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Modelling Risk Factors of Pedestrian Accidents on Trunk Roads In Ghana

Daniel Atuah Obeng[1], Mohammed Salifu[2]
[1]*(Department of Civil Engineering, Kwame Nkrumah University of Science and Technology, Ghana)*
[2]*(Department of Civil Engineering, Kwame Nkrumah University of Science and Technology, Ghana)*

ABSTRACT: *Ghana employs the Microcomputer Accident Analysis Package (MAAP 5) software which only provides basic synthesis of accident information for analysis. However, recent studies on accidents have centered on the use of models to describe data, explain and also forecast the phenomenon. This study sought to develop a prediction model for pedestrian accidents on trunk roads. Following the delineation of four (4) trunk roads into one hundred and sixty-one (161) road sections made up of ninety-nine (99) settlements and sixty-two (62) non-settlement units, data was collected on accidents and risk factors representing variables extracted from pedestrian and vehicular traffic, road and environment-related features of the study road sections. Using the Negative Binomial error structure within the Generalized Linear Model framework, a basic (flow-based) model was formulated based on accident data and exposure variables (road section, vehicle and pedestrian flows). Incremental addition of relevant explanatory variables further expanded the basic model into a comprehensive model. The developed models were then validated and tested using appropriate statistical measures. Findings indicate that the main risk factors influencing pedestrian accidents on trunk roads are predominantly flow variables, namely; daily pedestrian flow and total vehicle kilometers driven. To ameliorate the incidence of pedestrian accidents require the segregation of vehicles and pedestrian, traffic calming measures and land use control within settlements featuring trunk roads.*

Keywords – *Delineation, Modelling, Pedestrian accident, Safety, Trunk road.*

I. INTRODUCTION

1.1 Study Background

In developing countries, levels of motorization are generally low and pedestrians constitute significant proportion of users of road space. The requirements of pedestrians in the road transport system have not been given the needed attention thus pedestrians suffer considerable risks as a result of exposure to vehicular traffic. It is reported that pedestrians account for 86% of the fatalities in Addis Ababa and in five other Sub-Saharan countries over half of all road fatalities were reported to be pedestrians (Jacobs and Aeron-Thomas, 2000 [1]).

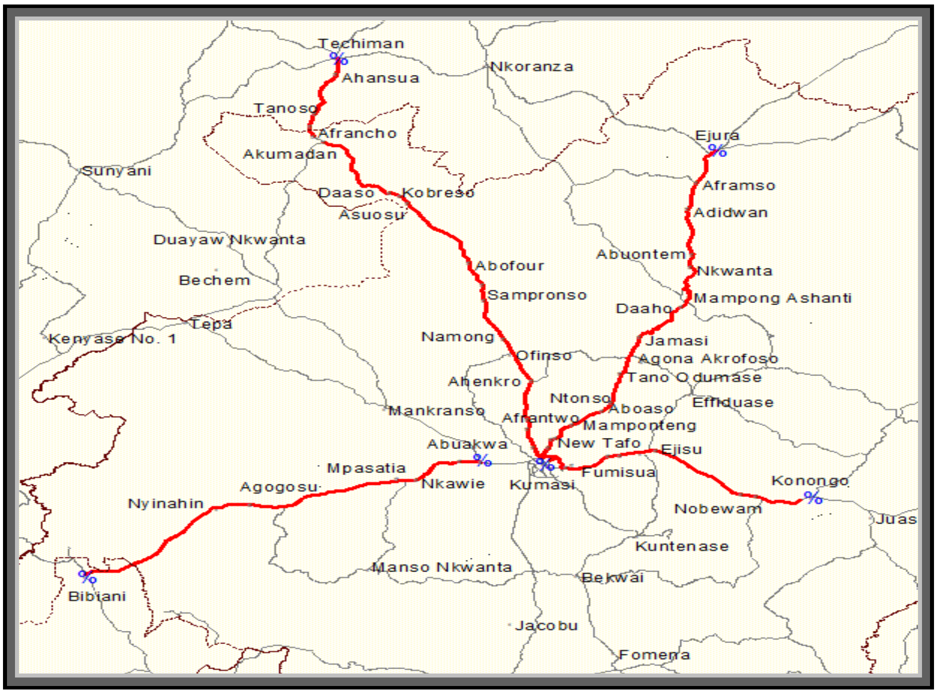
The situation is not different in Ghana, as statistics show that pedestrian deaths constituted 43% of the total road traffic fatalities; most of whom fall within the active age group of 16 – 45 years (Afukaar et al, 2008 [2]). Though fatal pedestrian accidents show no clearly discernible pattern over the years, it has averaged 44% of the total road traffic accidents over a 15-year period from 1991 to 2005. Studies by Afukaar (2001 [3]) showed that majority of pedestrian accidents occurred on roads within built-up areas. However, in terms of severity, pedestrian accidents on roads through settlements along trunk roads were observed to be severer than those on roads in urban corridors. In 2007 alone, 66% of road traffic fatalities occurred in non-urban environments (trunk roads) and this development makes trunk roads important corridors to situate any meaningful pedestrian accident investigation study (National Road Safety Commission, 2008 [4]).

In Ghana, the Microcomputer Accident Analysis Package (MAAP) software developed by the Transport Research Laboratory (TRL), United Kingdom, and which is widely documented, has been the main analysis tool for accident investigation. It is however a descriptive diagnostic tool and provides only basic synthesis of accident information at intersections and along road sections. Recent studies on road traffic accidents have centered on the use of models to describe data, explain and forecast the phenomenon. Thus, the use of prediction modeling is now gaining currency however the applicability and accuracy of the type of prediction model to employ is important as it impacts the outcome of the study (Tarko, 2006 [5]).

The study sought to develop a prediction model for pedestrian accidents on trunk roads. This was realized from the manipulation of data collected on pedestrian accidents and risk factors representing study variables extracted from pedestrian and vehicular traffic, road geometry features, and socio-economic characteristics of communities on delineated sections of the study roads.

1.2 Study Scope

Based on the availability of reliable data on accidents and road alignment details within the study period, four (4) trunk roads were selected for this study. Fig. 1 shows the location of the study roads and their adjoining communities, namely; Konongo – Kumasi, Abuakwa – Nyinahin – Bibiani, Kumasi – Mampong – Ejura and Kumasi – Techiman. The selected roads together make up a total of 327.5km of trunk road length with 162.6km of national roads (representing 49.7%) and 164.9km of inter-regional roads (representing 50.3%).



Source: CERGIS, Legon, 2008

Fig. 1 – Location map of study roads and communities

The road sections were delineated into settlement and non-settlement corridors. A "settlement" corridor is defined as the road section length from the first house to the last house of a community when traversing a study road. The "non-settlement" corridor represents the road section from the last house of a community to the first house of another community when traversing a study road. Following the delineation, the four (4) study roads were sub-divided into "homogeneous" sections of one hundred and sixty-one (161) road links made up of ninety-nine (99) settlements and sixty-two (62) non-settlement units.

1.3 Study Approach and Methodology

In order to establish the relationships between pedestrian accident counts and the study variables, as well as between the study variables, correlation matrices were developed. Though the analyses were exploratory, relevant and significant variables were identified and the strength of relationships between the dependent variable (pedestrian accident count) and independent variables (study variables) were assessed. The identified risk variables together with pedestrian accident counts were used as input variables in the Generalized Linear Model (GLM), a sub-model in the Stata software package version 9, which was employed in the development of the prediction models (Hauer, E, 2004 [6]).

The basic (flow-based) model was formulated based solely on the accident data and exposure variables (road section length, vehicle and pedestrian flows). With the incremental addition of the other relevant explanatory variables, the basic model was further expanded into a comprehensive model. The process of model expansion involved adding key relevant variables to the basic model and testing the significance of their estimated parameter coefficients (Harkey et al, 2007 [7]). Additionally, the parameter's significant contribution to the reduction of deviance in the model was also assessed. This fitting process continued until variables of significant contribution to the development of the comprehensive model were determined (Hermans et al, 2006 [8]).

Model evaluation was based on the description of how well the developed accident model fitted the overall data as assessed using the global goodness-of-fit measures of the Pearson Chi-squared Statistic, Deviance and the Coefficient of Determination R-Squared (Chatterjee et al, 2001 [9]). Using the Chi-Square Statistic, the predictive efficacy of the developed accident prediction model was also established.

II. DATA COLLECTION AND ANALYSIS

2.1 Accident Data

Relevant information for each pedestrian accident from 2005 to 2007 was retrieved and analyzed using the kilometer analysis facility and cross-tabulations available in the MAAP software. Accident and casualty data obtained included characteristics of victim (age and sex), type of vehicle involved and its movement, month, day and hour of accident, accident and casualty severity, visibility, direction and accident location type.

2.2 Vehicular Traffic Data

Historical traffic data in the form of annual average daily traffic (AADT) were obtained from the Traffic Unit of the Planning Division of the Ghana Highway Authority (GHA) for the study roads (Ghana Highway Authority, 2008 [10]). Additional traffic surveys were conducted for sections of the study roads for new traffic data using the standard 12-vehicle types adopted by the GHA. These are: cars, pick-ups, mammy wagons, small buses, large buses, light trucks, medium trucks, heavy trucks, semi-trailers (light), semi-trailers (heavy), truck trailers and others. The counts were undertaken at hourly intervals for 16 hours at each station and 24-hour counts were also conducted at selected census points to serve as a basis for the determination of daily traffic flow and also for purposes of traffic projections. The historical traffic data obtained from GHA came as Annual Average Daily Traffic (AADT) flows. Thus, for the average daily traffic flows that were determined from the surveys, there was the need to apply appropriate variation factors in order to estimate annual averages.

2.3 Pedestrian Data

Pedestrian volume counts were conducted within the study road sections along crosswalks at critical locations of major activity centers. For these crosswalks, pedestrian flows were counted at 15-minute intervals for durations of 12 hours between the hours of 06:00 and 18:00. Four-hour night-time counts were conducted between 18:00 and 22:00 at locations where pedestrian activities were more pronounced during the night. The pedestrian volume counts were undertaken for two (2) continuous days; one weekday and one weekend.

2.4 Population Data

Population figures were obtained for the various settlements along the study roads by either accessing information from published population data or through interviews (Ghana Statistical Services, 2001 [11]). With respect to the smaller localities, Assembly members, Unit Committee members and Health Officials were contacted for population data. The information usually came in the form of the Electoral Register for the community or some demographic data from Health Officials. These figures were projected, where it was necessary, based on the demographic distribution and population growth rates of the districts in which the settlements are located.

2.5 Socio-Economic Data

The numbers of social and economic facilities within specific road sections were determined together with the patronage of these facilities. For road sections in the settlement corridors, 12-hour counts from 0600 hours to 1800 hours were employed to determine the patronage for sampled social and economic facilities. Additional information was solicited by the use of selective interviews of proprietors, vendors and caretakers of various social and economic facilities to establish on average the number of clients that patronized their services. The average daily values obtained from the surveys were compared with the figures provided by the interviewees. This then became the average daily attendance to the stall or shop within the study road section.

2.6 Speed Data

The average speed of a vehicle passing a study road section was established using the “floating car method”. Using a digital stopwatch, the travel times over a section were recorded directly on a field sheet. The entry time was recorded as zero and the first study road section end time was recorded when the vehicle reaches the end of the section, which incidentally becomes the entry time of the second study road section. This process was followed till the end time for the last study road section had been captured. The floating vehicle made three runs for each study road in the morning, afternoon and evening to obtain a fair representation of the section mean speeds for the study roads. The field recording sheets had space also for study section identification, section chainage, section length and travel time. For the speed measurements, the section mean speeds were estimated by dividing the section distance by the travel time for the three (3) runs and the two day surveys. The section mean speeds computed for the road study sections were thus obtained from the average of the section mean speeds for the runs.

2.7 Road Geometric Data

Most road alignment features for the study roads were obtained from as-built drawings and engineering design reports. However, additional field surveys had to be conducted on all the study roads to validate the figures obtained from the desk study. Measurements of section length, road and carriageway widths, shoulder width, and the number of accesses were undertaken during the physical inspection of the study roads to validate what was obtained from the secondary sources.

III. DATA PRESENTATION

3.1 Pedestrian Accidents on Study Roads

In all, a total of 642 pedestrian accidents were recorded, out of which 460 represented fatal and injury accidents (71.7%) and 182 accounted for minor injury accidents (28.3%). The Kumasi – Ejura road recorded the highest number of accidents (43.5%) followed by Kumasi – Techiman road (26.9%), then, Abuakwa – Bibiani road (16%) and lastly, the Kumasi – Konongo road (13.6%). The reasons for the high incidence of pedestrian accidents especially on the Kumasi – Ejura road may be varied. However, the fact that substantial number of accidents occurred in settlement corridors attest to the fact that pedestrians are exposed to risks within the settlements because of intense roadside activities. Table 3.1 shows the distribution of accidents on the study roads.

Table 3.1 – Distribution of Accidents on Study Roads

Road Name	Fatal		Hospitalised		Not-Hospitalised		Total
	Number	(%)	Number	(%)	Number	(%)	
Kumasi - Konongo	23	16.4	51	15.9	13	7.1	87
Kumasi – Techiman	44	31.4	87	27.2	42	23.1	173
Kumasi - Ejura	49	35.1	130	40.6	100	55.0	279
Abuakwa - Bibiani	24	17.1	52	16.3	27	14.8	103
Total/Percentage	**140**	100.0	**320**	100.0	**182**	100.0	**642**

Source: Pedestrian Accident Data of Study Roads, 2005 – 2007, BRRI

3.2 Traffic Flow

The annual average daily traffic flow recorded on the study roads is presented in Table 3.2. It provides the spectra of minimum, average and maximum vehicular flows estimated for the study roads. The Kumasi – Konongo road experienced the highest average vehicular flow, which accounted for 39% of the cumulative traffic on the roads, followed by the Kumasi – Techiman road (26%). Abuakwa – Bibiani and Kumasi – Ejura roads recorded 18% and 17% of the cumulative total traffic respectively. With respect to the minimum and maximum flows, the huge variation observed for the study roads are attributed to the influence of substantial "local" traffic recorded in some settlement corridors. For example, the high traffic volumes estimated on the Kumasi – Konongo road was obtained in the Konongo Township.

Table 3.2 – Summary of Traffic Flows on Study Roads

Study Road	Daily Traffic Flow		
	Average	Minimum	Maximum
Kumasi - Konongo	8,884 (39%)	6,801	15,012
Kumasi – Techiman	5,846 (26%)	3,482	14,922
Kumasi - Ejura	3,821 (17%)	1,920	7,887
Abuakwa - Bibiani	4,180 (18%)	3,678	5,774

Source: Field Surveys, 2008

3.3 Pedestrian Flow

Table 3.3 presents daily pedestrian flows estimated at crosswalks around activity generating sections of the study roads. It is clear that significant volumes of human activities occurred within the settlement corridors of the Kumasi – Konongo and Kumasi – Techiman roads. The variation in the average and maximum values for the two (2) roads show the different levels and spread of human activities along the study roads. Though, the activities on the Abuakwa – Bibiani and Kumasi – Ejura roads are comparatively less intense, some roadside activities were observed in the settlements. A prominent feature observed on all the roads, was the intensity of roadside activities within settlement corridors, especially, on the Kumasi – Konongo and Kumasi – Techiman roads. However, some level of petty trading along roadside within some non-settlement corridors was also observed.

Table 3.3 – Summary of Average Daily Pedestrian Flows on Study Roads

Study Road	Daily Pedestrian Flow	
	Average	**Maximum**
Kumasi - Konongo	1,944 (30.1%)	13,399
Kumasi – Techiman	2,445 (37.8%)	32,816
Kumasi - Ejura	1,466 (22.7%)	9,445
Abuakwa - Bibiani	607 (9.4%)	5,954

Source: Field Surveys, 2008

3.4 Speed Data

The space mean speed estimated for the settlement and non-settlement corridors of the study roads are presented in Table 3.4. It was found that the non-settlement corridors experienced slightly higher speeds than within the settlement corridors. While an average of 68km/h was recorded in the settlement corridors, an average of 80km/h was realized for the non-settlement corridors. This is not surprising because of the many challenges drivers face while driving through settlements. They are usually constrained by human activities and interactions, thus, reducing their vehicle operating speeds. The differences between settlements and non-settlements notwithstanding, an average speed of 68km/h, is still considered high for driving through settlements located on highways. This may perhaps be responsible for the number of pedestrian accidents and fatalities in settlement corridors. Meanwhile, on highways traversing rural settlements, it is established that at impact speeds of 30km/h, the risk of death to a pedestrian is around 10%, and this risk increases rapidly to around 25% at 40km/h, 85% at 50km/h and, by 55km/h, the risk of death has reached 100% (Corben et al, 2004 [12]).

Table 3.4 – Summary of Travel Speed on Study Roads

Study Road	Travel Speed (km/h)	
	Settlement Corridor	**Non-Settlement Corridor**
Kumasi - Konongo	70	85
Kumasi – Techiman	68	74
Kumasi - Ejura	65	79
Abuakwa - Bibiani	68	82

Source: Field Surveys, 2008

3.5 Road Geometric Data

The road geometric data as extracted from the as-built drawings and the road surveys are described below:

Road Section: The length of the road sections, which represented the units of enquiry for data collection, ranged from 0.2km to 11.0km with a mean length of 1.8km.

Road Width: The road width was either 7.3m or 7.5m. This is not different from the standard road widths for national and inter-regional roads of 7.5m and 7.3m respectively.

Shoulder Width: The shoulder width varied from 1.5m to 2.0m on the study roads with the inter-regional roads featuring shoulder widths of 1.5m while the national roads had shoulder widths of 2.0m and 2.5m. There was no variability in the presence of shoulder as all the study roads had paved shoulders.

Horizontal Curves: Twenty-seven (27) out of one hundred and sixty-one (161) road sections did not feature a horizontal curve. Horizontal curve density (number of horizontal curves per section length) varied from 0 to 5.6 curves per km with a mean value of 1.5 curves per km.

Terrain Type: Seventy (70) out of one hundred and sixty-one (161) road sections featured a relatively flat terrain, representing 43.5% of the total road sections for the study. The remaining 57.5% lie in rolling/hilly terrain.

Accesses: Only seventeen (17) out of one hundred and sixty-one (161) road sections did not have an access. This implies that most of the road sections contained at least an access. Access density (number of access per section length) varied from 0 to 19.4 accesses per km with a mean value of 4.3 accesses per km.

3.6 Socio-Economic Data

The social and economic characteristics of communities along the study roads were measured by the number of socio-economic facilities at the roadside of the road sections. Though agriculture played an important role in the socio-economic development of the communities, a number of the communities, especially the towns, enjoy significant distributive trade and other services. There are considerable roadside activities for communities along the study roads and this is represented by the presence of socio-economic facilities (stalls, shops and mini-markets) which promote activities and interactions at the roadside.

Sixty-two (62) out of the one hundred and sixty-one (161) road sections did not feature any settlement. The implication is that about 38.5% of the road sections considered under the study was non-settlement corridors. However, this does not mean that no activities occur along the non-settlement corridors. For instance, the non-settlement corridors featured pockets of mini-markets where trip makers could stop and shop. For the settlement corridors, 76% of the road study sections feature at most 119 facilities and the remaining 24% had between 119 and 2,200 facilities. Therefore, the social and economic interactions within the settlement corridors were substantially more intense than in the non-settlement corridors.

IV. CORRELATION ANALYSIS

A prelude to the development of the accident prediction model was to examine the degree of correlation between pedestrian accident counts and some road and environmental-related variables. These relationships provided preliminary insight into the contributions of the variables to the occurrence of pedestrian accidents. The nature of the relationships and degree of variability between the dependent variable (pedestrian accident) and the independent variables (road section, travel speed, curve density, access density and facility density) were therefore explored.

As in many exploratory studies, the correlation coefficient (r), which indicates the strength of relationships between variables are assessed based on some thresholds (Okoko, 2001 [13]). For this study, the following thresholds were adopted:

- Low (weak) correlation, $0 < r < 0.5$;
- Moderate (fairly strong) correlation, $0.5 < r < 0.7$; and
- High (strong) correlation, $0.7 < r < 1.0$

Following the manipulation of the dependent and the independent variables, the relationships between pedestrian accident counts and the road and environment-related variables are presented. Table 4.1 shows a summary of correlation coefficients estimated for the independent (study) variables considered to influence pedestrian accidents.

Table 4.1 - Correlation Coefficient of Variables influencing Pedestrian Accidents

Variable	Correlation Coefficient (r)	Remarks
Average Daily Traffic	0.351	Weak relationship
Number of Accesses	0.420	Weak relationship
Travel Speed	0.431	Weak relationship
Road Section Length	0.459	Weak relationship
Horizontal Curves	0.595	Fairly strong relationship
Settlement Population	0.685	Fairly strong relationship
Daily Pedestrian Flow	0.696	Fairly strong relationship
Number of Facilities	0.713	Strong relationship

Source: Field Surveys, 2008

It is evident that pedestrian accidents show a strong relationship with the number of socio-economic facilities and moderate relationships with horizontal curves, settlement population and daily pedestrian flow. In terms of weak but significant relationships, average daily traffic, number of accesses, travel speed and road section length were all reasonably represented.

On relationships among the study variables, it was established that strong relationships existed between section length and number of horizontal curves, settlement population and number of socio-economic facilities on the study roads. Average daily traffic was found to be fairly strongly related with daily pedestrian flow. The relationships established provided indications to possible relevant and significant variables to be considered in developing the model and degree of collinearity among the study variables.

V. MODEL DEVELOPMENT

5.1 Modeling Procedure

Modeling was conducted within the framework of the Generalized Linear Models (GLM) of the Stata software package. The basic (flow-based) model was formulated and further expanded into a comprehensive (full variable) model by inputting relevant study variables. The basic and comprehensive models are mathematically expressed as below:

For the basic model,

$$E(Y) = a_0 L^{a_1} V^{a_2} \quad \text{..............................(5.1)}$$

For the comprehensive model,

$$E(Y) = a_0 L^{a_1} V^{a_2} \exp \sum_{j=1}^{n} b_j X_j \text{..................................(5.2)}$$

where,
E (Y) = predicted accident frequency,
L = section length (km),
V = average daily traffic (per day),
X_j = any variable additional to L and V,
exp = exponential function, e = 2.7183, and
a_0, a_1, a_2, b_j = model parameters.

In conformity with the GLM framework, equations 5.1 and 5.2 were transformed into the prediction mode using a log-link function as follows:
For the basic model,

$$\ln\left[E(Y)\right] = \ln\left(a_0\right) + a_1 \ln\left(L\right) + a_2 \ln\left(V\right) \text{ ....(5.3)}$$

For the comprehensive model,

$$\ln\left[E(Y)\right] = \ln\left(a_0\right) + a_1 \ln\left(L\right) + a_2 \ln\left(V\right) + \sum_{j=1}^{n} b_j X_j \text{ ....(5.4)}$$

The data set was over-dispersed so the Negative Binomial error structure was adopted as the most appropriate distribution and within the GLM framework to estimate the model coefficients (Caliendo et al, 2006 [14]). By specifying the dependent variable, the explanatory variables, the error structure and the link function, the models were fitted. Model parameters (coefficients) were estimated using the maximum likelihood approach. The procedure adopted in the model development was the forward procedure in which the variables were added to the model in a stepwise manner.

The decision on which variables to retain in the model was based on whether the t-ratio of the estimated parameter was significant at the 95% confidence level (p-value less than 5%) and whether the addition of the variable to the model causes a significant drop in the scaled deviance at 95% confidence level. Two statistical measures were used in assessing the validity of the model developed. These were the Pearson Chi square statistic and the Deviance statistic. The coefficient of determination (R^2) was also employed to determine the amount of variability in the response variable explained by the variation in the selected set of explanatory variables. The R-squared estimation was carried out by the method recommended by Miaou (1993 [15]).

5.2 Model Results

The results of the best fit model for the data set captured the differences in model variables for pedestrian accidents to enable comparisons and appropriate inferences to be made.

5.2.1 Basic Model

The parameter estimations for the log-linear equation of the basic (flow-based) model are as presented in Table 5.1.

Table 5.1 - Parameter Estimation of Basic Model for Pedestrian Accidents

No. of obs. = 124	Deviance ((1/df) = 1.19011
Residual df = 121	Pearson (1/df) = 0.94010
Log likelihood = -227.813105	AIC = 3.722792
	BIC = -439.251

Notation	Parameter	Coefficient	Standard Error	z
LV	Total vehicle kilometres driven	0.43066	0.10954	3.93
P	Daily pedestrian flow	0.44459	0.05730	7.76
a_0	Constant	-8.79247	1.61922	-5.43

The resulting basic model developed for the pedestrian accidents is as follows:

$$E(Y) = 2 \times 10^{-4} \times LV^{0.4} P^{0.4} \quad \text{.............................(5.5)}$$

where,
E (Y) = expected accidents along road section for 3 years,
LV = total vehicle kilometers driven (veh-km) of road section, and
P = daily pedestrian flow.

The exposure variables for the basic model are total vehicle kilometers driven and daily pedestrian flow. They were found to be statistically significant ($p<0.05$) with positive estimated model parameters, an indication that accident frequency will increase with increasing mileage (total kilometers driven) and pedestrian flow. The goodness-of -fit statistic for the model shows that the model fits reasonably well with the data. The Pearson Chi-square and deviance statistic divided by its degrees of freedom were estimated to be 0.94 and 1.19 respectively as shown in Table 5.1 (Sawalha, Z. and Sayed, T., 2006 [16]).

Judging by the estimated coefficient of determination, R-squared of 0.805, the variables in the basic model, namely, total vehicles driven and daily pedestrian flow could explain 80.5% of the systematic variation in the accident data. The basic model for pedestrian accidents is therefore regarded as a good estimator of accident frequency.

5.2.2 Comprehensive Model

The parameter estimations for the log-linear equation of the comprehensive model are as presented in Table 5.2.

Table 5.2 - Parameter Estimation of Comprehensive Model for Pedestrian Accidents

No. of obs. = 124	Deviance ((1/df) = 1.079903
Residual df = 119	Pearson (1/df) = 0.878201
Log likelihood = -220.065791	AIC = 3.630093
	BIC = -445.1051

Notation	Parameter	Coefficient	Standard Error	z
LV	Total vehicle kilometres driven	0.65985	0.12468	5.29
P	Daily pedestrian flow	0.39015	0.05865	6.65
RST	Road surface type	-0.78216	0.24310	-3.22
SWD	Shoulder width	-1.09034	0.28592	-3.81
a_0	Constant	-9.31674	1.62845	-5.72

The resulting comprehensive model developed for the pedestrian accidents is as follows:

$$E(Y) = 1 \times 10^{-4} \times LV^{0.7} P^{0.4} \times EXP^{(-0.8RST - 1.1SWD)} \quad \text{..............(5.6)}$$

where,
E (Y) = expected accidents along road section for 3 years,
LV = total vehicle kilometers driven (veh-km),
P = daily pedestrian flow,
RST = type of road surface (1 – asphalt, 0 – surface dressing),
SWD = shoulder width, and
EXP = exponential function, e = 2.718282.

The goodness-of -fit statistic for the model shows that the model fits reasonably well with the data. The Pearson Chi-square and deviance statistic divided by its degrees of freedom were estimated to be 0.88 and 1.08 respectively as shown in Table 5.2. The values are within the permissible range of 0.8 and 1.2, indicating that the Negative Binomial error structure assumption is acceptable (Dissanayeke, S., and Ratnayake, 2006 [17]).

The estimated coefficient of determination, R-squared value of 0.817, indicates that the comprehensive model could explain 82% of the systematic variation in the accident data. This implies that 18% of the variation in the data set remains unexplained by the model developed. The 'percentage unexplained' may be attributed to factors relating to human behaviour and the vehicle which were difficult to capture as variables in this study.

Following the model results, these significant risk variables were identified and their contributions to pedestrian accident occurrence have been explained.

Pedestrian accidents increase with increasing total vehicle kilometers driven and daily pedestrian flow. For instance, an increase in the total vehicle kilometers driven by 50% is expected to increase pedestrian accidents by 33%. With respect to pedestrian flow, a 50% increase is expected to increase pedestrian accidents by 18%. The estimated negative coefficients of shoulder width and road surface type are indicative of the beneficial influence of the two variables on pedestrian accidents. For the two types of road surfaces considered, asphaltic concrete and bituminous surface dressing, it was suggested that the use of bituminous surface dressing had a positive influence on pedestrian accidents.

5.3 Model Validation

The predictive efficacy of the model was performed using the chi-square statistic, mean absolute deviation and the mean absolute scaled deviation as validation measures. Appropriate data set was generated for two (2) new trunk roads, namely; Kumasi – Obuasi and Kumasi – Sunyani roads. The data included traffic, accident and road geometry characteristics obtained from GHA and BRRI for seventy-one (71) road sections; made up of 36 settlement and 35 non-settlement corridors. No outliers were removed from the accident data set. Table 5.3 shows the results of applying the prediction model developed for the study roads to the data set of the new trunk roads. The critical value $X^2_{95\%}$ has been listed for comparison purposes.

Table 5.3 - Validation of Pedestrian Accidents Model with New Data

	Sample size of data used in modeling	Sample size N of validation data	X^2_c	Critical value $X^2_{95\%}$	Z-score of X^2_c	Mean Abs. Dev (MAD)	Mean Abs. Scaled Dev. (MASD)
Pedestrian Accidents	124	71	29.453	31.461	-0.157	0.0225	0.0065

In adopting the null hypothesis that the new road sections are drawn from road sections with mean accident counts as given by the pedestrian accident prediction model, then, we fail to reject the null hypothesis based on the fact that the calculated chi-square value is less than the critical chi-square value. The fact that the null hypothesis was not rejected does not necessary implies that the two prediction models are the same. However, it can be inferred that the exposure variables of total vehicle kilometers driven and daily pedestrian flow, together with the other explanatory variables of road surface type and shoulder width are the main risk factors that cause pedestrian accidents on trunk roads based on available data. Additionally, the estimated values of the Mean Absolute Deviation (MAD) and the Mean Absolute Scaled Deviation (MASD) also indicate a reasonably good fit (Miaou, 1996 [18]).

VI. CONCLUSION

The objective of this study was to determine the risk factors that influence pedestrian accident occurrence on trunk roads and to develop prediction models to inform traffic management operations and make policy recommendations that would enhance pedestrian safety.

It is quite evident that the main risk factors influencing pedestrian accidents on trunk roads are the flow variables of daily pedestrian flow and total vehicle kilometers driven; which together explained 80% of the systematic variation in the pedestrian accident data. The other explanatory variables of shoulder width and road surface type only added 2% to the explanatory power of the comprehensive model. Considering the low levels of motorization in developing countries, pedestrians would remain the most dominant users of road infrastructure. The inaction of transport experts and decision makers in providing basic infrastructure for pedestrians in the road space has obvious dire social and economic consequences.

Findings of the study attributed the incidence of pedestrian accidents to the un-controlled interactions between pedestrians and vehicles in the traffic stream. Thus, to ameliorate this situation require interventions targeting the segregation of vehicles and pedestrian, addressing the intensity of roadside activity and deficiencies in alignment design, as well as providing appropriate traffic calming measures in settlements along trunk roads.

REFERENCES

[1]. Jacobs, G. and Aeron-Thomas A., *Africa Road Safety Review Report, Project Report PR/INT/659/00*, Transport Research Laboratory, 2000, pp ii.

[2]. Afukaar, F. K., Ackaah, W. and Mosi, I, Accident Statistics 2007, Building and Road Research Institute (Council for Scientific and Industrial Research), Kumasi, 2008.

[3]. Afukaar, F. K., The Characteristics of Pedestrian Accidents in Ghana, *Bi-Annual Journal of Building and Road Research Institute (Council for Scientific and Industrial Research), Ghana, Vol. 7*, 2001, pp. 1 - 4.
[4]. National Road Safety Commission, 2007 Annual Report, 2008.
[5]. Tarko, A. P., Calibration of Safety Prediction Models for Planning Transportation Networks, *Transportation Research Board, No. 1950,* Transportation Research Board of the National Academies, Washington D. C., 2006, pp. 83 – 91.
[6]. Hauer, E., Statistical Road Safety Modeling, Transportation Research Record: *Journal of the Transportation Research Board, No. 1897*, TRB of the National Academies, Washington D. C., 2004, pp. 81 – 87.
[7]. Harkey, D. L., Raghavan, S., Jongdea, B., and Council, F. M., Crash Reduction Factors for Traffic Engineering and ITS Improvement, *Draft Final Report NCHRP 17 – 25*, Highway Safety Research Centre, University of Carolina, Raleigh, N. C., 2007.
[8]. Hermans, E., Wets, G. and Van den Bossche, F., Describing the Evolution in the Number of Highway Deaths by Decomposition in Exposure, Accident Risk and Fatality Risk, *Transportation Research Board, No. 1950*, 2006.
[9]. Chatterjee, A., Wegmann, F. J., Fortey, N. J., and Everett, J. D., Incorporating Safety and Security Issues in Urban Transportation Planning, *Transportation Research Record: Journal of the TRB, No. 1777*, Transportation Research Board, National Research Council, Washington D. C., 2001, pp. 75 – 83.
[10]. Traffic Surveys Report 2005 - 2007, Ghana Highway Authority, Ministry of Roads and Highways, 2008.
[11]. 2000 Population and Housing Census, Summary of Final Results, Ghana Statistical Service, 2001.
[12]. Corben, B., Senserrick, T., Cameron, M. and Rechnitzer G., Development of the Visionary Research Model, Application to the Car/Pedestrian Conflict, Monash University Accident Research Centre, *Report No. 229*, 2004, pp. xi - xv.
[13]. Okoko E., *Quantitative Techniques in Urban Analysis*, 2001, pp. 116 – 117.
[14]. Caliendo, C., Guida, M., and Parisi, A., A Crash-Prediction Model for Multilane Roads, *Accident Analysis and Prevention Vol 39*, 2006, pp. 657 – 670.
[15]. Miaou, S. P. and Lum, H., Modeling Vehicle Accidents and Highway Geometric Design Relationships, *Accident Analysis and Prevention, Vol. 25, No.6*, 1993, pp. 689-703.
[16]. Sawalha, Z. and Sayed, T., Traffic Accident Modeling: Some Statistical Issues, *Can. J. Civil Engineering Vol. 33*, 2006, pp. 1115-1124.
[17]. Dissanayeke, S., and Ratnayake, I., Statistical Modeling of Crash Frequency on Rural Freeways and Two-Lane Highways using Negative Binomial Distribution, Advance in Transportation Studies, *International Journal, Section B.9*, 2006, .
[18]. Miaou, S. –P., Measuring the Goodness-of-Fit of Accident Prediction Models, FHWA-RD-96-040, Federal Highway Administration, Washinghton, D. C., 1996.