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Weather impacts on single-vehicle truck crash injury severity

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ABSTRACT

Introduction: The focus of this paper is on illustrating the feasibility of aggregating data from disparate sources to investigate the relationship between single-vehicle truck crash injury severity and detailed weather conditions. Specifically, this paper presents: (a) a methodology that combines detailed 15-min weather station data with crash and roadway data, and (b) an empirical investigation of the effects of weather on crash-related injury severities of single-vehicle truck crashes. *Method:* Random parameters ordinal and multinomial regression models were used to investigate crash injury severity under different weather conditions, taking into account the individual unobserved heterogeneity. The adopted methodology allowed consideration of environmental, roadway, and climate-related variables in single-vehicle truck crash injury severity. *Results and conclusions:* Results showed that wind speed, rain, humidity, and air temperature were linked with single-vehicle truck crash injury severity. Greater recorded wind speed added to the severity of injuries in single-vehicle truck crashes in general. Rain and warmer air temperatures were linked to more severe crash injuries in single-vehicle truck crashes while higher levels of humidity were linked to less severe injuries. Random parameters ordered logit and multinomial logit, respectively, revealed some individual heterogeneity in the data and showed that integrating comprehensive weather data with crash data provided useful insights into factors associated with single-vehicle truck crash injury severity. *Practical applications:* The research provided a practical method that combined comprehensive 15-min weather station data with crash and roadway data, thereby providing useful insights into crash injury severity of single-vehicle trucks. Those insights are useful for future truck driver educational programs and for truck safety in different weather conditions.

1. Introduction

The U.S. population is growing, accompanied with an increase in the consumption of goods—trends that have increased the demand for transportation. The U.S. transportation system moved 16 billion tons of goods in 2009, a quantity that is expected to increase to 27 billion tons by 2040 (U.S. Dept. of Commerce, 2012). Trucks are one of the dominant modes of freight transportation; nearly all goods consumed in the U.S. are transported by truck at some point. Substantial volumes of truck traffic, coupled with the large size and unique operational characteristics, contribute to crashes, injuries, and fatalities reported on U.S. highways. According to the National Highway Traffic Safety Administration (NHTSA), 3380 persons were killed and 74,000 injured as a result of the 286,000 police-reported truck crashes in 2009 (NHTSA, 2009). According to records obtained from the Nebraska Department of Roads (NDOR), a total of 2017 truck-involved crashes were reported in 2011, resulting in 33 fatalities and approximately 944 injuries. Such statistics underscore the need to further investigate truck-involved crashes at both the national and state levels.

The focus of this paper is on illustrating the feasibility of combining data from disparate sources to investigate the relationship between detailed weather conditions (recorded by weather stations and reported in 15-min intervals) and injury severities in single-vehicle truck crashes. Specifically, this paper presents: (a) a methodology that combines detailed 15-min weather station data with crash and roadway data, and (b) an empirical investigation of the effects of weather on crash-related injury severities of single-vehicle truck crashes. The adopted methodology allowed consideration of environmental, roadway, and climate related variables—wind speed was considered ranging from 0 to 60 mph, relative humidity from 0% to 100%, temperature from −16 °F to 100 °F, and weather (at the time of the crash) in eight different categories (e.g., rain, snow, clear).

The organization of the remainder of the study is as follows. Section 2 presents the reviewed literature and Section 3 describes collected data and the methodology for combining weather data with

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crash and roadway data. Section 4 introduces summary statistics for the data and regression models used in the analysis. Section 5 provides the crash injury severity modeling and results. A discussion of the results and conclusions are offered in Section 6.

2. Literature review

In comparison with passenger vehicles, freight trucks are large, have unique operational characteristics, and have a relatively higher center of gravity. Because of the larger size and higher center of gravity, trucks are more susceptible to weather-involved crashes such as rollovers due to high winds. As a consequence, several State Departments of Transportation (DOTs, e.g., Idaho DOT, Montana DOT, and Nevada DOT) alert truck drivers when high wind and/or winter weather conditions are detected within their jurisdictions (Goodwin, 2003).

From a methodological standpoint, a variety of research has been dedicated to modeling crash frequency and injury severity as related specifically to single vehicle truck crashes. Table 1 provides a summary of these previous studies in terms of research contribution, models used, and specific variables included (independent and dependent). Three general observations can be made from Table 1. First, there are limited studies that have explicitly considered some kind of weather information (i.e., Chen, Cai, & Wolshon, 2009; Mulinazzi et al., 2009; Rescot, Jasrotia, Hovey, Li, & Schrock, 2009; Young & Liesman, 2007). Second, in most of the studies that considered weather conditions, weather information was extracted from police crash reports. Weather information on a crash report may be subject to accuracy issues as the recorded conditions may be what were perceived by the person filling the crash report and not the actual weather conditions at the time of crash. Additionally, weather information on almost all crash reports is general in nature and frequently does not quantify or categorize magnitudes of weather conditions. As an example, Kecojevic and Radomsky (2004) and Chen et al. (2009) reported a positive relationship between wind and truck crashes. However, the wind condition (available from crash investigation reports) was stated simply as “windy” rather than as a specific speed (or range) in miles per hour.

Third, the studies that considered weather conditions at a categorized magnitude focused on investigating the relationship between weather conditions (mostly wind) and crash types. Young and Liesman (2007) employed a binary logit model to estimate the impact of wind speed on truck overturning crashes using weather data collected from local weather stations. Results showed that weather station data could be used as a predictor of overturning type truck crashes. However, the authors did not investigate a relationship between wind speed and

Table 1
Crash and injury severity studies of single vehicle truck crashes.

Authors	Research highlights	Model type	Independent	Dependent
Joshua and Garber (1990)	Established relationships between the number of truck-involved accidents per year at a section of highway with traffic and geometric variables	Multiple linear regression, Poisson regression	Traffic characteristics, geometric characteristics	Crash rates
Miaou, Hu, Wright, Rathi, and Davis (1992)	Established empirical relationships between the number of truck-involved accidents per year with traffic and geometric variables	Poisson regression	Traffic characteristics, geometric characteristics	Crash rates
Miaou (1994)	Evaluated the performance of regression models in establishing relationship between truck crashes and geometric design of road sections	Poisson regression, zero-inflated Poisson, negative binomial max likelihood	Traffic characteristics, geometric characteristics	Crash rates
Chang and Mannering (1999)	Established relationship between the vehicle occupant injury severity and vehicle occupancy and assessed most severely injured occupant differences between truck and non-truck crashes	Nested logit	Roadway conditions, traffic characteristics, driver characteristics	Injury severity
Duncan, Khattak, and Council (1999)	Examined the impact of various factors on injuries to passenger car occupants and explored factors influencing injury levels in rear-end collisions	Ordered probit	Roadway conditions, traffic characteristics, driver characteristics	Injury severity
Khattak, Schneider, and Targa (2003)	Attempted to understand how truck driver behaviors, vehicle factors and crash events influence large-truck rollovers and occupant injuries in single-vehicle crashes	Binary probit	Crash characteristics, vehicle characteristics, driver characteristics	Injury severity
Golob and Regan (2004)	Examined the conditions on freeway locations that were linked to truck-involved crash rates	Binomial logit	Roadway conditions, traffic characteristics, driver characteristics	Crash frequency
Hiselius (2004)	Established a relationship between accident frequency and traffic flow on Swedish rural roads	Poisson regression, negative binomial	Traffic flows	Crash frequency
Khorashadi, Niemeier, Shankar, and Mannering (2005)	Explored the differences between urban and rural driver injuries (both passenger-vehicle and large-truck driver injuries) in crashes that involve large trucks	Multinomial discrete probability	Geometric characteristics	Injury severity
Young and Liesman (2007)	Develops a quantitative model that correlates overturning freight vehicle crash records in Wyoming to measured wind speeds at nearby weather stations	Binary logit	Crash characteristics, wind data	Crash rates
Mulinazzi et al. (2009)	Explored the development of a model that could predict the likelihood of wind induced truck crashes	Multivariate linear regression	Crash characteristics, traffic data, wind data	Crash rates
Rescot et al. (2009)	Explored the development of a model that could predict the likelihood of wind-induced truck crashes	Multivariate linear regression	Crash characteristics, traffic data, wind data	Crash rates
Zhu and Srinivasan (2011)	Undertook an extensive analysis of the empirical factors affecting injury severity of large-truck crashes	Ordered probit	Crash characteristics, vehicle characteristics, driver characteristics	Injury severity
Lemp, Kockelman, and Unnikrishnan (2011)	Studied the impact of vehicle, occupant, driver, and environmental characteristics on injury outcomes for those involved in crashes with heavy-duty trucks	Ordered probit, heteroskedastic ordered probit	Crash characteristics, vehicle characteristics, driver characteristics	Injury severity
Qin, Wang, and Cutler (2013)	Identified the key contributing factors to the severity of crashes involving large trucks and to explore the relationship between the factors	Logistic regression	Crash characteristics, vehicle characteristics, driver characteristics	Injury severity
Cerwick, Gkritza, Shaheed, and Hans (2014)	Investigated the differences between two preferred methods for accommodating individual unobserved heterogeneity in exploring the relationship between heavy truck crash severity and its contributing factors	Mixed logit outcome, latent class method	Crash characteristics, vehicle characteristics, driver characteristics	Injury severity