Modelling public bus/minibus transport accident severity in Ghana
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1   **Modelling public bus/minibus transport accident severity in Ghana**

2   Enoch F. Sam[1,2], Stijn Daniels[2,3], Kris Brijs[2], Tom Brijs[2] and Geert Wets[2]
3   *[1]Dept. of Geography Education, University of Education, Winneba, Ghana*
4   *[2] UHasselt- Hasselt University, Transportation Research Institute (IMOB), Agoralaan, 3590*
5   *Diepenbeek, Belgium*
6   *[3] Vias Institute, Haachtsesteenweg 1405, 1130 Brussels, Belgium*

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8   ABSTRACT

9   The current safety concerns with buses/minibuses (public transport) in both developed and

10   developing countries have warranted a renewed interest in bus/minibus safety research. Prior

11   to this, there was a paucity of research in this domain especially in developed countries where

12   the safety associated with buses was deemed adequate. In this study, we examined the factors

13   that influence bus/minibus accident severity in Ghana using bus/minibus accident data from

14   2011-2015. We estimated the severity of bus/minibus accidents by fitting generalised ordered

15   logit models. Our findings revealed that weekends, the absence of road median, night-time

16   conditions, bad road terrain (curved, wet and rough roads), hit-pedestrian collisions, and

17   drunk driving are associated with more severe bus/minibus accident outcomes. Conversely,

18   minibuses, the absence of road shoulder, accidents in intersections, the presence of traffic

19   control and collision types (except hit-pedestrian) are associated with less severe bus/minibus

20   accidents.

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22   **Keywords**

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1. Introduction

Public bus/minibus transport is deemed a relatively safe mode of transport in developed countries, especially in the United States (US) and Europe. In these areas, the safety associated with this mode is considered adequate (Kaplan & Prato, 2012; Barua & Tay, 2010; Berntman, Wretstrand, & Holmberg, 2010). In addition, bus travel is considered the safest per distance travelled. For instance, studies using the number of fatalities per 100 million person-kilometres travelled have revealed that travelling by car entails eight times more risk compared to taking the bus; while walking is associated with 50 times more risk than taking the bus (Albertsson & Falkmer, 2005; Evans, 1994). The safety with public bus transport, especially in the developed countries, explains the paucity of empirical studies on bus accidents as well as the limited public interest in bus accidents relative to other transport modes (Cafiso, Di Graziano, & Pappalardo, 2013; Chimba, Sando, & Kwigizile, 2010). The general perception is that public transport use reduces traffic congestion and pollution, and improves road safety (Brenac & Clabaux, 2005).

Conversely, the situation in developing countries is quite different, where public bus/minibus transport has serious safety concerns as a result of frequent involvement in severe accidents (Barua & Tay, 2010; Iles, 2005; Hamed, Jaradat, & Easa, 1998). In these countries, bus/minibus accidents are rampant with alarming consequences (Kaplan & Prato, 2012; Chimba et al., 2010).

In the book "*Public transport in developing countries*", Iles (2005) observed that public transport vehicles (buses and minibuses) in developing countries are frequently involved in fatal accidents. Iles maintains that speed is the underlying cause of most of the accidents in these countries.

Based on recent developments in both developed and developing countries, research interest in bus and bus passengers' safety has emerged strongly. A couple of studies and interventions

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54 have been implemented in the bid to identify and tackle emerging challenges, and thus

55 improve bus safety. Kaplan and Prato (2012) for example, reports that in the United States

56 (US) the renewed interest in bus safety resulted in the new Motorcoach Enhanced Safety Act

57 of 2011 and the prioritisation of research on bus safety, and the subsequent creation of a new

58 training curriculum for bus operators.

59

60 **2. Magnitude and severity of public bus/minibus accidents in Ghana**

61 Public bus/minibus transport form the backbone of mobility in Ghana, as in other low- and

62 middle-income countries (Mohan, 2016). Unfortunately, bus/minibus passengers are a

63 significant road user group at risk of road traffic accidents (Odero, Khayesi, & Heda, 2003).

64 In Ghana, bus/minibus occupants are the third road users with the highest fatality risk

65 (National Road Safety Commission, NRSC, 2014). For the period 1991-2014, public

66 buses/minibuses constituted 23.9% (n=90,206) of the total number of vehicles involved in

67 accidents in Ghana producing 35.7% of the total recorded casualties (n= 327,994).

68 Generally, road traffic accidents cost 1.6% of Ghana's gross domestic product (GDP)

69 (Ackaah, Afukaar, Agyemang, & Debrah, 2008). Intuitively, the contribution of public

70 buses/minibuses (as a higher occupancy mode) to the total cost of road traffic accidents in

71 Ghana is expected to be higher (exact figures are not available). Addressing the public

72 bus/minibus safety concerns through evidence-based interventions will increase PT

73 passengers' confidence and patronage and hence promote sustainable PT use (Khoo &

74 Ahmed, 2018). In Ghana, PT has a positive impact on road space occupancy;

75 buses/minibuses utilise about 30% of road space but convey over 70% of person-trips

76 (Amoo-Gottfried, 2012).

77 The government through the Metropolitan, Municipal and District Assemblies (MMDAs)

78 regulate public transportation in their areas of jurisdiction. However, public transportation

79 operations are deregulated (with both government, quasi-government, and private ownership

80 and operations) (Sam & Abane, 2017; Yobo, 2013; Salifu, 2004).

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82 **2.1. Study objective**

83 In this study, we examine the factors that influence public bus/minibus accident severity in

84 Ghana using the national bus/minibus accident data from 2011 to 2015. Unlike previous

85 studies, this study considers both bus and minibus accidents for this reason: minibuses are

86 also important transport modes in developing countries and are associated with a relatively

87 higher accident risk (see Hamed et al., 1998). As Kaplan and Prato (2012) argue, examining

88 the factors that are associated with bus accident severity can alert PT operators of the

89 circumstances that are associated with injury risk for bus accidents. This knowledge can serve

90 as the basis for bus safety improvement strategies.

91 In this study, we applied the following definition to a public bus and minibus transport: a

92 commercial vehicle with a seating capacity of more than 25, and 10-25 seating capacity

93 respectively. To the best of our knowledge, this study is the first work to examine the factors

94 that bear injury risk for buses/minibuses (public transport) in Ghana. This is regardless of

95 their enormous safety concerns in the country. Obviously, addressing the safety concerns of

96 the buses and minibuses in the country needs a "local context" for it to be sustainable. At best

97 previously established significant bus/minibus accident severity predictors can be used for

98 probing purposes and a benchmark in the search for, and explanation of significant local

99 factors.

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101 **3. Descriptive statistics**

102 Public bus/minibus accidents in Ghana are basically high and severe. But for the period 2011-

103 2015, the situation followed a downward trend specifically from the year 2012. The 2012

104   figure constituted 23% of the total bus/minibus accidents for this period (N=33,694). Perhaps,

105   the downward trend is an indication of the effectiveness of the road safety interventions,

106   particularly those targeting buses/minibuses, in the country. This period under investigation

107   witnessed the launch of the UN Decade of Action for Road Safety 2011-2020, and

108   subsequently Ghana's adoption of this global action plan. In accordance with this global

109   action plan, a number of traffic safety interventions have been implemented nationwide

110   especially targeting the road users with high fatality risks. Towards bus/minibus safety, the

111   measures include increased educational campaigns and training for bus/minibus drivers,

112   safety audits of the transport operators' operations, and traffic police highway visibility

113   (especially on accident-prone roads). In a recent study, Sam and Abane (2017) observed that

114   the bus operators have equally adopted a number of measures to enhance bus/minibus safety:

115   strict adherence to routine bus maintenance schedules, periodic driver training and retraining,

116   and medical screening. In addition, the following have also been implemented: mandatory

117   rest stops for drivers on long distance journeys, driver awards schemes (awarding drivers who

118   record no road accident for a specified period), driver behaviour tracking in real time, and

119   surcharging of at-fault drivers with the cost of repairs on damaged buses and property.

120   The data revealed that there were more male bus/minibus drivers (99.7%) than their female

121   counterparts involved in road accidents over the period. This may be explained by the male

122   dominance in the industry (commercial bus/minibus driving) and also driving in general in

123   Ghana. The majority (64.8%) of these drivers could be classified as young (≤35 years), fully

124   licensed to drive (94.8%), even though 5.2% of them were either unlicensed or at best

125   partially licensed. Nearly 83% of the drivers involved in the accidents were uninjured.

126   Interestingly, about 70% of the accidents could be attributed to driver errors in the form of

127   lapses and errors (inexperience and inattention), and traffic violations (improper overtaking,

128   improper turning, over-speeding, fatigued driving and tailgating). On this phenomena, the

129 national road safety commission (NRSC, 2014) revealed that driver indiscretion and poor

130 judgement is a major cause of road fatalities among public transport users in the country. We

131 admit that this should be prioritised for training and remedial action by the public transport

132 operators and the other relevant road safety stakeholders. Addressing these issues will help

133 improve public bus/minibus safety in the country. We further observed that in many of the

134 instances, the buses/minibuses were going ahead (84%) than otherwise (turning, reversing

135 etc) at the time of their accidents.

136 Table 1 details the explanatory variables used in estimating bus/minibus accident severity.

137 For the 5-year period, there were more buses (72.1%) than minibuses (27.9%) involved in

138 accidents, resulting in more property-damage-only (33.2%) accident outcomes. Fatal

139 accidents constituted 15.6% of the accident outcomes. Nearly 70% of the accidents occurred

140 on weekdays with its huge traffic and thus increasing the exposure to risk.

141 Furthermore, Table 1 reveals that nearly 70% of the accidents occurred during the day, and

142 on straight and flat roads (89.4%) without median (69.4%). The vast majority of the accidents

143 occurred on dry (84.4%), and good (92.4%) road surfaces, with good shoulder conditions

144 (45.8%), though in some instances, there were no shoulders (42.0%). Furthermore, 74.5% of

145 these accidents happened on road sections than on intersections (25.5%), with no form of

146 traffic control (58.6%) resulting in an almost equal number of hit pedestrian (25.7%) and rear

147 end (22.8%) collisions. Only 1.9% of the cases involved drunk driving. We found some

148 correlations among these explanatory variables. For example, we observed a weak correlation

149 between the location of the accident and the type of traffic control (r=.17, p<.001). Table 4 in

150 the appendix presents the intercorrelations among the explanatory variables. It should be

151 noted that none of the variables was "highly correlated" (i.e. none of the correlations was

152 above the threshold of .80 to depict the existence of multicollinearity problems), thus our

153 decision to retain them in the model (see Pallant, 2016; Field, 2013).

154   Table 1 Explanatory variables used in the model (N= 33,694).

Variable	Categories	N	%
Accident severity	Fatal	5250	15.6
	Hospitalised	8748	26.0
	Injured not hospitalised	8497	25.2
	Damage only	11199	33.2
Day of week	Weekdays	23447	69.6
	Weekends	10247	30.4
Road separation	Median	10295	30.6
	No median	23399	69.4
Vehicle type	Bus	24296	72.1
	Minibus	9398	27.9
Light condition	Day	22563	67.0
	Night (no light or light off)	7056	20.9
	Night (light on)	4075	12.1
Road description	Straight and flat	30106	89.4
	Curved/ inclined/ bridge	3588	10.6
Road surface	Dry	28430	84.4
	Slippery	5264	15.6
Shoulder condition	Good	15441	45.8
	Poor	4088	12.1
	No shoulder	14165	42.0
Location	Section	25117	74.5
	Intersection	8577	25.5
Traffic control	None	19733	58.6
	Present (Signals, stop sign, give way, pedestrian-X)	4519	13.4
	Others (e.g. speed hump/ rumble strips)	9442	28.0
Collision type	Head-on	3242	9.6
	Rear end	7692	22.8
	Right angle	2408	7.1
	Sideswipe	4777	14.2
	Overturn	4302	12.8
	Hit object	2621	7.8
	Hit pedestrian	8652	25.7
Drunk driving	Tested negative	33064	98.1
	Tested positive	630	1.9
Surface repair	Good	31139	92.4
	Rough with potholes	2555	7.6

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4. Factors influencing bus/minibus accident severity

157   The available literature on bus accident injury severity is rather limited relative to the other

158   transport modes; even though it is important for remedial action to promote sustainable bus

159   use. However, the previous studies presented below bears greater significance to our current

160   work. Fortunately, a couple of these studies (Barua & Tay, 2010; Hamed et al., 1998) were

161   conducted in developing countries. This is important because of the peculiar mobility context

162   and traffic risk of developing countries (Machado-León, de Oña, Baouni, & de Oña, 2017).

163   In the literature, accident severity has been attributed to a number of factors relating to the

164   road user characteristics, prevailing traffic and road environment. These factors include

165   vehicle types involved, the speed of travel, manner of the vehicle collision, the road

166   environment and road user characteristics (see Prato & Kaplan, 2014; Barua & Tay, 2010;

167   Elvik, Vaa, Høye, & Sorensen, 2009; Hamed et al., 1998). In addition, some studies have also

168   estimated accident severity using the characteristics of the transport operators (see Hamed et

169   al., 1998; Chang & Yeh, 2005).

170   Regarding bus/minibus accident severity, Table 2 presents some explanatory variables used

171   in previous models. These include some proven significant predictors (*in italics*) with both

172   positive and negative effects. For instance, Prato and Kaplan (2014) using generalised

173   ordered logit models observed that bus accident severity increased with the presence of

174   vulnerable road users, high speed, night hours, elderly third-party vehicle drivers, and bus

175   drivers and other drivers crossing in the yellow or red light. They found age effects of bus

176   accident severity as well.

177   In an earlier study, Kaplan and Prato (2012) revealed that (bus) driver gender and age also

178   influence accident severity. They contend that male drivers reduce the probability of both

179   severe injuries and fatalities, but are associated with an increase in property-damage-only

180   accidents. Further, they demonstrate that both young and old age is associated with

181   aggravated accident severity probability.

182   On their part, Barua and Tay (2010) fitted an ordered probit model and revealed that bus

183   accident severity increases when the collisions occur in weekends, off-peak periods, on two-

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184 way lanes and is a single vehicle accident (involving pedestrians and other vulnerable road

185 users). On the contrary, they observed that the presence of a median, sideswipe collisions,

186 collisions with a parked vehicle and fixed objects, and the presence of signalised traffic

187 controls with police presence are associated with lower severity risks.

188 Moreover, Hamed et al. (1998) studied commercial minibus accident severity in Jordan using

189 a Poisson regression model. They found that the accident severity (in this case the number of

190 injuries) is influenced by the driver's age, accident type, accident location, surface pavement

191 conditions, the cause of the accident, time of day, daily distance travelled (indicative of the

192 level of exposure) and time since the previous accident. Specifically, they revealed that

193 accidents caused by younger drivers, single-vehicle accidents, resulting in vehicle rollover or

194 head-on collisions, involving higher speed as well as accidents occurring on intercity rural

195 roads are severe. However, they noted that dry road surface conditions, relative to wet

196 surfaces, are related to less severe injuries.

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198 Table 2 Explanatory variables used in previous bus accident severity studies.

Publication	Explanatory variables used
Prato and Kaplan (2014)	*Bus driver's age*; driver gender; driver's intoxication; *driver manoeuvre*; *driver manoeuvre at intersection*; bus type; accident type; *third party involved*; *third party's age*; third party's gender; *third party's intoxication*; third party's seat belt use; *third-party driver's manoeuvre*; *third-party driver's manoeuvre at intersection*; accident location; *speed limit*; number of lanes; light conditions; surface conditions; weather conditions; *year*; season; day; *time of day*; *land use* and *area*.
Kaplan and Prato (2012)	*Driver gender*; *driver age*; *driver behaviour*; *bus service type*; *bus type*; *other road users involved*; *other driver's age*; *other driver's behaviour*; *section type*; *number of lanes*; *road type*; *road alignment*; *road profile*; *road surface conditions*; *light conditions*;

	speed limits; *region*; and *year*
Barua and Tay (2010)	*Time trend; day of the week; time of the day; the number of vehicles involved; traffic control and operation; type of collision, and median availability*
Hamed et al. (1998)	*Driver age; type of accident; accident location, pavement surface condition; cause of the accident; time of accident occurrence; time of the previous accident; and distance travelled per day.*

5. Methods and data

We utilised econometric discrete choice modelling as a technique to model the severity of bus/minibus accidents in Ghana given a number of predictors or conditions.

5.1. Data

The bus/minibus accident data from 2011 to 2015 were extracted from the national accident database. This data comprised all bus/minibus accidents in both urban and rural environments over the period. This database is managed by the Building and Road Research Institute (BRRI) of the Council for Scientific and Industrial Research (CSIR), Kumasi, Ghana. The database is comprised of a police-compiled road traffic accidents occurring on Ghanaian roads, using a standard road accident report form. This report contains information obtained from surviving traffic accident casualties, witnesses, detailed accident sketches, hospital post-mortem reports in the event of fatal accidents, and detailed reports from accident investigators and vehicle examiners (NRSC, 2014). The data is stored in computers using the Transport Research Laboratory, UK (TRL)-developed Microcomputer Accident Analysis Package (MAAP, Windows version) software.

The database provides information on the driver, traffic elements, and road environment conditions at the time of the accidents. The driver information includes the name, sex, age,

219   injury sustained, license number and status, a declaration of whether drunk-driving was

220   involved and the driver errors associated with the accident (if any). Information related to the

221   traffic elements and road environment include the vehicle types involved, vehicle manoeuvre,

222   vehicle ownership and usage, the extent of damage, vehicle defects suspected and direction of

223   travel at the time of the incident. In addition, the road type and description, surface type,

224   shoulder type and condition, weather and light conditions, the presence of road separation,

225   surface condition, accident location, traffic control, collision type and surface repair are also

226   specified. Furthermore, the data also indicates the day and time of the accident, the number of

227   vehicles involved, the number of casualties killed and injured, and the accident severity,

228   measured on a four-point scale. The data provide important information on the nature and

229   extent of bus/minibus accidents in the country. Notwithstanding, the data is subject to some

230   under-reporting (basically as a result of shortfalls in recovery). According to the NRSC, the

231   data recovery rate is currently over 80%. Regarding the degree of under-reporting in Ghana's

232   official accident database, Salifu and Ackaah (2012) maintain that the level of non-reporting

233   varies significantly with the severity of the accident (from 57% for property damage only

234   accidents, 8% for serious injury accidents to 0% for fatal accidents). These levels of

235   underreporting are not exceptional in an international context but must be taken into account

236   when interpreting the results. Moreover, bus accidents are less likely to go unnoticed, and

237   hence the risk of under-reporting is reduced (Prato & Kaplan, 2014).

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242   *5.2. Model estimation*

243 We fitted generalised ordered logit models to estimate the severity of bus/minibus accidents

244 in Ghana (dependent variable). Previous models we fitted using the ordered logit failed the

245 test of parallel lines (proportional odds assumption) and thus our decision to use the

246 generalised ordered logit where the proportional odds assumption (i.e. equal coefficient

247 across thresholds, in this case, accident severity) is relaxed. Williams (2016) maintains that

248 "the use of an ordered logit model when its assumptions are violated creates a misleading

249 impression of how the outcome and explanatory variables are related" (p.11). The test of

250 parallel lines in IBM SPSS (Polytomous Universal Model- PLUM) indicates whether the

251 proportional odds assumption have been violated or not. It is important to note that a

252 significant value (0.05 or less) for this test indicates a violation of the proportional odds

253 assumption for which the use of the ordered logit is not advisable.

254 We utilised a two-stage procedure in selecting the most important predictors (variables with

255 the strongest impact) of bus/minibus accident severity in the country. In the first stage, we

256 fitted a full model. The full model included 25 bus/minibus accident-related variables

257 captured in the database and associated with the driver (6 variables), traffic environment (7

258 variables) and road environment (12 variables). Although the vehicle type (i.e. bus or

259 minibus) was not significant in the full model, we included it in the final model given its

260 established importance to accident severity outcomes (see Elvik et al., 2009; Wood, 1997).

261 The final model presented in this study comprised of the significant variables from the initial

262 full model. Fortunately, these variables have been established in previous studies to be

263 significant predictors of bus/minibus accident severity.

264 According to the traffic injury literature, the severity of an accident is determined by the road

265 user with the most severe injury outcome. Accordingly, we defined bus/minibus accident

266 severity as the most severe injury suffered by a bus/minibus occupant, or a road user where a

267 bus/minibus is involved (Prato & Kaplan, 2014; Barua & Tay, 2010).

268   In the police report, accident outcomes are captured in a categorical ordinal format (*fatal*,

269   *hospitalised*, *injured but not hospitalised* and *damage only*) defined as follows (NRSC,

270   2014):

271   • fatal accident: an accident where at least one casualty dies of injuries sustained within

272   30 days of occurrence;

273   • hospitalised or serious injury accident: at least one person is detained in hospital as an

274   in-patient for more than 24 hours;

275   • injured, but not hospitalised or minor injury accident: accident in which the most

276   severe injury sustained by a casualty is only minor, requiring at most first-aid

277   attention, and

278   • damage-only accident: an accident which results only in a vehicle or other material

279   damage.

280   Given the ordinal nature of accident severity outcomes (i.e. fatal, severe injury, slight injury

281   and damage only), an ordered logit model can be specified in terms of the probability of

282   injury severity *j* for a given accident *i* as (see Long, 1997; Prato & Kaplan, 2014):

$$P(y_i > j) = \frac{exp(X_i\beta - \phi_j)}{1 + exp(X_i\beta - \phi_j)} \qquad j = 1, 2, \ldots, M - 1 \qquad (1)$$

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284   where X_i is a vector of explanatory variables of accident *i*, β is a vector of parameters to be

285   estimated, ϕ_j are cut-off points for the thresholds of the ordered model to be estimated, and *M*

286   is the number of categories of the ordered-response variable.

287   However, the generalised ordered logit model expresses the probability of injury severity *j* for

288   a given accident *i* as (see Long, 1997; Williams, 2006; Prato & Kaplan, 2014):

$$P(y_i > j) = \frac{exp(X_{1i}\beta_1 + X_{2i}\beta_{2j} - \phi_j)}{1 + exp(X_{1i}\beta_1 + X_{2i}\beta_{2j} - \phi_j)} \qquad j = 1, 2, ..., M-1 \quad (2)$$

289

290   where β_1 is a vector of parameters associated to a subset X_{1i} of explanatory variables that do

291   not violate the proportional odds assumption (i.e. parallel lines), and β_{2j} is a vector of

292   parameters associated with a subset X_{2i} of explanatory variables that vary according to the

293   cut-off points of the ordered model. Positive coefficients on the explanatory variables imply a

294   likelihood of a more severe outcome on the dependent variable (i.e. more severe bus/minibus

295   accident outcome); the reverse is also true. The probability of injury severity has a closed-

296   form expression and the parameters β_1, β_{2j} and ϕ_j are estimated through the maximisation of

297   the log-likelihood function *LL*:

$$LL = \sum_{n=1}^{N} \sum_{j=1}^{J} d_{nj} ln P(y_i > j) \qquad (3)$$

where N is the number of accidents,
and

$$d_{nj} = \begin{cases} 1, & \text{if accident n results in severity category j} \\ 0, & \text{Otherwise} \end{cases}$$

298

299   We fitted the model using the GENLIN procedure in IBM SPSS Statistics version 24. The

300   dataset used in estimating the model contained 33,694 complete cases. All variables with

301   incomplete cases were excluded from the model estimation not to introduce inconsistencies.

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303   **6. Results and discussion**

304   *6.1. Model estimation results*

305   The goodness-of-fit of the model was established by a non-significant deviance value of

306   1.185 (χ^2 = 16801.16, df = 14173) indicating that the data is a good fit for the model. Table 3

307   presents the parameter estimates of the model. The Exp (B) stated in Table 3 indicates the

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308   change in the odds resulting from a unit change in the predictor. If the value is greater than 1,

309   it suggests that as the predictor changes (in this case increases), the odds of the outcome

310   occurring equally increases (positive correlation). Equally, a value less than 1 shows that as

311   the predictor increases, the odds of the outcome occurring decrease (negative correlation)

312   (Field, 2013).

313   From the model outcome (as illustrated in Table 3), we found the following variables to be

314   correlated with the severity of bus/minibus accidents in Ghana: day of week, road

315   separation, vehicle type, weather conditions, light conditions, road description, road surface,

316   surface repair, and shoulder conditions, accident location, traffic control type, collision type,

317   and the incident of drunk driving. Of this 13-factor model, we realised that 10 were road

318   environment related (road separation, weather condition, light condition, road description,

319   road surface condition, surface repair condition, shoulder conditions, accident location,

320   collision type and traffic control type), 2 traffic related (day of the week and vehicle type),

321   and 1 driver related (incident of drunk driving). However, we excluded the weather variable

322   from the model to address inconsistencies with the road surface condition variable.

323

324   Table 3 Parameter estimates of the model.

Variable	B	Std. Error	Exp(B)
Threshold			
Damage only	-1.510	.0456	0.221*
Injured (not hospitalised)	-.135	.0447	0.874***
Hospitalised	1.519	.0458	4.569*
Day of week (Reference category: Weekdays)			
Weekends	.090	.0223	1.095*
Road separation (Reference: Median)			
No median	.259	.0253	1.295*
Vehicle type (Reference: Bus)			
Minibus	-.079	.0231	0.924***
Light condition (Reference: Day)			
Night (Light ON)	.168	.0324	1.183*
Night (Light OFF)	.224	.0258	1.251*

Road description (Reference: Straight and flat)			
Curved/inclined	.388	.0341	1.475[*]
Road surface (Reference: Dry)			
Wet	.097	.0374	1.102[***]
Shoulder condition (Reference: Good)			
No shoulder	-.458	.0227	0.633[*]
Poor	-.031	.0373	0.969
Location (Reference: Section)			
Intersection	-.193	.0280	0.824[*]
Traffic control (Reference: None)			
Speed humps/ rumble strips	-.205	.0240	0.815[*]
Present	-.399	.0378	0.671[*]
Collision type (Reference: Head on)			
Hit pedestrian	.902	.0383	2.465[*]
Hit object	-1.267	.0509	0.282[*]
Overturn	-.655	.0433	0.519[*]
Sideswipe	-1.523	.0440	0.218[*]
Right angle	-.862	.0522	0.422[*]
Rear end	-1.626	.0414	0.197[*]
Drunk driving (Reference: Tested negative)			
Tested positive	.215	.0753	1.240[***]
Surface repair (Reference: Good)			
Rough with potholes	.109	.0469	1.115[**]

Note. *p<.001; **p<.05; ***p<.01; N=33694

Firstly, we observed that the severity of public bus/minibus accident is related to the day of

the week. With reference to weekdays, we observed that bus/minibus accidents occurring on

weekends are significantly associated with an increase of 9.5% in the severity of the

accidents. Thus, public bus/minibus accidents during weekends in Ghana are more severe

consistent with both our expectation and previous findings including Barua and Tay (2010)

and Michalaki, Quddus, Pitfield, and Huetson (2015). For instance, Barua and Tay (2010)

found that more severe bus accident outcomes are associated with weekends during which

time vehicle driving speed is relatively high as a result of the reduced traffic volumes.

According to the Ghana national road accident reports, weekends (especially Saturdays and

Sundays) record the most road traffic fatalities (NRSC, 2014). For example, of the 1,836

traffic deaths recorded in 2014, the highest number (323 or 17.6%) occurred on Sundays,

337   with the lowest occurring on Wednesday (178 or 9.7%). For the previous year (2013), most

338   traffic deaths (334 out of 1,898) occurred on Saturdays. This may be explained by the greater

339   tendency for unlicensed (as noted earlier, 5.2% of the drivers were unlicensed) and

340   inexperienced drivers (mostly minibus drivers) to drive on weekends given the low traffic

341   volume, and police enforcement and surveillance. Hence, there is the heightened tendency for

342   reduced concentration and reckless driving with severe accident consequences on weekends.

343   We also noted that the absence of a median (relative to the presence of a median) is

344   associated with an increase of 29.5% in the severity of bus/minibus accidents. Even though

345   there have been some mixed results on the impact of road medians on traffic safety, most

346   studies (including Barua & Tay, 2010; Polders, Daniels, Hermans, Brijs, & Wets, 2015;

347   Kaplan & Prato, 2012) have reported of positive safety impacts. From these studies, the

348   implication is that road medians are associated with lower accident severity (Barua & Tay,

349   2010); reduce fatalities (Kaplan & Prato, 2012) and prevents head-on collisions (Polders et

350   al., 2015) consistent with our present findings.

351   Surprisingly, we found that minibuses (relative to buses) are significantly associated with a

352   lower accident severity risk by 7.6%. This is contrary to the supposed safety benefits of

353   vehicle size and mass (see Evans, 1994; Wood, 1997; Elvik et al., 2009). For instance, Elvik

354   et al. (2009) claim that "small cars do not give as good protection against injury in an

355   accident as large cars" (p.64) and that "the greater the mass, the more protection people have

356   against being injured in accidents" (p.67). However, it is also important to note that a

357   vehicle's travelling speed is correlated with both the risk of accident involvement and also its

358   severity; and hence the greater the travelling speed, the greater the impact and the impact

359   outcomes (Kloeden, Ponte, & McLean, 1997; Michalaki et al., 2015; Peden et al., 2004). In

360   this regard, Kloeden et al. (1997) contend that the risk of severe accident outcomes (i.e. risk

361   of involvement in a casualty accident) doubles with each 5 km/h increase in vehicle speed

362   above 60 km/h. Therefore, in the event of an accident, the faster-travelling vehicle is

363   expected to be more severely impacted. By comparison, buses have a higher speed capacity

364   than minibuses and thus are more inclined to travel at a much higher speed. This is a

365   plausible reason behind the finding that minibuses are associated with a lower accident

366   severity. the Another reason for this finding is that, in Ghana, most long-distance bus

367   journeys (unlike minibuses) are scheduled for the night as it is presumed to be conducive to

368   the buses' ease of movement. However, as we will establish later in this study, night-time

369   conditions presents a lot of driving hazards including perceptual errors which impede safe

370   driving. Further, this period is associated with increased driver speeding and recklessness

371   given the "almost" absent traffic.

372   Similarly, relative to daytime, we observed that night-time conditions increase the severity of

373   bus/minibus accidents from 16% (i.e. during night-time with the artificial light on) to 18.7%

374   (night-time with the artificial light off (darkness)). Night conditions (whether there is

375   artificial light on or off) impede safe driving in view of the difficulty with visibility, and

376   hazard perception and response, potentially reducing the ability of the driver to avoid an

377   impact (Abdel-Aty, Ekram, & Huang, 2011). Jägerbrand and Sjöbergh (2016) further argue

378   that the correlation between road accidents and night conditions (darkness or low light

379   conditions) could be explained by drivers' failure to adjust their speed to the reduced

380   visibility. There is also an elevated tendency for perceptual/visual errors, drowsiness and

381   drunk driving during the night (Boyce 2003). In their study, Assum, Bjørnskau, Fosser, and

382   Sagberg (1999) observed that the introduction of road lighting increased vehicle driving

383   speed by nearly 3% compared with unlit road sections. In support of this finding, Bassani and

384   Mutani (2012) and Jägerbrand and Sjöbergh (2016) also found higher driver speed at night

385   time; attributable to the tendency for faster drivers to drive at night as the proportion of

386   slower drivers and vulnerable road users are reduced at that time. In accordance with this

387   reasoning, and for ease of movement (given the vehicle mass), most long-distance bus

388   departures in Ghana are scheduled for the night-time. However, it has also been argued that

389   night-time conditions influence drivers' perception of their travelling speed and the most

390   appropriate speed for the road environment (Edquist, Rudin-Brown, & Lenné, 2009). Taken

391   together, weather and light conditions and road lighting are believed to have an interaction

392   effect on vehicle speed (Jägerbrand & Sjöbergh, 2016).

393   In a similar vein, the road description (straight or curved), surface condition (dry or wet) and

394   surface repair (good or rough) have significant effects on the severity of bus/minibus

395   accidents. We observed that curved/inclined ($p<.001$), wet ($p<.01$) and rough ($p<.05$) road

396   surfaces are associated with increased bus/minibus accident severity by 47.5% on

397   curved/inclined roads, 10.2% on wet road surfaces, and 11.5% on rough roads with potholes.

398   Intuitively, it makes a lot of sense that these road conditions are associated with the fatal

399   accidents. Fortunately, earlier studies have confirmed this finding. For example, Prato and

400   Kaplan (2014) also found that slippery (wet) roads increase the probability of severe

401   accidents. Further, although curved and rough roads engender careful driving, these

402   conditions, notwithstanding, constitute driving hazards and thus risk factors for road

403   accidents. This explains the finding that more severe road accidents occur on curved roads

404   than straight roads (Chen, 2010; Rakotonirainy, Chen, Scott-Parker, Loke, & Krishnaswamy,

405   2015). This is in view of the fact that curved and rough roads make vehicle control difficult

406   (Elliott, McColl, & Kennedy, 2003) and are particularly associated with off-road/roll-over

407   collisions (Rakotonirainy et al., 2015).

408   In addition, we observed that the absence of road shoulder (no shoulder) and poor road

409   shoulder are associated respectively with 36.7% and 2.6% reduced bus/minibus accident

410   severity. Martens, Comte and Kaptein (1997) reasoned that drivers may perceive the presence

411   of a road shoulder as an extension of the road and thus compensate for the wider road surface

412   by speeding. It is thus not surprising that the absence of a road shoulder (which implies a

413   narrower road) is associated with reduced accident severity than a poor road shoulder (which

414   may also be perceived as an extended driving space).

415   Similarly, bus/minibus accidents on road intersections (i.e. crossroads, T junctions, staggered

416   crossroads, Y junctions, roundabouts, railway crossing) relative to road sections reduce

417   accident severity risk by 17.6%. This finding is inconsistent with the previous finding that

418   more severe accidents occur in road intersections (see Kaplan & Prato, 2012). A probable

419   reason for this finding is the possible impact of the presence of traffic controls in

420   intersections. Traffic controls regulate driver speeding and thus presents the possibility of

421   having less severe accident outcomes in intersections. This notwithstanding, further research

422   is needed to demonstrate this.

423   Further, we observed that the presence of traffic controls and speed calming measures are

424   related to a reduced bus/minibus accident severity by between 18.5%-32.9% relative to where

425   none exist, consistent with previous studies. In an earlier study, Zein, Geddes, Hemsing, and

426   Johnson (1997) found that traffic calming accounted for a reduction in collision frequency,

427   severity and the annual collision claim costs in the Greater Vancouver area, Canada.

428   Similarly, Barua and Tay (2010) observed the same accident-severity reduction effect of

429   traffic controls, particularly with police enforcement in Bangladesh. This is thus contrary to

430   the claim that traffic control systems are installed on roads mainly to regulate vehicle traffic

431   rather than improve safety (Kennedy & Sexton, 2009).

432   We also found the collision types to be related to the severity of bus/minibus accidents.

433   Consistent with previous studies (Barua & Tay, 2010; Prato & Kaplan, 2014; Michalaki e al.,

434   2015), we observed that "hit-pedestrian" collisions are associated with an increase in

435   bus/minibus accident severity by 146.5% relative to head-on collisions. The other collision

436   types specified (see Table 3) are also associated with reduced bus/minibus accident outcomes

437   (p<.001). It is common knowledge that pedestrians are the most vulnerable of all road users

438   and as such, any collision involving them is expected to result in a higher than usual severity

439   outcome, relative to the other collision types.

440   Lastly, we observed that the probability of more severe bus/minibus accident is more likely

441   where the drivers tested positive for alcohol (drunk driving) relative to where drunk driving

442   was not involved (p<.01). This is expected given the effect of alcohol on driver performance,

443   and both accident frequency and severity. For instance, Peden et al. (2004) maintain that

444   drunk driving is related both to a higher accident risk and severity. This is because alcohol

445   hinders driver performance in respect of coordination, judgement and vehicle control (Ogden

446   & Moskowitz, 2004). Alcohol consumption has also been linked to increased aggression in

447   general (Bushman & Cooper, 1990); implying that a drunk driver will drive more

448   aggressively with serious accident outcomes.

449

450   **7. Conclusion and recommendations**

451   Our findings suggest that weekends, the absence of road median, night-time conditions, bad

452   road terrain (curved, wet and rough roads), hit-pedestrian collisions, and drunk driving are

453   associated with a higher bus/minibus accident severity. Conversely, the minibuses, the

454   absence of road shoulder, accidents in intersections, the presence of traffic control and

455   collision types (except hit-pedestrian) are associated with less severe accident outcome.

456   Obviously, these results have research, policy, and practice implications for road safety

457   stakeholders (e.g. road safety researchers, public transport operators, the police, road and

458   traffic engineers and administrators) in view of implementing workable countermeasures and

459   strategies to reduce bus/minibus accident fatalities.

460   Our estimated model suggests that bus/minibus accidents occurring during weekends, night-

461   time conditions and on bad road terrain have worse outcomes. This finding implicates the

462 driving behaviour (driver speeding and risk-taking) exhibited in these conditions. It should be

463 noted that these conditions in themselves do not cause accidents (Iles, 2005), but drivers'

464 failure to adjust their behaviour to these conditions is the problem. Based on our model

465 outcome the following traffic safety strategies, which have the potential to reduce

466 bus/minibus accident severity in the country, are recommended:

467 Firstly, given that weekends are associated with more severe bus/minibus accidents in Ghana,

468 we recommend increased police enforcement and surveillance during these periods. Previous

469 studies (e.g. Barua & Tay, 2010) have found a positive effect of police presence and

470 enforcement on driver compliance and behaviour.

471 Secondly, as the absence of road median increases the severity bus/minibus accidents, we

472 recommend the implementation of road medians on major roads (especially accident-prone

473 roads) in the country. This should be extended to both current and future road infrastructural

474 developments in the country. Further, owing to the fatalities associated with vehicle-

475 pedestrian collisions and the fact that the road space in developing countries (particularly in

476 Ghana) is a shared space for all road users (especially in the urban environment), the

477 provision of road median and adequate pedestrian facilities will help separate pedestrians and

478 other vulnerable road users from the road environment and thus reduce their exposure levels,

479 and future vehicle-pedestrian collisions. In addition, we recommend that bus/minibus drivers

480 be trained to be very vigilant and expectant of pedestrians and other vulnerable road users in

481 the course of their travels, especially in the urban environment.

482 Thirdly, we also established that traffic controls and other speed calming measures have

483 safety benefits. Accordingly, we recommend that traffic control and speed calming measures

484 be implemented on major roads nationwide, especially within the urban environment.

485 On the finding that night-time conditions and bad road terrain increase the severity of

486 bus/minibus accidents, we recommend that public transport operators should invest much

487 effort in training and retraining their drivers to appropriately recognise, manage and respond

488 to the potential risks associated with driving in these conditions. This is important given the

489 findings that about 70% of the reported bus/minibus accidents were attributable to driver

490 errors (mainly traffic violations and lapses). The data also revealed that in most of the cases,

491 the drivers were not attentive (29.8%) and as such exhibited poor judgements. We

492 recommend that public transport operators adopt high standard internal safety policies,

493 monitor driver behaviour in real time and enforce strict compliance with road traffic rules.

494 Likewise, we recommend driver licensing and re-licensing procedures to test (practically or

495 otherwise) for bus/minibus drivers' ability to detect and manage road hazards with severe

496 injury consequences.

497

498 **8. Study limitation**

499 As we indicated earlier, our data is subject to some under-reporting resulting from the

500 shortfalls in data recovery. Even though the current accident data recovery rate of over 80%

501 is good, we admit some information may have been lost by way of under-reporting or

502 discrepancies in data reporting and capturing.

503

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637

638

Appendix

Table 4: Intercorrelations between explanatory variables

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13
Day of week	1												
Road separation	.02**	1											
Vehicle type	.002	-.02**	1										
Light condition	.04**	-.04**	.03**	.36**	1								
Road description	.02**	.16**	-.04**	.02**	-.02**	1							
Road surface	.01*	.25**	-.04**	.03**	-.03**	.17**	1						
Shoulder condition	-.01	.03**	.05**	-.05**	.01	.02**	.17**	1					
Location	-.001	-.25**	.02**	-.07**	.00	-.11**	-.15**	.07**	1				
Traffic control	-.003	-.15**	.06**	-.04**	.02**	-.05**	-.16**	-.08**	.18**	1			
Collision type	-.003	.09**	-.003	.01*	.01	.003	.05**	.03**	-.16**	-.05**	1		
Drunk driving	.01**	-.02**	.03**	.004	.01*	-.003	-.001	.01**	.006	.005	.005	1	
Surface repair	.002	.18**	-.03**	.03**	-.03**	.13**	.56**	.14**	-.11**	-.15**	.03**	-.005	1

NB: * p<.05; ** p<.001