



Characterizing commercial vehicle safety in rural Montana
by Patricia Walsh Burke

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering

Montana State University

© Copyright by Patricia Walsh Burke (2001)

Abstract:

This investigation focused on characterizing commercial vehicle safety in rural Montana on the basis of driver, vehicle, cargo, carrier, operating environment and crash characteristics using advanced statistical modeling methods. Montana, like other rural states experiences unique challenges in regards to commercial vehicle safety. Crashes typically involve a single vehicle, occur at higher speeds, are more severe and take longer to be detected.

In order to address these challenges, researchers utilized statistical modeling to characterize commercial vehicle safety levels on the basis of the various characteristics. Model interpretation was intended to assist public agencies in focusing scarce regulatory and enforcement resources on commercial vehicles highest at-risk for safety-related problems. The agencies would then be able to perform their duties more effectively and efficiently by addressing safety problems in a preventative rather than reactionary manner. An ordered probit model was used to model the 6524 crashes that took place over a seven-year period.

The results of this investigation were directly interpretable in regards to magnitude and direction. Independent variables that were found to have a significant influence on the severity of a crash included driver characteristics (age, condition-normal, condition-asleep, driver state residence), vehicle characteristics (vehicle configuration-single unit 2-axle), cargo characteristics (household goods), carrier characteristics (carrier physical address-Canadian Territories, number of trip leased and intrastate drivers, latest review-compliance review), operating environment characteristics (crash years 1996-1999, crash months-July, August, September and December, crash time-9am to 10am, light conditions-dark but lit) and crash characteristics (number of vehicles involved, specific crash counties). In addition, utilizing the ordered probit method to model crash severity proved to be successful as the significance of the variables were high as denoted through t-statistics and the overall goodness of fit was good ($p^2 = 0.57$).

In conclusion, focusing enforcement efforts toward variables that were found to increase the severity of a crash including specific driver state residences, vehicle configurations, carrier physical addresses, number of trip-leased drivers and the months of July, August, September and December would be the most effective and efficient method to improve commercial vehicle safety in Montana.

CHARACTERIZING COMMERCIAL VEHICLE SAFETY
IN RURAL MONTANA

by

Patricia Walsh Burke

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Civil Engineering

MONTANA STATE UNIVERSITY – BOZEMAN
Bozeman, Montana

April 2001

© COPYRIGHT

by

Patricia Walsh Burke

2001

All Rights Reserved

APPROVAL

X1378
B91729

of a thesis submitted by

Patricia Walsh Burke

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

Dr. Jodi L. Carson

Jodi L. Carson
(Signature)

4/18/01
Date

Approved for the Department of Civil Engineering

Dr. Donald Rabern

Don Rabern
(Signature)

4/18/01
Date

Approved for the College of Graduate Studies

Dr. Bruce McLeod

Bruce L. McLeod
(Signature)

4-18-01
Date

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University – Bozeman, I agree that the library shall make it available to borrowers under rules of the Library.

If I have indicated my intention to copyright this thesis by including a copyright notice page, copying is allowable only for scholarly purposes, consistent with "fair use" as prescribed in the U.S. Copyright Law. Requests for permission for extended quotation from or reproduction of this thesis (paper) in whole or in parts may be granted only by the copyright holder.

Signature



Date

April 18, 2001

ACKNOWLEDGEMENTS

I would like to thank my committee members: Jodi Carson, John Mounce and Jerry Stephens for their guidance, interest and encouragement in this research project. In addition, a special thanks to the Western Transportation Institute and its staff for their assistance in completing this research project and for sponsoring the Fellowship. Additionally, thanks are extended to two WTI undergraduates, who played a role in this project; Ryan Bylsma and Aaron Townsend.

Completion of this degree is due in part to the influential role of Dr. Jodi Carson. Her support and guidance were invaluable. I feel fortunate to have had the opportunity to work with such a talented engineer.

I would also like to thank my parents for their encouragement and support to pursue higher education for both my undergraduate and masters' degree.

Lastly, I would like to thank my husband Sean, who supported me throughout the course of my advanced degree and this thesis project during the first two years of our marriage. His continued encouragement and unending support made this thesis possible. Thank you.

TABLE OF CONTENTS

1. INTRODUCTION.....	1
Problem Description.....	3
Uniqueness of Montana's Commercial Vehicle Crashes.....	5
Vehicular Involvement.....	5
Speed.....	6
Severity.....	8
Description of the Study Area.....	9
Demographics.....	9
Economy.....	10
Roadways and Trade Corridors.....	10
Existing Efforts to Improve Commercial Vehicle Safety.....	12
Motor Carrier Safety Assistance Program (MCSAP).....	13
Roadside Inspections.....	15
LEVEL I: North American Standard (NAS) Inspection.....	15
LEVEL II: Walk-Around Driver/Vehicle Inspection.....	15
LEVEL III: Driver-Only Inspection.....	17
LEVEL IV: Special Inspections.....	17
LEVEL V: Vehicle-Only Inspection.....	17
LEVEL VI: Enhanced NAS Inspection for Radioactive Shipments.....	17
Inspection Selection System (ISS).....	18
Compliance Reviews.....	19
Safety Status Measuring System (SAFESTAT).....	20
Performance and Registration Information Systems Management (PRISM).....	21
Educational Contacts.....	23
Data Management.....	24
SAFETYNET.....	24
Motor Carrier Management Information System (MCMIS).....	25
National Highway Traffic Safety Administration.....	25
Implications for this Investigation.....	26
2. LITERATURE REVIEW.....	28
Driver Characteristics.....	28
Driver Fatigue.....	29
Age and Experience.....	37
Driver Condition.....	38
Vehicle Characteristics.....	39
Vehicle Configuration.....	41

Size and Weight	52
Vehicle Design	53
Mechanical Condition	53
Cargo Characteristics	55
Carrier Characteristics.....	55
Operating Environment.....	56
Crash Characteristics.....	61
Implications for this Investigation.....	62
3. METHODOLOGY.....	65
Data Collection.....	66
Data Sources.....	66
Data Elements	67
Data Collection Challenges.....	69
Crash Data.....	69
Carrier Data.....	70
Interstate Carrier Information.....	70
Intrastate Carrier Information.....	71
Review of Previous Methods	71
Univariate Methods	72
Multivariate Methods	73
Log-linear Methods	73
Logit Models	73
Ordered Probit Models.....	74
Recommended Methodology	75
Model Development.....	76
Overall Goodness of Fit	77
Significance of Model Variables.....	77
Implications for this Investigation.....	78
4. RESULTS.....	79
Descriptive Statistics.....	79
Driver Characteristics.....	79
Vehicle Characteristics.....	81
Carrier Characteristics.....	81
Operating Environment Characteristics	86
Crash Severity Model.....	94
Significant Factors Affecting Commercial Vehicle Severity.....	95
Driver Characteristics.....	95
Vehicle Characteristics.....	98

Cargo Characteristics	99
Carrier Characteristics.....	99
Crash Characteristics.....	101
Overall Model Goodness of Fit.....	103
Implication of Findings for Safety Monitoring Efforts.....	104
5. CONCLUSIONS AND RECOMMENDATIONS	106
State of the Practice.....	106
Investigation Challenges	108
Appropriateness of Methodology.....	109
Recommendations for Implementation.....	110
REFERENCES.....	112

LIST OF TABLES

Table	Page
1. North American Driver/Vehicle Inspections.....	16
2. Literature Related to Driver Characteristics.....	30
3. Literature Related to Vehicle Characteristics.....	40
4. Comparative Studies of Singles versus Doubles.....	43
5. Comparative Studies of Single versus Double Crash Severities.....	50
6. Literature Related to Operating Environment.....	57
7. Combined Data Elements.....	68
8. Ordered Probit Model Results.....	96

LIST OF FIGURES

Figure	Page
1. Montana's Commercial Vehicle Crashes, 1993-1999.....	6
2. Comparative Vehicular Involvement, 1993-1999	7
3. Comparative Fatal Crash Frequency by Speed, 1999	7
4. Comparative Crash Severity, 1993-1999	8
5. Montana's Interstate and Primary Roadway System	10
6. Rural Traffic Flow Map, 1999	11
7. Existing Efforts to Improve Commercial Vehicle Safety	14
8. Driver License State	80
9. Driver Age.....	80
10. Apparent Driver Condition.....	82
11. Vehicle License State.....	82
12. Vehicle Configuration	83
13. Number of Axles Including Trailers	83
14. Gross Vehicle Weight	84
15. Cargo Body Type	84
16. Carrier State.....	85
17. Type of Carrier	85
18. Carrier Classification.....	87
19. Carrier Operation.....	87
20. Fleet Size.....	88
21. Number of Drivers with CDL's	88

22. Type of Latest Review	89
23. Safety Rating	89
24. Trafficway	90
25. Access Control	90
26. Weather Conditions.....	92
27. Road Surface Conditions.....	92
28. Light Conditions.....	93
29. Time of Day	93
30. Month of Year	94

ABSTRACT

This investigation focused on characterizing commercial vehicle safety in rural Montana on the basis of driver, vehicle, cargo, carrier, operating environment and crash characteristics using advanced statistical modeling methods. Montana, like other rural states experiences unique challenges in regards to commercial vehicle safety. Crashes typically involve a single vehicle, occur at higher speeds, are more severe and take longer to be detected.

In order to address these challenges, researchers utilized statistical modeling to characterize commercial vehicle safety levels on the basis of the various characteristics. Model interpretation was intended to assist public agencies in focusing scarce regulatory and enforcement resources on commercial vehicles highest at-risk for safety-related problems. The agencies would then be able to perform their duties more effectively and efficiently by addressing safety problems in a preventative rather than reactionary manner. An ordered probit model was used to model the 6524 crashes that took place over a seven-year period.

The results of this investigation were directly interpretable in regards to magnitude and direction. Independent variables that were found to have a significant influence on the severity of a crash included driver characteristics (age, condition-normal, condition-asleep, driver state residence), vehicle characteristics (vehicle configuration-single unit 2-axle), cargo characteristics (household goods), carrier characteristics (carrier physical address-Canadian Territories, number of trip leased and intrastate drivers, latest review-compliance review), operating environment characteristics (crash years 1996-1999, crash months-July, August, September and December, crash time-9am to 10am, light conditions-dark but lit) and crash characteristics (number of vehicles involved, specific crash counties). In addition, utilizing the ordered probit method to model crash severity proved to be successful as the significance of the variables were high as denoted through t-statistics and the overall goodness of fit was good ($\rho^2 = 0.57$).

In conclusion, focusing enforcement efforts toward variables that were found to increase the severity of a crash including specific driver state residences, vehicle configurations, carrier physical addresses, number of trip-leased drivers and the months of July, August, September and December would be the most effective and efficient method to improve commercial vehicle safety in Montana.

CHAPTER 1

INTRODUCTION

Despite the fact that they are less frequent than other types of vehicular crashes, commercial vehicle crashes receive considerable attention in the U.S. due to their high severity and resulting economic loss. At a national level, the Federal Motor Carrier Safety Administration (FMCSA) has set stringent goals focused on enhancing commercial vehicle safety through reduced crash severity levels and improved: (1) consistency and effectiveness of enforcement, (2) identification and targeting of those at high-risk and (3) research efforts to enhance and promote commercial vehicle safety practices.

Montana, as with other predominantly rural states, faces somewhat unique challenges with respect to commercial vehicle safety. Unlike commercial vehicle crashes that occur in urban areas, rural commercial vehicle crashes typically involve a single vehicle, occur at higher speeds, are more severe and take longer to be detected and responded to. Further, available regulatory and enforcement resources for commercial vehicle safety monitoring are limited. Montana's large geographic expanse challenges post-crash improvements that could limit the occurrence of fatalities, such as reduced emergency medical response times to the crash. Hence, efforts to improve commercial vehicle safety in Montana must focus on commercial vehicle crash *prevention*, targeting those at highest risk for a severe crash.

The objective of this research is to characterize commercial vehicle safety levels in Montana on the basis of driver, vehicle, cargo, carrier and other characteristics (i.e., roadway geometry, traffic volumes, etc.) using advanced statistical modeling methods. As an example, if the commercial vehicle safety-related data were to indicate low safety levels for out-of-state drivers, carriers with small vehicle fleets and haulers of flatbed trailers, both roadside and on-site carrier-based safety inspections could be performed with these characteristics in mind. On the roadside, regulatory and enforcement personnel could adjust their selection of commercial vehicles for roadside safety inspections; currently vehicles are selected for safety inspections on the basis of historical accident or safety records. As part of a more detailed carrier-based safety inspection program, regulatory and enforcement personnel could increase the frequency of safety inspections for carriers possessing the characteristics that show a lower safety level.

Ultimately, an understanding of the driver, vehicle, cargo, carrier and other characteristics that are most likely to result in a crash, particularly a severe crash, can assist regulatory and enforcement agencies in addressing safety problems in a *preventative* rather than reactionary manner. An additional benefit of this effort, and certainly of concern to public agencies in predominantly rural states, is the ability to make better use of existing resources. Resources are typically more limited and geographic expanses greater in rural states. Having the ability to focus scarce regulatory and enforcement resources on commercial vehicles highest at risk for safety-related problems, public agencies can perform their duties more effectively and efficiently without additional personnel.

Note, that only large trucks having a gross vehicle weight (GVW) of 10,000 pounds or greater are considered in this investigation; buses are excluded. Differences with respect to cargo and passenger transport vehicles between safety protocol, regulation and enforcement activities for and vehicle-handling characteristics were thought to confound this investigation. Further, the proportion of bus-involved crashes is small compared to that of large truck-involved crashes.

This Chapter details the problem at hand nationally and with respect to Montana's commercial vehicle crashes, describes the study area, and provides background information pertaining to existing Federal, State and industry efforts to improve commercial vehicle safety.

Following this introductory material, Chapter 2 describes findings from recent literature pertaining to commercial vehicle safety. Chapter 3 describes this effort's methodology in identifying influential driver, vehicle, cargo, carrier and operating environment characteristics. Chapter 4 expounds on the findings of this investigation and Chapter 5 contains recommendations for implementation and future work.

Problem Description

In 1999, there were more than 452,000 traffic crashes involving large trucks in the U.S. These crashes accounted for approximately 13 percent of all traffic-related fatalities and 4 percent of all injuries. (1) Contributing to this elevated level of severity are the physical characteristics of large trucks: (1) the difference in mass between large trucks and non-trucks results in a near instantaneous velocity change upon impact, (2) the high

rigidity of a commercial vehicle's structure results in energy dissipation through the collapse of the smaller vehicle, and (3) the height of the truck results in damage to the upper and weaker parts of the smaller vehicle.

Despite this high rate of severity, truck-involved crash *rates* (i.e., crash frequency) tend to be lower than that of non-trucks because:

- trucks typically travel more interurban miles,
- trucks register higher mileage in general,
- truck drivers are generally more skilled, and
- vehicle maintenance of trucks is generally stricter. (2)

Given these noted observations of truck crash severity and frequency, much of the effort towards improved commercial vehicle safety focuses on severity levels. In the FMCSA's draft *2010 Strategy*, the primary goals relate to improving commercial vehicle crash severity: (1) reduce the number of injuries in large truck-related crashes by 20 percent by fiscal year 2008 and (2) reduce the number of large truck-related crash fatalities 50 percent by fiscal year 2009.

Nationally, efforts to improve commercial vehicle safety will be challenged by contrary traffic and industry trends:

- increasing international trade will lead to more intermodal freight shipments and north-south, cross-border traffic for long haul trucks;
- continued and growing demand for real-time visibility of shipments and just-in-time freight delivery will heighten competitive pressures already placed on drivers and carriers;

- growth in e-commerce will impact truck distances traveled and travel patterns (e-commerce, particularly business-to-consumer, favors transportation in smaller lot sizes delivered by carriers with nationwide distribution systems); and
- declining availability of commercial vehicle drivers will result in more new drivers with less experience. (1)

The effectiveness of these safety improvement measures is further challenged in a predominantly rural state such as Montana that experiences significant commercial vehicle traffic, a large geographic expanse and limited regulatory and enforcement resources.

Uniqueness of Montana's Commercial Vehicle Crashes

Each year, approximately 1,000 commercial vehicle crashes occur within the State of Montana. Between January 1, 1993 and December 31, 1999, 6,583 commercial vehicle crashes occurred; 6,524 involving large trucks (see Figure 1). As noted previously, Montana's commercial vehicle crashes typically involve a single vehicle, occur at higher speeds, take longer to be detected and responded to and are more severe than nationally reported averages.

Vehicular Involvement. Given Montana's rural environment and low traffic volumes, one would expect a higher proportion of single-vehicle rather than multiple-vehicle crashes as compared to national averages. For the four-year time span (1993 to 1999) large truck-involved crashes in Montana comprised 46 percent single-vehicle crashes and

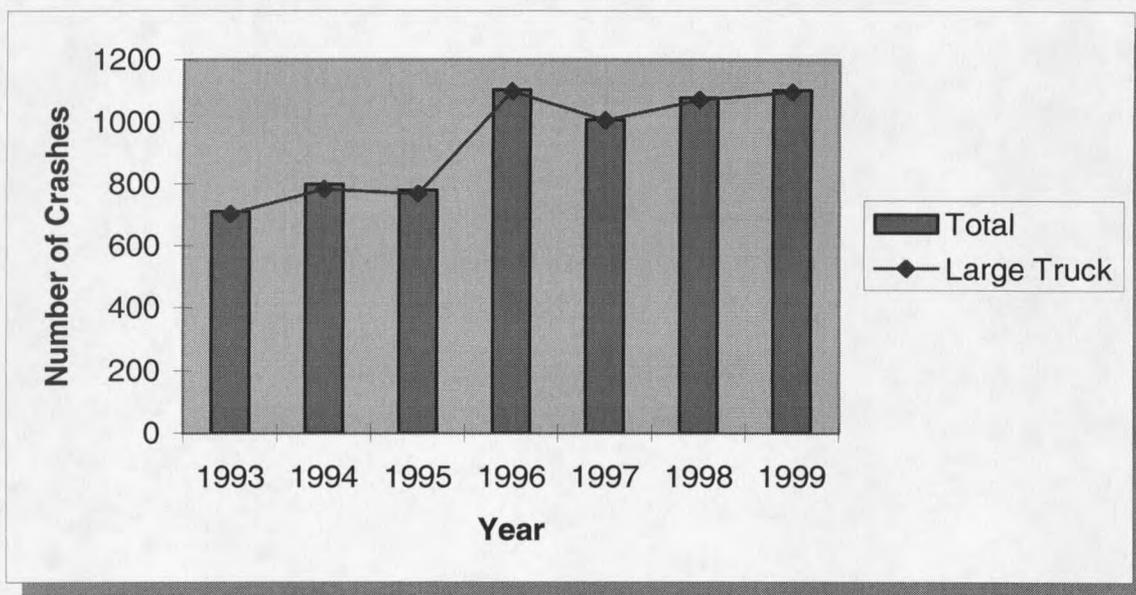


Figure 1. Montana's Commercial Vehicle Crashes, 1993-1999.

54 percent multiple-vehicle crashes. Figure 2 demonstrates the uniqueness of Montana's crashes as compared to national averages for this same time period. Nationally, large truck-involved crashes comprised only 28 percent single-vehicle crashes and 72 percent multiple-vehicle crashes. (3)

Speed. In general, vehicular crashes involving large trucks occur at higher speeds in Montana than they do nationally. Data from the Fatal Accident Reporting System (FARS) for the year 1999 illustrates that 60 percent of all fatal crashes in Montana occurred at speeds of 60 MPH or greater, while only 31 percent of fatal crashes nationally occurred at comparable speeds (see Figure 3). (3)

