Factors Contributing to School Bus Crashes

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School bus safety is a community concern because parents expect their children to be transported to and from school safely. However, relatively few studies have been devoted to examining the factors contributing to school bus crashes. In this study, a logistic regression model is used to delineate the factors that contribute to school bus collisions from collisions involving other types of buses. As expected, we find significant differences in crash factors arising from differences in exposure and operating characteristics. Surprisingly, we also find that school bus drivers are more likely to commit driving violations or errors than non-school bus drivers.

INTRODUCTION

Road safety is a serious issue around the world, with more than 1.2 million people killed every year (WHO 2004). In the Province of Alberta in Canada alone, nearly 400 people are killed and more than 27,000 people are injured in over 112,000 motor vehicle collisions each year (AT 2006). The direct social cost of motor vehicle collisions to Albertans is as much as $4.68 billion, or 2.4% of Alberta's gross domestic product. Although school buses (SB) were involved in only 0.4% of the total number of collisions occurring in Alberta in the last decade, these crashes tend to receive disproportionate attention in the media and the community because of the high safety expectations for SB and the intensity of emotions involved when school children are injured.

SB safety has a high priority in the community because parents put their trust in schools and SB drivers to transport their children to and from school safely. About 6,000 SBs in Alberta, Canada, travel over 76 million kilometres each year to transport approximately 126,000 students in rural areas and 139,000 students in urban areas (Opus Hamilton 2008) and they are considered to be one of the safest modes. The proportion of SB collisions resulting in injury is 13.7%, while the share of total collisions in Alberta that results in injury during the same time period is 15.2% (Opus Hamilton 2008). Thus, there is a slightly lower risk of SB collisions resulting in injuries compared to all collisions.

Nevertheless, SB accidents do occur and sometimes with tragic consequences. They also tend to be followed by public demand for actions that may not be supported by theory or evidence. Hence, any collision involving an SB is a cause for concern, especially when it results in casualties among our most vulnerable population. To ensure even greater safety of SB operation, it is necessary to identify the factors that are responsible for SB-related accidents in order to provide evidence-based recommendations to improve the safety performance of these buses.

The objective of this research is to identify the factors associated with SB crashes that significantly differ from the factors associated with other bus crashes in Alberta. Since very few previous studies pertaining to SB-related collisions are found, this research aims to provide valuable insight to transportation and safety professionals in identifying safety issues and assist them in making decisions that will enhance SB safety. To achieve this objective, this paper first reviews the relevant literature and develops a simple conceptual framework to identify some potential factors contributing to SB crashes that may be different from those contributing to crashes involving other types of bus collisions. To test the hypotheses, descriptive analyses and Chi-square tests of the characteristics of SB and non-SB collisions are performed using data from the Canadian province of Alberta. In addition, a logistic regression model of SB and non-SB crashes is estimated.

LITERATURE REVIEW

Despite being a considerable community concern, the literature survey did not find many studies on the statistical analysis of factors contributing to SB collisions. Most studies analyze collisions involving all types of buses and coaches but do not separate SBs from other buses, with a few studies investigating only transit buses or coaches (Albertsson and Falkmer 2005, Rahman et al. 2011, Evans and Courtney 1985, Barua and Tay 2010, Chimba et al. 2010, Zegeer et al. 1994, Tseng 2012, Mohamed et al. 2012). In one of the few studies that examine SB crashes, Yang et al. (2009) applied Chi-square tests to determine the differences in crash and injury characteristics between SBs and other vehicles in the state of Iowa. They found that day of week, time of day, speed limit, driver characteristics, and vehicle characteristics are significant factors associated with SB crashes and injuries, and that drivers of other vehicles are more likely to have caused SB crashes.

Besides these works, few published studies examine the prevalence of SB crashes and most analyze the biomechanics of SB occupant injuries and fatalities. For examples, Hinch et al. (2002) focus on design features inside SBs while McGeehan et al. (2006) use data from medical sources to identify different types of injury. They found that motor vehicle collisions account for 42.3% of SB-related injuries, followed by injuries sustained while boarding or alighting the bus (23.8%). Lapner et al. (2003) examine frontal collisions and rollover crashes, which are most likely to result in fatality or severe injuries, and found that they are relatively rare and contribute mainly to head, neck, and spine injuries. Some studies examine the annual cost of SB-related crashes. For example, Miller and Spicer (1998) found that SB injuries account for half of all school injury deaths in the United States and estimate the annual social cost of SB related collisions as $330 million.

CONCEPTUAL FRAMEWORK AND RESEARCH HYPOTHESES

There are several reasons why the characteristics of vehicle collisions involving buses should be different between SB and non-SB crashes. The most obvious is the difference in exposure, which has a direct influence on crash risks. Extant research finds that day-of-week and time-of-day have a significant impact on many types of vehicle crashes (Kim et al. 2008, Chen et al. 2012, Anowar et al. 2013). Unlike other types of buses (transit bus, tour coach, and private bus), SBs operate mostly during the beginning and ending of a school day. Thus, relative to non-SBs, SBs are hypothesized as being more likely to crash during weekdays relative to weekends. They are also hypothesized to be more likely to crash during morning and afternoon peak periods relative to night-time and off-peak periods. Moreover, since many schools are closed for extended periods during the summer calendar months, SBs are also hypothesized as being less likely to crash during summer (season of the year).

Besides the four seasons, weather and road surface conditions are other seasonal factors that affect vehicle crashes (Kim et al. 2007, Lee and Abdel-Aty 2005, Anowar et al. 2013). Although weather and road surface conditions are expected to be correlated, they do measure some distinctive effects. First, roads are more likely to be covered in snow during winter even though it may not be snowing on a particular day, especially for local roads where the SBs tend to ply. Second, bad weather affects visibility and sight distances more while a wet or snowy road surface condition affects mostly traction, steering, and control. In terms of visibility, however, SBs may be more visible in bad weather than non-SBs because of their bright yellow color, stop signs, and flashing lights. Consequently, relative to non-SBs, SBs are hypothesized as being more likely to crash on roads covered with snow (road surface condition) but less likely to crash during snowy weather (weather condition).

Another environmental factor that has been found to be significant in road safety is location. In this regard, there are some major differences in the locations where SBs operate compared with non-SBs. For example, unlike transit buses, which mostly operate in urban areas, SBs have a significant presence in rural areas. Past research has found that a higher proportion of rural students use SBs than their urban counterparts because travel choices are limited in rural areas (Tucker 2008). Furthermore, the distances travelled by school children are longer in the rural areas (Kmet and Macarthur 2006). Hence, relative to non-SBs, SB crashes are hypothesized to occur more in rural areas than urban areas.

SBs are also operated differently because of differences in their trip demands or usage, which may result in different types of crashes. The types of crashes have been found to be a significant factor in traffic safety (Abdel-Aty 2003, Haleem and Abdel-Aty 2010, Obeng 2007, 2011). For example, relative to non-SBs and especially non transit buses, SBs involve more frequent stops and starts to pick up or drop off school children. These stop and start operations increase the likelihood of rear-end collisions. Moreover, drivers are not supposed to overtake an SB that has stopped to pick up or drop off students. Therefore, relative to non-SBs, SBs are hypothesized as more likely to be involved in rear-end collisions than passing and sideswiping crashes. They are also hypothesized to be more likely to experience impact at the rear but less likely to experience impact at the front or side. Moreover, SBs are generally driven at lower speeds relative to non-SBs (e.g., non-transit buses like tour buses and private buses) and this contributes to their lower crash severity. Thus, relative to non-SBs, SBs are hypothesized to result in crashes of lower severities. Additionally, they are less likely to be involved in rear-end crashes, which usually involve single or multiple vehicles, but as posited above, they are more likely to be involved in rear-end crashes, which usually involve two vehicles. More importantly, they are less likely to speed and be involved in single vehicle run-off-road crashes. Also, because of their visibility and the tendency of drivers to slow down when approaching a stopped SB, they are less likely to be involved in crashes involving more than two vehicles. Hence, relative to non-SBs, SBs are hypothesized as being more likely to be involved in two-vehicle collisions than single or multiple vehicle collisions.

Besides the types of crashes, the types of roadways have been found to be an important determinant in traffic safety (Abdel-Aty and Keller 2005, Abdel-Aty and Haleem 2011, Haleem et al. 2010, Rifaat et al. 2012a). Since SBs tend to operate more often on local roads than non-SBs, they are hypothesized as more likely to crash at intersections without traffic signals. Also, vehicle characteristics are important factors in road safety (Obeng 2011, Tay et al. 2009, 2010, Barua et al. 2010, Tay 2003, 2002). And driver characteristics have been widely found to be a significant contributing factor (Obeng 2007, Wang and Abdel-Aty 2008, Anowar et al. 2013). SBs are more likely to be operated by female drivers compared with non-SBs. For example, according to one employment agency, 60% of SB drivers in 2011 in Canada were females while only 15% of non-SB drivers were females.[1] The dominance of female drivers is confirmed by Parkland School Division (approximately 60%) and Black Gold Regional Schools (71.2%).[2] Additionally, SBs are also more likely to be operated by older drivers (65 and above), and older drivers have been found to have higher crash risks (Tay 2012, 2008, 2006). Therefore, relative to collisions involving non-SBs, those involving SBs are hypothesized as more likely to involve a female driver and/or an older driver.

Finally, aberrant behaviors defined as driver errors and violations are widely considered to be major causes of road crashes (Rifaat et al. 2012b, Yasmin et al. 2012). Following, Reason et al. (1990) and Parker et al. (1995), driving errors are defined as the failure of planned actions to achieve their intended consequences (e.g., underestimating speed of oncoming vehicles when overtaking) and driving violations are defined as deliberate deviations (e.g., speeding) from those practices believed necessary to maintain the safe operation of a potentially hazardous system. Since safety is one of the major considerations in the selection of SB drivers, they are expected to be less likely to be assessed as having committed traffic violations and errors in the event of a crash. And there are many training programs available for SB drivers to improve their driving, some of which are subsidized by the government. Hence, relative to collisions involving non-SBs, drivers in collisions involving SBs are hypothesized as being less likely to be assessed as having committed a driving violation or error.

Of note, however, is that the factors contributing to any road traffic collision are numerous and often interrelated. The analytical framework developed thus represents only a partial view of these complex relationships, and the factors chosen are based primarily on data available in police collision reports. Nevertheless, it presents a reasonably strong case for the need to examine the different factors contributing to SB and non-SB collisions but does not determine the likelihood or frequency of a SB crash occurring. Although exposure variables are critical in crash likelihood or crash frequency models, they are not important in differentiating whether a bus that has already crashed is more likely to be an SB or another type of bus. However, it is reasonable to assume that traffic volume will have similar effects on SB and non-SB with respect to where the crash occurs, what time the crash occurs, what type of road the crash occurs on, and the weather and road surface conditions.

METHODS

Data

Data for this study are extracted from the official crash database provided by Alberta Transportation. The database consists of all police reported crashes in the province from 1999 to 2008. The severity of a crash is determined by the person with the most severe injury and a crash is considered fatal if at least one person dies within 30 days of the collision. Also, a crash is considered injurious if at least one person suffered injuries, and a property damage only crash is that in which no injury occurred but damage of at least $1,000 was sustained. The crash records contain common types of information on collisions including the time, location, and severity of collisions as well as data on the driver, crash types, vehicle, environment, and any special road features at crash locations.

Since the focus of this study is to identify the factors differentiating SB crashes from other bus crashes in Alberta, all crashes involving at least one bus are extracted for analysis. SBs include both the traditional yellow SBs and transit SBs, because some of the SB routes, especially for high schools, are operated by public transit agencies such as Calgary Transit. The comparison group include inter-city buses, non-school route transit buses, tour buses, and other special buses. The final sample consists of 8,576 bus-related collisions for the ten-year period (1999-2008), and of these, 38.1% are SB collisions and 61.9% are collisions involving non-SBs.

Preliminary Analyses and Chi-Square Tests

Based on the information available in the dataset, 20 factors are selected for analysis. Broadly, these factors are categorized into crash characteristics, vehicle characteristics, environmental conditions, traffic control, operational characteristics, and driver characteristics. Preliminary analysis excluded statistically insignificant factors resulting in the 14 factors in Table 1. The distributions of collision characteristics of SB and non-SB collisions are reported in Table 1, which also shows the Chi-square tests used to identify those factors that differ significantly between the two types of collisions.

Table 1: Distribution of Crash Characteristics (%)

Variables	School Buses	Other Buses	χ^2- Stat
Crash Severity			
Casualty (Fatal or Injury)	18.64	19.86	1.66
Property Damage Only	81.36	80.14	
Season***			
Winter	60.04	50.39	166.99
Spring	14.46	13.96	
Summer	9.16	20.37	
Autumn	16.34	15.28	
Day of Week ***			
Weekend	3.21	16.57	303.41
Weekdays	96.79	83.43	
Time of Day***			
6.00 a.m. - 8.59 a.m.	37.61	18.33	654.49
9.00 a.m. - 2.59 p.m.	28.27	32.82	
3.00 p.m. - 5.59 p.m.	30.98	28.00	
6.00 p.m. - 6.00 a.m.	3.14	20.84	
Region ***			
Rural	12.62	4.23	180.79
Urban	87.38	95.77	
No. of Vehicles Involved***			
Single	5.55	5.82	15.78
Two	88.93	86.28	
Three or more	5.52	7.90	
Primary Event***			
Struck Object	10.31	11.83	205.32
Off-road	2.24	0.89	
Passing	2.42	6.90	
Angular	23.62	24.98	
Sideswipe	18.61	23.28	
Rear-end	31.95	24.77	
Head-on	2.02	1.21	
Backing	7.10	3.51	
Other	1.73	2.61	
Weather Condition***			
Clear	80.60	79.03	21.32
Rain	3.03	4.70	
Hail/sleet	0.47	0.59	
Snow	13.20	13.94	
Other	2.70	1.74	

(Table 1 continued on p. 68)

Table 1: Distribution of Crash Characteristics (%) cont.

Variables	School Buses	Other Buses	χ^2- Stat
Road Surface***			
Dry	49.73	56.96	85.74
Wet	7.86	10.96	
Snowy	41.04	31.04	
Other	1.37	1.04	
Driver Gender ***			
Female	59.43	19.61	1226.67
Male	40.57	80.39	
Driver Age***			
Age less than 25	3.17	2.46	116.94
Age 25 to 44	46.52	40.60	
Age 45 to 64	43.89	54.30	
Age 65 and above	6.42	2.63	
Driver Action***			
Driving Properly	55.68	67.92	120.67
Driving Violation	17.67	11.15	
Driving Error	19.62	15.36	
Other Driver Action	7.03	5.57	
Point of Impact***			
Right Front	8.04	10.30	133.22
Right Center	5.48	9.73	
Right Rear	11.07	10.56	
Back Center	26.29	18.63	
Left Rear	5.63	8.41	
Left Center	6.02	6.35	
Left Front	9.34	11.64	
Front Center	26.61	23.18	
Other Point of Impact	1.51	1.19	
Traffic Control***			
Uncontrolled	58.24	59.02	169.12
Traffic Signal	22.47	31.15	
Stop Sign	10.64	5.40	
Yield Sign	4.69	1.95	
Other	3.97	2.49	
Note: *, ** & *** denote statistically significant differences at α=10, 5 & 1%, respectively			

Logistic Regression Model

Since collision characteristics tend to be multivariate and interrelated, a multivariate analysis is conducted. The dependent variable in this analysis (SB or other bus crash) is a dichotomous outcome which facilitates the application of a binary logit or probit model. The main difference between the logit and probit models lies in the assumption regarding the distributional form of the error term. The logit model assumes a logistic distribution, whereas the probit model assumes a normal distribution. In practice, however, many studies have found that the results from both models are similar (Maddala 1983, Kennedy 2001, Greene 2003). The binary logistic model is chosen in this study because it is more commonly used than the probit model (Kennedy 2001). With this choice, the conditional probability π of a positive outcome (SB) is determined in the following equations:

$$(1)\quad \pi(\mathrm{x}) = \frac{\exp(g(\mathrm{x}))}{1+\exp(g(\mathrm{x}))}$$

$$(2)\quad \ln\left[\frac{\pi(\mathrm{x})}{1-\pi(\mathrm{x})}\right] = \beta \mathrm{X}$$

where X is a vector of contributing factors and β is a vector of coefficients to be estimated. The likelihood function is given by:

$$(3)\quad l(\beta) = \Pi_{i=1}^{n}\, \pi(\mathrm{x}_i)^{y_i}\ (1-\pi(\mathrm{x}_i)^{1-y_i}$$

where n is the number of observations and denotes the i^{th} observed outcome, with the value of one for an SB crash and zero for a crash involving other types of buses (non-SB). The best estimate of β is obtained by maximizing the log likelihood function:

$$(4)\quad \mathrm{LL}(\beta) = \sum_{i=1}^{n}\{y_i \ln(\pi(\mathrm{x}_i)) + (1-y_i)\ln(1-\pi(\mathrm{x}_i))\}$$

The statistics software, Stata version 12, is used for the model estimation and hypothesis testing.

Since all contributing factors (e.g., day-of-week) are categorical, several dummy variables (e.g., weekdays and weekends) are defined for each, and one variable (e.g., weekdays) is used as the reference in the estimation. From the calibrated model, the effects of these identified factors on bus collisions are examined by comparing the β values of the dummy variables against the reference case (no coefficient estimated). If the estimated β_i is greater than zero it indicates the probability that a crash involving SB increases when a variable X_i changes from zero to one and vice-versa. In addition it is customary to calculate the odds ratios in a binary logistic model. The odds ratio (OR_i) of a variable X_i is equal to $\exp(b_i)$ and ranges from zero to positive infinity. This ratio indicates the relative amount by which the odds of an outcome (SB crash) increases ($OR_i > 1$) or decreases ($OR_i < 1$) when the value of a corresponding independent variable (X_i) increases by one unit or changes from zero to one.

Some of the coefficients of the variables within a factor were not statistically significant but are retained in the final model specification. This is done when at least one of the variables is statistically significant. Kockelman and Kweon (2002) suggest that variables with low statistical significance may be retained in the model if they belong to factors that have some significant effects on model outcome. Though this approach reduces the efficiency of the estimates, it is adopted for ease of comparison and interpretation of the estimates. This potential decrease in efficiency is compensated by using a more liberal confidence level of 90% instead of the traditional 95% (Tay et al. 2008, 2009, 2011).

RESULTS AND DISCUSSIONS

The descriptions and distributions of the significant variables are shown in Table 1. The differences in the distributions of all the contributing factors are found to be statistically significant using the Chi-square test. Moreover, the distributions of most of the contributing factors are consistent with the hypotheses except driver action. These results provide some support for our analytical framework and research hypotheses. The results of the binary logit model are reported in Table 2. Overall, they show that the model fits the data very well with a very large Chi-square statistic, very small p-value, and reasonably large pseudo R-Square. Again, a positive coefficient of a variable in the table indicates over-representation in SB crashes and a negative coefficient indicates under-representation in SB crashes in comparison with non-SB crashes. Clearly, the results support most of the hypothesized relationships about differences in the factors contributing to SB-involved collisions and non-SB-involved collisions except driver action.

In Table 2, the estimated coefficient and odds ratio ($\beta = -0.221$; OR = 0.802; $p = 0.005$) shows that casualty is less prevalent in SB-involved crashes than non-SB crashes, a finding that is consistent with Yang et al. (2009). This might be the result of improvements implemented in the school transportation sector of Alberta, including SB driver training programs, SB design, and the introduction of several safety devices on SBs (for example: reflective tapes, red flashing lights, strobe lights, and stop arms). The lower driving speed of SBs also contributes to the lower likelihood of a casualty collision.

The estimated odds ratio of seasonal distributions of these crashes suggests that SB crashes are less likely to occur during the summer (OR = 0.434; $p < 0.001$) than other seasons. This result is consistent with Yang et al. (2009) and can be attributed to the fact that most schools in Alberta normally close for vacation during the summer, resulting in lower exposure of SBs to crashes. Also consistent with Yang et al. (2009) is the finding in this study that SB crashes are less likely to occur during weekends (OR = 0.229; $p < 0.001$) compared with non-SB crashes. Again, this finding may simply be due to the fact that most schools are closed on weekends, thereby reducing the exposures of SBs to crashes. This exposure reduction will result in under-representation of SBs in crashes compared with non-SBs.

As expected (Yang et al. 2009), this study finds that SB collisions are more likely to occur during the morning (OR = 2.072; $p < 0.001$) and afternoon (OR = 1.162; $p = 0.041$) peak periods. These periods are times of highest activities for SBs: picking-up and dropping-off of students before and after school. And the close overlaps of the school start time with the general morning peak period and the school end time with the afternoon peak period increase the likelihood of an SB being involved in a crash during peak periods. The model estimates also show that SB crashes are more likely to occur in rural areas compared with non-SB crashes (OR = 3.937; $p < 0.001$). Past research identifies some differences between urban and rural school transportation operation, with a higher proportion of rural students using SB than their urban counterparts because travel choices are limited in rural areas (Tucker and Pollett 2008) and travel distances longer (Kmet and MacArthur 2006). Thus, the greater exposure on rural roads might lead to over-representation of crashes involving SBs in rural areas compared with urban areas.

Another result in Table 2 is that multiple vehicle SB collisions are less prevalent (OR = 0.706; $p = 0.003$) than single- or two-vehicle SB collisions. Drivers in Alberta are legally required to drive more cautiously (or come to a complete stop) when approaching or passing an SB, and the bright yellow color of SBs help drivers see these vehicles from a distance, which in turn reduces the probability of multiple-vehicle collisions. From the parameter estimate ($\beta = 0.464$; $p < 0.002$), it is inferred that a crash involving an SB driver backing or reversing is more likely to occur (OR = 1.591) compared with a rear-end or angular collision. This finding is consistent with Yang et al. (2009). Backing-up manoeuvres for SBs are also identified by Alberta Transportation (Opus Hamilton 2008) as high-risk activities. Poor lines of sight when backing might explain this risk.

Table 2: Estimation Results

Number of Observation	7480
Log-likelihood at Convergence	-3567.846
Log-likelihood at Zero	-4931.854
Chi-Square	2728.016
Pseudo R-square	0.277

Variables	**Coefficient**	**Std. Err.**	**P-value**	**Odds Ratio**
Crash Severity (Base: Property Damage Only)				
Casualty	-0.221	0.079	0.005	0.802
Season (Base: Winter, Spring, Autumn)				
Summer	-0.836	0.093	< 0.001	0.434
Day of Week (Base: Weekdays)				
Weekend	-1.476	0.128	< 0.001	0.229
Time of Day (Base: 9.00 a.m. - 2.59 p.m.)				
6.00 a.m. - 8.59 a. m	0.729	0.075	< 0.001	2.072
3.00 p.m. - 5.59 p.m.	0.150	0.073	0.041	1.162
6.00 p.m. - 6.00 a.m.	-1.627	0.132	< 0.001	0.196
Region (Base: Urban)				
Rural	1.370	0.124	< 0.001	3.937
No. of Vehicles Involved (Base: Single, Two)				
Three or more	-0.348	0.119	0.003	0.706
Primary Event (Base: Rear-end, angular)				
Struck Object	-0.172	0.103	0.096	0.842
Off-road	0.461	0.290	0.112	1.586
Passing	-0.763	0.164	< 0.001	0.466
Sideswipe	-0.185	0.085	0.029	0.831
Backing	0.464	0.147	0.002	1.591
Head-on	0.321	0.241	0.182	1.379
Other	-0.332	0.213	0.119	0.717
Weather Condition (Base: Clear, Rain)				
Hail/sleet	-0.676	0.402	0.093	0.509
Snow	-0.462	0.096	< 0.001	0.630
Road Surface (Base: Dry)				
Wet	-0.209	0.106	0.048	0.811
Snowy	0.176	0.075	0.018	1.193
Driver Gender (Base: Male)				
Female	1.748	0.062	< 0.001	5.746
Driver Age (Base: Age 25 to 44)				
Age less than 25	0.346	0.180	0.054	1.413
Age 45 to 64	-0.134	0.063	0.032	0.874
Age 65 and above	1.272	0.145	< 0.001	3.568

(Table 2 continued on p. 72)

Table 2: Estimation Results cont.

Variables	Coefficient	Std. Err.	P-value	Odds Ratio
Driver Action (Base: Driving Properly)				
Driving Violation	0.616	0.093	< 0.001	1.852
Driving Error	0.606	0.087	< 0.001	1.833
Other Driver Action	0.715	0.123	< 0.001	2.045
Point of Impact (Base: Right Rear, Left Center, Left Front, Front Center)				
Right Front	-0.122	0.106	0.249	0.885
Right Center	-0.462	0.120	< 0.001	0.630
Back Center	0.332	0.081	< 0.001	1.394
Left Rear	-0.366	0.122	0.003	0.694
Other Point of Impact	-0.374	0.285	0.189	0.688
Traffic Control (Base: Uncontrolled)				
Traffic Signal	-0.142	0.072	0.050	0.868
Stop Sign	0.488	0.114	< 0.001	1.628
Yield Sign	0.719	0.176	< 0.001	2.052
Other Traffic Control	0.294	0.167	0.078	1.342
Constant	-1.276	0.104	< 0.001	–

Among other primary events, striking an object (OR = 0.842; p = 0.096), passing (OR = 0.466; p < 0.001), and sideswipe (0.831; p = 0.029) are under-represented in SB-related collisions.

SB crashes are also found to be weakly related to hail and sleet (OR = 0.509; p = 0.093) and strongly related to snow (OR = 0.630; p < 0.001). This could be because SB drivers travel at slower speeds, maintain longer headways, and use more caution while driving in these adverse weather conditions. Again, the bright yellow color of the SB improves visibility in poor weather, thereby reducing the likelihood of these buses being involved in crashes. Further, its parameter estimate of 0.176 suggests that SB crashes are over-represented on road surfaces with snow (OR = 1.193), implying that SBs are more susceptible to collisions on such roads than non-SBs. This may be explained by the fact that SBs operate more than non-SBs on local roads where snow is not removed and the roads are not de-iced as often as main roads. This result also shows that SB collisions are under-represented on wet road surfaces (OR = 0.811; p = 0048), which can be explained by the fact that most SB drivers drive cautiously by maintaining longer headways and driving at lower speeds on wet road surfaces (Shankar and Mannering 1996).

On the issue of gender, this study finds that female SB drivers are involved in collisions more than male SB drivers compared with non-SB drivers (OR = 5.746; p < 0.001). As discussed earlier, females comprise approximately 60% of SB drivers in Alberta, and this increased exposure might explain their over-representation in crashes. This result may also be explained by the perceived behavior and driving skills of female drivers. Due to the size of an SB and the frequent on-street stops it makes, rear-end and sideswipe crashes are the most common SB crashes (Opus Hamilton 2008). In addition, compared with male drivers, female drivers have slower reaction times (Mehmood and Easa 2009) and are more prone to distractions, making perceptual and judgmental errors and lapses (Reason et al. 1990), which might also contribute to the higher likelihood of female SB drivers' involvement in collisions.

SB crashes involving young drivers aged less than 25 (OR = 1.413; p = 0.054) and older drivers aged 65 and above (OR = 3.568; p < 0.001) are over-represented compared with middle-aged drivers. Since no information is available on the age split of total SB drivers in Alberta, no firm conclusion can be drawn on over-representation of different SB driver groups in crashes. However, the result may be attributed to the operational characteristics of SBs such as decelerating or accelerating to or from stops more frequently than other bus drivers. This situation is complicated by frequent lane changes and merges they make to pick up and discharge passengers. Since younger drivers are less experienced and less skillful, while older drivers may have reduced perceptions and driving abilities, they are over-represented in SB crashes.

Driver actions are also found to contribute to more than 90% of road crashes (Rumar 1985). To conceptualize, two measures of inappropriate driving behaviors (aberrant driver behavior) are considered: errors and violations. Surprisingly, with respective coefficients of 0.606 and 0.616, which are statistically significant, both behaviors are found to be over-represented for SB drivers. Attitudes toward rule violation are identified by Rundmo (2000) as an important predictor of on-the-job risk behavior, and this relationship may also hold for SB driving. The over-representation of driving error of SB drivers may be attributed to in-vehicle distractions of SB drivers from their young passengers. McEvoy et al. (2006) identifies driver distraction inside the vehicle as one of the significant causes of road crash.

Furthermore, from the parameter estimates and the odd ratio ($\beta = 0.332$; $p < 0.001$; OR = 1.394), back center collisions are found to occur more often in SB collisions. When the center of the back of an SB is the principal point of impact in a collision, the SB is likely rear-ended by the vehicle following it. This is identified by Yang et al. (2009) as a major fault of drivers of other vehicles involved in crashes with SBs. Rear-end crashes are also found to be the main primary event in SB collisions in Alberta by Optus Hamilton (2008).

Stop (OR = 1.628; $p < 0.001$) and yield (OR = 2.052; $p < 0.01$) controlled intersections are likely to be locations of SB crashes, whereas traffic signal controlled intersections (OR = 0.868; $p = 0.078$) are less likely to experience SB crashes. As discussed earlier, SBs operate more frequently in residential areas characterized by close-packed local access points with stop/yield signs rather than traffic signals. The increased likelihood of SB crashes at these locations may also result from lower compliance with stop/yield sign regulations than traffic signals (Chipman 2004).

CONCLUSION

This study examines the contributing factors delineating SB crashes from crashes involving other buses. It uses a binary logit model and crash data from 1999 to 2008 for Alberta, Canada. The results show that relative to other types of buses, SB collisions are more likely to occur during the morning and afternoon peaks, in rural areas, and involve rear-end collisions by other vehicles or backing maneuvers. They are also likely to occur more on snowy road surfaces and at intersections controlled by stop or yield signs. Furthermore, SB collisions are more likely to involve female drivers, drivers under 25 or over 65 years old, are less likely to result in casualties, involve multiple vehicles, or result from passing or sideswiping collisions. They are also less likely to occur during the summer, on weekends, under hail/sleet/snow weather conditions, and at signalised intersections.

Although most of the results are consistent with the proposed analytical framework and hypotheses, two findings should be highlighted. First, passenger or driver injury is less prevalent in SB crashes than non-SB crashes due to low posted speeds on local roads where they mostly operate, and the implementation of SB improvement programs in Alberta. Second, compared with non-SB drivers, SB drivers are more likely to have committed traffic violations or made errors that resulted in collisions. This finding is in contrast with expectations and the hypotheses. More importantly, it is a cause for concern since scarce resources have been devoted to developing SB driver improvement programs in Alberta, and parents expect to have safe SB drivers. Hence, existing SB driver training and hiring processes should be reviewed and enhanced to reduce traffic violations and driver errors. In addition, as suggested by the results, SB safety awareness programs should be implemented and supplemented by traffic regulation enforcement programs at high-risk locations to minimize traffic violations.

Endnotes

1. PayScale. "PayScale Canada, Bus Drivers, School Wages, Hour Rates", available online at http://payscale.com/research/CA/job=bus_driver, _school/Hourly_Rate, accessed 30/4/2012.

2. Personal communications: emails by Sue Timmermans from Black Gold Regional Schools, dated 1/5/2012 and Brian Hampton from Parkland School Division, dated 30/4/2012.

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