Bus Operator Types and Driver Factors in Fatal Bus Crashes: Results from the Buses Involved in Fatal Accidents Survey

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

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FOREWORD

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Using BIFA data for 1999–2005, the present study focuses on factors associated with driver errors in fatal bus crashes involving different bus operator types. Five different carrier types are identified: School, transit, intercity, charter/tour, and "other" bus operators. There are substantial differences between these carrier types that are reflected in rates of bus driver errors in crashes and in the previous driving record of the bus drivers. Many factors are identified that are associated with driver error, including bus operation type, age, sex, hours driving, trip type, method of compensation, and previous driving record. A logistic regression model was used to model the probability of driver error. Bus operation type, previous violations, and previous crashes were significant parameters in the model. The other factors were not significant.

These findings may be of interest to passenger carriers as well as the agencies that regulate them.

NOTICE

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16. Abstract

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					LENGTH		
in	inches	25.4	millimeters	mm	mm	millimeters	0.039	inches	in
ft	feet	0.305	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	m	meters	1.09	yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
		AREA					AREA		
in^2	square inches	645.2	square millimeters	mm^2	mm^2	square millimeters	0.0016	square inches	in^2
ft^2	square feet	0.093	square meters	m^2	m^2	square meters	10.764	square feet	ft^2
yd^2	square yards	0.836	square meters	m^2	m^2	square meters	1.195	square yards	yd^2
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi^2	square miles	2.59	square kilometers	km^2	km^2	square kilometers	0.386	square miles	mi^2
		VOLUME					VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml	ml	milliliters	0.034	fluid ounces	fl oz
gal	gallons	3.785	liters	l	l	liters	0.264	gallons	gal
ft^3	cubic feet	0.028	cubic meters	m^3	m^3	cubic meters	35.71	cubic feet	ft^3
yd^3	cubic yards	0.765	cubic meters	m^3	m^3	cubic meters	1.307	cubic yards	yd^3
		MASS					MASS		
oz	ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.202	pounds	lb
T	short tons (2,000 lbs)	0.907	megagrams	Mg	Mg	megagrams	1.103	short tons (2,000 lbs)	T
		TEMPERATURE (EXACT)					TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C	°C	Celsius temperature	1.8 C + 32	Fahrenheit temperature	°F
		ILLUMINATION					ILLUMINATION		
fc	foot-candles	10.76	lux	lx	lx	lux	0.0929	foot-candles	fc
fl	foot-lamberts	3.426	candela/m^2	cd/m^2	cd/m^2	candela/m^2	0.2919	foot-lamberts	fl
		FORCE AND PRESSURE OR STRESS					FORCE AND PRESSURE OR STRESS		
lbf	pound-force	4.45	newtons	N	N	newtons	0.225	pound-force	lbf
psi	pound-force per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	pound-force per square inch	psi

* SI is the symbol for the International System of Units. Appropriate rounding should be done to comply with Section 4 of ASTM E380.

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LIST OF ACRONYMS

BIFA	Buses Involved in Fatal Accidents
CI	Confidence Intervals
DWI	Driving While Intoxicated
FARS	Fatality Analysis Reporting System
FMCSA	Federal Motor Carrier Safety Administration
TIFA	Trucks Involved in Fatal Accidents

INTRODUCTION

About 63,000 buses are involved in traffic crashes each year, including 325 with a fatal injury, 14,000 with a non-fatal injury, and about 48,000 in crashes that result in property damage only.[1,2] The number of buses in crashes is small in relation to other vehicle types: About 444,000 trucks are involved in a traffic crash each year, as are with 4.0 million light vehicles and 6.6 million passenger cars. About 375 people are killed in bus crashes each year, including about 50 bus occupants (including drivers), 225 occupants of other vehicles, and 100 pedestrians and bicyclists. These fatalities are a fraction of the roughly 5,500 deaths that occur in crashes involving trucks, or of the total of around 43,000 annual fatalities in all traffic accidents. Nevertheless, recently there has been an appropriate increase in focus on the safety of bus operations.

The authors in 2000 initiated a survey called the Buses Involved in Fatal Accidents (BIFA) project. This crash data collection, supported by the Federal Motor Carrier Safety Administration (FMCSA), supplements the Fatality Analysis Reporting System (FARS) file, compiled by the National Highway Traffic Safety Administration. FMCSA has supported data collection on buses involved in fatal crashes, to better understand the buses involved and the motor carriers that operate them. Since the BIFA survey focuses on buses alone, it can provide a much more detailed description of each bus involved in a fatal crash and the carrier that operated it.

The BIFA survey significantly improves the identification of buses and bus operators. Descriptions of buses in nationally representative crash data files have been relatively simple or lacking altogether. Until recently, the FARS file only distinguished "school," "cross-country/intercity," "transit," and "other" bus types. Common terminology for buses mixes physical characteristics with how they are operated, which adds to the difficulty in determining the scope and nature of bus safety problems. "School bus" connotes an identifiable bus type, but school buses often are converted to other uses. "Cross country" buses can be used by scheduled intercity carriers or as charter/tour buses or for private, personal transportation. In addition, both the vehicles used as buses and the entities that operate them are very diverse, including, along with the expected bus operators, hospitals and nursing homes, non-profit organizations and churches, shuttle services, and private companies. The BIFA survey captures this diversity. Enhancing the depth and detail of information on bus types and bus operators will improve our understanding of the different safety issues in bus transportation.

This study focuses on driver factors in fatal bus crashes involving different bus operator types. Previous work with the BIFA survey data has shown that the diversity of the types of motor carriers that operate buses is reflected in all aspects of their crash experience, including the time of day in which the crashes occur, the type of area and roads, and who in the crash is at risk. The work also showed differences between the operator types in terms of errors by the drivers in the crashes, and previous driver record. In that work, school bus drivers had the lowest rates of coded driver errors in the crash and the best driving record, in terms of previous crashes and traffic violations. Drivers of intercity buses on regular routes and charter bus drivers both had higher rates of driver errors and worse prior driving records.[3]

Corsi et al. found that passenger carriers had excellent safety records and measures compared to other motor carrier types.[4] He also found that passenger carriers with more power units (larger

fleets) tended to have better safety records than those with fewer, particularly as measured by violations and out-of-service rates in inspections, by crash rates, and by other safety measures.. Corsi's work was only able to distinguish for-hire from private passenger carriers, without any detail about specific types of operations. Lantz and Blevins found a significant correlation between the driving records of drivers and their carrier's crash rate, out-of-service rate, and the various SafeStat measures (Accident, Driver, and Vehicle).[5] In a review article, Hickman found a number of studies showing a relationship between prior crash record and crash involvement.[6] The present study extends the previous work on driver factors in the safety differences between different types of bus operators. In the previous work, only two years of BIFA crash data were available. This limited the number of cases available for analysis. At the present time, BIFA crash data is available for seven years: 1999 through 2005. The addition of five years of crash data provides a more robust data set for analysis.

DATA

Data used are from the BIFA survey for 1999–2005. Modeled on the Trucks Involved in Fatal Accidents (TIFA) program, the BIFA survey collects detailed information on all buses involved in fatal traffic crashes. For the purpose of the survey, a bus is defined as a vehicle with seating for nine or more occupants, including the driver, not for personal use (such as a family), or for 15 or more passengers. Buses operated by private, commercial, or non-profit organizations are included. Cases for the BIFA survey are selected from the FARS file, and supplement FARS data with a detailed description of the bus, the bus operator, type of trip, driver hours driving, type of driver compensation, and role of the bus in the crash.

Throughout this paper, we classify buses by the type of "carrier" operating them. Carrier here is determined by the type of operations. Thus, if a bus is used to transport pupils, it is classified as a school bus. If a "school bus," that is, a bus of the type commonly used by schools, is used by a private company to transport employees, it is classified as a private company bus. In most cases, the physical configuration of most school, transit, intercity, and charter buses corresponded to the expected type for each. The five carrier types distinguished here are defined as follows:

- School—Any public or private school or district, or contracted carrier operating on behalf of the entity, providing transportation for K–12 pupils.
- Transit—An entity providing passenger transportation over fixed, scheduled routes, within primarily urban geographical areas.
- Intercity—A company providing for-hire, long-distance passenger transportation between cities over fixed routes with regular schedules.
- Charter/tour—A company providing transportation on a for-hire basis, usually round-trip service for a tour group or outing. The transportation can be for a specific event or as part of a regular tour.
- Other—All bus operations not included in the previous categories. Includes private companies providing transportation to their own employees, non-governmental organizations (e.g., churches or non-profit groups, non-educational units of government such as departments of corrections), and private individuals. These groups can be identified by the BIFA survey, but are combined in the present analysis.

RESULTS

Buses involved in fatal crashes are operated by a extraordinarily diverse set of operator types. While the majority are operated by two well-known types, a significant number are operated by a varied collection of small operators, private groups, and as adjuncts to some other enterprise. Most buses involved in fatal crashes are either school or transit buses. Table 1 shows the distribution of buses involved in fatal crashes in 1999–2005 by operator type, as defined above. Schools buses account for about 38 percent of bus involvements and transit buses an additional 32.5 percent. Thus, those two bus types combined account for more than 70 percent of all buses involved in fatal crashes. Buses operated by charter or tour companies are the next most common, with about 11.4 percent of the total over the period. Intercity buses on regularly scheduled routes account for only 3.7 percent of the involvements.

Table 1. Buses Involved in Fatal Crashes by Operator Type, 1999–2005

Carrier Type	N	%
School	857	38.1
Transit	731	32.5
Intercity	83	3.7
Charter/Tour	256	11.4
Other:		
Private company	20	0.9
Non-profit organization	62	2.8
Government	33	1.5
Personal	3	0.1
Contractor for school district	40	1.8
Other	93	4.1
Other subtotal	*251*	*11.1*
Unknown operator type	74	3.3
Total	**2,252**	**100.0**

Source: Buses Involved in Fatal Accidents (BIFA) survey.

The "other" category encompasses a great diversity of bus operators. Buses are operated by companies to transport their own employees, by non-profits such as churches, by different units of governments, and for personal use. But these are just the types that are coded directly in the BIFA survey. There is even an "other" category nested within the "other" category, which includes shuttle operations for hotels and airports, farm labor carriers, nursing home buses to transport patients, and even companies that deliver new or used buses. Buses are used in an extraordinarily wide range of applications—from dedicated, regularly scheduled operations with professional drivers to occasional passenger transportation with drivers whose main job is something else.

The distribution of where the fatality occurred in fatal bus involvements illustrates the operational differences between bus types. Table 2 shows the distribution of fatally-injured persons in bus crashes by the type of bus involved in the crash. The table also identifies the person type of each fatality for each carrier type. (Only percentages are shown in the table to

minimize the number of columns. The subtotal rows show the proportion of bus, other vehicle, and non-motorist fatalities for each bus type. The total number of fatally-injured persons in crashes for each bus type is shown in the bottom row.)

Table 2. Percentage Distribution of Fatalities by Bus Carrier Type and Person Type, 1999–2005

Vehicle/Occupant Type	School	Transit	Intercity	Charter	Other	Unk.	Total
Bus occupants							
Driver	3.4	1.0	6.5	4.8	6.2	3.5	3.4
Passenger	4.8	1.7	11.2	29.5	30.6	17.4	11.4
Bus subtotal	*8.2*	*2.7*	*17.8*	*34.3*	*36.7*	*20.9*	*14.8*
Occupants of other vehicles							
Drivers	56.6	39.5	36.4	33.1	30.9	33.7	43.2
Passengers	16.1	12.2	25.2	15.9	14.5	17.4	15.1
Unknown occ. Type	0.0	0.1	0.0	0.8	0.0	0.0	0.2
Other vehicle subtotal	*72.7*	*51.8*	*61.7*	*49.7*	*45.4*	*51.2*	*58.5*
Non-motorists							
In parked vehicle	0.0	0.3	0.0	0.0	0.0	0.0	0.1
Pedestrian	16.6	40.5	17.8	13.9	17.0	26.7	23.7
Bicyclist	2.5	4.8	2.8	2.0	0.9	1.2	2.9
Non-motorist subtotal	*19.1*	*45.5*	*20.6*	*15.9*	*17.9*	*27.9*	*26.6*
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total fatalities	938	778	107	396	324	86	2,629

Source: Buses Involved in Fatal Accidents (BIFA) survey.

A total of 2,629 persons were killed in traffic crashes involving buses in 1999–2005, an average of about 376 per year. Crashes involving school buses accounted for the greatest number, with 938, and transit buses accounted for 778. The other bus operator types had many fewer. Crashes involving charter or tour buses accounted for 396 fatalities during the seven year period covered by the data. The diverse set of bus operators aggregated as "other" accounted for the next most, with 324. Scheduled intercity accounted for only 107 fatalities during the period, the fewest of the primary types of bus operators.

There are marked differences in where the fatalities occur between the different bus operations types. For most bus types, only a small proportion of the fatal injuries are to occupants of the bus. School and transit buses account for the greatest share of fatalities, but only a small proportion occurs to the occupants of the buses. Only 8.2 percent of fatalities in school bus crashes are to occupants of the school bus, and the on-bus proportion for transit buses is only 2.7 percent. In contrast, 34.3 percent of fatalities in crashes involving charter buses are to bus occupants, and 36.7 percent of the fatalities in "other" bus crashes occur to bus passengers.

One might expect a high proportion of pedestrian fatalities in school bus involvements, given that small passengers are frequently boarding, getting off, and moving around the buses. But in

fact, pedestrians and bicyclists only account for 19.1 percent of fatalities in school bus crashes, far less than the 45.5 percent in crashes involving transit buses. The proportion of non-motorist fatalities in transit bus crashes is more than twice that in any other bus operator type.

Overall, 58.5 percent of fatalities in bus crashes occur to occupants of other vehicles, but again the proportions vary widely by the type of bus operations. The proportion is highest for school buses, with 72.7 percent. Intercity buses have the next highest proportion of fatalities to occupants of other vehicles with 61.7 percent, and for the other bus types (transit, charter, and other) the proportion is about 50 percent.

The types of crashes also vary by bus operator type, reflecting differences in how and where the buses are used. Single-vehicle crashes, either through running off the road or striking an object (usually a pedestrian or other nonmotorist) in the road account for 22–28 percent of the crash involvements for school, intercity, charter, or other buses, but for more than 42 percent of transit bus involvements.

Table 3 shows the different crash configurations for the different bus types. (As in Table 2, the table cells show percentages, and the total number of involvements for each bus type is shown at the bottom of the table.) Virtually all single-vehicle transit bus involvements were collisions with pedestrians or bicyclists. Rear-end crashes accounted for 9–16 percent of crash involvements for each bus type, but transit and school buses are much more likely to be struck in the rear than to be the striking vehicle, while the other bus types are equally likely to be striking or struck. Again, this is likely related to their operations. Both transit and school buses have pick-up and dropoff operations in which the bus stops frequently in traffic. The other types operate more often in a point-to-point mode without frequent intermediate stops in traffic.

Table 3. Percentage Distribution of Crash Type by Bus Operator Type, BIFA 1999–2005

Accident type	School	Transit	Intercity	Charter	Other	Unknown	Total
Single vehicle							
Ran off road	1.9	0.3	6.0	5.5	6.0	0.0	2.3
Hit object in road	20.0	42.3	21.7	23.0	21.1	14.9	27.6
Same direction, same trafficway							
Rear-end, bus striking	1.4	1.5	8.4	7.8	4.4	1.4	2.8
Rear-end, bus struck	11.0	10.5	7.2	7.8	4.4	1.4	9.3
Sideswipe, in other's lane	0.0	0.0	0.0	0.8	0.4	0.0	0.1
Sideswipe, in bus's lane	0.5	1.0	2.4	0.8	1.2	0.0	0.8
Opposite direction, same trafficway							
Head-on, in other's lane	0.6	0.0	0.0	1.6	1.2	0.0	0.5
Head-on, in bus's lane	17.3	7.0	10.8	9.0	8.4	2.7	11.3
Sideswipe, in other's lane	0.2	0.1	0.0	0.4	0.0	0.0	0.2
Sideswipe, in bus's lane	6.0	1.6	2.4	4.3	7.6	1.4	4.3
Change trafficway, one vehicle turning							
Bus turn across path	7.5	3.8	2.4	2.0	4.0	0.0	4.8
Other turn across path	4.8	3.6	2.4	3.5	4.4	1.4	4.0
Intersecting paths, both going straight							
Bus into side of other	9.6	9.0	3.6	7.8	8.4	0.0	8.5
Other into side of bus	4.7	4.2	3.6	1.6	4.0	0.0	3.9
Other accident types							
Untripped roll	0.2	0.0	0.0	0.4	3.6	0.0	0.5
Other	11.7	10.9	22.9	19.1	20.3	5.4	13.5
Unknown	2.9	4.1	6.0	4.7	0.8	71.6	5.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total Crash Involvements	857	731	83	256	251	74	2,252

The proportions of different crash types are consistent with exposure to different risk types. For example, school and transit buses, which operate in stop and go travel in urban areas, have relatively small proportions of run off the road crash types, while (scheduled) intercity, charter/tour, and the diverse "other" group all have much higher proportions of run off road crashes. Evidently, where the operation is on low-speed roads with numerous pick-ups and drop-offs, the factors that contribute to running off the road are not strongly present. But in operations that likely involve (at least for the intercity and charter/tour operations) long intervals on high-speed roads, the proportion of run-offs is around three times higher. Similarly, "hit object in road"—typically collisions with pedestrians or other nonmotorists—account for 20–23 percent of the fatal involvements for most bus types, but for more than 40 percent of the fatal crash involvements of transit buses. Again, exposure to specific types of risks probably explains this result: Transit buses operate in urban areas, and inherent in their operations is exposure to foot

traffic, both in terms of the types of roads they operate on and also because their operations involve frequent episodes of pedestrians getting on and exiting the bus.

Certain crash types can indicate driver error or driver contribution to the crash. In rear-end crashes, the error leading to the crash is much more likely to have occurred in the striking vehicle than in the struck. Similarly, in head-on crashes, the vehicle crossing the centerline is much more often "at-fault" in the crash than the other vehicle. Other crash types are not so clear-cut without information on right-of-way and other factors. Currently there is not sufficient sample size to do more than note some suggestive differences between the carrier types.

However, the BIFA file includes information on driving errors and other conditions coded to the bus driver. These show significant differences among the carrier types. The following few tables show the distribution of driver errors and other "driver-related factors" coded for the drivers of the different bus carrier types. The source data are coded by analysts in the States when compiling the FARS file, which the BIFA survey supplements. The driver-related factors variables (up to four may be coded) are used to record driving errors and other driver actions or conditions that may have contributed to the crash. The remainder of this report explores the relationship between driver record and bus operation type to driver error in the crash.

FARS analysts code the driver-related factors data from police accident reports and other research materials. The coded errors represent the judgment of the original crash investigators, not the FARS analysts. As such, while not a comprehensive evaluation of the factors that contribute to crashes, they represent a useful identification of driving errors and other conditions related to the crash by the original investigators. These data can be interpreted to show the types of driving errors that contribute to crashes. Analysis of the data by bus operator type shows significant differences, which are in turn related to safety differences.

The primary driver errors coded are "failure to yield," "inattention," "driving too fast," and "not in lane." Table 4 shows the most frequent driver errors overall, and their distribution within each of the different carrier types. The proportions of specific types of errors differ significantly between the operator types. Failure to yield was a common driver error for all carrier types, ranging from five to twelve percent of drivers for each carrier type, with intercity carriers at the low end of the range and transit and school buses at the high end. About 7.2 percent of drivers of the "other" carrier type—typically nonprofit organizations or private companies transporting their own employees—were coded as inattentive, and another 3.6 percent as drowsy or asleep. In contrast, transit and school bus drivers are very seldom (0.1 percent) identified as drowsy or asleep. (It should be noted that fatigue and inattention are likely underreported, since, unlike alcohol or drug use, they are difficult to identify after the fact. However, difficulty of detection should not affect the differences between passenger carrier types.) Intercity and charter bus drivers were more likely to be coded as driving too fast (12.0 percent and 8.2 percent respectively) while both transit and school bus drivers had much lower percentages.

Table 4. Percentage of Selected Driver Errors by Carrier Type, BIFA 1999–2005

Driver error	School	Transit	Intercity	Charter	Other	Unknown	Total
Failure to yield	11.6	11.2	4.8	7.0	9.6	8.1	10.3
Inattentive	5.1	4.4	6.0	6.3	7.2	6.8	5.3
Driving too fast	2.1	1.4	12.0	8.2	6.8	10.8	3.7
Not in lane	2.7	1.1	2.4	3.5	7.2	2.7	2.8
Ran off road	2.0	0.8	7.2	3.5	5.2	4.1	2.4
Failure to obey	2.7	1.2	0.0	3.9	2.8	2.7	2.3
Erratic/reckless	1.1	1.1	0.0	3.5	3.6	4.1	1.7
Drowsy, asleep	0.1	0.1	4.8	2.7	3.6	2.7	1.1
Other improper turn	0.5	1.4	0.0	0.0	2.8	0.0	0.9
Over-correcting	0.4	0.0	2.4	0.4	4.4	1.4	0.8
Stopping in road	0.4	0.5	1.2	0.8	0.8	2.7	0.6
N =	857	731	83	256	251	74	2,252

Table 5 provides insight into the overall coding of factors relating to the driver's operation of the bus. For this table, the factors are aggregated either as "driver errors," which are actions or omissions by the driver that in the FARS analyst's judgment contributed to the crash, or as "other factors," which are conditions or events present that may have contributed to the crash. Typical "other factors" coded include vision obstructed by inclement weather or by parts of the vehicle, or swerving to avoid a vehicle in the road. The overall incidence of driver and other factors is about the same for both school and transit bus drivers. Overall, about 70 percent of school and transit bus drivers were not considered to have committed any driving error or had any other factor associated in connection with the crash. The percentages of drivers with no coded factors for intercity and charter/tour bus drivers were lower. About 63 percent of intercity drivers did not have any factor coded, and only 64.8 percent of charter/tour bus drivers had no driver factor coded. Only 55.8 percent of "other" bus drivers had no factor coded. (Up to four driver-related factors may be coded, so the proportions do not sum to the "any factor coded" cell because both a driving error and another factor can be coded for the same driver.)

Table 5. Driver Error and Other Driver-Related Factors by Carrier Type, BIFA 1999–2005

Driver factor coded	School	Transit	Intercity	Charter	Other	Unknown	Total
None	69.1	71.4	62.7	64.8	55.8*	64.9	67.5
Driver error	24.1	20.9	31.3	31.0*	38.7*	29.7	25.5
Other factor coded	9.4	9.5	8.4	9.9	11.3	9.5	9.5
Any factor coded	29.6	26.9	37.3	34.1	43.6*	35.1	32.5
N =	857	731	83	256	251	74	2,252

* Statistically different from school bus proportions at 0.05 level.

A driver error was coded for 24.1 percent of school bus drivers, and some other related factor was coded for 9.4 percent. For transit bus drivers, the proportions were 20.9 percent and 9.5 percent. In contrast, both scheduled intercity and charter/tour bus drivers had higher proportions of driver errors coded; charter bus drivers also had a slightly higher proportion of other factors

coded. “Other” bus drivers had the highest rate, with 38.7 percent coded with a driver error and 11.3 percent with another related factor.

Statistical tests were performed to determine the reliability of the differences, given sample sizes, at the 0.05 level. School buses were taken as the baseline case, to which the other carrier types were compared, because they had the smallest proportion of factors coded and because of the relatively large sample of school bus fatal involvements. Only charter/tour and “other” carrier type drivers differed by a statistically significant amount from school bus drivers in the proportion of driver and other factors coded. About 31.0 percent of charter/tour bus drivers were coded with a driving error, compared with 24.1 percent of school bus drivers and only 20.9 percent of transit bus drivers. Almost 39 percent of the “other” carrier type drivers were coded with a driving error that contributed to the crash.

There are also significant differences by carrier type with respect to the previous driving record of the drivers. Table 6 shows the incidence in the three years prior to the crash of accidents, suspensions, driving while intoxicated (DWI) convictions, speeding, and other moving violations. As with driver errors, school bus drivers were defined as the baseline case for comparison purposes, and statistical tests were performed to determine the reliability of the differences.

Table 6. Percentage of Drivers with Selected Previous Accidents or Violations by Carrier Type, BIFA 1999–2005

Driver history	School	Transit	Intercity	Charter	Other	All Buses
Accidents	15.9	29.9*	11.0	21.9	15.2	21.0
Suspensions	3.1	3.3	0.0	6.6*	8.5*	4.2
DWI	0.0	0.7*	0.0	0.0	0.0	0.2
Speeding	8.8	11.3	10.3	17.2*	12.6	11.1
Other moving violations	9.2	14.8*	12.8	18.9*	15.4*	13.3
All violations	18.0	24.2*	21.8	31.2*	27.9*	23.3
Any violation or accident	29.7	46.3*	32.4	44.0*	39.6*	38.5
N =	805	689	73	237	231	2,102

* Statistically different from school bus proportions at 0.05 level.

School bus drivers have the lowest incidence of previous accidents or violations, compared with other passenger carrier types. School bus drivers also have among the lowest percentages when the individual violation types are considered, such as license suspensions, speeding violations, or other moving violations. Only some of the differences are statistically significant in these data, however. Less than one percent of transit drivers had a DWI conviction in the prior three years, but no bus driver for the other carrier types had such a conviction. Transit bus drivers also had higher proportions than school bus drivers of previous accidents, speeding and other moving violations. The differences are statistically significant for the percentages of previous crashes and of other moving violations. In addition, when all the violation types are aggregated to measure any previous moving violation or any violation or accident, transit bus drivers had significantly worse driving records than school bus drivers.

Scheduled intercity bus drivers also had driving records with higher proportions of violations and of either a violation or a crash, but the sample size for intercity drivers is not large enough to attain statistical significance. However, charter/tour bus drivers had higher proportions on each measure except for DWI, and the differences were statistically significant at the 0.05 level for suspensions, speeding, other moving violations, and any violation or accident. The proportions of charter bus drivers with speeding violations or other moving violations within the last three years were each around twice that of school bus drivers. Almost 45 percent of charter bus drivers had either a traffic violation or crash within the last three years, compared with about 30 percent of school bus drivers.

The diverse "other" bus group also shows higher proportions of traffic violations on their driving records, though the proportion of prior crashes is about the same as the baseline school bus drivers. "Other" bus drivers had higher proportions of suspensions, speeding and other moving violations, and the combination of either a prior traffic violation or crash. Most of the differences were statistically significant at the stringent 0.05 percent level.

Both the incidence of driver errors in the current crash and the prior driving record of the bus drivers vary significantly by bus operation type. Previous work[3,4] has shown that driver record is predictive of crash involvement, and related to carrier safety. So, are the differences between carrier types in terms of driver errors in the crash related to differences in the prior driving record of the drivers, or are they related to other factors? Evidence has been presented here to show that carriers vary by their operations and that this may also be reflected in exposure to crash risk. In addition, other factors can be associated with driver error in crashes, and these may also vary for different carrier types. For example, the population of school bus drivers is disproportionately female compared with other bus operator types. Both transit and school bus drivers operate primarily on local trips, while intercity and charter/tour bus more often are involved in over-the-road trips. School bus and transit bus operations are predictable and have a daily routine, while charter/tour buses can have more lengthy schedules. There are also differences in terms of the types of compensation the drivers receive, whether hourly, on salary, or some other method.[1]

All of these factors may affect driver error in crashes, in addition to the previous driving record. The BIFA data set includes data on driver age and sex, driver compensation, trip type, and compensation. Table 7 shows that these characteristics of the driver and trip are associated with differences in the proportion of driver error. Drivers on over-the-road trips (longer than 50 miles) are more likely to be coded with a driver error than those on local trips. Males are somewhat more likely to be coded with a driving error than females; and younger (≤30 yrs) and older (>60 years) drivers are both more likely to be coded with an error than those in middle age. The BIFA file includes detailed information on how the driver was compensated, but the two most common methods for bus drivers are hourly compensation and salary. Drivers compensated by the hour have lower rates of coded driver errors than others, while the difference between salary and all other types of compensation is small. On the other hand, the group of drivers compensated by all other means (mileage, tips, and even no compensation) have the highest rates of coded driver errors.

[1] See, for example, *Buses Involved in Fatal Accidents Factbook, 2004.* Center for National Truck and Bus Statistics, University of Michigan Transportation Research Institute, Ann Arbor. Tables 4-3, 4-4, 4-9, 4-11.

Table 7. Percentage of Driver Error by Trip Type, Driver Age and Sex, and Compensation Type, BIFA, 1999–2005

Driver/Trip Characteristic	Characteristic Variable	N	Percent Driver Error
Trip type	Local	1,616	23.5
Trip type	Over-the-road	337	33.2
Driver sex	Male	1,473	27.2
Driver sex	Female	725	22.5
Driver age	≤30	211	29.4
Driver age	30–60	1,683	24.0
Driver age	60+	298	32.6
Driver compensation	Hourly: Yes	1,438	23.5
Driver compensation	Hourly: No	380	29.2
Driver compensation	Salary: Yes	147	26.5
Driver compensation	Salary: No	1,672	24.6
Driver compensation	All other: Yes	369	29.0
Driver compensation	All other: No	1,452	23.7

Table 8 shows number of coded driver errors by hours driving at the time of the crash. The number of hours driving varies from 1 to 10 hours. A logistic regression model can be fit to these data to estimate the probabilities of coded driver errors at each of the ten levels of hours driving. The model takes the form

$$\log\left(\frac{p_i}{1-p_i}\right) = \alpha + \beta\, x_i \qquad i = 1,\ldots,10$$

where α and β are parameters to be estimated, and x_i represents hours of driving at the time of the crash. The p_i are the probabilities of coded driver errors. Statistical software was used to fit this model to the data shown in Table 8. After fitting the model, the above formula can be solved to give the estimated probabilities of coded driver error.

Table 8. Coded Driver Errors by Hours Driving at the Time of the Crash

Hours Driving (x_i)	Coded Driver Errors: YES	Coded Driver Errors: NO	Total
1	99	370	469
2	66	234	300
3	66	147	213
4	39	115	154
5	32	102	134
6	32	84	116
7	13	32	45
8	11	31	42
9	8	15	23
10	3	8	11

Figure 1 shows a general trend to higher percentages of coded driver error the longer the driver has been at the wheel since the driver's last 8-hour period of rest. The figure shows the observed percentage of driver error, along with the fitted logistic regression line and a 95 percent confidence band. The observed percentages can be reproduced from Table 8 by dividing the number of coded driver errors "Yes" by the total in each row. Most of the observed percentages fall within the 95 percent confidence interval. Note that the interval widens significantly for cases with greater than 6 hours of driving. As shown by Table 8, sample sizes drop precipitously in that region, so that there were only 23 and 11 cases respectively for hours 9 and 10.

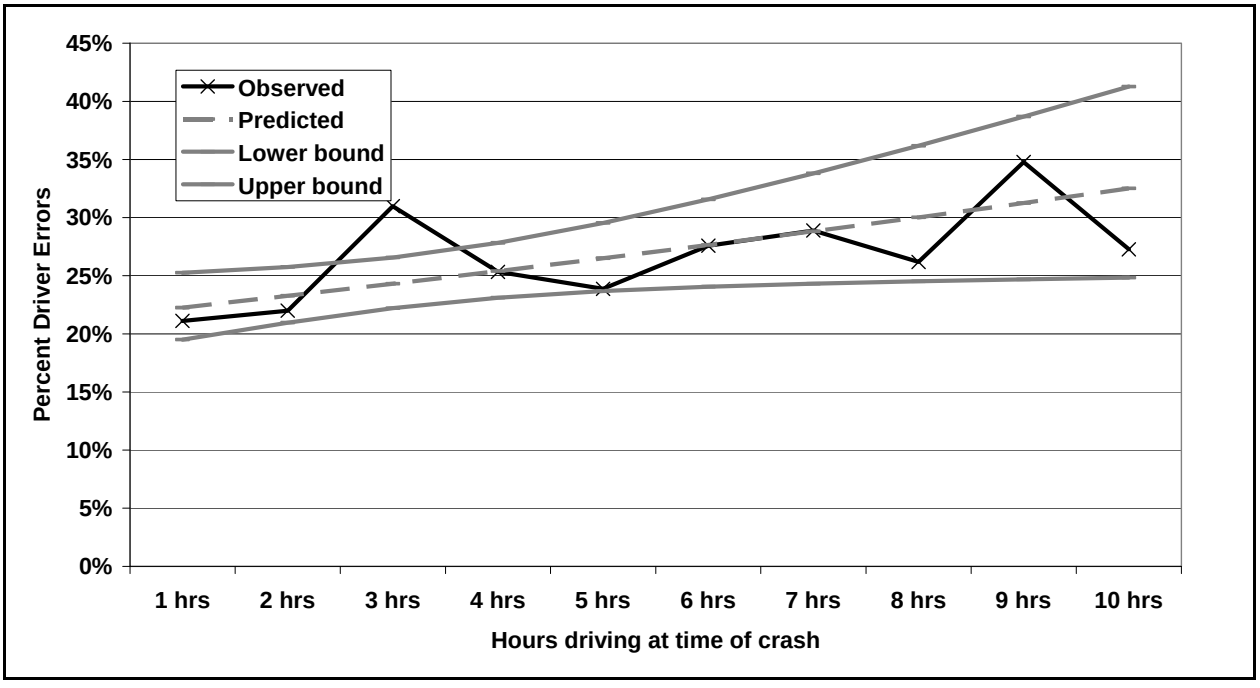

Figure 1. Percentage of Coded Driver Errors by Hours Driving, with Predicted and 95% Confidence Limits, BIFA 1999–2005

A number of factors have been identified that are associated with the probability of errors coded to the bus driver in fatal crash involvements. The factors are related to characteristics of the driver (age, sex, method of payment, and previous driving record), or of the type of bus operations (operation type and trip type). Given the large number of factors that are apparently associated with differences in the probability of a driving error coded to the bus driver, statistical models were fitted to the data to estimate the effect of each factor, holding the other factors constant.

The logistic regression model that was described and used above to model the relationship between coded driver errors and number of hours driving at the time of the crash can be extended to include multiple factors. The method is to include various variables in a model and to estimate the associated parameters simultaneously in order to judge their effects on the likelihood of coded driver error. Certain parameters in the model have interpretations as odds ratios on the log scale. The models estimate the effects of various factors on the odds of driver error, relative to a baseline case. Some of the levels of the variables were combined for the sake of interpretation. The parameters estimate the increase (or decrease) in driver error probability when the particular factor is varied from the baseline case. Table 9 represents the baseline cases for the initial driver error model.

Table 9. Factors in Initial Driver Error Model and Baseline Case

Factor	Baseline case
Bus type	Transit
Trip type	Local
Compensation	Hourly/Mileage
Age	≤30 years
Sex	Male
Previous suspensions	None
Previous DWI	None
Previous speeding	None
Previous moving violations	None
Previous crashes	None

Initially, the variable hours driving was incorporated in the model, but since the value is unknown for about 30.1 percent of the involvements, this was not practical. Cases with missing data on any of the predictor variables are deleted from the model. Including hours driving resulted in almost half of the cases being excluded from the model, which was not viable. So, while the results shown in Figure 1 suggest a relationship, it was not possible to test the relationship in combination with the other factors that are also apparently associated with coded driver error.

Table 10 shows the parameter estimates, standard errors of the parameters, and the statistical significance of the parameters. The initial model incorporates all the factors available that were identified above as associated with the probability of a bus driver coded with a driving error in a fatal crash. Negative parameters indicate that the factor reduces the probability of a driver error,

relative to the baseline and positive parameters indicate that the factor increases the probability of a driver error relative to the baseline.

Table 10. Parameters, Standard Errors, and Significance of Initial Driver Model

Parameter	Level	Parameter Estimate	Standard Error	*p* value
Intercept		-1.3807	0.2183	<.0001
Bus	School	0.2352	0.1513	0.1200
Bus	Intercity	0.4190	0.3434	0.2225
Bus	Charter	0.3303	0.2457	0.1789
Bus	Other	0.8039	0.1998	<.0001
Trip type	Over the road	0.2746	0.1976	0.1646
Driver sex	Female	-0.1177	0.1369	0.3899
Driver age 1	31–60	-0.2055	0.1989	0.3014
Driver age 2	61+	0.1749	0.2382	0.4628
Compensation	Hourly or mileage	0.0511	0.1483	0.7303
Previous suspensions	1 or more	0.6726	0.2814	0.0168
Previous DWI	1 or more	-12.4198	434.600	0.9772
Previous speeding	1 or more	-0.2412	0.1968	0.2203
Previous moving violations	1 or more	0.4306	0.1690	0.0108
Previous crashes	1 or more	0.1698	0.1416	0.2304

Many of the factors in Table 10 do not achieve statistical significance, using a *p* value of 0.05 as a rule of thumb for significance. Trip type, driver sex, driver age, and compensation type all fail, in these data, based on the usual test of statistical significance. Even though the tables above indicated a relationship, when the factors were considered one at a time, in a multi-factor model, their effect on driver error was not large enough to be reliable. The effects of some of the specific violation types were significant: for example, previous suspensions and previous moving violations. There were very few cases where a driver had a previous DWI, which probably accounts for the very high *p* value. In sum, the model incorporating all the factors previously identified as associated with driver error may be too ambitious for the data under investigation.

A systematic procedure was used to eliminate factors that were not significant one at a time to search for a statistically significant model. In addition, a new variable was created that captured whether the driver had any previous traffic violations, replacing the individual violation types. As a result of this stepwise procedure, a much simplified model was estimated, incorporating many fewer factors, but resulting in a much better model fit. This final model includes only the bus operation type, prior traffic violations, and prior crashes. Table 11 shows the parameter estimates, the standard error of the estimates, and the significance values. While not all the estimates are significant at the 0.05 level, all but one are significant at better than 0.10 which is a reasonable level for non-experimental, observational data. (The bus operation type variable has five levels; it is not useful to exclude individual levels.)

Table 11. Final Logistic Regression Model of Driver Errors Parameters, Estimates, and Significance

Parameter	Level	Parameter Estimate	Standard Error	*p* value
Intercept		-1.4991	0.1082	<0.0001
Bus	School	0.2371	0.1288	0.0657
Bus	Intercity	0.6404	0.2712	0.0182
Bus	Charter	0.5177	0.1728	0.0027
Bus	Other	0.9483	0.1678	<0.0001
Previous violation	1 or more	0.2433	0.1210	0.0444
Previous crash	1 or more	0.2403	0.1274	0.0592

The parameter estimates shown in Table 11 indicate that the primary factors affecting the probability of bus driver error in fatal crashes is the operation type of the bus, and the driver's previous record with respect to traffic violations and crashes. The size of the parameter for school bus is relatively small, and fails the 0.05 test of significance, reflecting the fact that the differences in proportion of driver error between school bus and transit bus drivers is not large. However, the parameters for the other bus operation types is larger, with the parameter for the diverse "other" type the largest in the model. All are statistically significant. A record of previous violations or previous crashes also is associated with a higher probability of driver error.

Table 12 shows the odds ratios associated with the factors, along with 95 percent confidence intervals (CI) for the odds ratios. Odds ratios are a way of expressing how much the factor increases the chance (odds) of the event modeled. Factors with ratios greater than 1 increase the odds, and those with ratios less than 1 decrease the odds. If the CI excludes 1, then the factor is statistically significant, in this case at the 5 percent level. If the CI includes 1, then it is not significant at that level.

Table 12. Odds Ratios for Final Driver Errors Model

Factor	Factor Level vs. Baseline	Odds Ratio Estimate	95% CI: Lower	95% CI: Upper
Bus	School vs. transit	1.268	0.985	1.631
Bus	Intercity vs. transit	1.897	1.115	3.228
Bus	Charter vs. transit	1.678	1.196	2.355
Bus	Other vs. transit	2.581	1.858	3.587
Previous violation	Previous violation vs. no previous	1.275	1.006	1.617
Previous crash	Previous crash vs. no previous	1.272	0.991	1.632

The model parameters show that both operations type and driver record have a substantial effect on the probability that a bus driver in a fatal crash will be coded with a driving error. School buses have the lowest odds ratio compared with the baseline, and note that the 95 percent confidence interval includes 1. Intercity, charter, and other all have odds ratios substantially higher, and their 95 percent confidence intervals do not include 1. For intercity, the odds increase by 1.9 times relative to transit buses, with the 95 percent confidence interval ranging from 1.1 to

3.2. The odds ratio for charter (including tour) buses is about 1.7 times higher than transit, while the odds ratio for the diverse "other" bus operations is about 2.6 times. The 95 percent confidence interval ranges from 1.9 to 3.6. The "other" type includes buses operated by companies to transport their own employees, by non-profits such as churches, by different units of governments, shuttle operations for hotels and airports, farm labor carriers, nursing home buses to transport patients, and even companies that deliver new or used buses.

Previous driving record also is significantly related to the probability of being coded with a driving error in the current crash. The variables record violations or crashes within three years preceding the crash. Both previous violations and previous crashes increase the odds of a driving error by about 1.3 times. The parameter for previous crashes just fails the usual 0.05 significance test, but such a test is likely too rigid for observational data. It is reasonable to conclude that the driver's record within the past three years is associated with the probability of a driver error being recorded. Bus drivers with marks on their driving record are about 27 percent more likely to commit a driving error in a fatal crash than those without.

DISCUSSION

Passenger carrier type has a significant effect on virtually all aspects of the experience of buses in fatal traffic accidents. Suggestive differences were found, in this and previous studies, between the four primary carrier types defined here—school, transit, scheduled intercity, and charter/tour—in virtually every dimension examined. These differences are reflected in the time of the crashes, the area and roads on which the crashes occurred, and who in the crash is at greatest risk of fatal injury. BIFA project data allow bus operators to be identified at a level of detail significantly greater than in any other crash data.

The passenger carrier types also differ in the percentages at which drivers involved in fatal accidents are coded with a driving error in the crash. The driver errors here are specifically identified on the original police accident report or other crash investigation. While not a comprehensive determination of contribution to the crash, they may be regarded as the judgment of the investigators as to the driver's role in precipitating the crash. In this way, they reflect on the safety performance of the different bus operator types.

In terms of previous driver record and driver errors in the crash, significant differences were found among the passenger carrier types examined. Some of these differences were great enough to be statistically significant, even given the limited data available. School bus drivers had the best driving records and were coded with relatively few driving errors in the crash, compared with the other bus carrier types. Both intercity and charter/tour bus drivers had much higher percentages than school bus drivers on most of the measures. Statistical significance could not be established for intercity drivers because of the number of cases available, but the differences for charter bus drivers were both large and statistically significant. Fully 44 percent of charter bus drivers had a conviction, suspension, or crash in the three years prior to the crash, compared with only about 30 percent of school bus drivers. And 31 percent of charter bus drivers were coded with a driving error in the current crash, compared with 24.1 percent of school bus drivers. This difference was statistically significant at the 0.05 level.

The bus operations types identified here differ in a number of respects, any of which are arguably related to safety and tend to influence the likelihood of driver error. Transit and school buses operate typically on predictable, regular schedules, and usually in urban areas on low speed roads. Scheduled intercity buses of course are scheduled, but have longer hauls and travel more on roads that may have lower traffic density, but higher speeds. Charter/tour buses may also have long hauls, but less predictable schedules. School buses have a higher proportion of female drivers, while the collection of "other" buses may include very inexperienced drivers whose main occupation is something other than driving. A wide variety of factors were considered, including age, sex, trip type (local or over-the-road), type of driver compensation, and hours driving, in addition to driver record and bus operations type.

A logistic regression model was used to estimate the effect of the different factors on the probability of bus driver error in the crash. This technique allows us to account for the separate effects of the different factors. A stepwise procedure was used, in which all the factors were included in the model initially; then nonsignificant parameters were eliminated until a good fit was achieved with significant parameters.

In the final model, driver record captured as violations and crashes within the previous three years, and bus operation types were the only factors with statistically significant parameters. Even though trip type, compensation, and even driver sex (i.e., the high proportion of female school bus drivers) are related to passenger bus operation types, none significantly contributed to the fit of the model—the ability of the model to predict driver error—and so were dropped. Prior driver record, captured as previous violations and previous crashes, both increase the probability that a driver will be coded with an error in the crash. Put another way, drivers with a record of driving violations, or who have been involved in a crash, are more likely to have contributed to the current crash than other drivers.

The type of bus operations is also a significant predictor of coded driver error in the current crash. Both transit and school bus drivers are the least likely to have contributed to the crash. Intercity operations are associated with an increase in the odds by 1.9 times, with a 95 percent confidence interval from 1.1 to 3.2 times. Both charter and the "other" bus operations were associated with significantly higher odds of driver error. The odds ratio for charter/tour bus operations was 1.7 (range of 1.2–2.4), while for "other" buses it was 2.6 (1.9–3.6).

The differences uncovered in this analysis have implications for safety improvements and validate the approach taken in the BIFA survey. Motor carrier type plays a major role in fatal bus crash involvements and, even at the level undertaken in this study, point to quite different safety interventions, depending on the operation type. Pedestrian/bicyclist crashes are, of course, a problem for school buses and improved driver vision around the bus remains an issue. Driver vision around the bus is clearly a major issue for transit bus drivers, in light of the very high proportion of pedestrian/bicyclist collisions. The high proportion of rear-end crashes in which the bus is struck suggests that conspicuity and awareness that the bus is stopped may need to be addressed. Driver issues are more of a focus for intercity, charter/tour bus, and the diverse "other" bus operations, although the small sample size for intercity involvements make conclusions tentative. Finally, there are safety differences associated with the operations themselves, beyond the type of drivers employed.

Given the significantly higher rate of driver error in the "other" bus group, future research might be focused on better defining this group and understanding the diversity of operations encompassed. The group ranges from airport shuttle buses, to companies transporting workers to the job, to nonprofits such as churches transporting members to social functions. Future work could explore the group to determine which subpopulations are driving the overall record. For example, airport shuttle operations bear some resemblance to how transit buses are operated, while church buses driven by volunteers likely have a very different experience. Charter/tour bus operations also warrant future research to determine the factors that contribute to their performance relative to the other bus types. Many charter/tour bus companies are small operations which may affect their safety performance. While passenger carriers as a whole do not contribute disproportionately to fatal crashes, there are clearly opportunities to understand the factors that contribute to poor performance and to address them.

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