missouri Department of Revenue 2015). Interestingly, as shown in Table 1, female Missouri CDL drivers contributed to only 5.8% of total truck crashes and 5.0% of fatal truck crashes from 2002 to 2012. This represents only 60% of the number of crashes that would be expected from female drivers based on the sample size.

This study analyzes specific contributing circumstances to better understand the underlying factors that contribute to crash injury severity for each gender. After a crash occurs, the circumstances contributing to the crash are determined by the investigating officer from the following list: vehicle defects, improperly stopped on the roadway, driving at a speed that exceeds the limit, driving too fast for conditions, improperly passing, violating a signal or sign, driving on the wrong side of the road when not passing, following too closely, improper signaling, improper backing, improper turn, improper lane usage or change, driving the wrong way on a one-way, improper start from park, improperly parked, failed to yield, alcohol intoxication, drug intoxication, physical impairment, distracted/inattentive, vision obstructed, animal(s) in roadway, other, and unknown, along with the following contributing circumstances added to the STARS database in 2012: driver fatigue/asleep, failed to dim lights, failed to use lights, improper towing/pushing, overcorrected, improper riding, failed to secure load/improper loading, and object/obstruction in roadway. Table 2 provides the frequency of crash injury severity by contributing circumstances by gender. It should be noted that the total number of cases shown does not equal the sum of the frequency of contributing circumstances, since more than one circumstance may be present in a given crash.

Table 2. Frequency of crash severity by contributing circumstance by CDL driver gender

Contributing Circumstance	Crash Severity						Total
	Fatality		Injury		Property Damage		
	Male	Female	Male	Female	Male	Female	
Vehicle Defects	24	2	527	44	2,637	62	3,272
Improperly Stopped	2	0	35	0	141	3	181
Speeding	8	2	51	3	56	4	124
Too Fast for Conditions	46	1	1,181	62	1,179	49	2,518
Improper Passing	3	0	83	3	373	12	474
Violating Stop Sign / Signal	10	0	250	12	307	10	589
Wrong Side	31	3	203	9	462	11	719
Following Too Closely	11	0	942	31	2,103	58	3,145
Improper Signal	0	0	19	1	69	2	91
Improper Backing	4	0	120	4	2,345	65	2,538
Improper Turn	6	0	187	11	2,139	91	2,434
Improper Lane Usage	42	1	799	49	3,507	130	4,528
Wrong Way (One-Way)	0	0	4	0	16	2	22
Improper Start from Park	0	0	6	0	83	2	91
Improperly Parked	0	0	10	1	41	2	54
Failed to Yield	33	0	780	43	1,834	65	2,755
Alcohol	2	0	42	2	43	2	91
Drugs	2	0	11	1	15	0	29
Physical Impairment	5	0	166	7	170	11	359
Distracted/Inattentive	70	5	1,796	75	8,056	240	10,242
Vision Obstructed	64	4	771	57	3,891	132	4,919
Driver Fatigue	0	0	5	0	12	0	17
Failed to Dim Lights	0	0	0	0	0	0	0
Failed to Use Lights	0	0	1	0	0	0	1
Improper Towing / Pushing	0	0	0	0	10	1	11
Overcorrected	2	0	14	2	24	0	42
Improper Riding	0	0	0	0	1	0	1
Failed to Secure Load	0	0	7	0	131	5	143
Animals in Roadway	1	0	40	5	533	27	606
Object in Roadway	0	0	3	0	33	2	38
Other	0	0	23	1	150	9	183
Total	342	18	8,076	423	30,361	997	40,217

METHODOLOGY

To assess the effect of these circumstances on crash severity, this study employed chi-squared automatic interaction detection (CHAID) decision tree models. The decision tree model is organized in a hierarchical structure that consists of a root node, internal nodes, and leaves, and partitions the data set into smaller, more homogenous groups that allow researchers to uncover complex patterns. CHAID decision trees create wider, non-binary trees, often with many terminal nodes connected to a single branch, and prune the decision tree to mitigate overfitting of the model (Bayam et al. 2005). The data are partitioned into a training set and a testing set to test the classification accuracy of the model and to examine for overfitting. Decision trees have several advantages over other techniques, including that nonlinear relationships between variables are examined, missing values are treated as a predictor category and accommodated automatically, the data partitioning yields insights into input/output relationships, and the output is simple to understand and interpret (Bernard 2015).

The cases provided by the Missouri State Highway Patrol that adhered to the following criteria were examined: the person involved in the crash was the driver of a large truck (single-unit truck with two or more axles, truck tractors, and other heavy trucks), held a valid Missouri CDL, and was found by the investigating officer to have contributed to the crash. The data set was partitioned based on gender, and each CHAID was developed using the contributing circumstances previously indicated as the predictor variables for the outcome of crash injury severity on three levels: fatal, injury, and property damage only. The build settings included an absolute value of a minimum of 10 records in the parent branch and a minimum of 5 records in the child branch; both the alpha for splitting and the alpha for merging were set to 0.05; and Pearson was the chi-square method employed. The data set was partitioned into a training set (75%) and a testing set (25%) for model validation and to evaluate model fit. The final model for male Missouri CDL drivers indicated an accuracy of 80.36% and 80.60% for the training set and testing set, respectively. The final model for female Missouri CDL drivers indicated 79.05% and 79.37% for the training set and testing set, respectively, both of which suggest that the models did not overfit the data set.

The predictor importance was calculated for each gender and indicated the relative significance of each circumstance in estimating the model. Figure 1 presents the CHAID model results for male Missouri CDL drivers, and Figure 2 presents the CHAID model results for female Missouri CDL drivers.

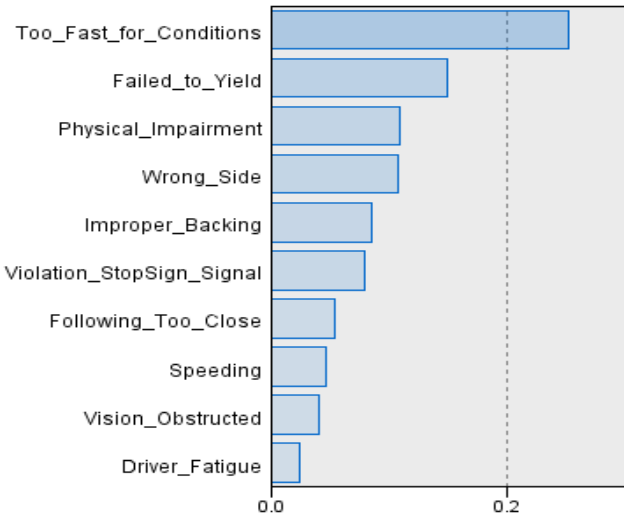


Figure 1. Predictor importance for crash severity for male Missouri CDL drivers

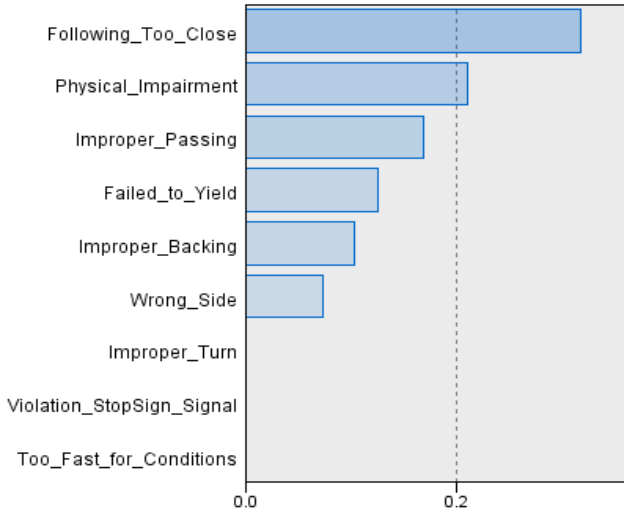
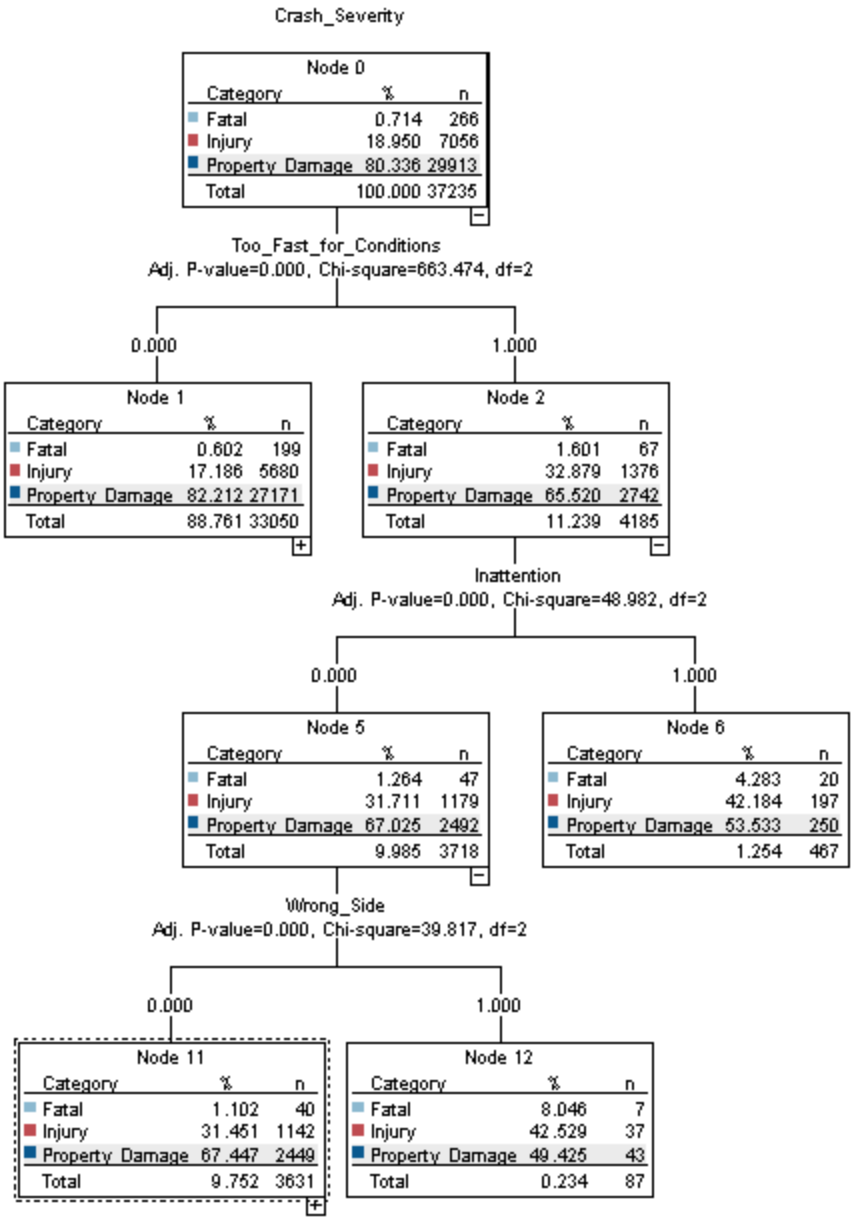


Figure 2. Predictor importance for crash severity for female CDL drivers

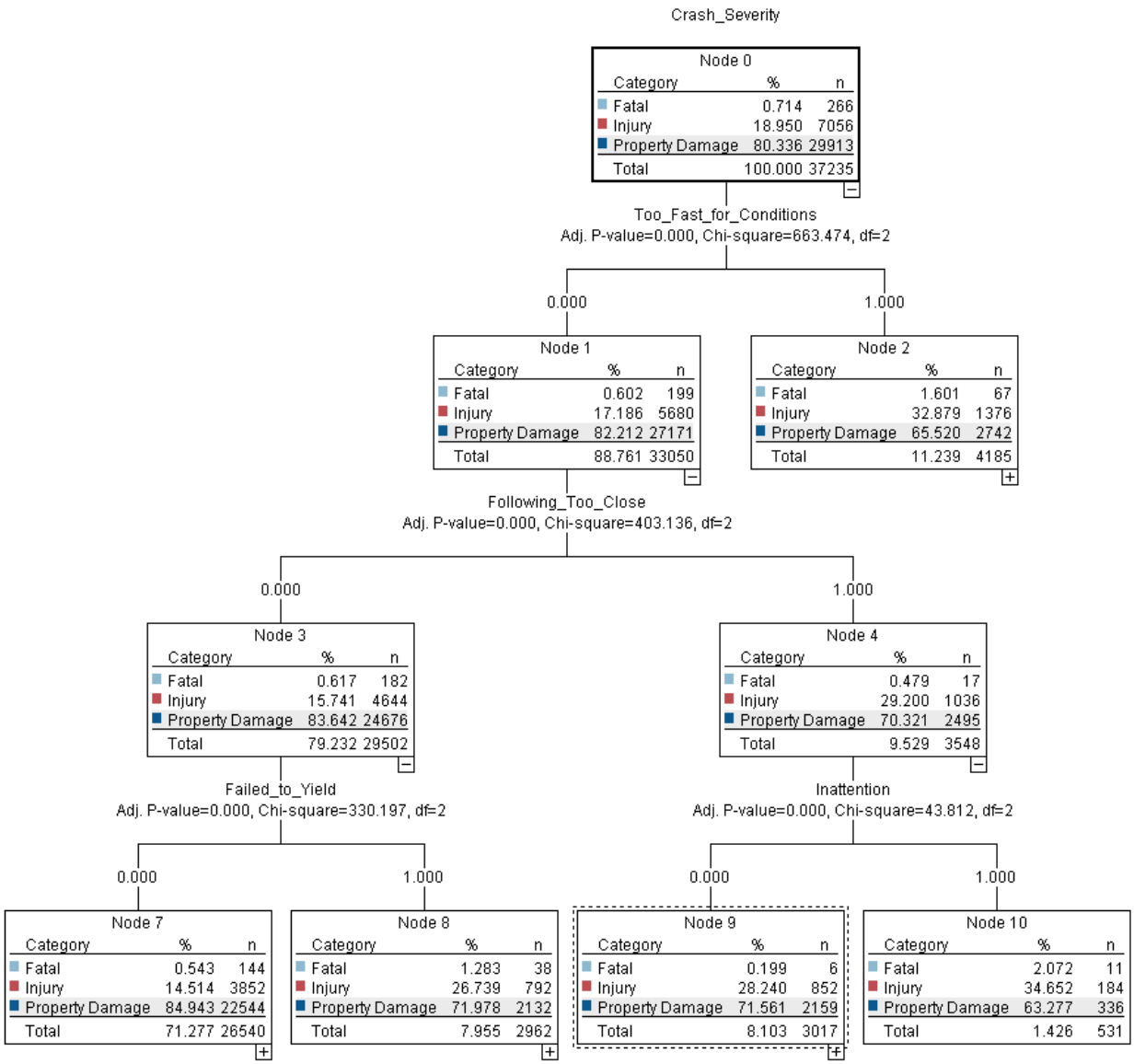
As illustrated in Figure 1, driving too fast for conditions, failing to yield, and physical impairment (which is defined by the Missouri Highway Patrol as having an illness and, prior to 2012, as being fatigued or asleep) have the greatest significance in predicting crash severity for male drivers, whereas for female drivers, as illustrated in Figure 2, following too closely, physical impairment, and improper passing have the greatest significance in predicting crash severity.

The CHAID results for male CDL drivers are presented in Figure 3 and Figure 4.



Note: Only a portion of the decision tree is shown

Figure 3. CHAID decision tree model results for male Missouri CDL drivers when driving too fast for conditions is present



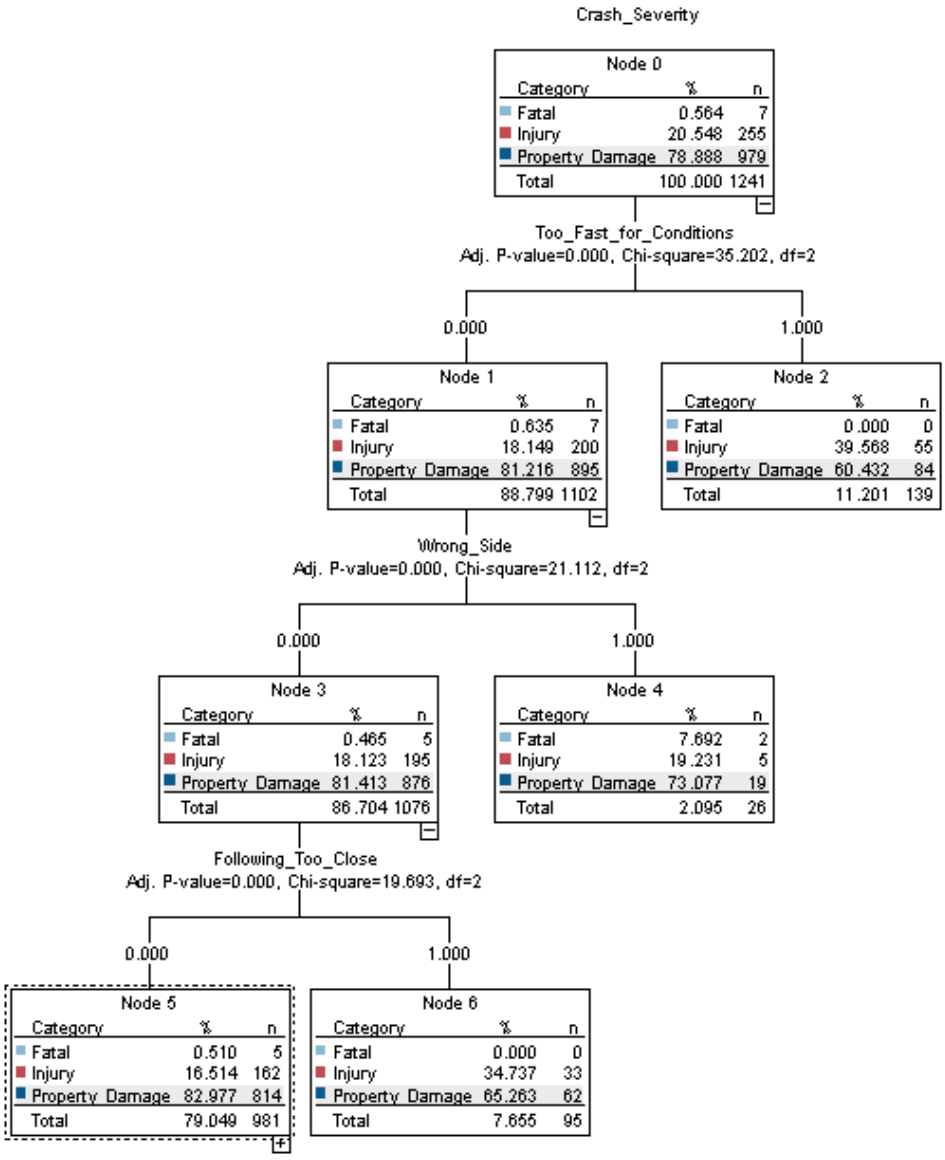
Note: Only a portion of the decision tree is shown

Figure 4. CHAID decision tree model results for male Missouri CDL drivers when driving too fast for conditions is not present

Each tree illustrates that the root node split for male CDL drivers is the explanatory variable of driving too fast for conditions. The number 1.000 indicates that the circumstance is present, and, as illustrated in Figure 3, when driving too fast for conditions is present, a 1.6% chance of a fatal outcome and a 32.9% chance of an injury outcome exist. Yet, when adding the presence of distraction/inattention to driving too fast for conditions, the chances of a fatal outcome or injury outcome increase to 4.3% and 42.2%, respectively. Additionally, when the contributing factors of driving too fast for conditions while on the wrong side of the road (e.g., head-on collisions) are present, the chance of a fatal outcome jumps to 8.1%. When driving too fast is not a contributory crash factor, as illustrated in Figure 4, but the driver is following too closely to

another vehicle while not paying attention, the probability of a fatal outcome is 2.1% and the probability of an injury outcome is 34.7%.

When considering female CDL drivers, as illustrated in Figure 5, the root node split is also the variable of driving too fast for conditions.



Note: Only a portion of the decision tree is shown

Figure 5. CHAID decision tree model results for female Missouri CDL drivers

When this circumstance is present, a 39.6% probability of an injury outcome exists. When driving too fast for conditions is not a contributory factor, yet driving on the wrong side of the road is present, the chance of an injury outcome decreases to 19.2%, while the chance of a fatal outcome increases to 7.7%. Interestingly, the CHAID model does not suggest interaction effects

between the explanatory factors. Therefore, it appears that the contributing circumstances for crashes involving female CDL drivers affect crash severity in isolation.

ENVIRONMENTAL FACTORS

In addition to the effect of behaviors on crash severity, it is important to consider how environmental factors affect the outcome of a crash depending on CDL driver gender. Prior research has examined the effect of environmental circumstances on large-truck crash rates and large-truck crash severity. For instance, Young and Leisman (2007) developed a binary logistic model to investigate the effect of wind speed on overturning trucks in Wyoming. Their findings suggested that icy road conditions significantly reduce the rate of an overturned truck, which the authors attributed to drivers using slower speeds on icy roads. Additionally, Islam and Hernandez (2013) examined large-truck crashes using ordered probit models and evaluated the effect of lighting conditions on crash severity probability. Their results suggested that 76.2% of crashes that occur in dark conditions have a probable outcome of less severe injuries, which was attributed to truck drivers being more cautious during poor lighting conditions. Islam et al. (2014) developed a mixed logit model to examine large-truck crashes on rural and urban roadways in Alabama. The authors estimated four separate models: single-vehicle rural, multivehicle rural, single-vehicle urban, and multivehicle urban; results indicated that environmental characteristics generally exhibited a weak positive effect on the likelihood of a fatal crash. The authors concluded that time of day had weakest effect in the single-vehicle rural model and wet curve had the strongest effect in the multivehicle rural model.

To expand upon current literature, this study expanded the CHAID models presented above to address the effect of environmental circumstances on large-truck crash severity as a function of gender. The authors estimated CHAID models for male and female truck drivers using the build requirements described above and included the aforementioned contributing circumstances and environmental factors as explanatory variables. The environmental factors are presented in Table 3.

Table 3. Environmental factors included as explanatory variables

Lighting Conditions		
Daylight	Dark - Streetlights On	Dark - Streetlights Off
Dark - No Streetlights	Indeterminate	Unknown
Weather Conditions		
Clear	Cloudy	Rain
Snow	Sleet	Freezing
Fog/Mist	Indeterminate	
Road Characteristics		
Road Surface		
Concrete	Asphalt	Brick
Gravel	Dirt/Sand	Multi-Surface
Road Conditions		
Dry	Wet	Snow
Ice/Frost	Mud	Slush
Standing Water	Moving Water	Other
Road Alignment		
Straight	Curve	Unknown
Road Profile		
Level	Hill/Grade	Crest
Unknown		

The explanatory variables presented in Table 4 were found to be statistically significant at the 0.05 level and are included in the model estimation for male CDL drivers.

Table 4. Explanatory variables found to be statistically significant for male Missouri CDL drivers

Contributing Circumstances	Environmental Factors
Vehicle Defects	Light Conditions
Too Fast for Conditions	Road Alignment
Wrong Side	Road Conditions
Following Too Closely	
Improper Turn	
Improper Lane Usage	
Failed to Yield	
Physical Impairment	
Inattention	
Violation of Stop Sign/Signal	
Vision Obstructed	

The explanatory variables presented in Table 5 were found to be statistically significant at the 0.05 level when estimating the model for female CDL drivers. As presented in Table 5, no

environmental variables were found to be statistically significant, and model results remain unchanged.

Table 5. Explanatory variables found to be statistically significant for female Missouri CDL drivers

Contributing Circumstances	Environmental Factors
Failed to Yield Following Too Closely Improper Backing Improper Passing Improper Turn Inattention Physical Impairment Too Fast for Conditions Violation of Stop Sign/Signal Wrong Side	

The CHAID model for male Missouri CDL drivers renders a classification accuracy of 80.35% and 80.61% for the training and testing sets, respectively. This slight increase in accuracy for the testing set over the previous model suggests that environmental factors have a marginal effect on the crash severity outcome and that the crash severity outcome is largely dependent on the other factors involved. For example, results suggest that for male Missouri CDL drivers, environmental factors interact with behaviors at the secondary level when an interaction is indicated between driving too fast for conditions and road conditions. Interestingly, results suggest that lighting conditions affect crash severity throughout the tree if a male CDL driver is driving too fast for conditions or driving on the wrong side of the road. However, findings do not indicate any environmental predictor to be greatly important (see Figure 6).

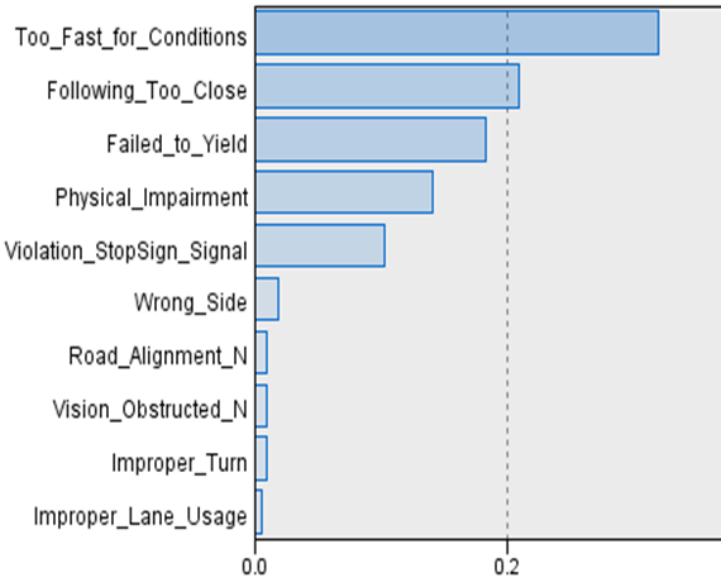


Figure 6. Predictor importance for crash severity with environmental factors for male Missouri CDL drivers

With the driver shortage and anticipated recruitment push, it is important to understand the danger that inclement environmental factors pose to truck drivers and motorists as they share the roadway. An improved understanding of how environmental factors affect crash outcomes will help educational programs better train the next generation of truck drivers to safely handle dangerous environmental conditions.

CONCLUSIONS

This analysis uncovers the differing factors that affect crash injury severity as a function of CDL drivers' gender so as to improve training programs and enhance driver safety. For example, the most significant predictors when modeling crash injury severity for male Missouri CDL drivers were found to be driving too fast for conditions and failing to yield, which contrasts with the top predictors for female Missouri CDL drivers of following too closely and physical impairment. This suggests that for male CDL training, aggressive driving behaviors should be highlighted, while female CDL training should highlight proper distance between vehicles and the importance of avoiding driving while ill or fatigued. Such a customized approach has a greater potential to graduate safer truck drivers than previous driver education curricula.

Additionally, the CHAID model results for male and female Missouri CDL drivers suggest differences in crash predictors and interactions effects. For instance, the results for female CDL drivers did not identify interaction effects among variables. Conversely, the model results for male CDL drivers indicated many interaction effects, with the most prominent interaction occurring when driving too fast for conditions on the wrong side of the road was present. As a result, future education programs for male drivers should incorporate training that focuses on the interaction of behaviors rather than addressing issues in isolation.

Results suggest that environmental factors have a marginal effect on crash injury severity, which supports the findings of prior research. While the findings of the present study indicate that lighting, weather, and road characteristics are not significant in predicting the severity of crashes involving female Missouri CDL drivers, results do suggest that light conditions, road conditions, and road alignment are significant yet marginal in predicting the severity of crashes involving male Missouri CDL drivers.

LIMITATIONS AND FUTURE RESEARCH

The major limitation of this analysis is the small sample size of female drivers, and future research may mitigate this by combining sources of data. Additionally, crash severity analysis may be broadened to states surrounding Missouri to increase the sample size as well as increase driver safety endeavors. Since many truck drivers cross state borders on a regular basis, broadening the crash data analysis could allow for enriched policy recommendations grounded upon differing state laws and requirements. However, while policy and procedure guidelines enhance standardization, many of the crash report data are subjective and are based on the discretion of the investigating officer; this subjectivity makes a true comparison of objective facts difficult. Finally, additional assessment of the impact of differing environmental conditions on the severity of crashes involving Missouri CDL drivers in Missouri and bordering states could enhance Missouri CDL education.

REFERENCES

Bayam, E., J. Liebowitz, and W. Agresti. 2005. Older drivers and accidents: A meta-analysis and data mining application on traffic accident data. *Expert Systems with Applications*, Vol. 29, No. 3, pp. 598–629.

Bernard, J. 2015. An application of data analytics to outcomes of Missouri motor vehicle crashes, PhD dissertation. University of Missouri, St. Louis, MO.

Bunn, T., S. Slavova, and M. Robertson. 2013. Motor Vehicle Injuries among Semi Truck Drivers and Sleeper Berth Passengers. *Journal of Safety Research*, Vol. 44, pp. 51–55.

Cantor, D. E., T. M. Corsi, C. M. Grimm, and K. Özpolat. 2010. A Driver Focused Truck Crash Prediction Model. *Transportation Research Part E: Logistics and Transportation Review*, pp. 683–692.

Chang, L. and H. Wang. 2006. Analysis of traffic injury severity: An application of non-parametric classification tree techniques. *Accident Analysis & Prevention*, Vol. 38, No. 5, pp. 1019–1027.

Choi, S., C. Oh, and M. Kim. 2014. Risk Factors Related to Fatal Truck Crashes on Korean Freeways. *Traffic Injury Prevention*, Vol. 15, No. 1, pp. 73–80.

Guest, M., M. Boggess, and J. Duke. 2014. Age Related Annual Crash Incidence Rate Ratios in Professional Drivers of Heavy Goods Vehicles. *Transportation Research Part A: Policy and Practice*, Vol. 65, pp. 1–8.

Islam, M. and S. Hernandez. 2012. 1 Multi - Vehicle Collisions Involving Large Trucks on Highways: An Exploratory Discrete Outcome Analysis. *Journal for the Transportation Research Forum*, Vol. 54, No, 1.

Islam, M. and S. Hernandez. 2013. Large Truck–Involved Crashes: Exploratory Injury Severity Analysis. *Journal of Transportation Engineering*, Vol. 139, No. 6, pp. 596–604.

Islam, M. and S. Hernandez. 2014. Modeling Injury Outcomes of Crashes Involving Heavy Vehicles on Texas Highways. *Proceedings of the Transportation Research Board Annual Meeting*, Washington, DC.

Islam, S., S. L. Jones, and D. Dye. 2014. Comprehensive Analysis of Single- and Multi-Vehicle Large Truck At-Fault Crashes on Rural and Urban Roadways in Alabama. *Accident Analysis & Prevention*, Vol. 67, pp. 148–158.

Javers, E. and J. Schlesinger. 2014. *Truck Accidents Surge, But There's No National Outcry*. Information and data available on NBC News website: https://www.nbcnews.com/business/autos/truck-accidents-surge-theres-no-national-outcry-n168346.

Kin, X, K. Wang, and C. Cutler. 2014. Logistic Regression Models of the Safety of Large Trucks. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2392, pp. 1–10.

Missouri Department of Revenue. 2015. *Commercial Drivers*. https://dor.mo.gov/drivers/commercial/.

Missouri STARS Committee. 2012. *Missouri Uniform Crash Report Preparation Manual, Main Page - Engineering Policy Guide*. http://epg.modot.org/files/1/11/907.4_MUARP.pdf.

Stewart, J. R. 1996. Applications of classification and regression tree methods in roadway safety studies. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 1542, No. 1, pp. 1–5.

Young, R. K. and J. Liesman. 2007. Estimating the Relationship between Measured Wind Speed and Overturning Truck Crashes Using a Binary Logit Model. *Accident Analysis & Prevention*, Vol. 39, No. 3, pp. 574–80.

Zhu, X. and S. Srinivasan. 2011. A Comprehensive Analysis of Factors Influencing the Injury Severity of Large-Truck Crashes. *Accident Analysis & Prevention*, Vol. 43, No. 1, pp. 49–57.

THE INSTITUTE FOR TRANSPORTATION IS THE FOCAL POINT FOR TRANSPORTATION AT IOWA STATE UNIVERSITY.

InTrans centers and programs perform transportation research and provide technology transfer services for government agencies and private companies;

InTrans manages its own education program for transportation students and provides K-12 resources; and

InTrans conducts local, regional, and national transportation services and continuing education programs.

IOWA STATE UNIVERSITY

Visit www.InTrans.iastate.edu for color pdfs of this and other research reports.