The Safety Performance of Passenger Carrier Drivers

U.S. Department of Transportation
Federal Motor Carrier Safety Administration

December 2012

FOREWORD

The study of the Safety Performance of Passenger Carrier Drivers was initiated to expand understanding of the key driver factors that contribute to an increased likelihood of a bus crash. The research advances a driver-focused truck crash prediction model. Its spotlight is on drivers for passenger carriers, with a special emphasis on motorcoach drivers—their individual characteristics, their employment history, and their roadside inspection record in terms of both driver and vehicle safety violations. The model investigates the contribution of each driver factor on the dependent variable—the number of State-reportable crashes in which the driver was involved. The findings suggest that driver weight, height, gender, and employment stability, as well as previous driver and vehicle violations and past crashes, are significantly related to the likelihood of a crash occurrence.

The results of this research could have significance regarding both motor carrier and Federal Motor Carrier Safety Administration (FMCSA) imperatives to improve safety.

NOTICE

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or the use thereof.

The contents of this report reflect the views of the contractor, who is responsible for the accuracy of the data presented herein. The contents do not necessarily reflect the official policy of the U.S. Department of Transportation.

This report does not constitute a standard, specification, or regulation.

The United States Government does not endorse products or manufacturers named herein. Trade or manufacturers' names appear herein solely because they are considered essential to the objective of this report.

Technical Report Documentation Page

1. Report No. **FMCSA-RRA-12-002**	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle **The Safety Performance of the Passenger Carrier Drivers**		5. Report Date **December 2012**
		6. Performing Organization Code
7. Author(s) **Thomas M. Corsi, Curtis M. Grimm, David E. Cantor**		8. Performing Organization Report No.
9. Performing Organization Name and Address **University of Maryland** **The Robert H. Smith School of Business** **Van Munching Hall** **College Park, MD 20742-1815**		10. Work Unit No. (TRAIS) 11. Contract or Grant No. **DTMC75-06-H-00001**
12. Sponsoring Agency Name and Address **U.S. Department of Transportation** **Federal Motor Carrier Safety Administration** **Office of Analysis, Research, and Technology** **1200 New Jersey Ave., SE** **Washington, DC 20590**		13. Type of Report **Final Report** 14. Sponsoring Agency Code **FMCSA**
15. Supplementary Notes **Contracting Officer's Technical Representative: Mark Johnson (202) 366-4752.**		

16. Abstract

This paper examines the safety performance of passenger carrier drivers. Special emphasis is given to the motorcoach segment. A model that investigates the contribution of driver factors on the number of State-reportable crashes in which the driver was involved is presented for passenger carrier drivers. The findings suggest that the following factors are significantly related to the likelihood of a crash occurrence: driver weight, height, gender, and employment stability as well as previous driver and vehicle violations and past crashes. The results could have significance regarding the Federal Motor Carrier Safety Administration (FMCSA) imperative to improve safety of the passenger carrier segment of the industry.

17. Key Words **Bus, commercial motor vehicle safety, driver factors, motorcoach, safety performance, crash occurrences**	18. Distribution Statement **Unlimited**		
19. Security Classif. (of this report) **Unclassified**	20. Security Classif. (of this page) **Unclassified**	21. No. of Pages **28**	22. Price **N/A**

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

SI* (MODERN METRIC) CONVERSION FACTORS

TABLE OF APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
In	inches	25.4	millimeters	mm
Ft	feet	0.305	meters	m
Yd	yards	0.914	meters	m
Mi	miles	1.61	kilometers	km
		AREA		
in²	square inches	645.2	square millimeters	mm²
ft²	square feet	0.093	square meters	m²
yd²	square yards	0.836	square meters	m²
Ac	Acres	0.405	hectares	ha
mi²	square miles	2.59	square kilometers	km²
		VOLUME	1,000 L shall be shown in m³	
fl oz	fluid ounces	29.57	milliliters	mL
Gal	gallons	3.785	liters	L
ft³	cubic feet	0.028	cubic meters	m³
yd³	cubic yards	0.765	cubic meters	m³
		MASS		
Oz	ounces	28.35	grams	g
Lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE	Temperature is in exact degrees	
°F	Fahrenheit	5 × (F-32) ÷ 9 or (F-32) ÷ 1.8	Celsius	°C
		ILLUMINATION		
Fc	foot-candles	10.76	lux	lx
Fl	foot-lamberts	3.426	candela/m²	cd/m²
		Force and Pressure or Stress		
Lbf	poundforce	4.45	newtons	N
lbf/in²	poundforce per square inch	6.89	kilopascals	kPa

TABLE OF APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
Mm	millimeters	0.039	inches	in
M	meters	3.28	feet	ft
M	meters	1.09	yards	yd
Km	kilometers	0.621	iles	mi
		AREA		
mm²	square millimeters	0.0016	square inches	in²
m²	square meters	10.764	square feet	ft²
m²	square meters	1.195	square yards	yd²
Ha	hectares	2.47	Acres	ac
km²	square kilometers	0.386	square miles	mi²
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m³	cubic meters	35.314	cubic feet	ft³
m³	cubic meters	1.307	cubic yards	yd³
		MASS		
G	grams	0.035	ounces	oz
Kg	kilograms	2.202	ounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2,000 lb)	T
		TEMPERATURE	Temperature is in exact degrees	
°C	Celsius	1.8C + 32	Fahrenheit	°F
		ILLUMINATION		
Lx	lux	0.0929	foot-candles	fc
cd/m²	candela/m²	0.2919	foot-Lamberts	fl
		Force & Pressure Or Stress		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in²

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003, Section 508-accessible version September 2009.)

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

BMI	body mass index
CDL	Commercial Driver's License
CDLIS	Commercial Driver's License Information System
CMV	commercial motor vehicle
CMVSA	Commercial Motor Vehicle Safety Act
DIR	Driver Information Resource
FMCSA	Federal Motor Carrier Safety Administration
HM	hazardous material
MCMIS	Motor Carrier Management Information System
MVA	Motor Vehicle Administration
OOS	out of service
USDOT	U.S. Department of Transportation

[This page intentionally left blank.]

EXECUTIVE SUMMARY

The contractor has undertaken this report to fulfill the research component of its cooperative agreement and in support of the U.S. Department of Transportation's (USDOT) Motorcoach Safety Action Plan**,** which included an initiative for the Federal Motor Carrier Safety Administration (FMCSA) to identify motorcoach driver safety risk factors. The report, sponsored by the FMCSA, examines individual driver characteristics (age, gender, height, weight) and past driver records as predictors of future involvement in crashes. Appropriate comparisons are made with regard to passenger carrier drivers versus the driver profile and crash prediction factors for non-passenger carrier drivers.

Recent high profile, fatal motorcoach crashes have only served to reinforce the need to develop data on driver performance as part of an ongoing effort to reduce motorcoach crashes and fatalities. By early June 2011, there had already been 10 motorcoach crashes in the United States resulting in more than 20 fatalities and 130 injuries. Greater understanding of the role of drivers in contributing to the causes of these crashes is an essential component of an overall effort to reduce their frequency in the future.

The study team used a predictive model of crash likelihood based on drivers' demographics and their prior safety experience to further understand the critical contribution of drivers to the motorcoach crash problem. The model is based on a comprehensive sample of drivers that included more than 500,000 individuals for whom the study team had access to Commercial Driver's License (CDL) demographic data and past safety performance data over a 5-year period to establish a record on which to base a predictive model. In addition, the study team collected data on the crash involvement of these drivers during a 2-year period subsequent to the development of the drivers' safety performance records. The database included information on 2,580 passenger carrier drivers.

The major findings of the predictive model of crash likelihood are:

- The greater the commercial motor vehicle (CMV) driver's involvement in past motor vehicle crashes, the greater is the likelihood of future crash involvement (established at the 0.01 level). The higher the CMV driver's percentage of inspections with driver or vehicle out-of-service (OOS) violations, the greater the likelihood of future crash involvement. The greater the CMV driver's body mass index (BMI), the greater the likelihood of future crash involvement. Male drivers have a greater likelihood of future crash involvement than do female drivers. The fewer the number of individual motor carriers that a driver has worked for, the lower the likelihood of future crash involvement. Finally, there is no statistically significant relationship between older drivers (age 55 and older) and greater crash likelihood.
- Of special interest is the impact that driving for a passenger carrier, in and of itself, has on future crash involvement. The key finding is that driving for a passenger carrier, holding constant all driver characteristics, significantly decreases the likelihood of future crash involvement. Secondly, the study team finds that the impact of the driver factors on future crash involvement does not vary significantly between passenger and other commercial drivers. In order to test the latter, the study team included a series of terms to

account for interaction between driving for a passenger carrier and a number of the driver characteristic variables. The inclusion of interaction terms between the passenger carrier variable and the driver characteristic variables showed statistical insignificance for each of the interaction terms in the passenger model. This indicates that each of the individual driver characteristics, by itself, has a statistically significant impact on future crash involvement, regardless of whether the driver is employed by a passenger carrier or non-passenger carrier. Thus, for example, drivers with a high BMI will have a greater likelihood of future crash involvement than will drivers with a low BMI, regardless of whether the driver is working for a passenger carrier.

- When the model was run comparing just motorcoach drivers to non-passenger carrier drivers, the results were the same as for the comparison of passenger carrier drivers to non-passenger carrier drivers.

1. INTRODUCTION

In 2008, there were 41 motorcoach passenger fatalities—a significant increase over the fatalities experienced in this industry segment on an annual basis during the 1991–2008 time period. Three tragic motorcoach crashes accounted for more than 85 percent of the 2008 fatality total. A rollover crash at Mexican Hat, Utah, involved 9 fatalities; a crash in Sherman, Texas, caused 17 fatalities; and a rollover crash near Williams, California, caused 9 fatalities. In order to address the safety of motorcoach operations on the Nation's highways, Secretary of Transportation Ray LaHood released the U.S. Department of Transportation's (USDOT) Motorcoach Safety Action Plan[1] on November 16, 2009.

The Motorcoach Safety Action Plan recognized that motorcoach drivers are a critical factor in this upsurge in fatalities resulting from motorcoach crashes. The Action Plan cited research from the University of Michigan's Transportation Research Institute (UMTRI) to indicate that driver error is a factor in 31 percent of all fatal crashes involving motorcoaches.[2] Furthermore, the Federal Motor Carrier Safety Administration's (FMCSA) own Bus Crash Causation Study (2005 and 2006) evaluated 39 fatal or serious injury bus crashes in New Jersey and identified driver error as the primary factor in 80 percent of the cases in which researchers assigned the critical reason for the crash to the bus (50 percent of the total crashes).[3] As a result, the Action Plan recognized that "increased focus must be placed on improving driver performance, and that includes a number of initiatives to enhance driver performance by addressing distraction, fatigue, and medical issues." In addition, the Action Plan states: "As it evaluated the safety of motorcoach operations, USDOT determined that more complete and accurate data about motorcoach drivers and carriers would improve future efforts to enhance the safety of motorcoach operations. Thus, USDOT will also implement several initiatives to gather and assess detailed data on motorcoach drivers and carriers."[4]

This study was carried out to provide more complete and accurate analysis of the safety performance of the Nation's passenger carrier drivers, many of whom are classified as motorcoach operators. The study focuses on individual driver characteristics (e.g., age, gender, height, and weight) and past driving records as predictors of future driver involvement in crashes. Comparisons are made regarding profile and crash prediction factors between drivers of passenger carriers and non-passenger carrier drivers. The report presents a profile of the drivers for the passenger carrier segments as well as a comprehensive predictive model of crash likelihood based on drivers' demographics and their prior safety experience. It relies on a unique database of driver records compiled for the FMCSA.

Recent high profile fatal motorcoach crashes have only served to reinforce the need to develop data on driver performance as part of an ongoing effort to reduce motorcoach crashes and fatalities. In fact, in a June 6, 2011, joint letter to Secretary of Transportation LaHood, Senators Sherrod Brown, Jim Webb, Mark Warner, Kirsten Gillibrand, and Patty Murray stated: "In 2011 there have already been at least 10 motorcoach crashes resulting in more than 20 fatalities and more than 130 injuries—including 15 deaths in a single tragic crash earlier this year in New York. These crashes indicate the urgency in addressing these critical safety deficiencies—improving occupant protection with currently available vehicle safety technology as well as upgrading driver and operator oversight and regulations."[5] Clearly, there is a defined need for systematic evaluation of motorcoach driver performance and an identification of driver characteristics and performance patterns most closely associated with increased likelihood of an involvement in a future crash.

2. A DRIVER-BASED ANALYSIS OF THE SAFETY PERFORMANCE OF THE PASSENGER SEGMENT: PRESENTATION OF FINDINGS

This report enhances the understanding of the role of the driver in passenger/motorcoach crashes. Specifically, it presents a model that assesses how drivers' attributes/characteristics and their past on-the-road performance contribute to the increased likelihood of a future crash occurrence. The model analyzes a database created by merging data from FMCSA's Driver Information Resource (DIR) database with data from the Commercial Driver's License Information System (CDLIS).

2.1 DATA SOURCES AND STUDY POPULATION

The DIR database was developed by FMCSA in 2006 to sort Motor Carrier Management Information System (MCMIS) data by driver. DIR, the data source for the FMCSA Pre-employment Screening Program, "provides up to 5 years of driver crash data and 3 years of inspection information. Program data is provided monthly by FMCSA's MCMIS, which is comprised of driver performance data such as inspection and compliance review results, enforcement data, State-reported crashes and carrier census data."[6] Crash and inspection reports in MCMIS include both driver and the employing carrier's information. Each State first enters the crash and inspection reports into their SAFETYNET database and then reports this information to the MCMIS database.

CDLIS provided data on driver height, weight, age, and gender. CDLIS is a nationwide database that was mandated by the Commercial Motor Vehicle Safety Act (CMVSA) of 1986 to enforce the policy of "one license and one record for each driver, nationwide." The CDLIS database contains information from commercial drivers' licenses (CDLs). The CDL information is linked to each State's motor vehicle administration (MVA). Each State maintains detailed driver data such as convictions, withdrawals, and other license information such as weight, height, and date of birth. Convictions received in another State are reported to the State of issuance and recorded in the driver's electronic file. Each State's MVA office is required to query the CDLIS database before issuing a CDL to make sure that no other MVA has previously issued a driver's license to the applicant.

The dataset used for this study consisted of those drivers in the database with complete demographic information available from their CDLs. In addition, the drivers were required to have at least three or more roadside inspections during the 2-year period prior to September 2007, the time at which the data collection request was initiated. This screen was instituted so that there would be a past safety performance record for each driver. A record of crashes was collected for each driver during the 5-year period prior to September 2007 as additional information on a driver's past safety performance record. For the model's dependent variable, future crashes, the study team collected information on each driver's crash record from October 2007 through October 2009. Thus, there is a 2-year period to observe how driver characteristics and past performance impact their future involvement in crashes.

There are 560,695 unique records of commercial motor vehicle (CMV) drivers with three or more inspections during the 2-year period prior to September 2007. These drivers meet the requirements for inclusion in the study frame and thus constitute the study sample. Passenger carriers employed 2,580 of these drivers during the September 2002–September 2007 time period. The remainder, or 558,115 drivers, had no affiliation with any passenger carriers during the September 2002–September 2007 time period.

2.2 MEASUREMENT OF VARIABLES

This section outlines the specifics regarding each variable in the crash prediction model. To measure driver safety performance, the dependent variable chosen was crashes that involve the CMV driver. For each driver in the dataset, the study team collected data from the MCMIS database on the number of State-reportable crashes between October 1, 2007 and October 20, 2009. Thus, the dependent variable consisted of all crashes that occurred in the 2-year time window subsequent to the time period of the independent variables.

Next, is a discussion of the independent variables used in the model (see Table 1). The variables chosen were those hypothesized to be predictive of future crash involvement. The first independent variable is the driver's past safety performance (LAGGED CRASHES), which is defined as the number of previous crashes that the driver was involved in during the 5-year period ending September 2007. The next independent variable is the driver's out-of-service (OOS) rate (DRIVER OOS RATE), which is measured as the number of inspections with driver OOS violations divided by the number of total driver inspections during the 2-year period ending September 2007. The next independent variable is the VEHICLE OOS RATE, which is calculated as the number of inspections with vehicle OOS violations divided by the number of total vehicle inspections during the 2-year period ending September 2007. An OOS violation is a serious infraction of FMCSA rules and the driver and/or vehicle may not continue to operate until the violation is addressed. Another measure is the number of unique companies (NO. OF COMPANIES FOR DRIVER) that the driver drove for during the 5-year period ending September 2007, based on the company a driver is associated with at the time of each inspection and crash. The age of the driver (DRIVER 55 AND OLDER) is measured using a dummy variable. The coding of DRIVER 55 AND OLDER is a 1 if the age of the driver is 55 or older (as of September 2007), and 0 if the age of the driver is younger than 55. Following the Center for Disease Control and Prevention's definition, the driver's body mass index (DRIVER BMI) is calculated by dividing the driver's weight in pounds by height in inches squared and multiplying by a conversion factor of 703.[7] The coding of DRIVER GENDER is 1 if the gender of the driver is male, and 0 if the gender of the driver is female. Finally, the study team identifies whether each individual has driven for a passenger carrier (PASSENGER CARRIER DRIVER) at any time during the study period. The coding of PASSENGER CARRIER DRIVER is a 1 if the individual has driven for a passenger carrier and a 0 otherwise.

Table 1. Variables

VARIABLE	DEFINITION
FUTURE CRASHES	The number of State-reportable crashes between October 2007 and October 2009.
LAGGED CRASHES	The number of previous crashes that the driver was involved in during the 5-year period ending September 2007.
VEHICLE OOS RATE	Number of vehicle OOS inspections/number of total vehicle inspections.
DRIVER OOS RATE	Number of driver OOS inspections/number of total driver inspections.
DRIVER BMI	BMI of driver.
DRIVER 55 OR OLDER	Age of the driver: 1 if the driver is 55 years of age or older; 0 if the driver is less than 55 years old.
DRIVER AGE	Average age of drivers (descriptive variable, not used in models).
DRIVER GENDER	Gender of driver: 1 for male, 0 for female.
NO. OF COMPANIES FOR DRIVER	Number of unique companies that the driver drove for based on the company a driver is associated with at the time of each inspection and crash.
PASSENGER CARRIER DRIVER	Passenger Carrier Experience: 1 if driver worked for a passenger carrier; 0 if driver never drove for a passenger carrier.

It is interesting to see that, on average, 95 percent of the passenger carrier drivers are male, while the comparable figure among the non-passenger carriers is 98 percent. The average age of the passenger carrier drivers is 49.28, while the non-passenger drivers average 45.57 years of age. Among the passenger carrier drivers, 33 percent are age 55 or older, while among the non-passenger carrier drivers only 21 percent are age 55 or older. The passenger carrier drivers have a mean BMI value of 28.28, while the average BMI value for non-passenger carrier drivers is 28.55. The FMCSA's Medical Review Board has formally recommended that all drivers with a BMI of 30 or greater be tested for sleep apnea. A BMI of 30 or greater indicates obesity.[8] The mean BMI values for both passenger carrier and non-passenger carrier drivers are below the obesity threshold. Table 2 provides a summary of all the variables along with their descriptive statistics.

Passenger carrier drivers had an average driver OOS rate of 5 percent, while the non-passenger carrier drivers had an average OOS rate of 7 percent. Among the passenger carrier drivers the average OOS rate for vehicle inspections was 16 percent, while the rate among the non-passenger carrier drivers was 21 percent. During the 5-year study period, passenger carrier drivers drove on average for 2.04 carriers, while the comparable figure among the non-passenger carriers is 1.83. The NO. OF COMPANIES FOR DRIVER variable is potentially underestimated since this variable is based on the company a driver is associated with at the time of each inspection and crash. Drivers could conceivably have been associated with carriers other than the ones that involved inspections and/or crashes.

Table 2. Driver Characteristics Descriptive Statistics

Variable	Observations Passenger	Observations Non-Passenger	Mean Passenger	Mean Non-Passenger	Std Dev Passenger	Std Dev Non-Passenger
Future Crashes	2,580	558,115	0.05	0.06	0.11	0.15
Driver Age	2,580	558,115	49.28	45.57	11.90	11.00
Driver 55 or Older	2,580	558,115	0.33	0.21	0.47	0.41
Male Driver	2,580	558,115	0.95	0.98	0.21	0.15
Driver BMI	2,580	558,115	28.28	28.55	4.92	5.29
No. of Companies for Driver	2,580	558,115	2.04	1.83	1.26	1.03
Lagged Crashes	2,580	558,115	0.17	0.19	0.42	0.46
Vehicle OOS Rate	2,580	558,115	0.16	0.21	0.23	0.27
Driver OOS Rate	2,580	558,115	0.05	0.07	0.12	0.13

2.3 MODEL SPECIFICATION

Poisson regression models are used to investigate the relationship between the driver level characteristics, including driving for the passenger carrier industry segment, and driver safety performance. Wooldridge (2003),[9] Gittelman and Kogut (2003),[10] Jensen (1987),[11] and Shane (2002)[12] specifically note that when the dependent variable is defined in terms of non-negative count data, as is the case here with crashes, Poisson regression is an appropriate methodology. This method has frequently been used in crash studies by a variety of researchers such as Cantor, Corsi, and Grimm (2009)[13] and Rose (1990).[14] As is the case with the data in this study, Shane (2001, p. 1,179)[15] points out that "ordinary least squares regression is inappropriate for count-dependent variables that have large numbers of zero observations and remaining observations taking the form of small positive numbers." The functional form of the initial model is presented in Figure 1:

$$\text{FUTURE\_CRASHES} = \exp[\beta_0 + \beta_1 \text{ LAGGED CRASHES} + \beta_2 \text{ VEHICLE OOS RATE} + \beta_3 \text{ DRIVER OOS RATE} + \beta_4 \text{ DRIVER BMI} + \beta_5 \text{ DRIVER 55 OR OLDER} + \beta_6 \text{ DRIVER GENDER} + \beta_7 \text{ NO. OF COMPANIES FOR DRIVER} + \beta_8 \text{ PASSENGER CARRIER DRIVER}]$$

Figure 1. The Functional Form of Initial Model

2.4 RESULTS

The study team first checked for overdispersion of the Poisson regression model. An assumption of the Poisson model is that the variance of the dependent variable equals its mean. Accordingly it is appropriate to examine whether this assumption is violated; if so, the Poisson model is overdispersed (Hausman, Hall and Griliches, 1984).[16] The team found that the Poisson model is not overdispersed. The overdispersion statistic (alpha), as shown in Table 3, is not greater than the acceptable threshold of 1.0.

Table 3. Poisson Regression Results: Passenger Carrier Model

Independent Variables	Model 1: Poisson Regression (Dependent Variable: CRASH)
LAGGED CRASHES	0.211† [0.011]
VEHICLE OOS RATE	0.062† [0.021]
DRIVER OOS RATE	0.175† [0.041]
DRIVER BMI	0.007† [0.001]
DRIVER 55 OR OLDER	0.013 [0.014]
MALE DRIVER	0.243† [0.041]
NO. OF COMPANIES FOR DRIVER	0.090† [0.005]
PASSENGER CARRIER DRIVE	-0.223* [0.092]
Constant	-3.530† [0.051]
Observations	560,695
Alpha (Overdispersion Parameter) =	0.7464

Note: Log Likelihood=124,536.39. Standard errors in brackets
*Significant at 5%
†Significant at 1%

Table 4 presents the results from the Poisson regression model. In regards to driver past performance, the model shows that the greater the CMV driver's involvement in past motor vehicle crashes, the greater is the likelihood of future crash involvement. (The model was re-estimated without the LAGGED CRASHES variable since individuals who have driven fewer that the full 5 years of the sample period cannot be identified. The results do not change.) The higher the CMV driver's percentage of inspections with vehicle or driver OOS violations, the greater is the likelihood of future crash involvement. The fewer the number of individual motor carriers that a driver is involved with, the lower the likelihood of future crash involvement. All four results were statistically significant at the 0.01 level.

Considering driver characteristics, the model shows that the greater the CMV driver's BMI, the greater the likelihood of future crash involvement. It also shows that male drivers have a significantly greater likelihood of future crash involvement than do female drivers. Both were statistically significant at the 0.01 level. However, the relationship between older drivers (i.e., age 55 and older) and future crash likelihood is statistically insignificant. (Data from the regression analysis are presented in Appendix A.)

To explore further the relationship between driver age and crash likelihood, crash rates were calculated based on the number of crash occurrences during the October 2007 through October 2009 time period and the respective number of passenger carrier drivers in specified age groups. Figure 2 indicates that younger drivers (less than 30 years old) have the highest crash rates. (In fact, the model was run with an alternative dummy variable differentiating drivers older and younger than age 25 and a greater likelihood of future crashes for the 25-and-younger age group was found to be statistically significant.) As age increases, there are declines in crash rates among drivers in the 30–34, 35–39, and 40–44 age groups. After an increase in crash rates among drivers in the 45–49 age group, there is a decline in crash rates among drivers in the 50–54 age group. However, the crash rate increases again among drivers in the 55–59 age group, declines for the 60–64 age group to the lowest observed crash rate, and then increases slightly among drivers in the 65-and-older age group.

Figure 2. Crash Rates by Driver Age—Passenger Carriers

Of special interest is the impact that driving for a passenger carrier, in and of itself, has on future crash involvement. A key finding is that driving for a passenger carrier, holding constant all driver characteristics, significantly decreases the likelihood of future crash involvement. As indicated in Table 3, the coefficient for the passenger carrier driver dummy variable is negative and significant at the 0.05 level.

The study team also investigated whether there are differential effects of the driver characteristics on crashes between passenger and non-passenger carrier drivers by running an additional model with interaction terms between the passenger carrier variable and the driver characteristic variables. None of these interaction terms were statistically significant. This indicates that, while each of the individual driver characteristics, by itself, has a statistically significant impact on future crash involvement, there is no significant difference in the effect of these characteristics on crashes whether the driver is employed by a passenger carrier or non-passenger carrier. (Results of these interaction term analyses are presented in Appendix A). Table 4 focuses on the passenger carrier drivers who drove for motorcoach carriers. Table 4 extends the data from Table 2 to include descriptive statistics on all the passenger carrier drivers (2,580) as well as the subset of drivers who drove for motorcoach operators. As noted, the motorcoach drivers have an average age that is slightly older than the average age for all passenger carrier drivers. Indeed, approximately 40 percent of the motorcoach drivers are older than age 55, while the comparable figure among all passenger carrier drivers is 33 percent. In addition, the motorcoach drivers have more company stability, with an average number of companies they drove for equal to 1.89 compared to the average among all passenger carrier drivers of 2.04.

Table 4. Passenger Carrier Driver Descriptive Statistics

Variable	Observations Passenger	Observations Motorcoach	Mean Passenger	Mean Motorcoach	Std Dev Passenger	Std Dev Motorcoach
Future Crashes	2,580	1,631	0.05	0.01	0.11	0.10
Age of Driver	2,580	1,631	49.28	51.41	11.9	11.7
Driver 55 or Older	2,580	1,631	0.33	0.40	0.47	0.49
Male Driver	2,580	1,631	0.95	0.96	0.21	0.20
Driver BMI	2,580	1,631	28.28	28.04	4.92	4.71
No. of Companies for Driver	2,580	1,631	2.04	1.89	1.26	1.19
Lagged Crashes	2,580	1,631	0.17	0.15	0.42	0.40
Vehicle OOS Rate	2,580	1,631	0.16	0.13	0.23	0.22
Driver OOS Rate	2,580	1,631	0.05	0.05	0.12	0.12

Table 5 revisits the analysis provided in Table 3 with an alternative dummy variable reflecting whether the driver is associated with a motorcoach company, as opposed to the original analysis using all passenger companies. As noted earlier, individuals driving for passenger carriers are significantly less likely to have future crash involvement than are the drivers without passenger carrier experience in their records. When the passenger carrier base is limited to the passenger carrier operators with a predominance of motorcoach equipment (as distinguished from passenger carriers with school buses, limousines, and minivans) and compared to non-passenger carriers, the results are comparable (Table 5). The coefficient remains negative and statistically significant at the 0.05 level, indicating that employment as a motorcoach driver results in a lower likelihood of being involved in future crashes than for those driving for non-passenger carriers. The results for all the other variables remained the same as the earlier analysis involving all passenger carrier drivers.

Table 5. Poisson Regression Results: Motorcoach Driver Model

Independent Variables	Model 1: Poisson Regression (Dependent Variable: CRASH)
LAGGED CRASHES	0.211† [0.011]
VEHICLE OOS RATE	0.062† [0.020]
DRIVER OOS RATE	0.174† [0.041]
DRIVER BMI	0.006† [0.001]
DRIVER 55 OR OLDER	0.012 [0.014]
MALE DRIVER	0.243† [0.041]
NO. OF COMPANIES FOR DRIVER	0.090† [0.005]
MOTORCOACH DRIVER	-0.230* [0.117]
Constant	-3.530† [0.050]
Observations	560,695
Alpha (Overdispersion parameter)	0.7466

Note: Log Likelihood= 124,537.4, Standard errors in brackets
*Significant at 5%
†Significant at 1%

2.5 LIMITATIONS AND FUTURE RESEARCH

This study identified the contribution of selected driver characteristics and past driver over-the-road performance to future crash likelihood by examining the driving records of more than 500,000 interstate drivers compiled over a 7-year period. In this group were 2,580 passenger carrier drivers. The extensive study frame allowed the study team to separate out the influence of a driver's past on the likelihood of a future crash. There was no overlap in the time periods between the independent variable timeframe (September 2002–September 2007) and the dependent variable timeframe (October 2007–October 2009). Despite these contributions, we recognize limitations in the model.

First, the study does not differentiate crashes on the basis of environmental conditions at the time of the crash or on the basis of the most significant contributing factor. Thus, in some crashes, the truck/bus driver may not be the responsible party. Second, the model does not include any exposure measures. It does not control for the annual miles driven, which would provide measures of crash frequency. Third, while the models do include a number of driver characteristics, the study team did not have information on driver experience or driver annual income. Fourth, while the study included all motor carrier drivers in the database, this is a relatively small number of passenger carrier drivers compared to the total number of commercial vehicle drivers.

Future research could potentially utilize a richer set of independent variables, which would enhance the knowledge about driver characteristics and behaviors that contribute to increased crash likelihood. Such a rich independent variable set would require in-depth interviewing and data collection over a broader sample of motorcoach drivers. These interviews could accumulate more detail about the drivers' work patterns and hours-of-service as well as their compensation levels. This more detailed data would contribute to an overall understanding of crash contribution factors and enhance our ability to design crash avoidance policies in the selection, training, and monitoring of motorcoach drivers.

This investigation focusing on driver characteristics could also be supplemented with a thorough analysis of carrier behavior. It would be instructive to examine carrier policies toward driver work patterns, compensation levels, and monitoring programs, along with the impact of these factors on crash rates. The development of crash avoidance policies and programs for drivers should, indeed, be accompanied by a set of policies and programs for the carriers, based upon a systematic analysis of how carrier policies and programs influence crash rates.

2.6 CONCLUSIONS

To analyze the relationship between various driver characteristics and safety performance, a predictive model of crash likelihood based on drivers' demographics and their prior safety experience was developed. The model used a comprehensive sample of drivers that included more than 500,000 individuals for whom CDL demographic data and past safety performance data were available over a 5-year period to establish a record on which to base the predictive model. In addition, data were collected on the crash involvement of these drivers during a 2-year period subsequent to the development of the driver's safety performance record. The database included information on 2,580-passenger carrier drivers, of which 1,631 drove for motorcoach companies.

The major findings of the predictive model of crash likelihood are:

- The greater the CMV driver's involvement in past motor vehicle crashes, the greater is the likelihood of future crash involvement. The higher the CMV driver's percentage of driver or vehicle OOS violations, the greater the likelihood of future crash involvement. The greater the CMV driver's BMI, the greater the likelihood of future crash involvement. Male drivers have a greater likelihood of future crash involvement than do female drivers. The fewer the number of individual motor carriers the driver is involved with, the less likely future crash involvement occurred. Finally, the relationship between older drivers (i.e., 55 and older) and crash likelihood is statistically insignificant.
- Of special interest is the impact that driving for a passenger carrier, in and of itself, has on future crash involvement. The key finding is that driving for a passenger/motorcoach operator, holding constant all driver characteristics, significantly decreases the likelihood of future crash involvement. Secondly, the impact of the driver factors on future crash involvement does not vary significantly between passenger and other CMV drivers. In order to test the latter, a series of terms was included to account for interaction between driving for a passenger carrier and a number of the driver characteristic variables. The inclusion of interaction terms between the passenger carrier variable and the driver

characteristic variables showed statistical insignificance for each of the interaction terms in the passenger model. This indicates that each of the individual driver characteristics, by itself, has a statistically significant impact on future crash involvement, regardless of whether the driver is employed by a passenger carrier or non-passenger carrier. Thus, for example, drivers with a high BMI will have a greater likelihood of future crash involvement than will drivers with a lower BMI, regardless of whether the driver is working for a passenger carrier.

When the model was run comparing just motorcoach drivers to non-passenger carrier drivers, the results were the same as for the comparison of all passenger carrier drivers to non-passenger carrier drivers.

APPENDIX A: POISSON REGRESSION ANALYSIS

Table 6. Poisson Regression Analysis Passenger Carrier Model

Characteristic	Coefficient	Standard Error	Z	p > | z |	[95% Confidence Interval]	
Driver 55 or Older	0.0126277	0.0139216	0.91	0.364	-0.0146582	0.0399135
Male Driver	0.2428292	0.0411687	5.90	0.000	0.1621401	0.3235184
Driver BMI	0.0065290	0.0010376	6.29	0.000	0.0044953	0.0085627
Lagged Crashes	0.2112043	0.0107235	19.70	0.000	0.1901867	0.2322219
Vehicle OOS Rate	0.0623307	0.0206193	3.02	0.003	0.0219177	0.1027438
Driver OOS Rate	0.1747462	0.0408159	4.28	0.000	0.0947484	0.2547440
No. of Companies for Driver	0.0903078	0.0049404	18.28	0.000	0.0806249	0.0999908
Passenger Carrier Driver	-0.2229697	0.0918789	-2.43	0.015	-0.4030490	-0.0428904
Constant	-3.5299180	0.0512092	-68.93	0.000	-3.6302860	-3.4295500

Note: Number of observations: 560,695, LR $chi^2(8)$: 986.13, Prob > chi^2: 0.0000, Pseudo R^2: 0.0039, Log likelihood = -124536.39

Table 7. Poisson Regression Analysis: Age Interaction Model

Characteristic	Coefficient	Standard Error	Z	p > | z |	[95% Confidence Interval]	
Driver 55 or Older	0.0126245	0.0139218	0.91	0.365	-0.0146617	0.0399106
Male Driver	0.2428324	0.0411687	5.90	0.000	0.1621432	0.3235217
Driver BMI	0.0065290	0.0010376	6.29	0.000	0.0044953	0.0085627
Lagged Crashes	0.2112041	0.0107235	19.70	0.000	0.1901865	0.2322218
Vehicle OOS Rate	0.0623292	0.0206193	3.02	0.003	0.0219161	0.1027423
Driver OOS Rate	0.1747489	0.0408160	4.28	0.000	0.0947510	0.2547468
No. of Companies for Driver	0.0903073	0.0049404	18.28	0.000	0.0806243	0.0999903
Passenger Carrier Driver	-0.2225415	0.0922665	-2.41	0.016	-0.4033806	-0.0417024
Age Interaction Term	-0.0496574	1.0042440	-0.05	0.961	-2.0179400	1.9186250
Constant	-3.5299170	0.0512092	-68.93	0.000	-3.6302850	-3.4295490

Note: Number of observations: 560,695, LR $chi^2(9)$: 986.13, Prob > chi^2: 0.0000, Pseudo R^2: 0.0039, Log likelihood = -124536.39

Table 8. Poisson Regression Analysis: Gender Interaction Model

Characteristic	Coefficient	Standard Error	Z	p > | z |	[95% Confidence Interval]	
Driver 55 or Older	0.0126270	0.0139216	0.91	0.364	-0.0146588	0.0399129
Male Driver	0.2427313	0.0413036	5.88	0.000	0.1617776	0.3236849
Driver BMI	0.0065290	0.0010376	6.29	0.000	0.0044953	0.0085627
Lagged Crashes	0.2112045	0.0107235	19.70	0.000	0.1901869	0.2322222
Vehicle OOS Rate	0.0623303	0.0206193	3.02	0.003	0.0219172	0.1027434
Driver OOS Rate	0.1747470	0.0408160	4.28	0.000	0.0947492	0.2547449
No. of Companies for Driver	0.0903072	0.0049404	18.28	0.000	0.0806241	0.0999902
Passenger Carrier Driver	-0.2373467	0.5016734	-0.47	0.636	-1.2206080	0.7459151
Gender Interaction Term	0.0148794	0.5102995	0.03	0.977	-0.9852893	1.0150480
Constant	-3.5298200	0.0513168	-68.78	0.000	-3.6303990	-3.4292410

Note: Number of observations: 560,695, LR $chi^2(9)$: 986.13, Prob > chi^2: 0.0000, Pseudo R^2: 0.0039, Log likelihood = -124536.39

Table 9. Poisson Regression Analysis: BMI Interaction Model

Characteristic	Coefficient	Standard Error	Z	p > | z |	[95% Confidence Interval]	
Driver 55 or Older	0.0125869	0.0139217	0.90	0.366	-0.0146990	0.0398729
Male Driver	0.2429161	0.0411689	5.90	0.000	0.1622266	0.3236056
Driver BMI	0.0066041	0.0010390	6.36	0.000	0.0045676	0.0086405
Lagged Crashes	0.2111807	0.0107233	19.69	0.000	0.1901634	0.2321981
Vehicle OOS Rate	0.0623516	0.0206192	3.02	0.002	0.0219387	0.1027646
Driver OOS Rate	0.1747329	0.0408153	4.28	0.000	0.0947364	0.2547294
No. of Companies for Driver	0.0903105	0.0049403	18.28	0.000	0.0806277	0.0999932
Passenger Carrier Driver	0.4805911	0.5495142	0.87	0.382	-0.5964369	1.5576190
BMI Interaction Term	-0.0250056	0.0194537	-1.29	0.199	-0.0631341	0.0131229
Constant	-3.5321530	0.0512365	-68.94	0.000	-3.6325750	-3.4317320

Note: Number of observations: 560,695, LR $chi^2(9)$: 987.84, Prob > chi^2: 0.0000, Pseudo R^2: 0.0040, Log likelihood = -124535.54

Table 10. Poisson Regression Analysis: Driver OOS Interaction Model

Characteristic	Coefficient	Standard Error	Z	p > | z |	[95% Confidence Interval]	
Driver 55 or Older	0.0126440	0.0139216	0.91	0.364	-0.0146418	0.0399298
Male Driver	0.2428297	0.0411687	5.90	0.000	0.1621405	0.3235188
Driver BMI	0.0065290	0.0010376	6.29	0.000	0.0044953	0.0085627
Lagged Crashes	0.2112057	0.0107235	19.70	0.000	0.1901880	0.2322233
Vehicle OOS Rate	0.0623043	0.0206194	3.02	0.003	0.0218911	0.1027176
Driver OOS Rate	0.1735959	0.0408823	4.25	0.000	0.0934681	0.2537238
No. of Companies for Driver	0.0902911	0.0049406	18.28	0.000	0.0806078	0.0999744
Passenger Carrier Driver	-0.2449113	0.1018367	-2.40	0.016	-0.4445075	-0.0453150
Driver OOS Interaction Term	0.3583347	0.6829239	0.52	0.600	-0.9801714	1.6968410
Constant	-3.5297990	0.0512095	-68.93	0.000	-3.6301680	-3.4294300

Note: Number of observations: 560,695, LR $chi^2(9)$: 986.39, Prob > chi^2: 0.0000, Pseudo R^2: 0.0039, Log likelihood = -124536.26

Table 11. Poisson Regression Analysis: Vehicle OOS Interaction Model

Characteristic	Coefficient	Standard Error	Z	p > | z |	[95% Confidence Interval]	
Driver 55 or Older	0.0125718	0.0139219	0.90	0.367	-0.0147147	0.0398583
Male Driver	0.2429240	0.0411690	5.90	0.000	0.1622343	0.3236137
Driver BMI	0.0065296	0.0010376	6.29	0.000	0.0044960	0.0085633
Lagged Crashes	0.2112162	0.0107234	19.70	0.000	0.1901987	0.2322338
Vehicle OOS Rate	0.0630718	0.0206445	3.06	0.002	0.0226092	0.1035343
Driver OOS Rate	0.1748121	0.0408159	4.28	0.000	0.0948143	0.2548099
No. of Companies for Driver	0.0903333	0.0049403	18.28	0.000	0.0806505	0.1000161
Passenger Carrier Driver	-0.1769152	0.1116176	-1.59	0.113	-0.3956817	0.0418513
Vehicle OOS Interaction Term	-0.2815877	0.4058802	-0.69	0.488	-1.0770980	0.5139228
Constant	-3.5302400	0.0512113	-68.93	0.000	-3.6306120	-3.4298670

Note: Number of observations: 560,695, LR $chi^2(9)$: 986.63, Prob > chi^2: 0.0000, Pseudo R^2: 0.0039, Log likelihood = -124536.14

[This page intentionally left blank]

REFERENCES

[1] U.S. Department of Transportation, Motorcoach Safety Action Plan, November 16, 2009, pp.1-52.

[2] University of Michigan Transportation Research Institute, *Bus Operator Types and Driver Factors in Fatal Bus Crashes: Results from the Buses Involved in Fatal Crashes Survey*, June 2008.

[3] Federal Motor Carrier Safety Administration, The Bus Crash Causation Study Report to Congress (A Report Pursuant to Section 224 of the Motor Carrier Safety Improvement Act of 1999, Public Law 106-159), February 2009.

[4] U.S. Department of Transportation, Motorcoach Safety Action Plan, November 16, 2009, p. 16.

[5] Letter from Senators Brown, Webb, Warner, Gillibrand, and Murray to Secretary LaHood, June 6, 2011 (http://schumer.senate.gov/Newsroom/record_print.cfm?id=333092), accessed on 6/22/11.

[6] Federal Motor Carrier Safety Administration's Web site, (http://www.ccjdigital.com/fmcsa-starts-driver-pre-employment-program/), accessed on 6/22/11.

[7] Center for Disease Control, 2009 (http://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html), accessed 6/22/11.

[8] Federal Motor Carrier Safety Administration (http://www.formerlyfluffy.com/safety-admin-requires-truckers-to-keep-bmi-under-30-to-reduce-sleep-apnea/), accessed on 6/22/11.

[9] Wooldridge, J.M. 2003. *Introductory Econometrics: A Modern Approach*, 2nd ed. South-Western Publishing, Mason, OH.

[10] Gittelman, M, Kogut, B. 2003. "Does good science lead to valuable knowledge? Biotechnology firms and the evolutionary logic of citation patterns," *Management Science* 49(4), 366-382.

[11] Jensen, E. 1987. "Research expenditures and the discovery of new drugs," *Journal of Industrial Economics* 36(1), 83-95.

[12] Shane, S. 2002. "Selling university technology: Patterns from MIT," *Management Science* 48(1), 122-138.

[13] Cantor, D.E., Corsi, T.M., Grimm, C.M. 2009. "Do electronic logbooks contribute to motor carrier safety performance?" *Journal of Business Logistics* 30(1), 203-222.

[14] Rose, N.L. 1990. “Profitability and Product quality: Economic determinants of airline safety performance,” *Journal of Political Economy* 98(5), 944-964.

[15] Shane, S. 2001. “Technology regimes and new firm formation,” *Management Science* 47(9), 1173-1191.

[16] Hausman, J., Hall, B.H., Griliches, Z. 1984.Econometric models for count data with an application to the patents-R&D relationship. Econometrica 52(4), 909-938.