

**CRASH PREDICTION MODELS AND RISK FACTORS FOR TWO-LANE
URBAN ROADWAYS**

By

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DECLARATION

I hereby declare that this submission is my own work towards the PhD and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

Ghana's road network has claimed over twenty thousand lives in the last decade. More than ten thousand persons suffer various degrees of injuries that require medical attention annually since year 2000. This does not include those that go unreported and unrecorded. The situation is worse on the trunk road network where over sixty percent of all fatalities occur. In highway safety planning prediction models enable the transportation planner to study those factors or parameters that influence crash experience based on historical record. No models have been developed for roads sections in urban environment.

The primary aim of this research was to develop crash prediction models after a comprehensive analysis of crash data for the period 2000-2009 to establish and identify the main risk factors associated with crashes and casualties on two lane urban roadways. The specific objectives of the research were to 1) Determine the characteristics and trends of crashes and traffic factors on two lane roadways from an analysis of historical data. 2) Determine the risk factors associated with the trends in traffic and crashes and 3) Develop statistical models for the prediction of crashes on two-lane urban roads.

Data was collected for Traffic volumes, crashes, and road geometry and road side environment for a five year period. Risk factors were determined from trends and correlations of historical traffic, road and crash data. Using generalised Linear modelling techniques with binomial error structure in Statistical Analysis Software STATA, statistical models were developed for Total injury crashes and two vehicle crashes. Model variables were evaluated at 95% confidence Interval for all explanatory variables after the core model with the exposure variables of Traffic and Road length had been constituted. The Akaike information criterion was the main basis for accepting or rejecting a model.

The results show that there is a rapid growth in vehicle population averaging about 10% per annum without a proportional increase in number of injury crashes. The population of vehicles operating on a network is a risk factor for crashes and they are linearly correlated. More than 50% of crashes involve pedestrians, but pedestrians involved in crashes were neither crossing the road nor walking along the road. This means that the prediction of crashes should contain a pedestrian factor. Models have been developed to predict Total injury crashes and Two vehicle crashes with sidewalk width and number of pedestrian crossing points in a section as the main explanatory variables for injury crashes. From the analysis of historical data and modelling, the vehicle population on a network, presence of pedestrian sidewalk, width of sidewalk and average speed are risk factors. The study recommends that road safety on two lane urban roadways can be improved through the control of activities in the road corridor which increase pedestrian presence and concentration. Also, carefully designed wide shoulders can reduce crashes involving two vehicles on two lane roadways. Transportation planners can apply these models to predict crashes during highway planning and cost benefit analysis.

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CHAPTER 1 INTRODUCTION

1.1 Background

Road crashes kill at least 1.3 million people each year and injure 50 million, a toll greater than deaths from malaria. Ninety percent of these road casualties are in low and middle income countries. Each year 260,000 children die on the road and another million are seriously injured, often permanently disabled. By 2015, road crashes are predicted by WHO to be the leading cause of premature death and disability for children aged 5 and above (CGRS, 2008). Without increased effort and new initiatives, the total number of road traffic deaths and injuries worldwide is predicted to rise by some 65% between 2000 and 2020 (WHO, 2004), and in low income countries the death toll is forecasted to rise by as much as 80%. Most of the victims would be the most vulnerable road users such as pedestrians, motor cyclists and bicyclists. In high income countries, death for car occupants continues to dominate even though per capita vulnerable road users suffer most.

Injuries represent 12% of the global burden of diseases and the third most important cause of overall mortality. Road traffic injuries constitute the main cause of death among 1-40 year old people. Globally, between 750,000 and 1,183,492 people are killed annually through road crashes, this translates into over 3000 people dying daily on the world's roads.

Analysis of available data (Afukaar et al, 2007) shows that over 23,731 people have died in Ghana from road traffic crashes alone from 1991-2007 and over 197,187 people have suffered injuries which required medical attention. This does not include those which were not reported to the police. The situation is worse on the trunk road network where 66% of all fatalities occur. The proportion of annual fatalities among road user groups are as follows: pedestrians 43%, mini-bus passengers 22% and heavy goods vehicle and car occupants 11%. Each day at least three (3) persons are killed on trunk roads and one on urban roads. Sixty eight percent (68%) of those killed are 1- 45 years old, of which 73% are male. The vehicles more likely to be involved in crashes are cars/pick up (55%), buses and mini buses (25%), heavy goods vehicles (12%). The most crash prone regions are Greater Accra (42%), Ashanti (17%), and Eastern (13%). In terms of fatalities, however, the order is very different as follows; Ashanti (20%), Greater Accra (18%), Eastern (17%), Central (11%), Western (9%), Volta (7%), Northern (4%), Upper East(3) and upper west (1%) (Afukaar, 2010).

According to Driver and Vehicle Licensing Authority data (DVLA, 2010), the vehicle registration in Ghana has just hit the over 1.2 million count. Compared to those of industrialised countries, Ghana's car ownership ratio of 40 vehicles per thousand population is low and the country is yet to launch into the rapid motorization phase (more than 150 per 1000 population) as the economy improves. Over the last decade, car ownership levels have seen a rapidly growing trend and along with it will come increasing potential for crashes, injuries and fatalities which will worsen the already existing safety problem on Ghana's roads.

In most industrialized countries, a lot of concerted effort has been made over the years to sustain a consistent downward trend in road fatalities (per 10,000 vehicles) even with the increasing number of motor vehicles. Consistent actions and policies in areas such as legislation and enforcement, driver training and licensing, road safety campaigns, improvement in vehicle design and higher standards and improved road engineering and interventions among others are required to sustainably improve the safety situation.

The National Road Safety Commission since its establishment in 2000, has shown some commitment in tackling the road safety challenge by providing leadership; direction, coordination of plans and programmes of stakeholders and implementation of a more structured approach to safety. Two (2) five-year strategies have so far been rolled out with some successes and a third is still running to date. The Commission publishes the national crash statistics annually through the Building and Road Research Institute (BRRI). Data collection and management has seen tremendous improvement. However, over the same period, apart from occasional studies and action research by the BRRI, not much research has been conducted to underpin the plans and policies of the road safety strategies. This thesis seeks to make a contribution towards the national effort to use data-led approach through the development of prediction models and analysis of risk factors that can assist in road safety planning.

1.2 Problem Statement and Justification of the Research

Most classified roads in Ghana are two-lane roadways and play a very important role in the network. According to the National Road Safety Commission (NRSC, 2007), the

public health significance of crashes in Ghana is growing; more people as a proportion of the national population are being killed through road crashes. The road safety challenge may be to reduce pedestrian fatalities in urban and non-urban environments through improved crossing and pedestrian facilities.

In municipal and metropolitan areas, with increasing traffic and roadside activities the crash rate and fatalities are soaring on urban roads even though at a slower rate compared to the trunk road network. In order to determine the strategy to minimize crashes or fatalities resulting from crashes, it is important to analyze the underlying factors which contribute to crashes such as the roadway design and condition, road environment, traffic flow and speed, presence of road signs or appurtenances.

An analysis of historical crash and traffic data can assist in the identification of risk factors which may trigger crashes on certain roads and environment. In highway safety planning, it is important to realize that crashes are generally the result of bad decisions by drivers made in an environment created by the engineer, urban planners and those responsible for development control and enforcement within the road corridor. According to Anderson(1976), the engineer has a good deal of influence on the likelihood of a driver making a bad decision and sometimes even the consequences of the crash. He also noted that engineers could attack the lion's share of the safety problem if they got behind the driver error myth.

Prediction models enable the transportation planner to study those factors or parameters that influence crash experience based on historical record. In Ghana, no such models have been developed for urban road links. Rambol and Comptran Engineering and Planning (2005) undertook feasibility studies for the design of urban arterial roads in the

Ashanti Region of Ghana. In the absence of local crash prediction models, a Danish predictive model was applied to predict crash frequencies. The result was ten (10) times less than the recorded crashes retrieved from the MAAP 5 suite at the Building and Road Research Institute. This underscores the need for a locally developed crash prediction model for the road links in the country. According to recent researches, Ghana loses an estimated 1.6% of gross domestic product through injuries, fatalities and damage to property in road traffic crashes (Adams et al, 2006). Without appropriate tools and prediction models it becomes difficult to estimate the likely benefits of safety interventions.

According to Fletcher et al (2005), attempts by the Transport Research Laboratory (TRL) to develop models to predict crashes on urban road links have yet to report acceptable results. In any case locally available models would always be preferred to region-wide ones due to variations in driver behaviour, vehicle mix, traffic flow characteristics, road safety practices etc. in various countries of Africa or developing countries.

1.3 Benefits of Risk Factors and Crash Predictive Models

Crashes result when at least two of the interacting elements of the transportation system, namely; drivers, vehicles and the roadway, are engaged in a conflict. Hence if one is to create an environment to reduce the likelihood of a conflict among these elements, one must have a thorough knowledge of the complex relationships that exist between them. Highway safety research aims at understanding the relationships better whilst still serving traffic demand. Risk factors refer to those factors that act individually or collectively to influence the occurrence of crashes (WHO, 2004). An understanding of the underlying

risk factors which contribute to crash occurrence is important for planning and policy regarding the road network and its operation, traffic control and management and other elements responsible for crashes. By learning how to predict future occurrence of crashes on road links we can be better enabled to plan for new infrastructure facilities to accommodate demand and regulate existing networks to minimize their occurrence.

A scientifically-based risk management method is needed for transportation decision making processes. Empirically based predictive models and risk factors will be very useful in road design and planning considerations. With today's methods especially in Ghana, roadway risk assessment becomes a concern only after construction when the consequences of unsafe design become vividly realized. The practice of road safety auditing and design reviews have not benefitted from empirical analysis of available data such as what this present study seeks to do. Several geometric design suites are applied and with appropriate local models, the consequences of geometric variables for safety can be evaluated and taken into account.

Risk factors and prediction models will aid in cost benefit analysis assessment of the introduction of safety measures and the benefits of ensuring development control along road corridors especially in built environment. Another important need for this research is in the economic appraisal of projects during cost-benefit analysis. It is envisioned that the results of this research will provide a simple, practical and easy to use model which can be considered for application in roadway risk analysis in decision making for maintenance and rehabilitation projects and the provision of safety budget and funds for road works.

1.4 Research objectives

The primary aim of this research was to develop crash prediction models after a comprehensive analysis of crash data for the period 2000-2009 to establish and identify the main risk factors associated with crashes and casualties on two lane urban roadways.

The specific objectives of the research were to:

- 1) Determine the characteristics and trends of crashes and traffic factors on two lane roadways from an analysis of historical data.
- 2) Determine the risk factors associated with the trends in traffic and crashes
- 3) Develop statistically valid models for the prediction of crashes on two-lane urban roads.

1.5 Scope of the study

Crash data and vehicle population data for the period 2000-2009 and other data were retrieved and analysed for trends and characteristics to establish any factors which affect the incidence of crashes in Ghana. The data for the development of prediction models were taken from Kumasi and therefore the models are location specific.

1.6 Dissertation outline

The contents of this dissertation report are as follows; Chapter one gives an overview of the research work by stating the problem being researched. A justification is given as to the relevance and benefit to be derived from the outcome of the research. Research objectives are clearly stated to guide the work and the scope of the entire research is well defined. Chapter two presents the state of the art of published and other research material

reviewed in order to situate the work in the context of the body of knowledge. The review also covers methodologies which have been applied previously in similar researches worldwide and summarizes by indicating what could be utilized and how the research would adopt or modify existing approaches reviewed. Chapter three describes the various methods and tools utilized in the study. The various data types and their content are described along with the means of determining parameters measured. The methodology gives an overview of the analytical procedures for risk factor assessment and the modelling techniques utilized to arrive at the results of the study. Chapter four presents the results of comprehensive analysis of data from MAAP5 for windows. The results form the basis of the risk factor determination and set the tone for determining the dominant factors and collision types to be considered in the modelling. Chapter five gives an introduction to the case study and present data on the network and data used for the modelling. It also summarizes the variables to be included in the eventual models. Chapter six shows the model forms and the criteria adopted for model variable selection and fit. Chapter seven presents the results of the models developed for the prediction of crashes on two lane urban roads. Chapter eight deals with model testing, Chapter nine concludes the study and makes recommendations for further research.

CHAPTER 2: LITERATURE REVIEW

2.1 Safety Effects of Highway Geometric Variables and Traffic

Greibe (2003) reported the results of two separate studies on crash modelling in which data from 1036 junctions and 142 km road links in urban areas in Denmark were used in generalised linear modelling to relate crash frequencies to explanatory variables. The estimated crash prediction models for road links were capable of describing more than 60% of the systematic variation while the models for junctions had lower values. He concluded that modelling crashes for road links is less complicated than for junctions, probably due to a more uniform crash pattern and a simpler traffic flow exposure or due to lack of adequate explanatory variables for junctions. Explanatory variables describing road design and road geometry proved to be significant for road link models but less important in junction models.

The first model tested contained only variables for motor vehicle traffic flow as follows:

$$E(\mu) = 2.44 \times 10^{-3} N^{0.75} \dots\dots\dots (2.1)$$

where $E(\mu)$ is the expected number of crashes (per km per year), and N the motor vehicle traffic flow measured as AADT. The model with other explanatory variables describing the total number of crashes (Injury and damage only crashes) had a 'percentage explained' value for the model above 69%.

In general, variables describing traffic flow, land use, number of minor crossings, parking facilities and speed limits ~~proved to be~~ the most important variables in the models.

A number of studies have attempted to quantify the effects of highway geometric design variables and traffic volume on crash rates or frequencies. For example, Jovanis and Chang (1986) estimated Poisson regression models using crash, travel mileage, and

environmental data. Their models revealed that crash occurrence increases with the vehicle miles of travel (VMT). Agent and Deen (1975) attempted to identify high-crash locations with respect to the functional type and geometry of the highway, using crash and volume data from rural highways in Kentucky collected from 1970 through 1972. They found that four-lane undivided highways had the highest crash, injury and fatality rates. Also, two-lane highways had the highest percentage of crashes that involved curvature. Milton and Mannering (1996) attempted to develop a model for arterial streets in Washington State. They found that narrow shoulder width, sharp horizontal curve, reduced lane width and high volume of traffic all had a potential effect on increasing crash frequency. They also found that the number of lanes is a highly significant factor in predicting crash frequency. More lanes tend to increase crash frequency. Knuiman et al. (1993) studied the effect of median width on crash rates using a Negative Binomial regression model. For a median without barrier, they found that the crash rate declines rapidly when median width exceeded about 7.6 m (25 ft). The decreasing trend seemed to level out at median widths of approximately 18.9–24.4 m (60–80 ft). Several studies have presented crash relationships for design elements of horizontal curves. In general, crash rate increases as a function of increasing degree of curvature, although the relationship is affected by other variables, including the lane and shoulder widths, roadside design, and the length of curve (McGee et al., 1995).

Zegeer, et al. (1987) found that crashes per mile decreased with an increase in average annual daily traffic (AADT) because higher volumes are associated with higher classes of roads, which normally have wider lanes and shoulders, and less and more gradual curvature than lower-volume facilities. They reported that, through lane widening,

runoff- the-road and opposite direction crashes can be decreased. They also claimed that the number of access points per kilometer is associated with crash rates.

Zeeger (1998), based on data for two-lane roads of 5,000 miles from seven (7) states in the US, developed a crash model with subordinate variable of crash rates by crash types and independent variables of the whole width of shoulder, the width of lane, road vertical alignment, average daily traffic volume. Hadi and Aruldas (1998) developed a crash model by road-grade for Florida state. The independent variables used were constant road length, AADT, the width of lane and shoulder, and the types and width of median barrier, existence of curve, speed limit, grade and the number of intersections. It was found that to widen the width of median barriers on four-lane roads enhanced safety while roads with two-way and left-turn median barriers were safer than non-separation roads.

Karlaftis and Golias (2002) in a review of a study of the relationship between crashes and geometric variables using a non-parametric methodology stated that, Negative Binomial (NB) regression has accounted for most of the theoretical issues in count data research. Nevertheless, there still remain a number of issues that have not been addressed (Hadi et al., 1993; Mohamedshah et al., 1993; Tarko et al., 1996; Karlaftis and Tarko, 1998). First, NB regression, much like multiple linear and Poisson regression, is a parametric procedure requiring the functional form of the model to be known in advance. Second, it is easily and significantly affected by outliers. Third, it cannot handle missing data well. Fourth, it does not treat satisfactorily discrete variables with more than two levels. Fifth, it does not deal well with multicollinear independent variables. Hierarchical Tree Based Regression (HTBR) is a tree-structured non-parametric data analysis methodology that was first used in the 1960s in the medical and the social sciences (Morgan and Sonquist,

1963). An extensive review of the methods used to estimate the regression trees and their applications can be found in Breiman et al. (1984). HTBR is technically binary, because parent nodes are always split into exactly two child nodes, and is recursive because the process can be repeated by treating each child node as a parent. In essence, the HTBR algorithm proceeds by iteratively asking the following two questions: (i) which of the independent variables available should be selected for the model to obtain the maximum reduction in the variability of the response (dependent variable) and (ii) which value of the selected independent variable (discrete or continuous) results in the maximum reduction in the variability of the response? These two steps are repeated using a numerical search procedure until a desirable end-condition is met.

Increasing the number of vehicles on a road can increase the chances of a crash disproportionately. Increase in the number of vehicles on a roadway increases the opportunity for conflict and vehicular interaction and therefore the chance of crash occurring. The motor vehicle traffic flow is the most important variable in the models. Beharnu (2004) reported that crash frequencies are related to the AADT raised to power of 0.8–1.0. However, for some crash types, e.g. rear-end and single vehicle crashes, the parameter value were 1.23 and 0.52, respectively. He further indicated that the results were corroborated by Summersgill and Layfield (1996) who also had similar deviations.

Even though the models developed failed the significance test at 5% significance, Beharnu (2004) plotted the trends of the predicted total, multiple-vehicle, and pedestrian crash risks on undivided and divided roads against the average daily traffic. On undivided

roads, all types of road crash risks decreased with an increase of ADT. The rate of the decrease of multiple-vehicle crash risks, however, is lower than the risks of pedestrians. On the contrary, the total and multiple-vehicle crash risks on divided roads increased with increase of the ADT. He concluded that higher ADT levels result in higher total crash rates, higher multiple-crash rates, and lower pedestrian crash rates on divided roads. Joshua and Garber (1990) used multiple linear and Poisson regression to estimate truck crash rates using traffic and geometric independent variables. Jones and Whitfield (1991) used Poisson regression with data from Seattle to identify the daily characteristics (traffic, weather, etc.) that may influence the number of traffic crashes. Miaou et al. (1992) used Poisson regression on traffic data from 8779 miles of roadway from the Highway Safety Information System (HSIS) to establish quantitative relationships between truck crash rates and highway geometric characteristics. Their results indicated that surrogate measures for mean absolute curvature (for horizontal alignment) and mean absolute grade (for vertical alignment) are the most important variables for crash rate estimation.

In a study of approximately seven thousand miles of roadway logs in Utah, Mohamedshah et al. (1993) used linear regression to predict truck crash involvement rate per mile per year, based on average Annual Daily Traffic (AADT) and truck AADT per lane, shoulder width, horizontal curvature, and vertical gradient. The results suggested that truck crash involvement rate increased with truck AADT, degree of curvature and gradient. Hadi et al. (1993), using data from the Florida Department of Transportation's Roadway Characteristics Inventory (RCI) system, estimated Negative Binomial (NB) regression for crash rates on various types of rural and urban highways with different

traffic levels. Their results suggested that higher AADT levels and the presence of intersections were associated with higher crash frequency, while wider lanes and shoulders were effective in reducing crash rates. In that paper, the authors also provided an extensive review of earlier findings relating crash rates and geometric characteristics. More recently, Ivan and O'Mara (1997), using NB regression on 1991–1993 data from the Traffic Crash Surveillance Report of Connecticut found that annual average daily traffic was a critical crash prediction variable, while geometric design variable and speed differential measures were not found to be effective predictors of crash rates. Karlaftis and Tarko (1998), based on a county crash data set from Indiana, estimated macroscopic crash models that attempted to explicitly control for cross-section heterogeneity in NB regression that may otherwise seriously bias the resulting estimates and invalidate statistical tests. Data collected from the States of Minnesota and Washington on rural two-lane highways, estimated crash models for segments and three-legged and four-legged intersections stop-controlled on the minor legs. Independent variables for their models included traffic, horizontal and vertical alignments, lane and shoulder widths, roadside hazard rating, channelization, and number of driveways. The results indicated that crashes on segments depended significantly on most of the roadway variables collected, while intersection crashes depended primarily on traffic.

Salifu (2003) developed models for total crashes and for different types of collisions for unsignalised Tee and Cross road urban junction in Ghana using Negative Binomial regression.

The modelling in some studies showed that road links with high speed limits tends to have lower crash risk. This does not mean that high speeds in general are safer; rather the

results for this variable illustrate the correlation problems within the data set. High speed roads tend to have few vulnerable road users and to be situated in sparsely built-up areas. One of the early studies on the effect of geometry on traffic crashes was Zeeger et al (1981) which concluded that lane and shoulder width had a marked effect on crashes. Since then several studies have confirmed this trend (Milton and Mannering, 1997).

Bared and Vogt (1997) have reported in separate studies that single vehicle crashes are associated with narrow shoulder whereas wide shoulders increase multiple vehicle collision

In Beharnu (2004), the length of road sections varied between 0.40 and 3.21 km. The study covered nearly 60% of the arterial roads of Addis Ababa. Each homogeneous road section formed a record with data on crashes, traffic and road. He indicated that where the traffic volumes on the sections were similar, the section length correlated with traffic volume and should not be used as exposure variable.

Road links with only one lane (no marked centre line) have more crashes involving motor vehicles going in the same direction than road links with two or more lanes (Greibe, 2003). Road links with a road width (from kerb to kerb) of 8–8.5m have the lowest crash risks for most crash types. A study by Kim Tae-wan (1996), reported that crash frequency reduced as the number of lanes increased.

According to Greibe (2003) road links with speed reducing measures have a higher risk of single vehicle crashes. Even though it is well-known that speed reducing measures usually improve safety, the explanatory variable describing the presence of speed

reducing measures in the models was not significant in most cases. It should be noted that only a few kilometres of road with speed reducing measures were represented in the data.

The relation between crash risk and the number of accesses (exits from private properties, parking places, etc.) seems to be an inverted 'U-shape'. Roads with no accesses and roads with a large number of accesses have the lowest crash risk, while roads with a medium number of accesses have the highest crash risk (Greibe, 2003).

Mountain et al. (1996) developed crash prediction models for road links with minor junctions and concluded that the presence of minor junctions had an important influence on link crash frequencies; account may be taken of these either by including the number of minor junctions per kilometre as an explanatory variable.

Road links with parked motor vehicles along the roadside (at kerb) or in marked parking bays have the highest crash risk, particularly for crashes involving pedestrians, crashes involving motor vehicles from access roads or minor side roads, and for crashes involving parked vehicles. Other studies (Elvik et al., 1997) also find that marked on street parking bays increases risk.

The road environment (type and function of buildings along the road) has a considerable influence on the crash risk. Shopping streets and city centre roads have significantly higher crash risk than, for example, residential roads in less densely built-up areas. In general, the lower the building density, the lower the crash risks. Since exposure data for vulnerable road users were not included in the models, it must be presumed that the

variable 'land use' to some extent also represents the level of pedestrian and cyclist activity.

2.2 Multicollinearity and size of Variable Samples in the Data

One of the major problems in modelling crashes is strong internal correlation within the data: this has been reported severally by many researchers (Greibe, 2003), Washington 2010). Variables describing traffic flow tend to correlate strongly with other variables like road width, number of lanes, the presence of a central island, speed limit, etc. Hence, the safety effects from a single explanatory variable may be difficult to estimate since it may be affected by other variables in the model. Another well-known problem in safety analysis is the relatively small number of observed crashes in the data, which may cause problems in the statistical studies. In the study on junctions for example, less than 50% of the three-armed non-signalised junctions had any police reported crashes, which limited modelling possibilities. Efforts were made to estimate crashes involving cyclists or moped riders, but since less than 10% of these crashes are reported by the police, the reliability of the data is limited, which complicates the modelling (Greibe, 2003).

Greibe (2003) has reported that the safety effect from factors like road geometry and road environment can be estimated in various ways. The most reliable way is by use of controlled 'before-after' studies. However, 'before-after' studies require a large number of sites and long study periods. An alternative is to make multidimensional cross-tabulation of crash rates by different safety factors, a so-called 'with-or-without' study, e.g. crash rates for junctions with or without signal control. However, it is only possible

to cross-tabulate for a limited number of variables/factors and these variables cannot be continuous. Furthermore, comparing crash rates at different sites can be complicated since differences in geometry, etc. can rarely be explained by a few variables.

The use of models has some advantages over the above mentioned study methods. Models relate the number of crashes to selected factors that can be explained by either continuous or class variables. In addition, in the models, the crash number is assumed to follow a certain statistical distribution, e.g. the Poisson or Negative Binomial distribution. However, the safety effects from various factors found in one study were not always absolutely comparable to the safety effects found in other studies, e.g. traditional 'before-after' studies. The reason for this could be the internal correlation problems within the data sets as mentioned earlier. Greibe (2003) recommended interpreting the safety effect of a single variable with caution. Nevertheless, the accuracy of safety effects found by modelling must be considered better than that of 'with-or-without' studies, but worse than that of 'before-after' studies.

2.3 Variable Selection Criteria in Developing Predictive Models

Maher and Summersgill (1996) in examining the methodology for developing comprehensive crash prediction models indicated that regression analysis is a powerful tool for identifying the variables that affect crashes, but it should not be used blindly. Engineering judgment is always an essential part of the model building process.

Also, the total variation in the crash count consists of a random part (presumed Poisson distributed) and a systematic part. The model's 'goodness-of-fit' is measured by how

much of the systematic variation the model could explain and is referred to as “percentage explained”. The method was proposed by Kulmala (1995) as being suitable for Poisson models. The percentage explained is estimated on the basis of the scaled deviance of the studied model, the zero model (a model with only one constant parameter) and the expected scaled deviance of a model describing the total systematic variation. Some problems arise in using this method when the average number of crashes is low (<0.5). In general, the results (as described below) showed ‘percentage explained’ values for the models in the area of 30–80%. The best models were produced for road links.

A number of researchers (e.g., Pasupathy et al, 2000; Beharnu, 2004) have indicated that in order to decide which set of independent variables should be included in crash predictive models, correlations between explanatory variables were studied to avoid the multicollinearity problem, and the Akaike’s information criterion (AIC) was used. AIC is an approximation of the real model by a lower dimensional model so as to minimize the average estimated error and is defined as: $AIC = -2ML + 2K$, where ML is the maximum log-likelihood, and K the number of unknown parameters. Starting with the full set of independent variables and following a stepwise procedure, the insignificant variables were cancelled and models with smaller AIC values were selected. Inclusion of individual variable in the relationships was made after checking that its estimated coefficient carried the expected sign and by examining whether the coefficient is significantly different from zero. Estimated coefficients of the “wrong” sign were examined carefully to see whether the finding was robust.

The significance of coefficients was checked using the method analogical to the t-test used in the conventional regression analyses referred to as Wald statistic (Agresti, 1996). The goodness of fit of the proposed models was then assessed using the Pearson's χ^2 -statistic at the 0.05 significant levels. The coefficient of determination, Pearson's R^2 , was also calculated to indicate how much of the variation of crashes is explained by the derived regression models. Beharnu (2004) developed crash models for total number of crashes, multiple vehicle and pedestrian crashes. Various road and traffic explanatory variables were considered in the analyses to test the significance of their effects on the occurrence of crashes. The variables investigated include vehicle-kilometres, lane width, number of lanes, median width, U-turn median openings, width and surfacing of sidewalk, presence of kerb, grade, road curviness, pedestrian traffic, parking, number of minor junctions, traffic density, and 85th percentile speed. Variables measured on a continuous scale were entered into the model as a linear term. All categorical variables which group the data into mutually exclusive subsets were treated as dummy variables by defining a two-level factor, which has a value of zero for links without the feature and a value of one for those which have the feature in order to suit the analyses using LIMDEP software.

All the derived QP and NB models failed to pass the χ^2 goodness of fit test at the 0.05 significant levels. Variables on a continuous scale were entered into the model as a linear term. All categorical variables which group the data into mutually exclusive subsets were treated as dummy variables by defining a two-level factor, which has a value of zero for links without the feature and a value of one for those which have the feature links without

the feature and a value of one for those which have the feature in order to suit the analyses using LIMDEP software.

2.4 Data and methodological issues

Important data and methodological issues have been identified in the crash-frequency literature over the years. These issues have been shown to be a potential source of error in specifying statistical models and inferences relating to the factors that determine the frequency of crashes. Some of the issues are discussed in the sections below.

2.4.1 Over-dispersion and Under-dispersion

One notable characteristic of crash-frequency data is that the variance exceeds the mean of the crash counts. This is problematic because the properties of the most common count-data modelling approach (the Poisson regression model) restrict the mean and variance to be equal. When the data are over-dispersed, estimating a common Poisson model can result in biased and inconsistent parameter estimates which in turn could lead to erroneous inferences regarding the factors that determine crash-frequencies (Maycock and Hall, 1984; Miaou, 1994; Maher and Summersgill, 1996; Cameron and Trivedi, 1998; Park and Lord, 2007).

Although rare, crash data can sometimes be characterized by under-dispersion. This occurs where the mean of the crash counts on roadway entities is greater than the variance, especially when the sample-mean value is very low. Previous work has shown that many traditional count-data models produce incorrect parameter estimates in the presence of under-dispersed data (Oh et al., 2006).

Maier and Summersgill (1996) undertook a comprehensive modelling of a number of intersections in the United Kingdom in which they tried a variety of explanatory variables consistent with engineering judgement. For each crash type, the most important term in the model was the relevant flow or flows (for example, particular turning flows at the junction), followed by explanatory variables which measured relevant physical characteristics of the site (such as entry width or entry path curvature) and control variables (such as which movements receive green together at traffic signals).

Nevertheless, despite such painstaking efforts, it was virtually inevitable that the final models should be, in the technical sense, “inadequate”. That is to say, the explanatory variables do not provide a complete explanation of the between-site variation, so that the residual variation is more than would be expected on the basis of the pure Poisson model.

There are several possible reasons for this:

- a) There are other, unobserved, explanatory variables at work which effectively add to the random error, or “noise”.
- b) There are errors in some of the explanatory variables, most particularly the flows. The flow estimates, taken to be representative of the flow across the whole of the observation period, are often merely “snapshots”, taken on one occasion.
- c) The model may be mis-specified. Miaou (1994) has similarly commented on the occurrence of, and reasons for, overdispersion.

However, there are certain technical problems which need to be addressed in order to ensure that the application of GLMs will produce robust and reliable results. Some of the

problems are; the low mean value problem, overdispersion, the disaggregation of data over time, allowing for the presence of a trend over time in crash risk, random errors in the flow estimates, aggregation of predictions for different crash types by allowing for the correlation between the prediction errors, and the combination of model predictions with site observations.

2.4.2 Time-varying explanatory variables

Because crash-frequency data are considered over some time period, the fact that explanatory variables may change significantly over this time period is not usually considered due to the lack of detailed data within the time period. Ignoring the potential within-period variation in explanatory variables may result in the loss of potentially important explanatory information. For example, suppose we are modeling the number of crashes per month and precipitation is one of the explanatory variables. The distribution of precipitation over the month (by hour or even minute) is likely to be highly influential in generating crashes, but generally the analyst only has precipitation data that is much more aggregated and thus important information is lost by using discrete time intervals with larger intervals resulting in more information loss. This can introduce error in model estimation as a result of unobserved heterogeneity (Washington et al., 2010).

2.4.3 Temporal and spatial correlation

To avoid the information lost in time-varying explanatory variables, data are often considered in small time intervals. For example, one may have a year's worth of crash data and divide these data into 12 monthly observations and consider the number of crashes per month. However, this now means that the same roadway entity (roadway segment, intersection) will generate multiple observations, and these observations will be

correlated over time because many of the unobserved effects associated with a specific roadway entity will remain the same over time. From a statistical perspective, this sets up a correlation in the disturbances used for model estimation, which is known to adversely affect the precision of parameter estimates. In a similar vein, there can be correlation over space, because roadway entities that are in close proximity may share unobserved effects. This again sets up a correlation of disturbances among observations and results in the associated parameter-estimation problems (Mountain et al., 1998; Lord and Persaud, 2000; Washington et al., 2003, 2010).

2.4.4 Low sample-mean and small sample size

Because of the large costs associated with the data collection process, crash data are often characterized by a small number of observations. In addition, crash data for some roadway entities may have few observed crashes which results in a preponderance of zeros. Data characterized by small sample size and low sample-mean can cause estimation problems in traditional count-frequency models. For example, with small sample sizes, the desirable large-sample properties of some parameter-estimation techniques (for example, maximum likelihood estimation) are not realized. With low sample-means (and a preponderance of zeros), the distribution of crash counts will be skewed excessively toward zero which can result in incorrectly estimated parameters and erroneous inferences.

Crash data have been shown to exhibit over-dispersion, meaning that the variance is greater than the mean. The over dispersion can be caused by various factors, such as data clustering, unaccounted temporal correlation, model misspecification, but it has been shown to be mainly attributed to the actual nature of the crash process, namely the fact

that crash data are the product of Bernoulli trials with unequal probability of events (this is also known as Poisson trials). Lord et al. (2005b) have reported that as the number of trials increases and becomes very large, the distribution may be approximated by a Poisson process, where the magnitude of the over-dispersion is dependent on the characteristics of the Poisson trials. According to Miaou and Song (2005), the over-dispersion can be minimized by using appropriate mean structures of statistical models. Although different Poisson-based distributions have been developed to accommodate the over-dispersion (e.g., Poisson lognormal, etc.), the most common distribution used for modelling crash data remains the Poisson-gamma or Negative Binomial (NB) distribution. The Poisson-gamma distribution offers a simple way to accommodate the over-dispersion, especially since the final equation has a closed form and the mathematics to manipulate the relationship between the mean and the variance structures is relatively simple (Hauer, 1997). Recent research in highway safety has shown that the variance structure can potentially be dependent on the covariates (Heydecker and Wu, 2001; Miaou and Lord, 2003; Lord et al., 2005a). As opposed to data collected in other fields of research, crash data have the uncommon attribute to frequently exhibit a distribution with a low sample mean. Similarly, it is not unusual for researchers and practitioners to develop statistical models using a limited number of observations (or sites) where data can be collected (see e.g., Lord, 2000; Oh et al., 2003; Kumala et al., 2003). Small sample sizes are attributed to the prohibitive costs of collecting crash data and other relevant variables (Lord and Bonneson, 2005). Data characterized by a low sample mean has been sporadically studied in the traffic safety literature. As such, Maycock and Hall (1984) first raised the issue related to the low sample mean. Fridstrøm

et al. (1995) further discussed this issue, while Maher and Summersgill (1996) showed how the goodness-of-fit of statistical models could be affected by a low sample mean. They defined this issue as the “low mean problem” (LMP). Subsequent to the identification and its effects on the development of statistical models, Wood (2002) proposed a method to test the fit of statistical models developed using data characterized with low sample mean values. Despite the important work done on this topic, nobody has so far examined how the LMP affects the dispersion parameter of a Poisson-gamma model. In the traffic safety literature, the dispersion parameter is often relegated to a second-tier term and assumed to be estimated without any uncertainty (i.e., many studies did or still do not provide any uncertainties associated with the estimated dispersion parameter or its inverse).

2.4.5 Under-reporting

Because less severe crashes are less likely to appear in crash databases, there is a potentially serious problem relating to under-reporting of crashes. Although the magnitude of the under-reporting rate for each severity level is usually unknown, recent research has shown that count-data models are likely to produce biased estimates when under-reporting is not considered in the model-estimation process (Kumara and Chin, 2005; Ma, 2009).

2.4.6 Omitted-variables bias

It is often tempting to develop a simplified model with few explanatory variables (for example, using traffic flow as the only explanatory variable in the model). However, as with all traditional statistical estimation methods, leaving out important explanatory variables results in biased parameter estimates that can produce erroneous inferences and

crash-frequency forecasts (Washington et al., 2003, 2010). This would especially be the case if the omitted variable is correlated with variables included in the specification, which is often the case.

2.4.7 Endogenous variables

There are times when the explanatory variables in models can be endogenous, in that their values may depend on the frequency of crashes. An example of this problem is the frequency of ice-related crashes and the effectiveness of ice-warning sign in a crash-frequency model. An indicator variable for the presence an ice-warning sign would be one way of understanding the impact of the warning signs. If this endogeneity is ignored, the parameter estimates will be biased. However, ice-warning signs are more likely to be placed at locations with high numbers of ice-related crashes, and are therefore endogenous (the explanatory variable will change as the dependent variable changes). The case of the ice-warning sign indicator, ignoring the endogeneity may lead to the erroneous conclusion that ice-warning signs actually increase the frequency of ice-related crashes because the signs are going to be associated with locations of high ice-crash frequencies. Kim and Washington (2006) studied a similar problem when studying the effectiveness of left-turn lanes at intersections. This is again endogenous because left-turn lanes are more likely to be placed at intersections with a high number of left-turn related crashes. Accounting for endogenous variables in traditional least-squares regression models is relatively straight forward (Washington et al. 2003, 2010). However, for count-data models, the modelling processes typically applied do not lend themselves to traditional endogenous-variable correction techniques. As a consequence, accounting for

endogenous variables adds considerable complexity to the count-data modelling process (see Kim and Washington, 2006).

2.4.8 Functional form and structure of models

The functional form of a model establishes the relationship between the dependent variable and the explanatory variables and is a critical part of the modelling process. Most count-data models assume that explanatory variables influence the dependent variables in some linear manner. However, there is a body of work that suggests that non-linear functions better characterize the relationships between crash-frequencies and explanatory variables. These non-linear functions can often be quite complex and may require involved estimation procedures (Miaou and Lord, 2003; Bonneson and Pratt, 2008).

Relationships in earlier research works have typically been studied using the conventional multiple linear regression technique. Basically, this method assumes that the dependent variable is continuous and normally distributed with a constant variance. However, the conventional multiple linear regression technique lacks the distributional property necessary to describe adequately random, discrete, and non-negative events such as traffic crashes. As proved by Miaou et al. (1992), Miaou and Lum (1993), and many others, the test statistics derived from these models are, therefore, questionable.

In recent studies (Hadi et al., 1995; Maher and Summersgill, 1996; Amis, 1996), a significant advance has been made to describe the discrete count traffic crash data and produce more accurate and reliable models by the use of generalized linear models with a Poisson and Negative Binomial (NB) error structure.

The models relate the number of observed crashes to traffic flow and road design parameters. Generalised linear modelling techniques were used to fit the model, and the distributions of crash counts were assumed to follow a Poisson distribution. The regression analyses were performed by use of the GENMOD procedure in SAS. Whether it is reasonable to assume that crash counts are Poisson distributed is a recurrent issue.

The main advantage of the Poisson distribution is its simplicity, e.g. the variance is equal to its mean. However, difficulty arises concerning the phenomenon of “overdispersion” when the observed variance is actually greater than the mean. Overdispersion does not affect the coefficient estimates but does cause their standard errors to be underestimated (Miaou et al., 1992). Recent studies have proved that the Negative Binomial distribution might be more appropriate because it allows greater variance in the data and thereby deals with the over dispersion.

Different ways to relate crash frequencies to traffic flows have been investigated in a number of previous studies, e.g. Hauer et al. (1988), Brüde and Larson (1993), Maher and Summersgill (1996). For road links the general opinion is that crash frequencies can be described by a flow function raised to a power. Often the flow function consists simply of the motor vehicle traffic flow along the link (AADT), but some studies (e.g. Summersgill et al., 1996) also include flows for pedestrians along or across the link.

Recent studies (Mountain et al., 1998) include variables that allow for changes in risk over time in order to take any possible trend into consideration. This would ensure that the models do not become rapidly outdated. They found a 6% annual decrease in risk per year for junctions. However, to estimate annual changes in risk, large time series data are required.

2.4.9 Fixed parameters

Traditional statistical modelling does not allow parameter estimates to vary across observations. This implies that the effect of the explanatory variable on the frequency of crashes is constrained to be the same for all observations (for example, the effect of an exposure variable such as the number of vehicle miles travelled over the time period being considered is the same across all roadway segments). However, because of unobserved variations from one roadway segment to the next (unobserved heterogeneity), one might expect the estimated parameters of some explanatory variables to differ across roadway segments. If some parameters do vary across observations and the model is estimated as if they were fixed, the resulting parameter estimates will be biased and possible erroneous inferences could be drawn. Estimation techniques do exist for allowing parameters to vary across observations, but the model-estimation process becomes considerably more complex (Anastasopoulos and Mannering, 2009; El-Basyouny and Sayed, 2009b; Washington et al., 2010).

2.5 Modelling methods

To deal with the data and methodological issues associated with crash-frequency data (many of which could compromise the statistical validity of an analysis if not properly

addressed), a wide variety of methods have been applied over the years. The following sections provide a discussion of methods previously applied to crash-frequency analysis along with their strengths and weaknesses.

2.5.1 Poisson regression model

Because crash-frequency data are non-negative integers, the application of standard ordinary least-squares regression (which assumes a continuous dependent variable) is not appropriate. Given that the dependent variable is a non-negative integer, most of the recent thinking in the field has used the Poisson regression model as a starting point. Over the last decade some researchers Jovanis and Chang (1986), Miaou and Lum (1993), and Miaou (1994) have used Poisson regression model for intersections and links. For typical motor vehicle crashes where the event has a very low probability of occurrence and a large number of trials exists, the binomial distribution is approximated by a Poisson distribution. Under the Binomial distribution with parameters N and p , let $p = \lambda / N$, so that a large sample size N will be offset by the diminution of p to produce a constant mean number of events λ for all values of p . Then as $N \rightarrow \infty$

$$P(Y = n) = \binom{N}{n} \left(\frac{\lambda}{N} \right)^n \left(1 - \frac{\lambda}{N} \right)^{N-n} \cong \frac{\lambda^n}{n!} e^{-\lambda} \quad \dots \quad \dots \quad \dots \quad (2.2)$$

where, $n = 0, 1, 2, \dots, N$ and λ is the mean of a Poisson distribution (Lord et al., 2004).

The mean or expected value of the Poisson distribution Y is assumed to be equal to its variance. That is,

$$E(Y_i) = Var(Y_i) = \lambda \quad \dots \quad \dots \quad \dots \quad (2.3)$$

where, $E(Y_i)$ is the expected number of crashes on section i and $Var(Y_i)$ is the variance of observed number of crashes. For a given set of explanatory variables (highway geometrics, speed, traffic and other data), λ can be estimated using the formulation,

$$\ln(\lambda) = \beta X_i \quad \dots \quad \dots \quad \dots \quad (2.4)$$

where, X is a vector of explanatory variables and β is a vector of parameters to be estimated.

Although the Poisson model has served as a starting point for crash-frequency analysis for several decades, researchers have often found that crash data exhibit characteristics that make the application of the simple Poisson regression (as well as some extensions of the Poisson model) problematic. Specifically, Poisson models cannot handle over- and under-dispersion and they can be adversely affected by low sample-means and can produce biased results in small samples.

2.5.2 Negative Binomial (Poisson-gamma) regression model

The Negative Binomial (or Poisson-gamma) model is an extension of the Poisson model to overcome possible over-dispersion in the data. The Negative Binomial/Poisson-gamma model assumes that the Poisson parameter follows a gamma probability distribution. The model results in a closed-form equation and the mathematics to manipulate the relationship between the mean and the variance structures is relatively simple. The Negative Binomial model is derived by rewriting the Poisson parameter for each

observation i as $k_i = \text{EXP}(bX_i + e_i)$ where $\text{EXP}(e_i)$ is a gamma-distributed error term with mean 1 and variance a . The addition of this term allows the variance to differ from the mean as $\text{VAR}[y_i] = E[y_i][1 + aE[y_i]] = E[y_i] + aE[y_i]^2$. The Poisson regression model is a limiting model of the Negative Binomial regression model as “ a ” approaches zero, which means that the selection between these two models is dependent upon the value of “ a ”. The parameter “ a ” is often referred to as the over-dispersion parameter. Other variance functions exist for Negative Binomial/Poisson-gamma models, but they are seldom used in highway safety studies (Maher and Summersgill, 1996). Usually the over-dispersion parameter or its inverse is assumed to be fixed, but recent research in highway safety has shown that the variance structure can potentially be dependent on explanatory variables (Hauer, 2001; Miaou and Lord, 2003; Lord et al., 2005a).

The Poisson-gamma/Negative Binomial model is probably the most frequently used model in crash-frequency modelling. However, the model does have its limitations, most notably its inability to handle under-dispersed data, and dispersion- parameter-estimation problems when the data are characterized by the low sample-mean values and small sample sizes (Lord, 2006).

2.5.3 Poisson-lognormal model

Recently, some researchers have proposed using the Poisson-lognormal model as an alternative to the Negative Binomial/Poisson-gamma model for modeling crash data (Miaou et al., 2003; Lord and Miranda-Moreno, 2008; Aguero-Valverde and Jovanis, 2008). The Poisson-lognormal model is similar to the Negative Binomial/Poisson-gamma model, but the $\text{EXP}(e_i)$ term used to compute the Poisson parameter is lognormal-rather than gamma-distributed. Although the Poisson-lognormal potentially offers more

flexibility than the Negative Binomial/Poisson-gamma, it does have its limitations. For example, model estimation is more complex because the Poisson-lognormal distribution does not have a closed form and the Poisson-lognormal can still be adversely affected by small sample sizes and low sample-mean values (Miaou et al., 2003)

2.5.4 Zero-inflated Poisson and Negative Binomial

Zero-inflated models have been developed to handle data characterized by a significant amount of zeros or more zeros than one would expect in a traditional Poisson or Negative Binomial/Poisson-gamma model. Zero-inflated models operate on the principle that the excess zero density that cannot be accommodated by a traditional count structure is accounted for by a splitting regime that models a crash-free versus a crash-prone propensity of a roadway segment. The probability of a roadway entity being in zero or non-zero states can be determined by a binary logit or probit model (see Lambert, 1992; Washington et al., 2003, 2010). Since its inception, the zero-inflated model (both for the Poisson and Negative Binomial models) has been popular among transportation safety analysts (Shankar et al., 1997; Carson and Mannering, 2001; Lee and Mannering, 2002; Kumara and Chin, 2003; Shankar et al., 2003). Despite its broad applicability to a variety of situations where the observed data are characterized by large zero densities, others have criticized the application of this model in highway safety. For instance, Lord et al. (2005, 2007) argued that, because the zero or safe state has a long-term mean equal to zero, this model cannot properly reflect the crash-data generating process

2.5.5 Gamma model

The gamma model has been proposed by Oh et al. (2006) to analyze crash data exhibiting under-dispersion (see also Cameron and Trivedi, 1998). The model can handle over-

dispersion and under-dispersion and reduces to the Poisson model when the variance is roughly equal to the mean of the number of crashes. Although this model performs well statistically, it is still a dual-state model, with one of the states having a long-term mean equal to zero. The gamma model has seen limited use since it was first introduced by Oh et al. (2006).

2.5.6 Random-effects models

According to Washington (2010) there may be reason to expect correlation among observations in a model. This correlation could arise from spatial considerations (data from the same geographic region may share unobserved effects), temporal considerations (such as in panel data – where data collected from the same observational unit over successive time periods could share unobserved effects), or a combination of the two. To account for such correlation, random-effects models (where the common unobserved effects are assumed to be distributed over the spatial/temporal units according to some distribution and shared unobserved effects are assumed to be uncorrelated with explanatory variables) and fixed-effects models (where common unobserved effects are accounted for by indicator variables and shared unobserved effects are assumed to be correlated with independent variables) can be considered. In the context of count models, Hausman et al. (1984) first examined random-effects and fixed-effects Negative Binomial models for panel data (which has temporal considerations) in their study of research and development patents. Random-effects in the context of crash-frequencies have been studied by a number of researchers including Johansson (1996), who studied the effect of a lowered speed limit on the number of crashes on roadways in Sweden, Shankar et al. (1998) (who compared standard Negative Binomial and random effects

Negative Binomial models in a study of crashes caused by median crossovers in Washington State), Miaou et al. (2003) (who used random effects in the development of crash-risk maps in Texas), and others.

2.6 Crash frequency Modeling: Methodological Advances

Crash frequency data have been analyzed using a number of statistical methodologies. Initially multiple linear regression was used for model formulation. However, as pointed out by Joshua and Garber (1990), linear regression models do not describe the nature of the crash frequency data adequately. Poisson or Negative Binomial (NB) regression models, instead, are better suited for defining the random, discrete, and nonnegative nature of crash occurrence (Milton & Mannering, 1998). The log-linear model is the best known example of Poisson regression. It essentially is a generalized linear model (GLM) for Poisson-distributed data and specifies how the size of a cell frequency depends on the levels of categorical variables for that cell. The nature of this specification relates to the association and interaction structure among the categorical variables (Agresti, 2002). It should be noted that the Poisson model formulation requires the mean and variance of the crash data to be equal. Therefore, the NB model, which has all the desirable statistical properties and also relaxes this constraint, is the most popular model formulation for crash frequency estimation. A detailed comparison between Poisson and Negative Binomial crash frequency models may be found in Miaou (1994). The findings suggested that since crash data tend to be overdispersed (i.e., variance > mean), Negative Binomial modelling is the more appropriate technique of the two. The findings from studies mentioned so far were based on the ability of the model formulation (such as Poisson or

NB regression) to capture the underlying distribution of the crash frequency data. Recently some researchers have proposed 'distribution free' methodologies for the analysis of crash data. These methodologies include decision trees and artificial intelligence techniques such as the neural networks. No inherent assumptions about the distribution of the crash frequency data are needed to apply these techniques, which are essentially driven by observed data. For example, Abdel-Aty and Keller (2005) adopted Classification and Regression Tree (CART), the most commonly applied data mining technique, for crash frequency estimation. Since these data-driven techniques do not require any pre-defined underlying relationship between target (dependent) variable and predictors (independent variables), they are powerful data analysis tools. Based on this detailed review of the literature it may be concluded that while the researchers have employed a wide array of tools to model crash frequency/rate, more recent studies have explored the potential of 'data-driven' techniques.

2.7 Methods of Comparing Model Quality and Model Selection

2.7.1 Coefficient of Determination (R^2)

To measure the overall goodness-of-fit in linear regression models, the coefficient of determination, R-squared is often used. The R-squared value indicates the amount of variability in the response variable explained by the variation in the selected set of explanatory variables. Different R-squared measures may yield substantially different answers, or even answers larger than 1, particularly for models that are not linear (Vogt and Bared, 1998; Fridstrøm *et al.*, 1995; Kvalseth, 1985). In the estimation of model parameters in both the Poisson and Negative Binomial models, the Maximum Likelihood

estimation method is usually used. To the extent that we want to use R-squared statistics as a basis for testing goodness-of-fit, the way the model parameters are estimated becomes relevant, since R-squared is maximized by ordinary least squares estimation but not by maximum likelihood. Fridstrøm *et al.* (1995) developed several alternative goodness-of-fit methodologies for generalized Poisson regression models. Miaou (1996) also investigated different approaches to calculate R-squared values for different regression techniques using different distribution assumptions including Poisson and Negative Binomial. The R-squared estimation based on dispersion parameter for Negative Binomial models has the following form,

$$R_{\kappa}^2 = 1 - \frac{\kappa}{\kappa_{\max}} \quad \dots \quad \dots \quad \dots \quad (2.5)$$

where κ and $\kappa_{\max}$ are the overdispersion parameters estimated using the model under consideration and the model with no covariates (only intercept) respectively. Based on simulations, Miaou (1996) concluded that this measure shows promise. It is simple to calculate, it yields a value between 0 and 1, it is independent of the choice of intercept term in the model and it has the proportionate increase property. Miaou (1996) proposes as a criterion that independent variables of equal importance, when added to a model, increase the value of the measure by the same absolute amount regardless of the order in which they are added.

2.7.2 Akaike Information Criterion

When conducting statistical analyses, we often strive to estimate the effect (magnitude) of a given variable on a response variable and its precision. In certain instances, our objective is to go beyond and assess whether the effect is sufficiently important to include the parameter in the model in order to make predictions, an issue of model selection. This is often the case in observational studies, where a number of variables are believed to explain a given ecological process or pattern. Whereas classical techniques such as tests of null hypotheses are well-suited for manipulative experiments, their widespread use and abuse to tackle issues such as parameter estimation and model selection only reflects the slow migration of superior techniques from the distant world of statistics into ecological disciplines. Indeed, hypothesis testing is problematic as it indirectly addresses these issues (i.e., the effect is or is not significant), and it does not perform particularly well in model selection (e.g., variables selected by forward, backward, or stepwise approaches). Though this is debated by some (Robinson and Wainer 2002), better approaches do exist (Anderson et al. 2000, 2001, Guthery et al. 2001, Johnson 1999, 2002).

One such approach, developed in the early 1970's, rests on Akaike's information criterion (AIC) and its associated measures. This framework is also known as the information-theoretic approach, as it has arisen from information theory, a field encompassing a number of methods and theories pivotal to many of the sciences. Because information theory *per se* goes beyond the scope of the present paper, the reader should consult Kullback and Leibler (1951), Cover and Thomas (1991), and Burnham and Anderson (2002) for further discussions on the issue. In ecology, the AIC and its related measures were first applied almost exclusively in the context of model selection in

capture-recapture analyses (Lebreton et al. 1992, Anderson et al. 1994), but have gained popularity since the last decade in more general situations (Johnson and Omland 2004).

Burnham and Anderson (2001) have pointed out that , three principles regulate our ability to make inferences in the sciences: 1) simplicity and parsimony, 2) several working hypotheses, and 3) strength of evidence. Simplicity and parsimony is a concept based on Occam's razor, which suggests that the simplest explanation is probably the most likely. This is a quality often strived for in science. Parsimony is particularly evident in issues of model building, where the investigator must make a compromise between model bias and variance. Here, bias corresponds to the difference between the estimated value and true unknown value of a parameter, whereas variance reflects the precision of these estimates; a common measure of precision is the SE of the estimate. Thus, a model with too many variables will have low precision whereas a model with too few variables will be biased (Burnham and Anderson 2002).

Two measures associated with the AIC can be used to compare models: the delta AIC and Akaike weights. These are easy to compute, as calculations remain the same regardless of whether the AIC or AIC_c is used, and also have the advantage of being easy to interpret. The simplest, the delta AIC (Δ_i), is a measure of each model relative to the best model, and is calculated as

$$\text{Delta AIC} = \Delta_i = AIC_i - \min AIC \quad \dots \quad (2.6)$$

where AIC_i is the AIC value for model i , and $\min AIC$ is the AIC value of the « best » model. As a rule of thumb, a $\Delta_i < 2$ suggests substantial evidence for the model, values

between 3 and 7 indicate that the model has considerably less support, whereas a $\Delta_i > 10$ indicates that the model is very unlikely (Burnham and Anderson 2002).

Akaike weights (w_i) provide another measure of the strength of evidence for each model, and represent the ratio of delta AIC (Δ_i) values for each model relative to the whole set of R candidate models:

$$w_i = \frac{\exp(-\Delta_i / 2)}{\sum_{i=1}^R \exp(-\Delta_i / 2)} \quad \dots \quad \dots \quad \dots \quad (2.7)$$

In effect, we are simply changing the scale of the Δ_i 's to compare them on a scale of 1 (i.e., so that the sum of the w_i equals 1). The interpretation of Akaike weights (w_i) is straightforward: they indicate the probability that the model is the best among the whole set of candidate models. For instance, an Akaike weight of 0.75 for a model, indicates that given the data, it has a 75% chance of being the best one among those considered in the set of candidate models. In addition, one can compare the Akaike weights of the « best » model and competing models to determine to what extent it is better than another. These are termed evidence ratios and are calculated as

$$\text{Evidence ratio} = \frac{w_i}{w_j} \dots \dots \dots . \quad (2.8)$$

where model j is compared against model i .

2.8 Summary and conclusions

This brief review of some of the existing literature suggests that a variety of traffic and design elements such as AADT, cross-section design, horizontal alignment, roadside features, access control, pavement conditions, speed limit, lane width (LW), and median width, affect crash rates. Most of these results have been based on multiple linear or Poisson and NB regression models. Much of the early work in the empirical analysis of crash data was done with the use of multiple linear regression models. As the literature has repeatedly pointed out, these models suffer from several methodological limitations and practical inconsistencies in the case of crash modelling (Lerman and Gonzales, 1980). To overcome these limitations, several authors used Poisson regression models that are a reasonable alternative for events that occur randomly and independently over time. Despite its advantages, Poisson regression assumes equality of the variance and mean of the dependent variable. This restriction (which, when violated, leads to invalid t-tests of the parameter estimates), can be overcome with the use of NB regression which allows the variance of the dependent variable to be larger than the mean. As a result, most of the recent literature has used NB regression models to evaluate crash data. But, while NB regression has been instrumental in overcoming most of the problems associated with models involving count data, it still remains a parametric procedure requiring the functional form of the model to be specified in advance, it is not invariant with respect to monotone transformation of the variables, it is easily and significantly influenced by outliers, it does not handle well discrete independent variables

with more than two levels, and it is adversely affected by multicollinearity among independent variables (Hadi et al., 1993; Mohamedshah et al., 1993; Tarko et al., 1996; Karlaftis and Tarko, 1998). It is likely, for example, that while the crash models have been correctly specified, multicollinearity has inflated the variance of some of the independent variables coefficient estimates, leading to lower t-statistic values and to coefficients that are not significant and/or are counter-intuitive.

In this work the Negative Binomial approximation to the poisson will be employed for the modelling. The Akaike information criterion shall be used to determine the best final models after variables have been included and accepted at 5% significance level.

CHAPTER 3: METHODOLOGY FOR DATA COLLECTION

3.1 Introduction

The study aimed to build on the existing knowledge on crash models and methods of analyzing crash data to establish risk factors to encourage the use of the outcome and also to promote safety assessment in road projects during the planning and design stage. From the literature survey, the data collection and analysis methods determined to be appropriate for the study are elaborated below.

3.2 Data collection

3.2.1 Categories of Data collected

Variables which have been reported to have some effect on crashes on link sections of roads were identified. Review of literature and engineering judgment based on available information and exploratory analysis were used to eliminate some of the variable. The data collected for all study road sections for the study included:

- Road inventory, environment and condition data
- Road traffic crash data
- Traffic flow data
- Vehicle registration data

3.2.2 Selection of urban road link sections

The main task involved an assessment of the road network and selection of a list of road links and lengths for the study. Kumasi, the capital city of Ashanti Region was selected based on availability and ease of accessing the historical crash and traffic data. Also

Ashanti Region has the highest vehicle and driver population and number of crashes apart from the Greater Accra region. It is also the network with the most annual fatalities and injuries nationwide (Afukaar , 2010).

The core paved road network for which crash data, classification and some traffic data exist were all included in the survey.

Kumasi urban roads network was selected due to the high level of its traffic flow, variations in the terrain, roadside and land use making it representative of road through typical urbanized environment.

Also, an initial analysis of trends of crashes on urban and non-urban sections of the Ashanti Region and national network revealed that when non-urban crashes are split into village (built up) and rural sections, the trends and characteristics of the crashes were similar to those of urban crashes except that the number of crashes were higher. This further informed the need to model crashes on sections. Table 3.1 describes the roads surveyed, the length and types of facilities.

Table 3.1 Characteristics of study roads

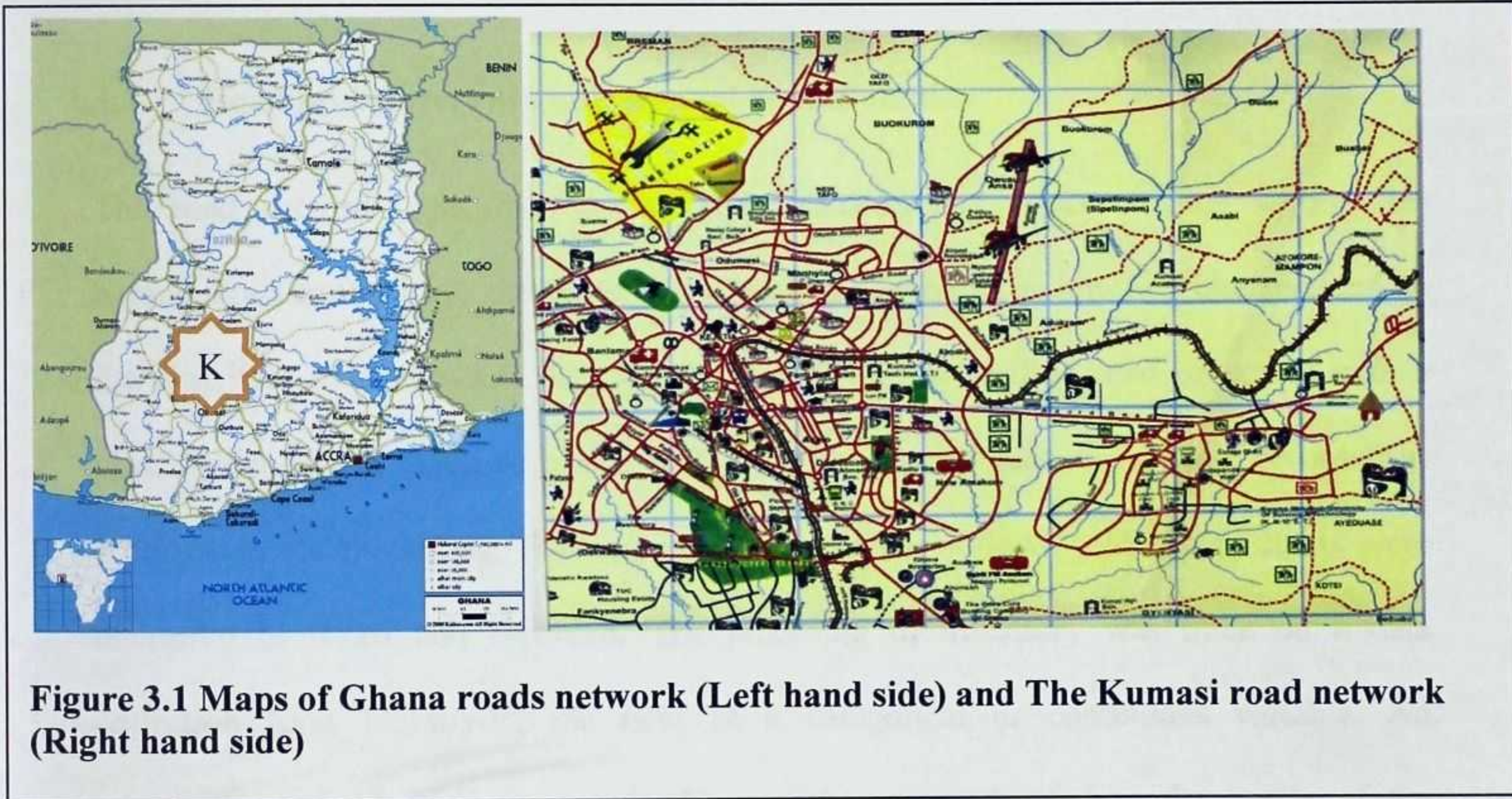
No.	Functional class	Type of facility	lanes	Length (km)	Number of sections
1	Principal arterial	Single carriageway	2	31	42
2	Principal arterial	*Dual carriageway	4	13	20
3	Minor arterial	Single carriageway	2	11	17
4	Collector	Single carriageway	2	8	11
	Total			63	90
* These were separated into 2- two lane roads					

Figure 3.1 shows the road network surveyed in the Kumasi Metropolitan Area. This constitutes more than 50% of the classified road network and most of the highly

trafficked roads in the metropolis for which reliable traffic data and historical crash records are available. Altogether 63 km of urban roadways divided into 91 link segments were used for the modelling. Table 3.2 presents a summary of the road links selected for the Kumasi data collection. Dualised sections were taken as separate two lane sections in the course of the analysis.

Road history data:

The maintenance history for roads under the jurisdiction of the Department of Urban Roads of the Kumasi Metropolitan Road Unit for the period 2000-2010 was obtained.



The components of the data were collected

- Maintenance activities on sections yearly for the last five years
- Rehabilitation and major changes in road alignment
- Major decongestion activities in the road corridor which could change road environment
- Major improvement in infrastructure that has affected road traffic on the sections or pedestrian volumes
- Major resurfacing works on the sections

This was used to eliminate those sections where alteration and rehabilitation has affected the geometry or traffic flow.

3.3 Road inventory, environment and condition data

The road network was divided into links sections and nodes. A link section has homogenous traffic flow and is typically the roadway between any two intersections on the classified road network. The intersection of an unclassified road or access with a classified road was taken as access to the section. Such intersections were recorded as accesses in the modelling. For each road section, the following inventory items were measured or noted and recorded. The recording of inventory was done on a data collection form identifying the item as a categorical or continuous variable. An intersection was defined to include 20m of the approach road to the centre of the intersection. Road environment information was collected within 3 m of the edge of the roadway.

Table 3.2 List of Candidate Roads surveyed

Road Name	Type of facility	Characteristics Sampled links		
		Links from/Link to	Length	Number links
Mampong Rd	Arterial	Pankrono Estate int- Kejetia T Lite	4.93	6
Sunyani Rd	Arterial	Siloam Hosp. Jn - Bekwai R/A	3.30	5
Lake Rd	Arterial	Dompooase Junction - UTC T'lte	5.86	8
Antoa Rd	Arterial	Dr Mensah - Boukrom Int	5.50	7
24th February Rd NB	Arterial	Femusua - UTC T'lte	5.40	8
24th February Rd SB	Arterial	Femusua - UTC T'lte	5.40	8
Harper Rd	Arterial	Ahodwo Rabout- Kingsway RAbout	2.53	3
Yaa Asantewaa Rd	*Collector	Starlet 91 Ave.- Burma Road Int.	1.90	5
Bantama High Street	*Collector	Abrepo Junction- Kath R'About	1.35	2
Offinso Rd	Arterial	Breman Junction - Suame R'About	3.26	4
Odumase Rd	*Collector	Antoa Road Int - Komfo Anokye Rd	2.60	4
Barekese Rd	Arterial	Ampaabame- Abrepo junction	1.15	1
Southern By-pass	Arterial	Bekwai R'About -Harper rd Int	4.15	4
Western By-pass	Arterial	Odumase Road Int - Krofroum T'Lte	5.33	6
Hudson Rd	Arterial	Kath R'About- Hotel rexmar	2.3	2
Maxwell Road	*Collector	Lake Road int- Zongo rd int	2.0	4
New Bekwai Rd	Arterial	Kath Roundabout -Rexmar Hotel	3.95	4
Pine Ave.	Arterial	Bekwai R'About - Harper Road Int	2.25	4
Pinanko Rd	Arterial	Odumasi Rd Int - Krofroum T'Lite	1.45	4
Okomfo Anokye Rd	Arterial	Anloga Junction- Suame R'About	6.35	5
Old Bekwai Rd	Arterial	Ahodwo Roundabout -Sir max Juctn	1.78	3
Cedar Ave.	*Collector	Pine Road Intersection- New Bekwai Rd	2.35	2
*Collector street were included because the character of flow, traffic mix , speeds were comparable to other roads being considered				

Categorical Variables: this utilized two level factors to indicate the presence or otherwise and the conclusion of the geometric variables

- ✓ Pedestrians crossing at unmarked locations (Yes/No)
- ✓ Presence of curb (Yes/No)
- ✓ Road marking Condition (Good/Poor)
- ✓ The degree of side friction imposed by pedestrians, shop fronts, parked vehicles, bus stops on passing traffic (High/ Low)
- ✓ The nature of off road environment or land use (Residential/commercial)
- ✓ Presence of Side walk (Yes/No)
- ✓ Presence of Shoulder (Yes/No)
- ✓ Presence of Bus stops in section (Yes/No)

Continuous Variables: These were variables for which measurements were taken and recorded.

Continuous variables comprised the following:

- ✓ Length of section (m)
- ✓ Width of roadway (m)
- ✓ Number of lanes (Number)
- ✓ Width of shoulder (left and right)
- ✓ width of pedestrian sidewalk (m)
- ✓ Number of side accesses
- ✓ Number of road signs road signs in section

The reduced data in tables is presented in tables in Appendix A

Additionally, the presence or otherwise of some of these data items was indicated as part of the categorical data set. This enabled their inclusion in the modelling as categorical variables during the preliminary modelling.

The data collection encompassed most of the classified road network for which data exist in MAAP5 software. Altogether 63 kilometres of classified road sections under the jurisdiction of the Kumasi Metropolitan Area Roads Unit (Department of Urban Roads) were surveyed by trained observers using the moving pedestrian observer and in some cases the windshield technique (Patterson and Scullion, 1992); observers traverse the section in a slow moving vehicle (30-50 km/hr.) observing and recording inventory and condition items, stop briefly near the end of a section to record data items on survey forms. Each survey section was driven through at least once to collect the data. Surveys were carried out at periods of low traffic flow including Sundays when the road network is sparsely used. All the surveys were undertaken in March 2008.

The effect of side friction was recorded using a two level factor to determine the presence of parked vehicles, trading activities or some other road side activities which impact on the flow of vehicles in the section. Side friction is the extent to which parking and other commercial activities affect the flow. Typical photographs of High and Low side friction were made to guide the data collection. The picture below (Figures 3.2 and 3.3) presents side friction levels. Appendix D presents the picture legend of all other variables used for the data collection.



Fig. 3.2 Urban two lane road with low level of side friction (Residency Link).



Fig. 3.3 Road with high levels of side friction.

These sections were located by use of topographical maps and measurements were taken with tape measures and pedometers.

3.4 Road Traffic Crash Data

Data for all crashes and casualties were retrieved from the National Road Traffic Crash Database at the Building and Road Research Institute (BRRI). The database is compiled

from police files using a standard crash reporting form. Information on police reported crashes are coded and stored in computers at the BRRI using the Micro-computer Crash Analysis Package (MAAP, Windows version) software developed by the Transport Research Laboratory (TRL), United Kingdom (UK). The crash data were retrieved and analysed with the help of the cross tabulation and kilometre analysis facilities available in the MAAP software. The data consisted of all reported injury crashes occurring at the sites.

3.4.1 Crash and casualty data

Crash data was retrieved from the MAAP 5 for windows software at the BRRI. Two types of crash data were retrieved; the first was to determine trends, characteristics and risk factors. This covered a period from 2000-2009, the data is presented in Appendix C.

The second type of road traffic crash data was collected for the road sections surveyed for urban road networks. Road traffic crash data were retrieved for 2000-2004 for all sections surveyed. Care was made to ensure that the sections were the same as the strip map sections in the software. The data was validated by sampling sections and tallying the crashes on the forms. The following road traffic crash data were.

- Total number of crash for 2000-2004 for selected urban sections divided into collision types.
- Total number of crashes for 2000-2009 for all roads in Ghana divided into Collision types for all crashes, severity of crashes, total casualties and type, time of collision, age distribution of fatalities and light condition.

It was not possible to obtain data on the urban network for the period 2005 to 2008 due to technical difficulty with the software: the road link map which aid in the selection of crashes for the urban sections in Kumasi could not be linked to the data as was the case for the 2000-2004.

3.4.3 Traffic flow data

Traffic flow data for the urban network were retrieved from earlier studies by ACON/BCEOM and ABLIN Consult traffic studies for Kumasi. AADT values were retrieved and assumed for the network of roads for which any census point represents. This was checked against recent comprehensive data collection obtained from the Department of Urban Roads and field studies conducted at selected census points on the network. These were validated with some 12 hour three day volume counts in May 2010 undertaken at selected master count stations obtained from Gold Associates. The data is presented in Appendix A

3.5 Exposure determination

Three types of exposure variables were considered as follows, Length of Road section, Traffic volume expressed as the Average Daily Traffic (ADT) and crash rates which are defined as the number of crashes per million vehicles. Crash rates were calculated by dividing the Number of crashes by the number of vehicle kilometres travelled as follows.

The Number of hundred million vehicle kilometres travelled (VKT):

$$VKT = 365 \times (\text{number of years of crashes}) \times (\text{sum of all motorized vehicle flow}) \times (\text{length of road km}) / 10^8.$$

$$R = (\text{Crashes in Reporting Period}) / VKT$$

R: Crash rate per 100 million vehicles kilometres

This rate (R) was calculated for

- Total Injury Crashes
- All Killed and Serious Injury crashes
- Fatal crashes

The rate was also calculated for collision types for all injury crashes as follows

- Two vehicle crashes (head on, rear end, right angle and sideswipe crashes)
- Single vehicle crashes (ran off road, hit object on road, hit object off road, hit parked vehicle, hit pedestrian)
- Single vehicle crashes without pedestrians
- Hit pedestrian crashes

The tables in Appendix A show the various calculated values.

3.6 Model Quality and Final Model Selection Criteria

Modelling was undertaken by first undertaking a pairwise correlation between road section variables, traffic and crash rates using the STATA software application. All variables were correlated and tested at a significance level of 5% (Appendix E). This was considered important to eliminate multicollinearity effects (Washington, 2010). Variables considered as having a potential for inclusion in modelling were selected. For each of them the summary statistics was determined and the distribution of crashes over various section geometric variables and traffic items. A forward stepwise regression procedure was adopted in which variables were introduced and the model parameters assessed for

significance. Those which were found to improve the model coefficients and overall structure and made engineering sense were retained.

The modelling was begun with the inclusion of the exposure variables in the selected model form to define the "Core" model. Exposure variables are those which must necessarily be included in the model for the model to be acceptable and make sense. For example Traffic flow, road lengths are exposure variables for any motor vehicle crash.

The following criteria were taken into account in developing the models:

- a) **The level of statistical significance.** This was by far the dominant criterion. No variables were accepted at less than the 5% level, whilst none were rejected at the 1% level or better without very careful consideration.
- b) **The stability of the model.** If variables are associated with each other, then introducing one will tend to strongly affect the model parameters for the other. Since causal models are sought, such instability was carefully investigated. Care was taken at the site selection stage to minimize where possible the correlation between variables that were likely to appear in the models.
- c) **The comprehensibility of the effect.** It is desirable that the effect of a variable is in some sense understandable and that the models have a logical structure. For example, models for total crashes should not have the vehicle and pedestrian flows simply as a product, since this implies that total crashes tend to zero as pedestrian flow tends to zero. Models with estimated coefficients of the "wrong" sign were examined carefully to see whether the finding was robust.

d) **The size of the effect and ease of measurement.**

Variables that had a large effect on crashes in relation to their range and which were straightforward for the engineer to measure were preferred.

The best model that fits the observed data were assessed based on the Akaike's information criterion (AIC), the AIC was used to select the best non-linear model of the multivariate ratio of polynomials type of model. The derived model for the AIC is defined as:

$$AIC = -2 \ln (L) + 2k \dots \dots (3.1)$$

Where,

L is the Gaussian likelihood of the model

k is the number of free parameters in the model

The first term in the AIC equation measures the badness of fit, or bias, when the maximum likelihood estimates of the parameters are used. The second term measures the complexity of the model, thus penalizing the model for using more parameters. The goal for selecting the best model is therefore a minimization of the criterion, thus selecting the best fit with the least complexity.

3.7 Analysis of Crash Trends and Characteristics

The historical crash records for the period 2000-2009 were analysed to establish patterns and rates of increases and indices. This analysis was undertaken for the national crash and casualty data. Analysis was also done in some cases for the Ashanti Region and the

Kumasi Metropolitan area in order to determine patterns and factors which lend themselves to further investigation to determine models.

Data for the sections are presented in Appendix A. The results of the trend analysis are presented in Chapter 4.

CHAPTER 4: CRASH TRENDS AND RISK FACTORS

4.1 Introduction

This chapter presents the results of objective one; a retrospective analysis of crash records for the period 2000-2009 retrieved from the MAAP5 suite at the BRRI. The crash records were analysed for trends, characteristics in different environments, and locations to identify risk factors. The main aim of this chapter was to establish the basis and identify the factors which may be considered as important indicators and subjects for predictive crash modelling of two lane roadways in Ghana. Also, the general state of crashes and factors influencing their occurrence and indices has been studied.

The analysis of crashes in this chapter covers both urban and rural environments; this was deliberate. This was occasioned by the researcher's desire to establish the need to make suitable models that reflect the state of crashes in Ghana and to prevent in-breeding during the research. It would be recalled that during the period of the study two other researchers researching on road safety had settled on rural environment. This analysis therefore sought to establish the trends and risk factors and then identify the environment within which some original work could be made based on need.

Although crash records exist for as far back as 1991 in the MAAP system, in this study the analysis was undertaken with 2000 as the baseline year for a number of reasons: First, the National Road Safety Commission (NRSC) since 2000 has coordinated the implementation of a systematic and consistent data-led approach to road safety interventions. Secondly, the Ministry of Roads and Highways (MRH) reclassified all roads in the year 2000. In that exercise, some roads shifted from the trunk roads network

to be re designated as urban and feeder roads and vice versa. Also vehicle registration and licensing records and data computations have improved and been streamlined with the establishment of the Driver and Vehicle Licensing Authority (DVLA). Concerning data management there have been software changes, from Dos platform to Windows platform. It was therefore considered prudent to use year 2000 as baseline. In the analysis of trends, all total annual crashes were divided by the total crashes for the year 2000 to obtain the index value of the crashes. This was done to compare by how much the crashes have increased or decreased annually compared to the values in 2000.

4.2 Crash Characteristics and Trends

Crashes have increased even though marginally since 2000. Many damage only crashes may not be reported especially where drivers propose to settle out of the police station. Crashes resulting in injury are more likely to be reported and recorded by the police.

Figure 4.1 presents the trends in injury traffic crashes in Ghana for the period 2000-2009 reported with 2000 as baseline. It shows that whereas generally injury crashes have increased marginally, the consequences in terms of fatalities and injuries have increased more than marginally. From the figure, Personal Injury crashes (PIA); one in which at least one person was injured and Fatal crashes in which at least one person is killed have rather increased by 13% and 51% respectively. For the rapid increase (about 80%) in the number of registered vehicles since 2000, it was expected to result in more road traffic crashes but that did not necessarily happen.

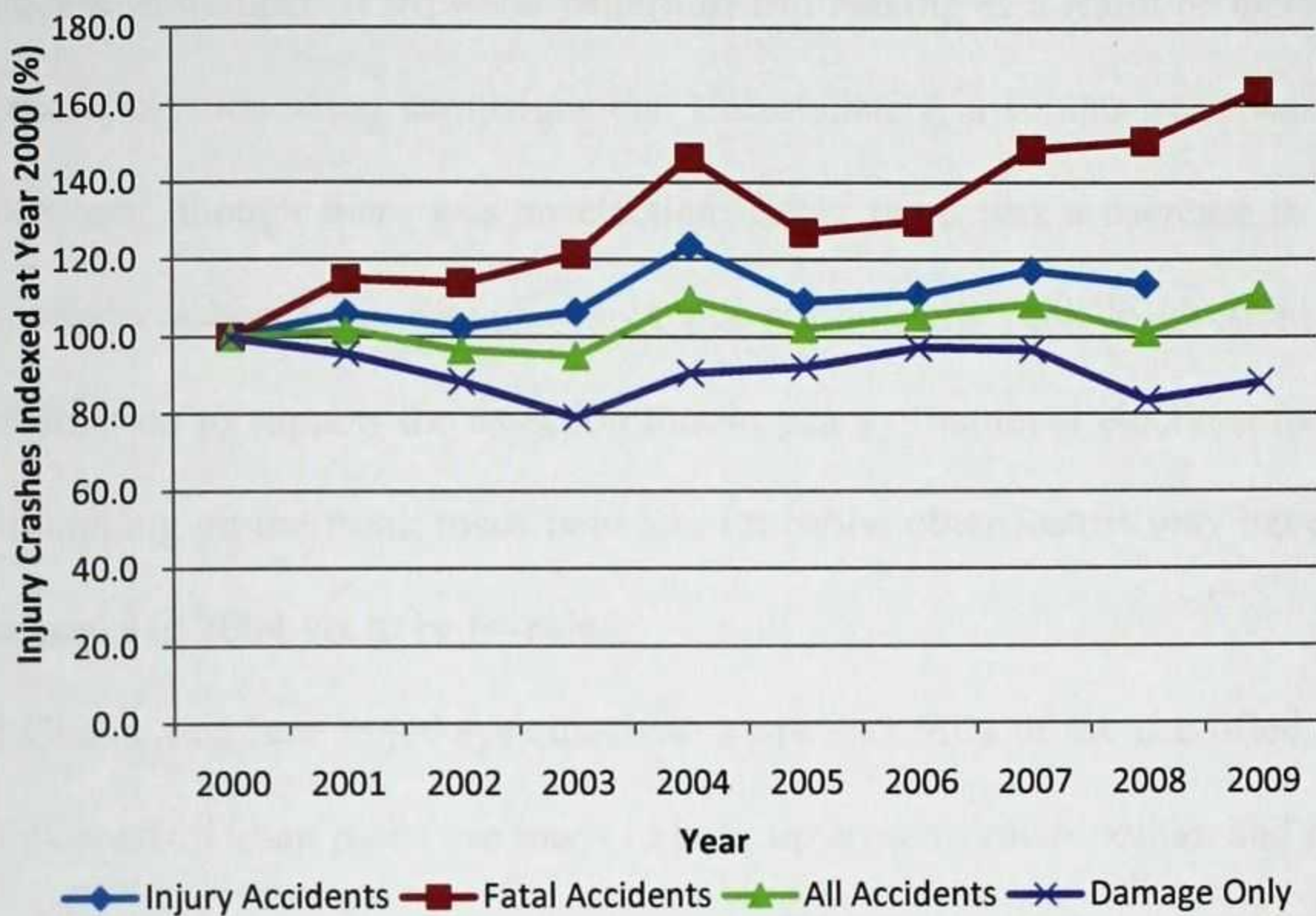


Fig. 4.1 National Trends in Injury Traffic Crashes (source: Authors analysis of data)

Vehicle records trends analysed from the DVLA data have shown there is a rapid growth in vehicle registration averaging about 10% per annum; this vehicle growth has not resulted in much increase in number of injury crashes according to the analysis. We may attribute this to some possible modest gains in road safety management in Ghana. Regarding growth in fatalities, we can say that the growth indeed shows that perhaps the consequences of crashes have been more serious or fatal. Salifu (1996) and Afukaar (2002) have reported in different studies that speeding is a major concern leading to fatalities especially for pedestrians on roads in Ghana.

From the trends in the graph, peaks in crashes occurred in the year 2004 with high and devastating fatality consequences. The reason for this peak occurrence is not clear, however, this is could be the result of increased exposure which may be due to sudden

increase in number of trips and pattern of trip making as a result of increased economic activity, electioneering campaigns etc. Unfortunately, a similar trend was not evident in 2008 even though there was an election; rather there was a decrease in the number of reported crashes. Even though we cannot attribute the peak to elections, there is local information to support the assertion that in years of national elections there is increased trip making on the trunk roads network. Probably, other factors may have contributed to the peaks in 2004 yet to be revealed.

In Ghana, two lane roadways constitute more than 90% of the classified paved urban or trunk roads. Urban roads are roads in built up areas of metropolitan and municipal cities and towns. They have an operational speed limit (reasonable speed limit) of 50km/h and are classified as arterials, collectors or local roads. Trunk roads are classified as National, Inter Regional and Regional roads, these traverse the length and breadth of the country. It is common to find developments along roads where they traverse villages and small communities especially when they divide such communities into two halves. According to the national crash statistics report (Afukar, 2007), crashes are categorised into urban, rural or village depending on the location and the class of road involved. Urban crashes are those which occur on roads within municipal or metropolitan areas. Village and Rural crashes occur on trunk roads network; however, village crashes are those which occur on sections traversing a settlement on the Trunk road. Rural crashes occur on sections of trunk roads where there is no settlement along the road corridor. Village crashes are those which occur on road sections outside municipal or metropolitan area. These trunk road sections through communities serve as the single most important road, with most developments, commercial activities and pedestrian traffic concentrated along them

especially in the evening and night hours. Figure 4.2 shows the growth of injury crashes on urban and village environment.

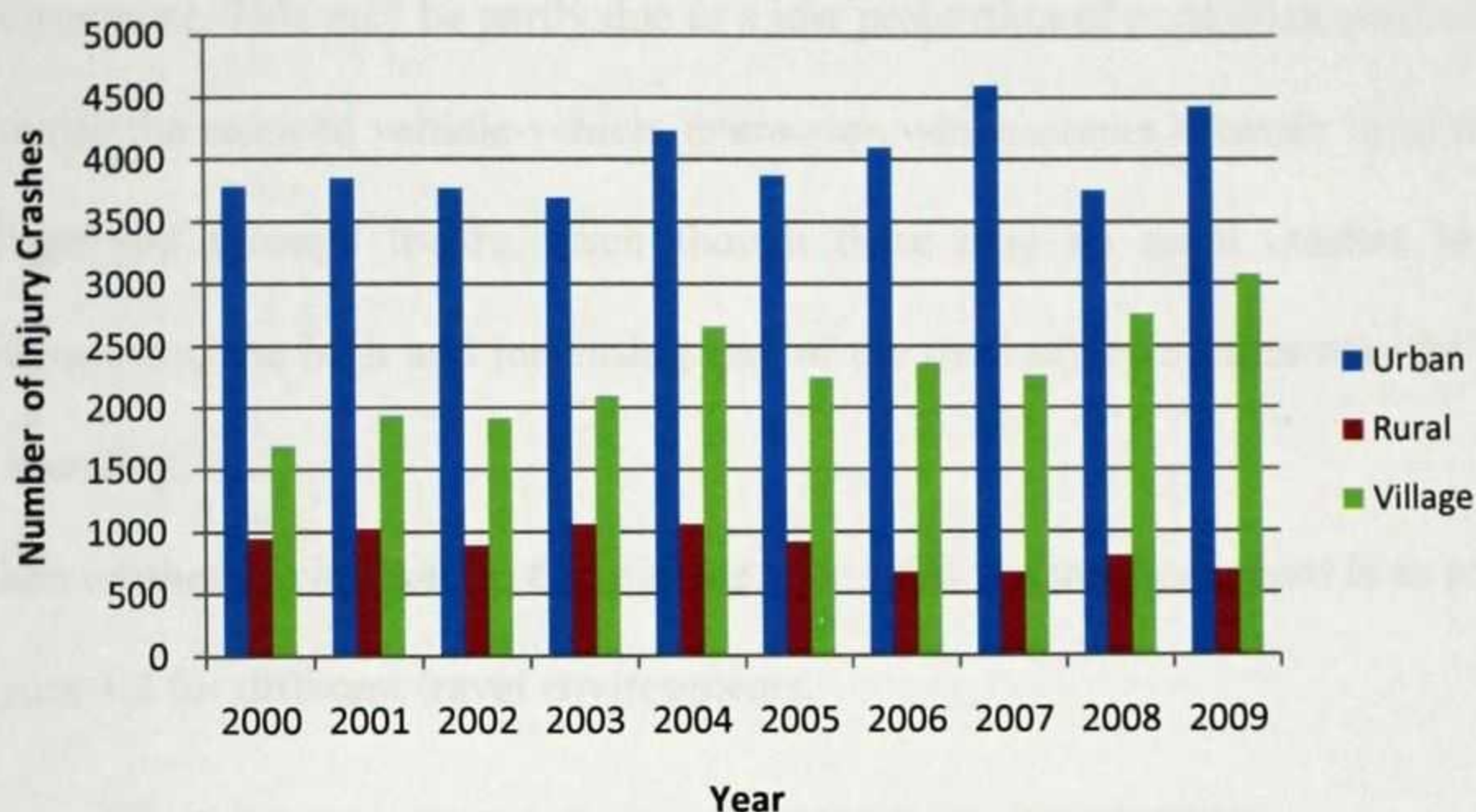


Fig. 4.2 Trends in injury crashes for different road environments (source Author data analysis)

It is clear from the Figure 4.2 that on the average the urban and village crashes are both increasing at different rates. Crashes on village sections of trunk routes have the highest rate (twice that of urban sections) for injury and fatal crashes. According to BRRI (2009) the split between fatalities for urban and non-urban (trunk) roads is 34% and 66% respectively. This may well be indicative of the effect of speed on crash severity outcomes. The pedestrian activity, commercial stalls, and general environment in village sections of trunk roads have some similarities with typical urban sections. However, the principal difference is the vehicular speeds and the intensity of traffic (vehicular and pedestrian). Village sections may experience average speeds well above the mandatory or posted limits of 50km/h. Speeds of 80km/h and above are common for sections without road humps or other traffic calming measures such as speed tables.

The trend in Figure 4.3 shows consistently decreasing number of crashes in the rural environment. This may be partly due to a low proportion of pedestrian crashes in the data and also the reduced vehicle-vehicle interaction which occurs between local traffic in the village and through traffic. Even though there may be more crashes in the urban environment, the high and increasing rate of the rural injury crashes may be attributable to speeding.

When crashes are indexed to those in the year 2000, the trend observed is as presented in Figure 4.3 for different travel environments.

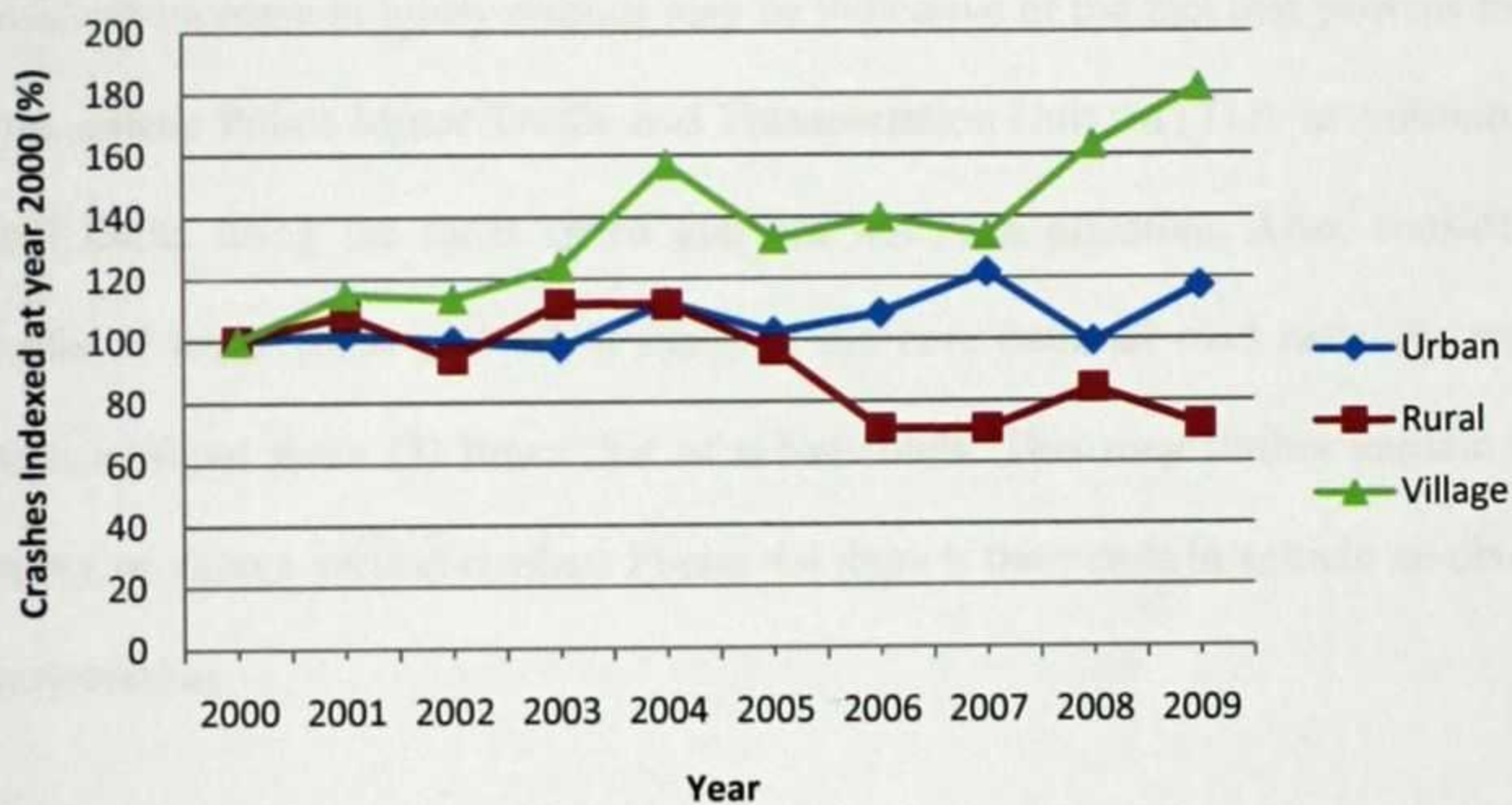


Fig. 4.3 Injury crashes trends indexed at year 2000 as baseline (source: Author analysed data)

According to Figure 4.3, rural injury crashes peaked at 2004 and 2008 even though the general trend shows a decreasing incidence compared to the baseline. Whereas in all road environment peaks in injury crushes were observed, no such trend was observed in 2008.

Even with the rapid increases in vehicle fleet over the last decade, injury crashes have generally declined on rural sections of roads. However, such crashes have increased on village sections of trunk routes which traverse communities, and only marginally increased on urban road networks in towns and cities. The trend shows that the efforts of the National Road Safety Commission and its stakeholders such as Department of Urban Roads, in calming traffic and the awareness campaigns on “killing of speed” may be yielding some dividends in urban areas.

The consistent reduction in crashes in rural environments is worthy of note as it may reflect general improvement in the quality of driving and vehicles. On the other hand the consistent increase in injury crashes may be indicative of the fact that perhaps the efforts of the Ghana Police Motor Traffic and Transportation Unit (MTTU) at enforcing posted speed limits using the radar speed gun has not been effective. Also, considering the lengths of trunk roads and urban roads in the core national road network, trunk road length is about three (3) times that of urban roads. This may further explain the high number of village section crashes. Figure 4.4 depicts the trends in vehicle involvement in injury crashes.

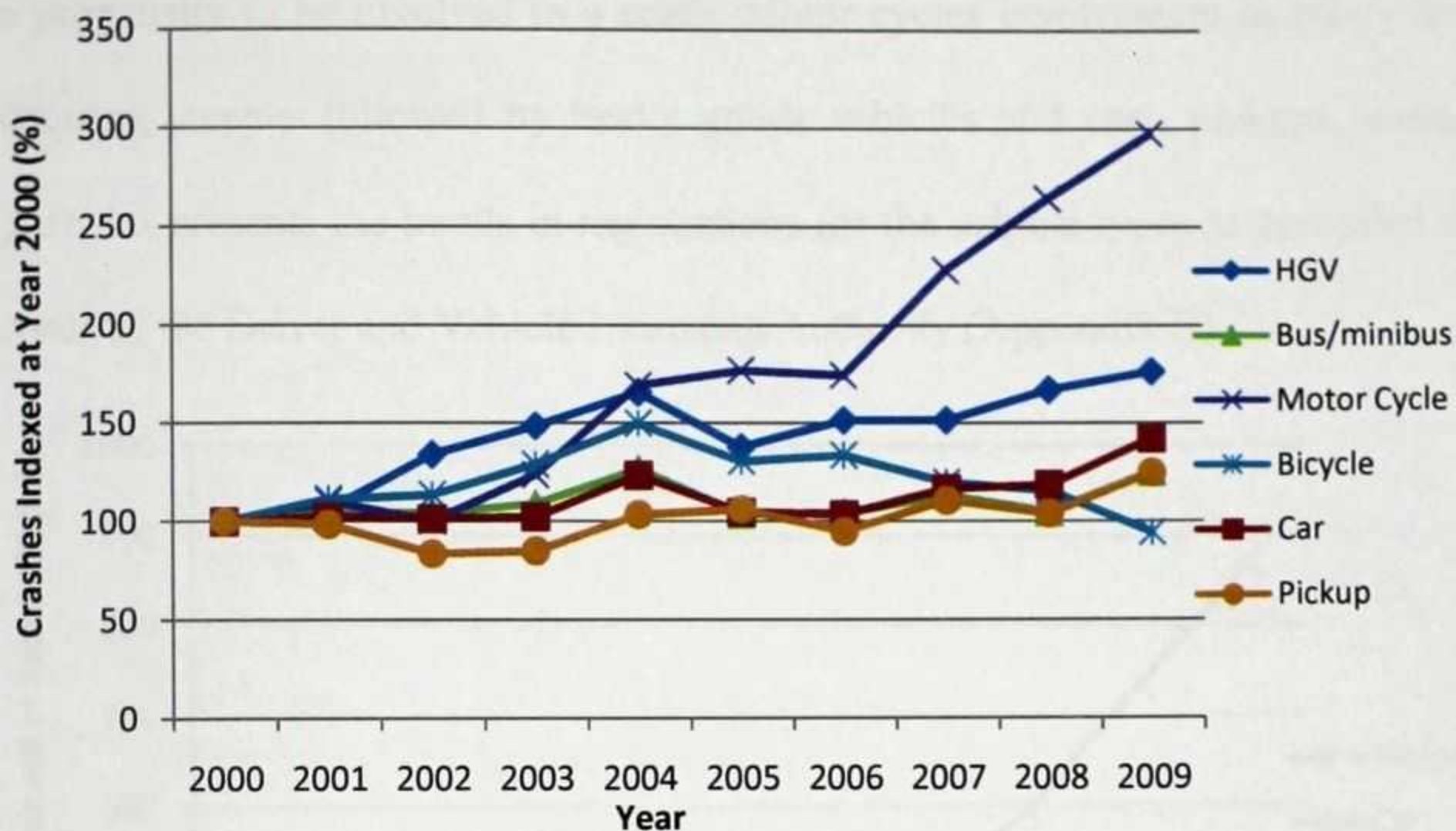


Fig. 4.4 Road user involvement in injury crashes

It is seen that the involvement of pickups, cars and mini buses' in crashes have increased only marginally over the period. Bicycle involvement in injury crashes increased to a peak in 2004 but has since seen a rapid decrease. This could be the result of low patronage of bicycles in favour of motorbikes as the economy improves. Heavy goods vehicle involvement in crashes has increased by 80% compared to 2000 values. This is alarming since by their sheer size, any crash involving HGV can be very serious or fatal. Roadside observations also show that the speeds of HGV's when unladen are in some cases comparable to those of small cars. Recent data reported by Goal Associates (2010) revealed that the proportion of medium vehicles (not car or pickup) and heavy trucks in the stream were between 10%-70% for certain road links in Kumasi. BRRI (2007) has also reported similar results for truck involvement in crashes compared to their presence in the traffic stream. Generally, the higher the vehicle –kilometres travelled, the higher

the propensity to be involved in a crash. Motor cycles involvement in injury crashes is increasing steeply followed by heavy goods vehicles and cars, pickups, bus/minibus. Figure 4.5 presents the trends in registrations for the vehicle types as compiled from the records of the Driver and Vehicle Licensing Authority (Appendix B).

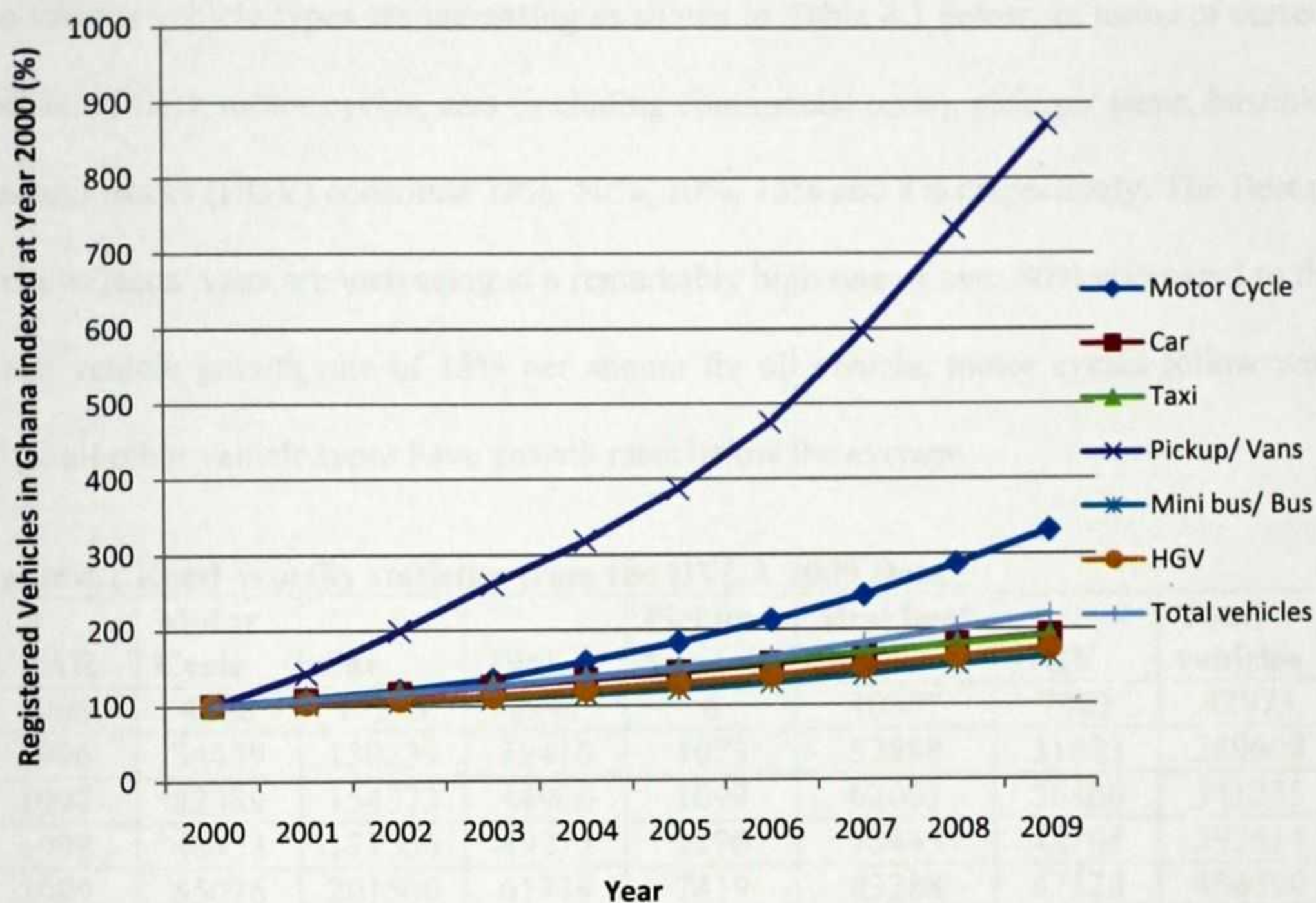


Fig. 4.5 Vehicle registration trends for the different vehicle types

The record of vehicle fleet does not take care of bicycles. From the trends in crashes as depicted in Figure 4.5, the rate of bicycle crash increased up to 2004 and subsequently took a consistent downward trend. This may be due to modal shift in favour of motor cycles. The sustained increases in the registration of motor cycles may be indicative of this trend.

Motorcycle involvement in crashes is increasing at alarming rates, this is because since 2006 annual increases in the registration of Motor cycles exceeds 15,000. Some of these

are operated as Taxis on very busy streets. Even though registration of these motor vehicles are being done their regulation in the traffic stream leaves much to be desired.

When this is combined with road worthy inspections data for 2009, it can be deduced that the various vehicle types are increasing as shown in Table 4.1 below. In terms of current registered fleet, motor cycles, cars (including commercial taxis), pickups/ jeeps, bus/mini bus and trucks (HGV) constitute 18%, 50%, 10%, 13% and 8% respectively. The fleet of pickups/jeeps/ vans are increasing at a remarkably high rate of over 80% compared to the mean vehicle growth rate of 13% per annum for all vehicle, motor cycles follow with 25%, all other vehicle types have growth rates below the average.

Table 4.1 Road Worthy statistics from the DVLA 2009 Data

YEAR	Motor Cycle	Car	Taxi	Pickup/ Vans	Mini bus/ Bus	HGV	Total vehicles
1995	4908	17248	2941	6	10387	7483	42973
1996	34459	130239	39416	1073	52888	31533	289608
1997	42389	154373	44906	1099	62002	36466	341235
1998	48453	177066	49775	1170	73445	42705	392614
1999	55076	201500	61779	7419	83288	47528	456590
2000	61516	229052	66883	12615	88757	50005	508828
2001	67574	247005	72451	17958	91433	51854	548275
2002	74004	265517	78466	25101	94034	53818	590940
2003	82781	286081	83576	32879	96950	55913	638180
2004	97243	306414	91218	40068	101832	59846	696621
2005	112379	329363	97904	48783	107417	64191	760037
2006	130430	353169	105153	59910	114816	68894	832372
2007	150750	382802	112910	75206	124607	74891	921166
2008	176225	414430	119950	92580	136344	81425	1020954
2009	203806	439558	127818	109994	145154	87156	1113486
%	18.30	39.48	11.48	9.88	13.04	7.83	100.00

Source DVLA statistics

The pickups/vans growth rate of 2.5 % has further increased since 2006 to levels comparable to cars. Heavy goods vehicles growth rate averaged 8% and corresponds well to their involvement in injury crashes which averaged 7% over the last decade. An analysis of road user involvement in injury crashes from the MAAP 5 data shows that motor cycles, cars, pickups, Buses (large and mini bus) and trucks (HGV) are involved in 8%, 41%, 6%, 27% and 13% respectively (Table 4.2). Buses/ mini buses and trucks seem to contribute more to crashes in which at least one person is injured than their proportion in the national fleet.

Table 4.2 Road User Involvement in Crashes in Ghana (2000-2009)

	Vehicle Type									
	Car	HGV	Tract	Bus	Minibus	Motor Cycle	Pickup	Bicycle	Other	Unknown
Total Crashes	25442	10236	424	12523	5245	5840	4206	4049	313	224
Vehicles involved (%)	41	13	0	19	8	8	6	5	0	1
Collision Type	Percentage of Vehicles (%)									
Head On	13	12	6	10	11	14	12	12	7	2
Rear End	14	17	26	13	14	18	14	21	20	9
Right Angle	11	6	7	7	8	19	11	20	9	3
Side Swipe	10	13	15	9	10	17	11	25	12	8
Ran Off Road	5	12	8	9	13	3	10	1	3	0
Hit Object On Road	0	1	1	1	1	0	1	0	1	0
Hit Object Off Road	2	2	1	2	2	1	2	0	1	0
Hit Parked Vehicle	2	5	4	2	2	1	2	1	1	1
Hit Pedestrian	37	19	14	33	36	22	28	15	26	73
Animal	0	0	0	0	0	0	0	0	0	0
Other	6	14	17	14	4	4	10	5	17	3
Total (%)	100	100	100	100	100	100	100	100	100	100

Whereas HGV constitute about 8% of the national fleet of vehicles (Table 4.1) their involvement in crashes averages 13%. This means that trucks have a high tendency to be involved in a crash. This observation has been reported by Salifu et al. (2004) and

Afukaar et al. (2008) that HGV involvement in fatal crashes is over represented in the national crash statistics of Ghana.

4.3 Regional Distribution of Crashes, Casualties and Risk factors

Even though the national vehicle fleet is increasing rapidly, it is not evenly distributed in all the ten regions. Traffic volumes and road network lengths vary from one region to another. This has some significant effect on the distribution of crashes and fatalities in Ghana. Table 4.3 shows some statistics of the regional road networks as they relate to crashes and fatalities. The national roads (i.e. N roads) are reputed to contribute to more than 60% of all fatalities on link sections. Most national road traffic traverses urban centres of the regional capitals and towns. Similarly, major towns and villages are also traversed by regional and inter regional trunk roads which carry high speed traffic through the city centres where there are significant vehicular and pedestrian conflicts. There have been over 115000 crashes of which 63% involve an injury or fatality resulting in 161820 casualties on all types of roads in the study period. Of the casualties, 11% were fatalities, 36% were seriously injured and hospitalized and the rest were slightly injured. The Greater Accra, Ashanti and Eastern Regions collectively produced 72% of all crashes and 55% of all fatal crashes annually. These three regions have the most crash prone road networks producing 54% of fatalities. The Ashanti Region leads in the number of fatal crashes and fatalities. The three Northern Regions altogether produce only about 394 (4%) crashes and 9% of fatalities, a reflection of the low proportion of vehicle fleet operational and the national road network length in those regions.

Based on the data the Greater Accra Region has the highest vehicle fleet (57%) and also the highest proportion of all crashes (44%). The Ashanti Region has 17% of vehicles and contributes about 16% of all crashes annually. Regarding crash outcomes, 21% of fatal crashes occur in Ashanti, 19% in Greater Accra and 15%, 11% and 10% in Eastern, Central and Brong Ahafo Regions respectively. An analysis of the twenty (20) most crash prone sites in each region revealed that regions traversed by trunk roads have the

Table 4.3 Regional Statistics of road networks, crashes and fatalities

Description	Regional Characteristics										Total
	Ashanti	Brong Ahafo	Central	Eastern	Greater Accra	Northern	Upper East	Upper West	Volta	Western	
Trunk Network(Km)	1712	1875	920	1415	416	2611	488	963	1326	1643	13369
Paved Network (Km)	860	715	619	886	370	578	174	66	595	670	5321
Number of Vehicles	189300	44500	33400	66.8	634700	11100	11100	22300	33400	189300	1113500
Vehicle fleet (%)*	17	4	3	6	57	1	1	2	3	6	
All Crashes	18337	6166	8818	14153	50206	2354	1701	748	5489	7106	115078
% Crashes	15.9	5.4	7.7	12.3	43.6	2.0	1.5	0.6	4.8	6.2	100.0
All Fatal Crashes	3013	1380	1526	2195	2707	684	496	224	1109	1181	14515
% Fatal crashes	20.8	9.5	10.5	15.1	18.6	4.7	3.4	1.5	7.6	8.1	100.0
Fatalities	4075	1882	1995	2917	3046	988	589	268	1445	1457	18662
% Fatalities	21.8	10.1	10.7	15.6	16.3	5.3	3.2	1.4	7.7	7.8	100.0
Casualties	29979	12308	17305	28931	37972	5602	2720	1479	12587	12149	161032
% Casualties	18.6	7.6	10.7	18.0	23.6	3.5	1.7	0.9	7.8	7.5	100.0
All Crashes	18337	6166	8818	14153	50206	2354	1701	748	5489	7106	115078
*Based on 2009 roadworthy renewals, Source: Author construct from various sources of data											

worst crash and casualty statistics especially in non-urban environment. With more than 65 % of fatalities and 58% of casualties in non-urban environment, the length of trunk road network within any region seems to be a risk factor for crashes. Figure 4.6 shows a strong correlation between the proportion of registered vehicles operating in each region and the proportion of crashes ($R^2=0.95$)

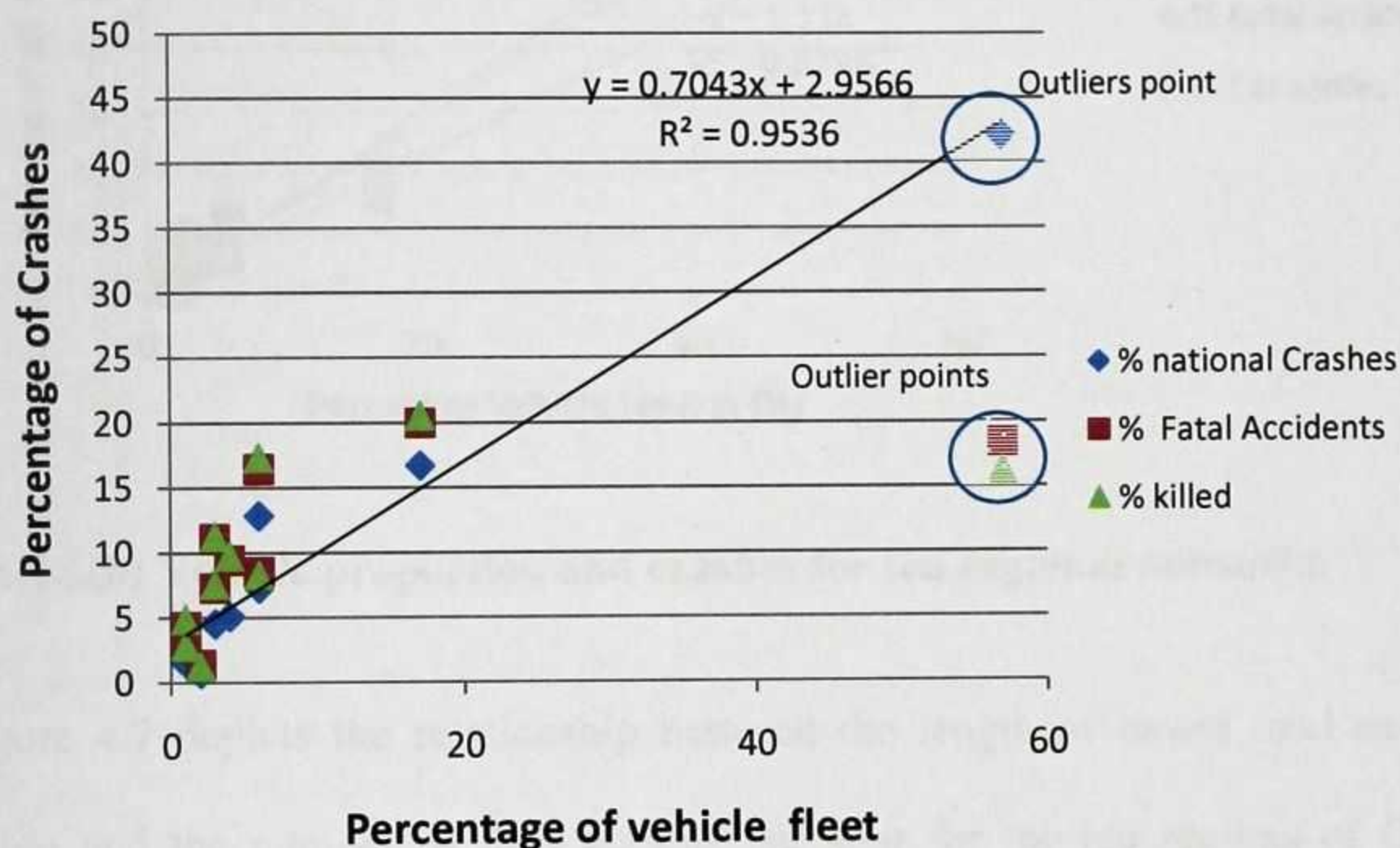


Fig. 4.6(a) Vehicle proportion and crashes for ten regional networks

This means that there is a strong linear relationship between the volume of traffic (represented by the vehicle population) and the number of injury crashes resulting from their operations. Therefore, the population of vehicles operating on the network is a risk factor for crashes. We can conclude that as the proportion of vehicles on a road network increases the crashes also increases linearly. In Figure 4.6 (b) the extreme right point was removed as an outlier to see the relationship which will result. The results show that

Injury crashes, fatal crashes and casualties all correlate with the fleet size even though this was not very strong.

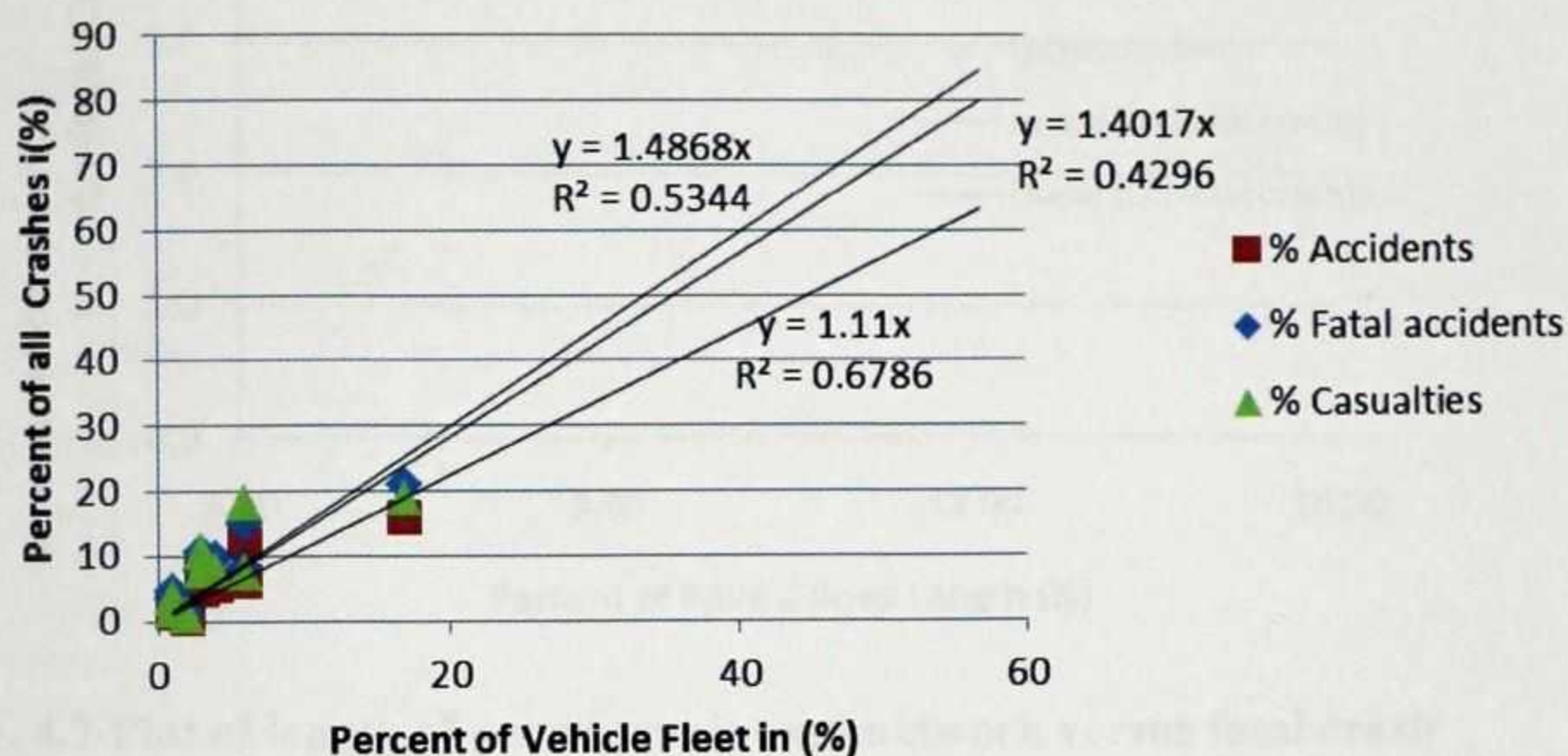


Fig. 4.6(b) Vehicle proportion and crashes for ten regional networks

Figure 4.7 depicts the relationship between the length of paved road network in any region and the number of fatal crashes per year for the ten regions of Ghana for the period of study.

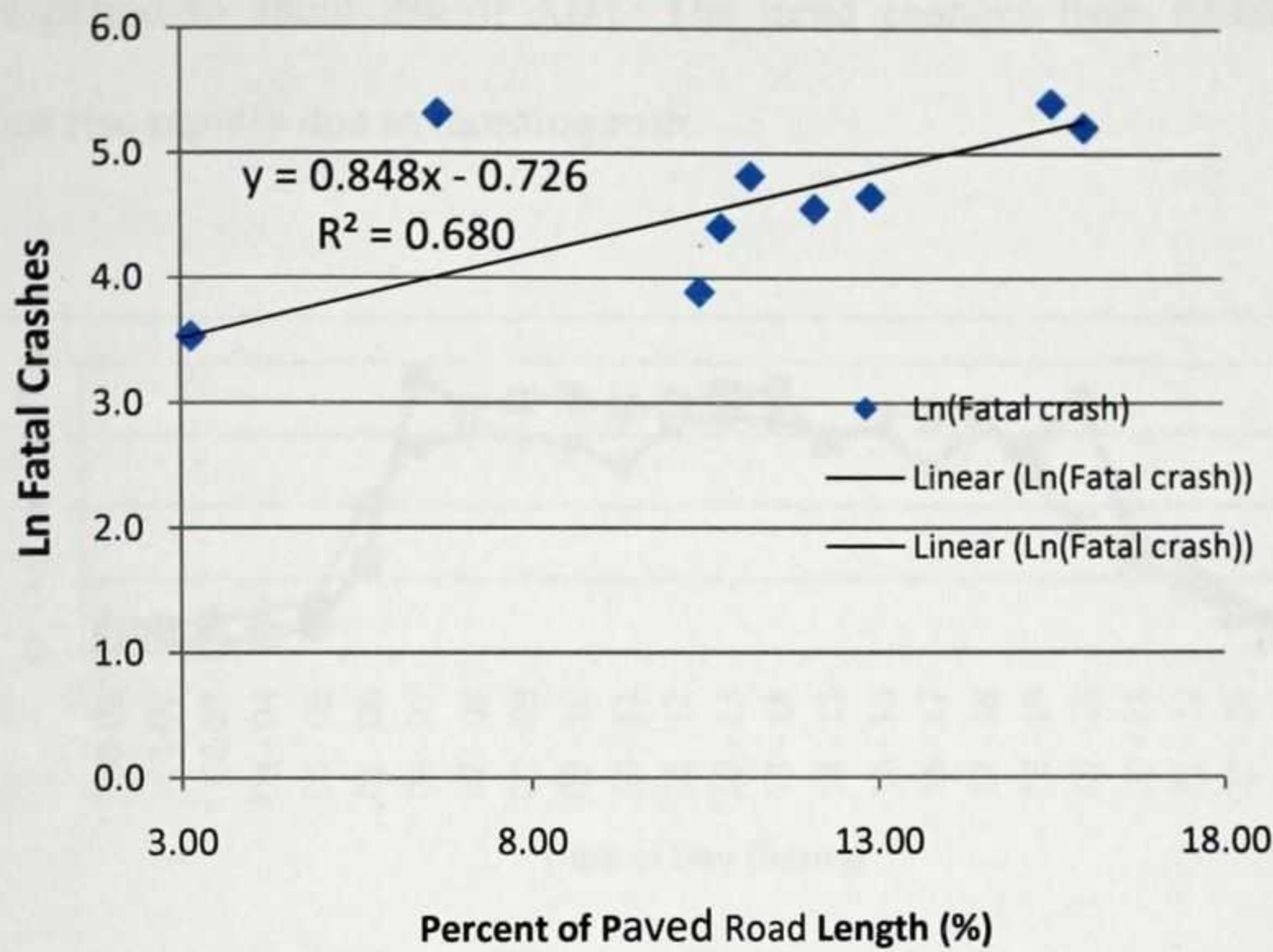


Fig. 4.7 Plot of length of paved trunk road network versus fatal crash

From Figure 4.7, the number of fatal crashes is exponentially correlated ($R^2=0.68$) with the length of paved trunk roads. A similar relationship was observed between the length of trunk roads and crashes. In Ghana the ratio of fatalities on the trunk to the urban network is 2:1. The more the length of paved roads within a regional network, the greater the injury crashes and fatalities. Associating paved trunk road with speeding, it can be reported that there is an influence of speeding in the causation of crashes on the road network.

4.4 Vehicular Traffic Flows on Road Sections

Traffic flow on roads varies considerably during the day. Figure 4.8 shows typical variation of ADT on some roads in Kumasi. From midnight (00:00 hours) to dawn (04:00 hours), volumes are very low and average speeds are highest. Volumes increase gradually

in this period to about 2% of ADT. The trend changes from 04:00 to 07:00; traffic volumes rise rapidly due to morning rush.

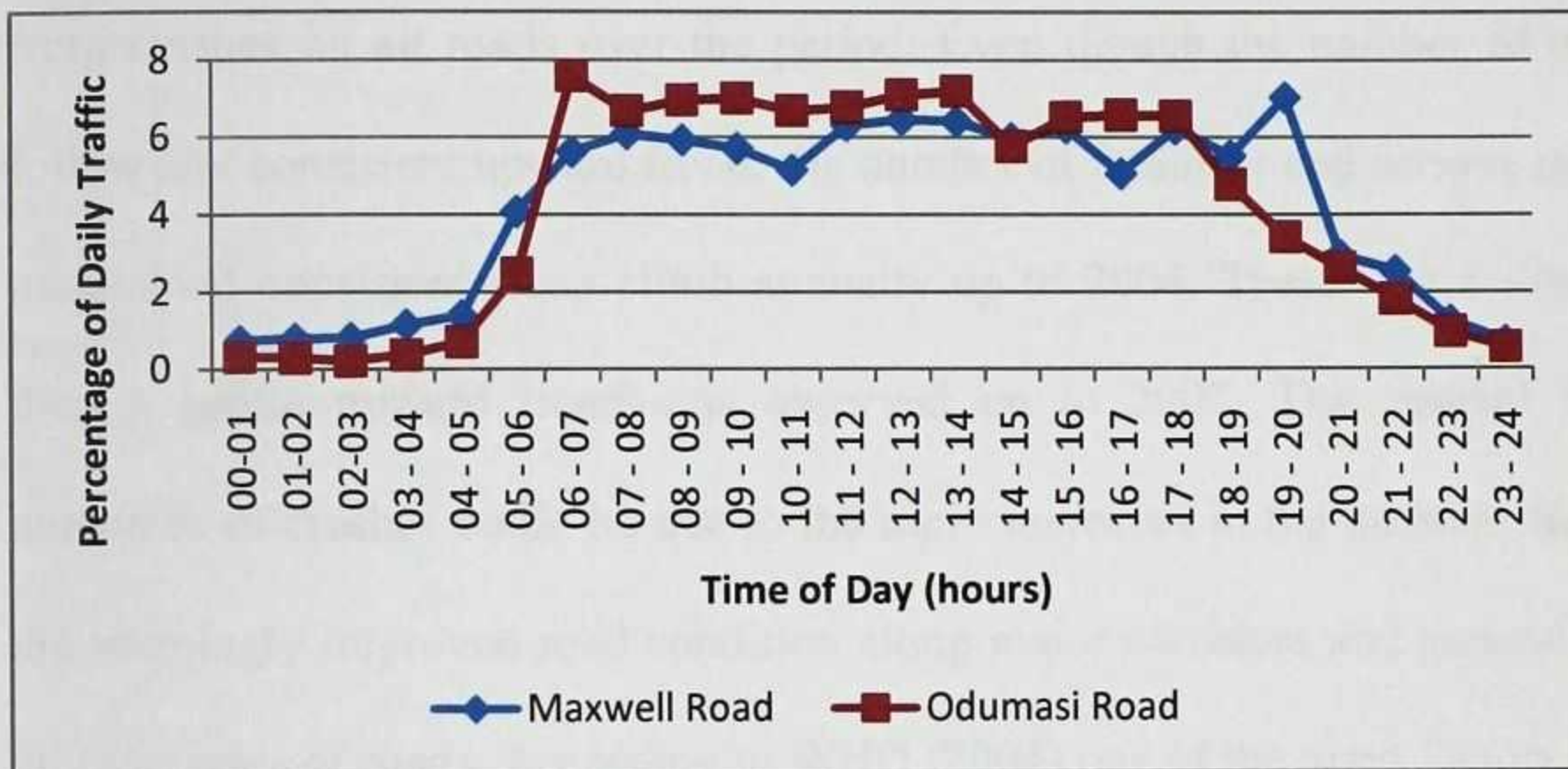


Fig. 4.8 Hourly variation of daily traffic on selected roads in Kumasi

During this period speeds are generally low and congestion sets in but the concentration of pedestrian builds up due to increased roadside activity. Traffic volume peaks at 07:00 hours and is sustained up to 09:00 especially on major roads in towns and cities. After the morning peak, traffic flow normalises and gradually speeds begin to increase with flows up to the evening peak at 18:00 hours when they drop again. The evening peak is usually characterised by high pedestrian presence on roadside and increased commercial activities in the road corridor. It is important to note that because of the unidirectional nature of peak traffic, low speeds characterise only the traffic in the congested direction; in the opposing lanes this is not so. During the congestion, the low speed and near bumper to bumper traffic condition encourage pedestrians to cross the congested lane between vehicles which action increases their risk of being hit by oncoming traffic in the opposing lane.

4.5 Casualty Trends and Characteristics

Table 4.4 presents the casualty situation and trends for the entire road network for the period 2000 to 2009. The table shows close to 35% increase in the casualties resulting from crashes on all roads over the period. Even though the number of crashes did not follow any consistent upward trend, the number of fatalities and serious injury casualties maintained consistent steep climb annually up to 2004. There was a drop in 2005 and then a gentle upward trend was observed up to 2007. The general rising casualty outcomes of crashes could be due to the rapid increases in the national fleet of vehicles, the seemingly improved road condition along major corridors and generally speeding on all categories of roads. According to WHO (2004) one of the main factors contributing to the increase in global road crash injury is the growing number of motor vehicles. Since 1949, when Smeed (1949) first demonstrated a relationship between fatality rates and motorization, several studies have shown a correlation between motor vehicle growth and the number of road crashes and injuries. While the motor vehicle and subsequent growth in the number of motor vehicles and road infrastructure has brought societal benefit, it has also led to societal cost to which road traffic injury contributes significantly.

There is a large amount of evidence of a significant relationship between mean speed and crash risk: Empirical evidence from speed studies in various countries has shown that an increase of 1 km/h in mean traffic speed typically results in a 3% increase in the incidence of injury crashes (or an increase of 4–5% for fatal crashes), while a decrease of 1 km/h in mean traffic speed will result in a 3% decrease in the incidence of injury crashes (or a decrease of 4–5% for fatal crashes) (Finch et al, 1994)

Table 4.4 Casualty and crash severity indices

Year	All Casualties	Index	Killed	Index	Seriously Injured	Index	Slightly Injured	Index
2000	13747	100.0	1437	100.0	5180	100.0	7130	100.0
2001	14838	107.9	1660	115.5	5210	100.6	7968	111.8
2002	15077	109.7	1665	115.9	5741	110.8	7671	107.6
2003	16185	117.7	1716	119.4	5960	115.1	8509	119.3
2004	18445	134.2	2186	152.1	6222	120.1	10037	140.8
2005	15813	115.0	1779	123.8	5138	99.2	8896	124.8
2006	16348	118.9	1856	129.2	5882	113.6	8610	120.8
2007	16416	119.4	2043	142.2	6287	121.4	8086	113.4
2008	16455	119.7	1938	134.9	5809	112.1	8722	122.3
2009	18496	134.5	2237	155.7	6242	120.5	10017	140.5
2010								
All	161820		18517		57671		85646	

Over the last decade or so there have been over 102052 crashes resulting in 161,820 casualties; 18,517 were killed, 57,671 seriously injured and hospitalized and 85646 slightly injured who were treated and discharged at hospital outpatient departments. Compared to the year 2000, annually most crashes outcomes are fatal.

4.6 Casualty Age and Gender

Whereas averagely, 56% of injury crashes occur in urban road environment, fatalities in the non-urban environment exceed (68%) those of the urban environment. Also 59 % of casualties occur in non-urban sites on trunk roads and 69% of all casualties are men; this is against the backdrop that within the national population the ratio of men: women tilts slightly in favour of women. It is not strange for casualty figures to have less than 50% females as females are generally known to be more careful at crossing roadways than the male counterparts (see for example Table 4.5).

Table 4.5 .Annual distribution of Fatalities by Gender

Year	Sex		Total
	Male	Female	
2000	1091	441	1532
2001	1193	441	1634
2002	1175	480	1655
2003	1280	437	1717
2004	1568	587	2155
2005	1292	463	1755
2006	1348	492	1840
2007	1554	489	2043
2008	1448	490	1938
2009	1655	582	2237
Total	13604	4902	18506
%	73.5	26.5	100.0

Also roadside observations show that in the afternoons and late evenings, more males are seen in the road corridors making more risky crossing manoeuvres. Also, there is empirical evidence and data that males usually patronize high speed cars, buses and jeeps/vans which have been found to have a high involvement in crashes and therefore contribute to the high male involvement in casualties.

Figure 4.9 shows the distribution of age of casualties. At least 15% of all fatalities are children (<15 years). For the elderly (>65) few (<5%) were involved in fatalities. Those in the active working age class (16-55 years) were the majority; of this, 26-35 years was the group most prone to fatalities.

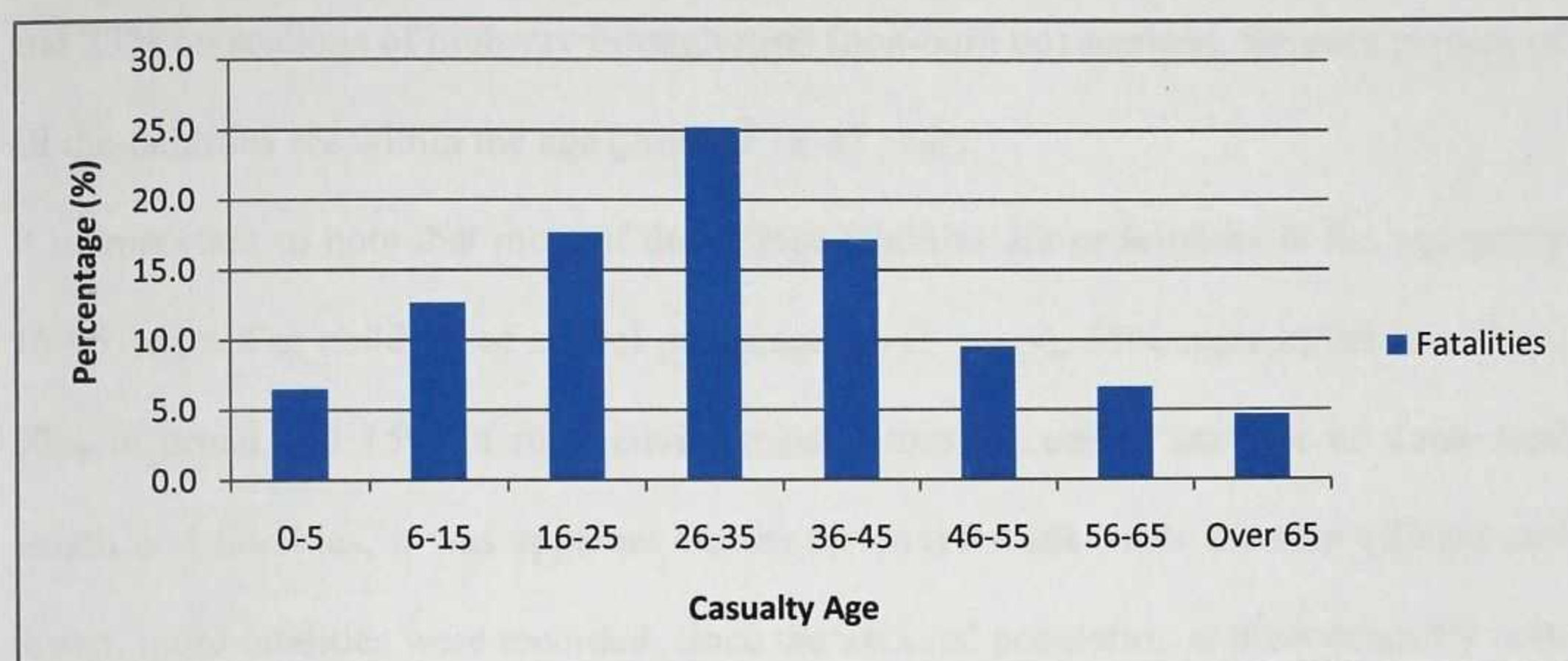


Fig. 4.9 Distribution of fatalities by age group

On the basis of the data, it is clear that persons in the age group 16-45 years have a higher risk of being a fatality than those in any other age group. A detailed assessment of fatalities for the period 2005-2009 for urban, village and rural crashes is presented in Table 4.6.

Table 4.6 Total number of people killed in road traffic crashes in Ghana (2005 -2009)

Total killed	Age of Persons killed (years)								Total
	1 - 5	6- 15	16 - 30	31 - 45	46 - 60	61 - 70	71 - 80	81+	
urban	324	591	2300	1723	753	236	112	43	6082
village	453	1084	4561	4067	1576	363	147	31	12282
Rural	138	283	2265	1895	646	128	35	11	5401
Total	915	1958	9126	7685	2975	727	294	85	23765
Ave age (Annually)	183	391.6	1825.2	1537	595	145.4	58.8	17	4753
% of Persons Age killed	3.9%	8.2%	38.4%	32.3%	12.5%	3.1%	1.2%	0.4%	100.0%

This period was used because data for the period 2000-2009 could not be retrieved from the MAAP 5 suite because of technical difficulties at the time. For the period analysed, altogether 23765 fatalities were recorded of which 26% were in urban, 52% in villages

and 23% on sections of highway through rural (non-built up) sections. Seventy percent of all the fatalities are within the age group of 16-45 years.

It is important to note that most of the village fatalities are pedestrians in the age group 16-45 years. For children of school going age (6-15 years), 55% were killed in village, 30% in urban and 15% in rural environment. From the earlier analysis of trunk road length and fatalities, it was apparent that as the paved trunk roads traverse villages and towns, more fatalities were recorded, since the national population is predominantly non-urban (>60%). Since the roads through the towns and villages are important commercial and communing points, pedestrians especially children are at a higher risk in villages than urban or rural sections of two lane highways (Derry et al, 2010).

4.7 Casualty Trends and Road Safety Indices

Table 4.7 shows the trends in national population, registered vehicle fleet and various crash statistics for the ten year period. The motorization level i.e., vehicles per 1000 population when plotted against the crashes does not correlate with the number of crashes ($R^2=0.008$). This is contrary to earlier studies by Smeed (1949) and others that the increase in motorisation results in high number of crashes. The data for the study has a high proportion of damage only, single vehicle crashes and pedestrian crashes. The motorization level rather may be inducing more vehicle-vehicle conflicts. This means that the higher the motorization level the more is the likelihood of injury crashes. The more the crashes the higher the likelihood of an increase in fatal crashes when speeds are high.

Table 4.7 National Casualty Statistics and Road Safety Indices

Year	National Population (millions)	Registered motor vehicles	Injury Crashes			All Crashes				motorization level vehicles per 1000 pop	fatalities per 100 crashes	Casualties per 100 Crashes	Injuries per 100 crashes
			Total	R1	R2	Total	Persons Killed	Persons Injured	R3	R4			
2000	18.8	511063	6429	34.1	NA	11087	1437	12310	7.6	28.1	13	124	111
2001	19.3	567780	6831	35.3	NA	11293	1660	13178	8.6	29.2	15	131	117
2002	19.8	613153	6593	33.3	NA	10715	1665	13412	8.4	27.2	16	141	125
2003	20.5	643824	6849	33.4	NA	10542	1716	14469	8.4	26.7	16	154	137
2004	21.1	703372	7952	37.7	NA	12175	2186	16259	10.4	31.1	18	151	134
2005	21.7	767067	7025	32.4	NA	11320	1779	14034	8.2	23.2	16	140	124
2006	22.3	841314	7137	32.0	NA	11668	1856	14492	8.3	22.1	16	140	124
2007	22.9	922748	7533	32.9	NA	12038	2043	14373	8.9	22.1	17	136	119
2008	23.5	942000	7309	31.0	NA	11214	1938	14531	8.2	20.6	17	147	130
2009													
2010													

R1=injury crashes (n) per 100,000 population

R2= injury Crashes per 100 million vehicle -Km

R3=persons Killed in road crashes per 100,000 population

R4= Fatality rate Persons Killed per 10,000 registered vehicles

Motorization Level=motor vehicles per 1000 population

na= insufficient data computations

Figures 4.10 present a relationship between injury crashes and vehicle population. The number of vehicles in the year correlates even though weakly with the number of injury Crashes ($R^2=0.473$).

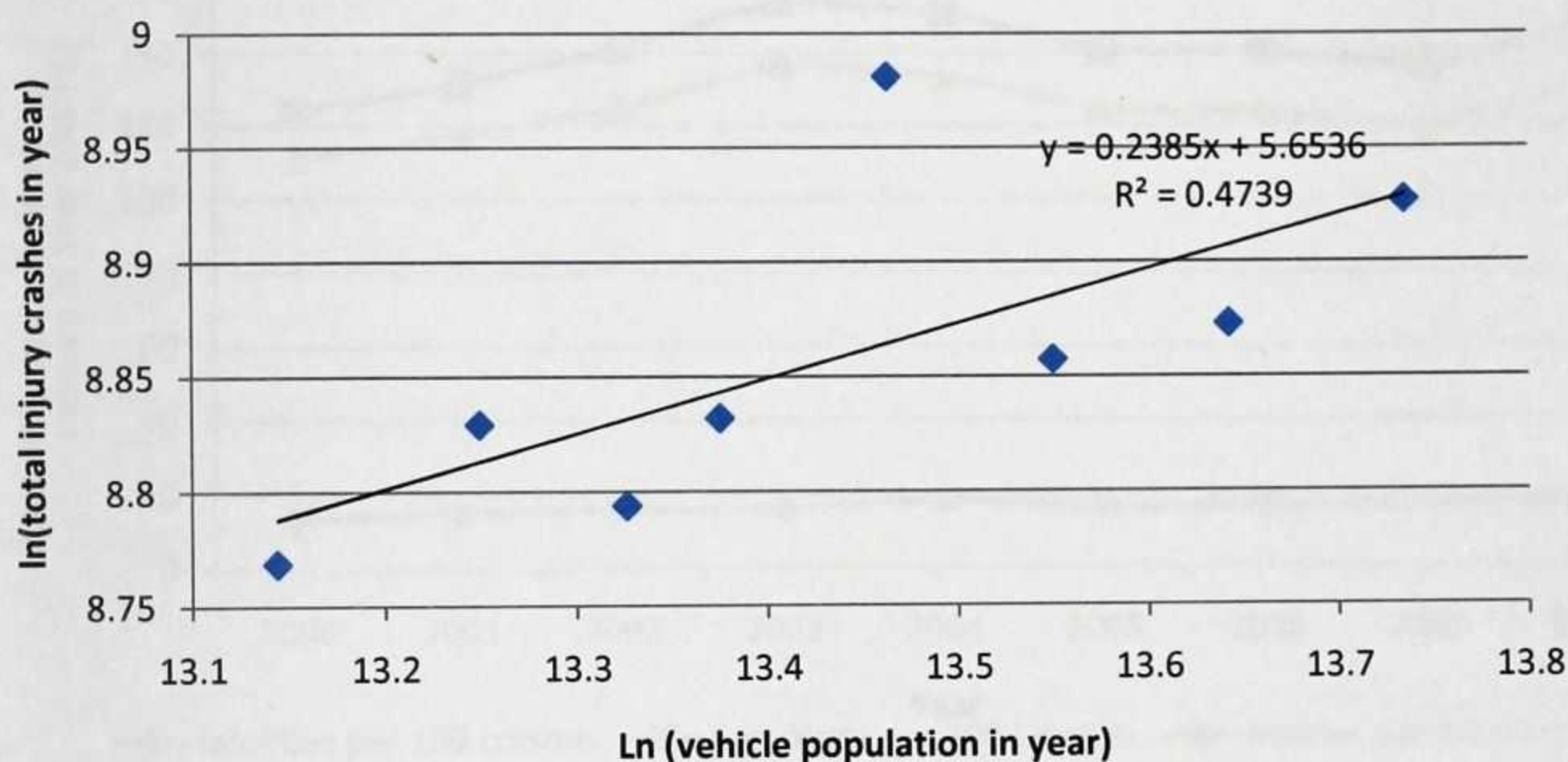


Fig. 4.10 Injury crashes versus vehicle population

Only 47% of the injury crashes are explained by the vehicle population. Injury crashes result from collision between vehicles and other road users or the environment. When injury crashes occur the speeds of the colliding vehicles are important variables which influence the injury level and casualty numbers. Also the presence of a high proportion of pedestrian crashes ($>50\%$) in the data may account for the unexplained 53%. Even after removing the outliers, the correlation did not improve much for the same reasons provided above. We can conclude that the models to be developed for predicting injury

crashes ought to have variables that relate to pedestrian exposure either as main predictor variables or explanatory variables.

Figure 4.11 presents casualty indices per 100 crashes for the period 2000- 2008.

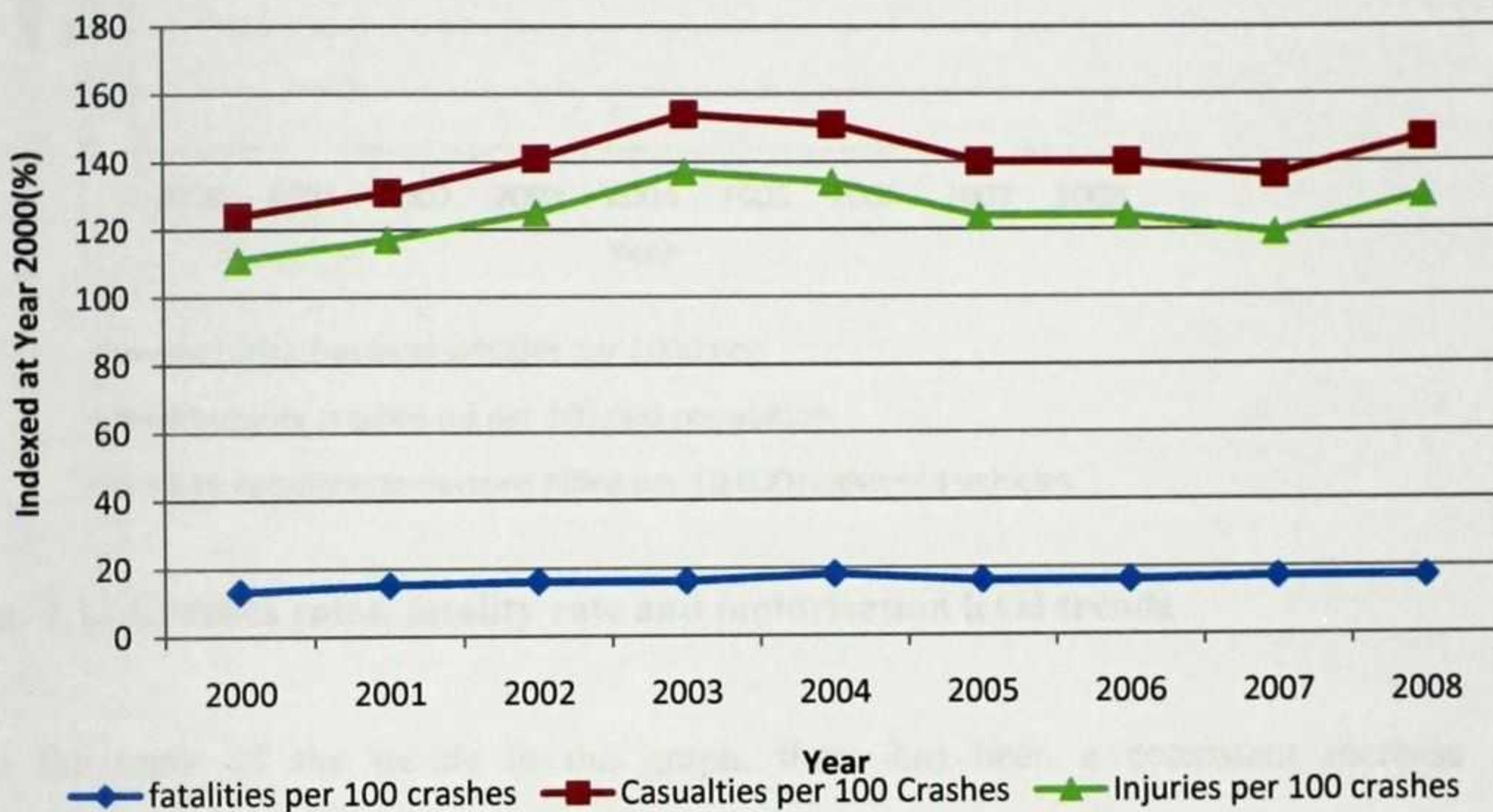


Fig. 4.11 Casualty indices per 100 crashes

From the figure, injuries, casualty and fatalities per 100 crashes increased averagely by over 10% annually from 2000 till 2004. All indices declined from 2005 to 2008 by an average of 14 - 29% annually. Figure 4.12 shows trends in motorisation levels and indices on injury and fatality rates.

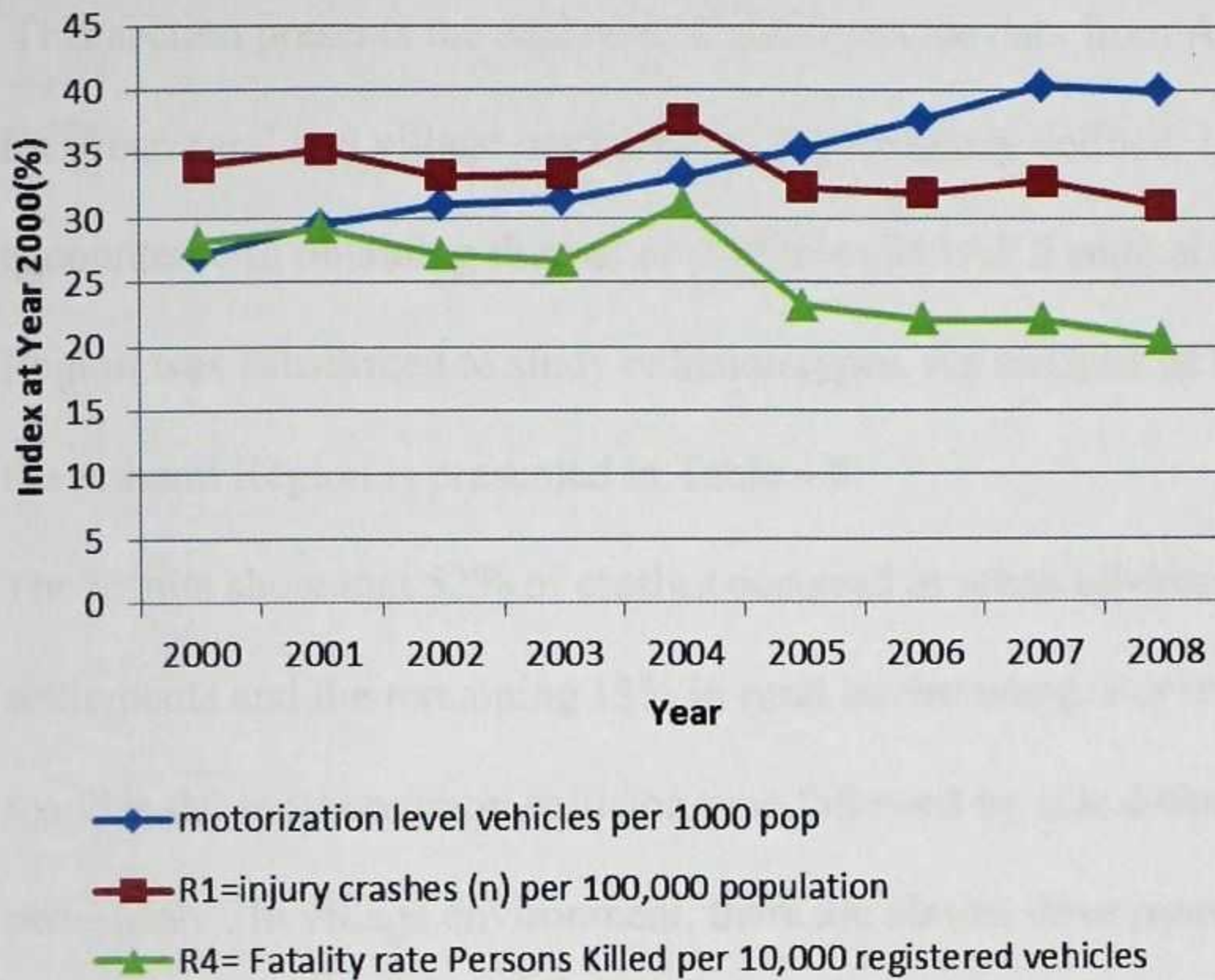


Fig. 4.12 Crashes rates, fatality rate and motorisation level trends

On the basis of the trends in the graph, there has been a consistent increase in motorization level from 27 to 40 vehicles per 1000 population. This figure is likely to be an understimation as there are several motorcycles, bicycles and even motor vehicles that are used on the network which are not in the DVLA database for registered vehicles. For the data being analysed, the number of persons killed peaked in 2004 and since then fatalities have seen a downward trend up to 2007. It is important to realise that this trend occurred within the decade when the NRSC implemented two five- year programmes to reduce fatalities and injuries on Ghanaian roads. The trend so far indicates a stabilisation of the situation rather than a period of consistent reductions of casualty indices. Fatality rate has gradually reduced since 2000.

4.8 Collision Types and Road Environment

This section presents the analyses of collision type data from Ashanti Region of Ghana for urban rural and village environment as previously defined. Due to difficulty encountered in obtaining this set of data from MAAP 5 suite at BRRI, that for Ashanti Region was substituted to study collision types. An analysis of 9439 injury crashes in the Ashanti Region is presented in Table 4.8.

The results show that 52% of crashes occurred in urban environments, 35% in village settlements and the remaining 13% in rural environment. For rural sections, "ran off the road" is the most common collision type followed by side swipe and then "hit pedestrian". In village environment, there are almost three times as many crashes with "hit pedestrian" being almost ten times that for rural environment and "ran off the road", "rear end" and "head on" collisions all being more than twice the numbers in the rural environment. For urban environment the situation is similar to village settlement but the hit pedestrian crashes are almost thirteen times that for the rural sections. Almost 50% of all pedestrian crashes occur on urban sections. Between urban and village sections, urban sections have more crashes but the proportion that result in fatalities is more in village environment due to higher speeds on trunk roads which traverse village settlements.

Table 4.8 Crashes in different road environment in Ashanti

Collision Type	Rural Environment			Village (Non-Urban) Environment			Urban Environment			Total All Crashes
	Fatal	Injury	All Crashes	Fatal	Injury	All Crashes	Fatal	Injury	All Crashes	
Head On	34%	52%	89	36%	46%	249	10%	61%	222	560
Rear End	16%	38%	87	11%	44%	362	4%	33%	722	1171
Right Angle	23%	38%	13	11%	64%	183	5%	45%	628	824
Side Swipe	10%	58%	120	9%	50%	363	3%	36%	560	1043
Ran Off Road	17%	66%	340	19%	61%	570	6%	45%	292	1202
Hit Object On Road	25%	75%	12	14%	55%	29	4%	60%	90	131
Hit Object Off Road	22%	61%	23	15%	58%	91	4%	35%	178	292
Hit Parked Vehicle	44%	44%	34	23%	42%	83	7%	32%	139	256
Hit Pedestrian	63%	37%	104	37%	63%	1198	19%	80%	1412	2714
Animal	22%	52%	67	5%	32%	19	23%	76%	396	482
Other	28%	53%	386	30%	41%	162	12%	46%	216	764
Total	26%	54%	1275	25%	56%	3309	11%	55%	4855	9439

Fig 4.13 show collision types for crashes categorised into Pedestrian, head on, rear end, hit pedestrian, hit object off road, hit parked vehicle, side swipe, right angle, ran off road, hit object off road. These are the standard collision types in the MAAP 5 suite.



Fig. 4.13 Collision types for injury crashes

For the purposes of modelling it is prudent to aggregate collision types that may be similar in order to ensure few zero crashes on sections during analysis. Also it is useful to aggregate in order to formulate few models that can predict the main collision type categories. The collision types were aggregated as follows: *Two vehicle crashes* comprise head on, rear end, side swipe, right angled and hit parked vehicle. *Single vehicle crashes* also include hit object off road and ran off road. Overall 37% of all crashes involve hit pedestrian (pedestrian), 42% involve two vehicles and 17% are single vehicle crashes. Figure 4.14 presents the results of the aggregation of the collision types.

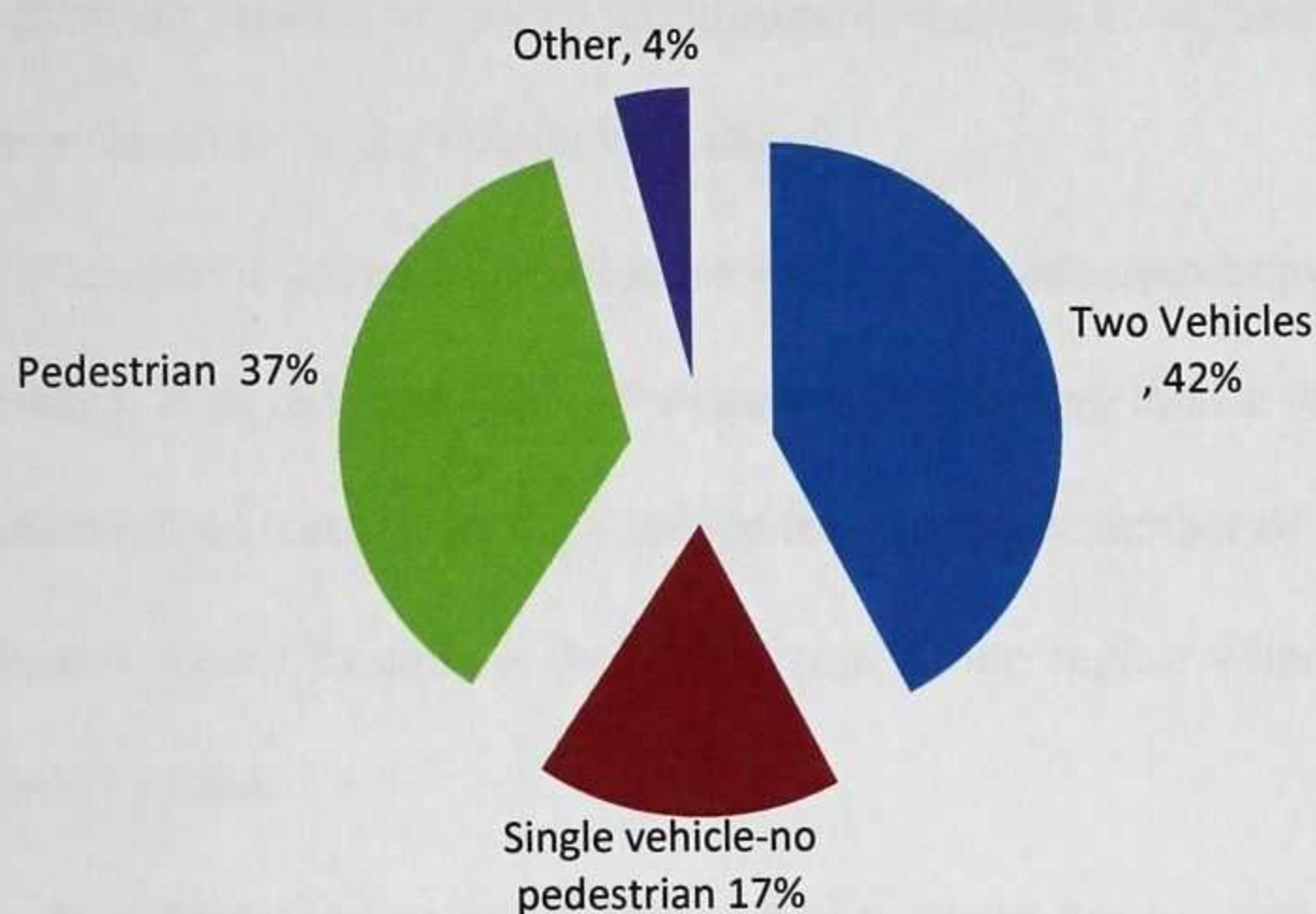


Fig. 4.14 Aggregated collision types for injury crashes modelling

For rural environments 40% are single vehicle crashes, 27% involve two vehicles and 15% involve pedestrians. It is worthy to note that the proportions of single vehicle and two vehicle crashes in very high and pedestrian crashes are low in rural environments. Two vehicle crashes has high inclusion of side swipe and head on collisions which are indicative of speeding and probably poor overtaking manoeuvres leading to crashes.

Summary

- There is a rapid growth in vehicle population averaging about 10% per annum over the last decade. However, this has not resulted in a proportional growth in number of injury crashes
- There is a linear correlation between the number of registered vehicles and the number of injury crashes on a network
- Children of school going age 6-16 years are most vulnerable in village environment and are twice more likely to be killed than their counterparts in urban areas.

- Pedestrian crashes are more predominant in urban compared to village although there are more fatalities in the village casualties.
- The length of paved trunk road network in an area correlates linearly with the number of crashes. If paved roads are associated with speeding then it can be inferred that increasing the length of roads with high speeds increases the number of injury crashes.
- Greater Accra Region is the most crash prone region whereas Ashanti Region is more fatality prone.
- Crashes involving pickups, cars and mini buses have increased only marginally over the period. Bicycle involvement in injury crashes increased to a peak in 2004 but has since seen a nose dive at a rapid rate. This could be due to the decline in the patronage of bicycles for motorbikes as the economy improves. Heavy goods vehicle involvement in crashes has increased by 80% compared to 2000 values. This is alarming since by their sheer size, any crash involving HGV tend be very serious or fatal.
- The population of vehicles operating on the network is a risk factor for crashes. Also the length of paved trunk roads network in a region is a risk factor for injury crashes and fatalities.
- Traffic volume, pedestrian volume or presence and speeds are major indicators of the occurrence of pedestrian crashes

CHAPTER 5 ANALYSIS OF MODELLING DATA

5.1 Preliminary analysis of variables

The road network for Kumasi was divided into 91 segments for data collection. Road Segments have same traffic flow but cross sectional characteristics may differ. A statistical analysis of the variables for means, standard deviation and maximum and minimum values are indicated in Table 5.1. For categorical variable indicating the presence or otherwise e.g. kerb presence, no such numbers were found. The picture guide and variable names are defined in appendix D.

Table 5.1 Summary statistics of modelling variables

Crash Data						
Variable Description	Notation	Observations	Mean	Std. Dev.	Min	Max
Total Injury Crashes	TOT_INJ_ACC	91	19.8	26.9	0	152
Hit Pedestrian Crash	HITPED_ACC	91	5.5	8.1	0	44
Traffic Data						
Pedestrian Volume	PEDVOL_4HRS	91	1481.1	274.8	1200	2158
Total Flow rate	TOTFLOW_Q	91	0.3	0.3	0	1.4
Average Daily Traffic	WAY_AADT	91	23795.6	8643.0	11400	44100
Average speed	AVE_SPEED	91	14.1	8.3	2	37
Road inventory						
Variable Description	Notation	Observations	Mean	Std. Dev.	Min	Max
Length of Section	LENGTH_KM	91	0.8	0.5	0.1	2.75
Number of lanes	NUMB_LANES	91	-	-	0	2
Width of sidewalk	SWALK_WIDTH	91	1.3	1.1	0	3.5
Width of Shoulder	SHOULDR_WDTH	91	1.0	1.1	0	3.2
Roadway width	ROAD_WIDTH	91	9.3	3.1	6	15.2
Number of Pedestrian Crossing points	PEDX_NUMB	91	-	-	0	11
Number of road Signs	ROADSIGNS_NUMB	91	-	-	0	31
other Variables						
	Variable	Observations	Mean	Std. Dev.	Min	Max
Number of Bus stops	BUSSTOP_NUMB	91	-	-	0	6
Number of Accesses	ACCESS_PUB	91	-	-	0	15
Access Density	ACCESS_PUB~Y	91	5.7	5.3	0	30

The means and standard deviation give an indication that the total injury crashes and pedestrian crashes are over dispersed because the mean is more than the variance. A similar assessment for two vehicle and single vehicle (roll over) crashes showed similar results. Figure 5.1 presents a distribution of the injury crashes over the five year period on sections included in the model database. The data set does not have many sections with zero crashes; almost 45% of the sections had more than 10 injury crashes, and 13% had zero crashes in 5yrs. The rest had between two (2) and ten (10) crashes. The average number of crashes per site was 20 for five years.

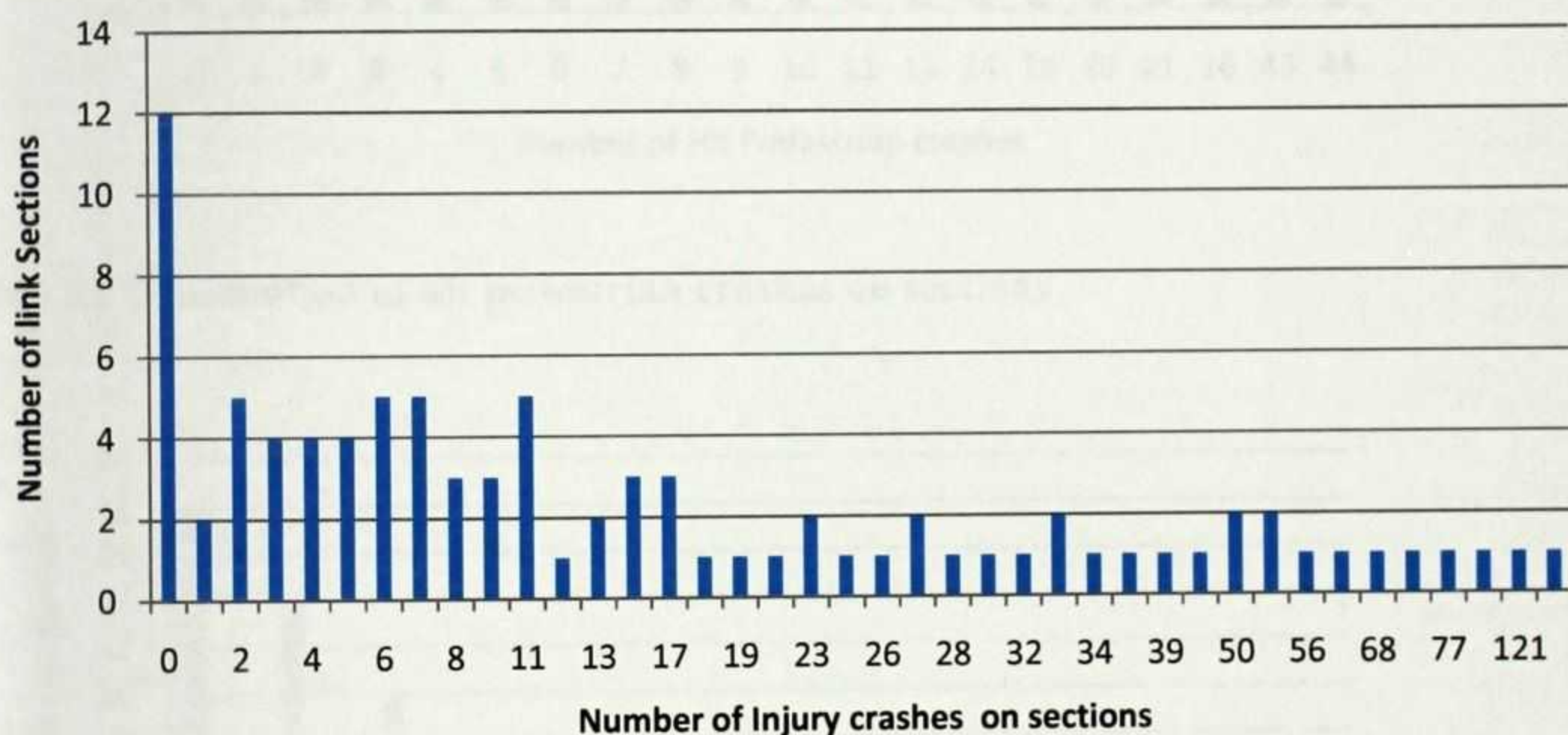


Fig. 5.1 Distribution of injury crashes on link sections

The distribution of pedestrian crashes on sections is shown in Fig. 5.2. For link sections, 72% had up to 5 crashes in 5 years. The numbers of sections with zero crashes were 24%. This shows that most of the sections being modelled had at least one pedestrian crash. About 28% of the sections had between 2 and 4 pedestrian crash which involved injury. A few sections (18%) had

between 10 and 44 link pedestrian crashes in 5 years. The average number of pedestrian crash per site was estimated as 6.

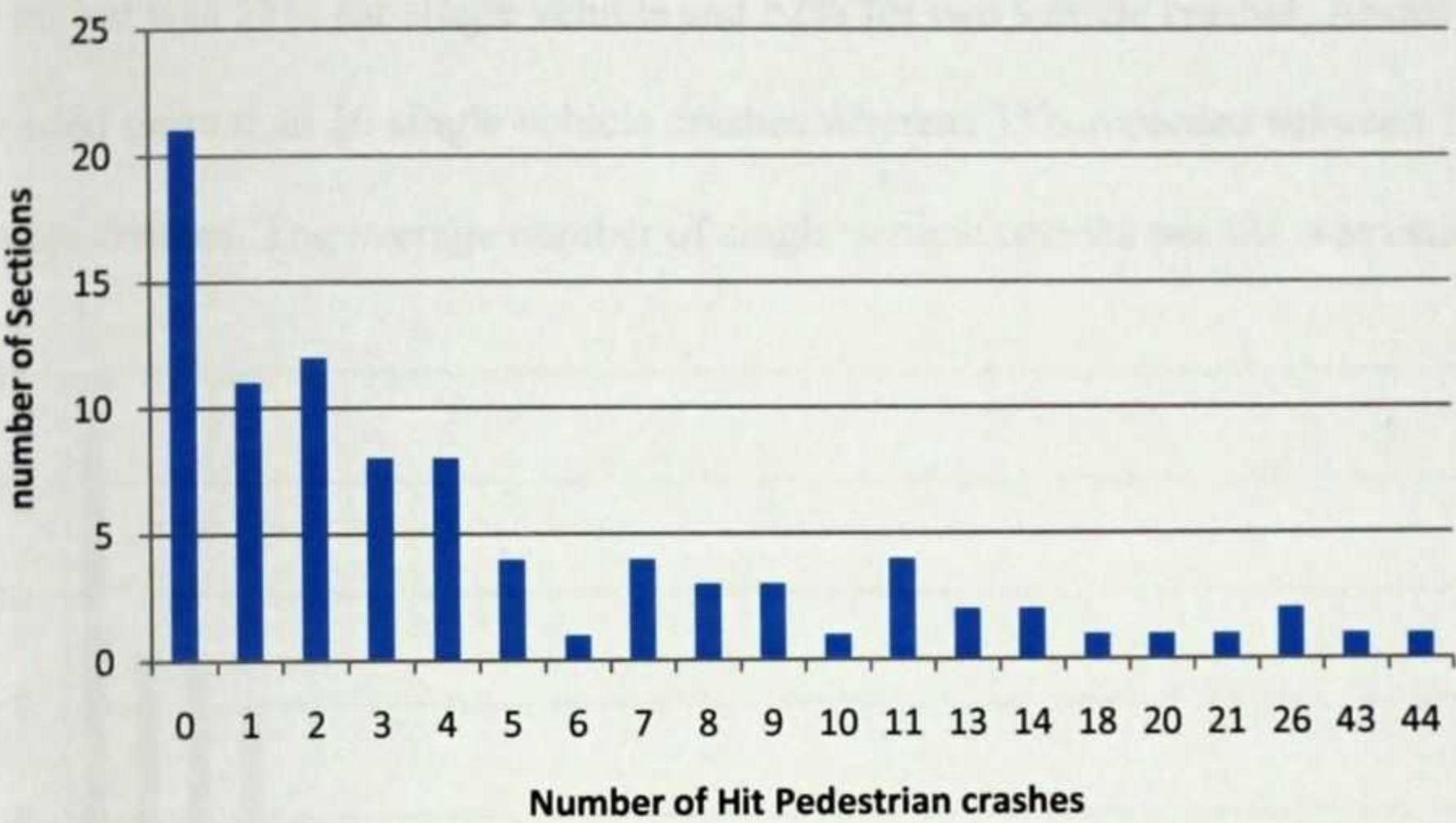


Fig. 5.2 Distribution of hit pedestrian crashes on sections

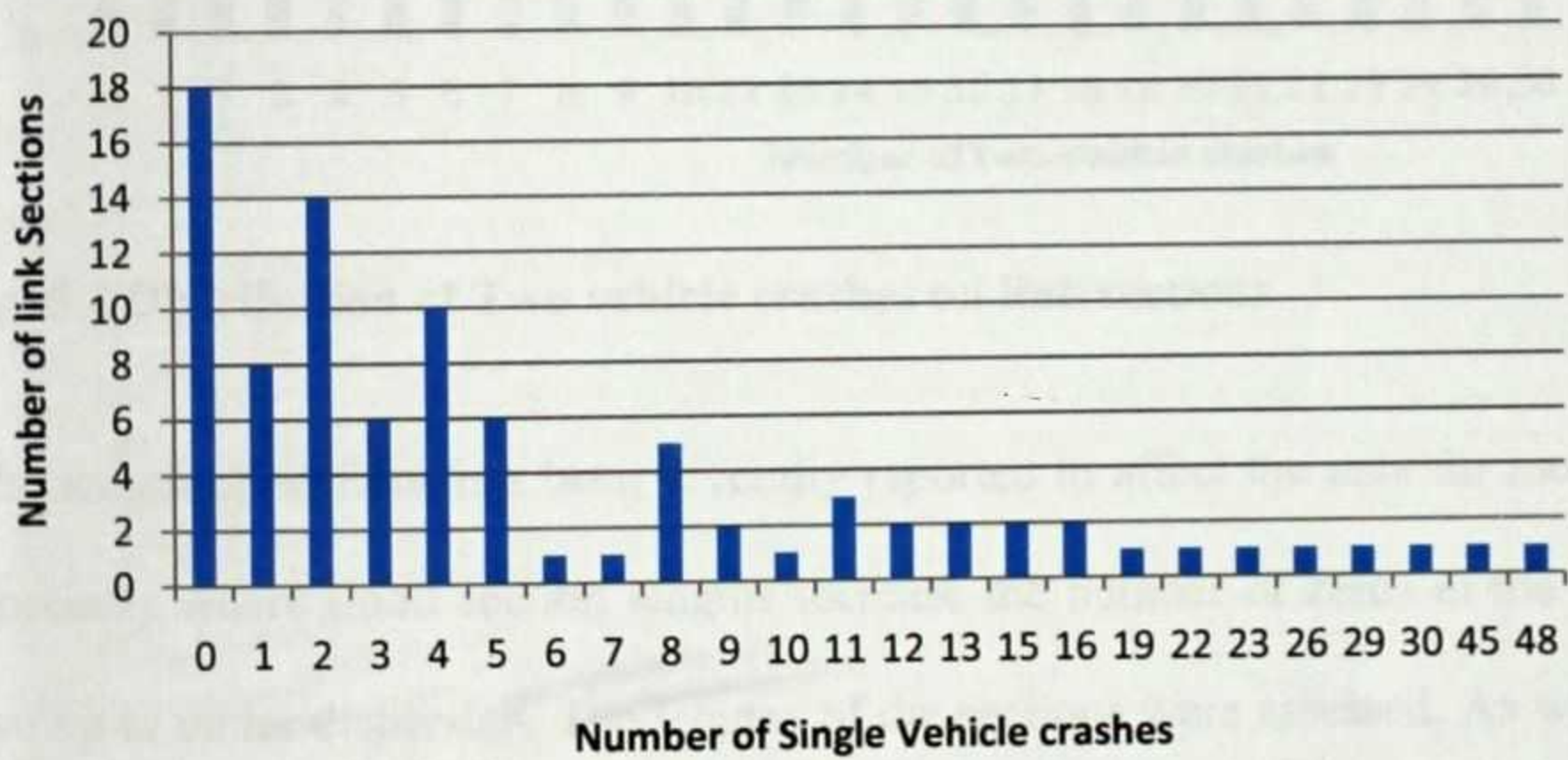


Fig. 5.3 Distribution of Single Vehicle crashes on sections

Figure 5.3 and Figure 5.4 present the distribution for single vehicle crashes and two vehicle crashes respectively. The single vehicle comprise those for which only one vehicle was involved in a crash, rolled over or hit some other object on the road; it does not include hit pedestrian

crashes. About 20% had no single vehicle crashes (Figure 5.3), whereas 14% had no two-vehicle crashes (Figure 5.4). The proportion of sections which recorded between 1 and 5 crashes within the period was 58% for single vehicle and 52% for two vehicle crashes. About 21% of links recorded more than 10 single vehicle crashes whereas 33% recorded between 11 and 88 two vehicle crashes. The average number of single vehicle crashes per site was estimated as one (1).

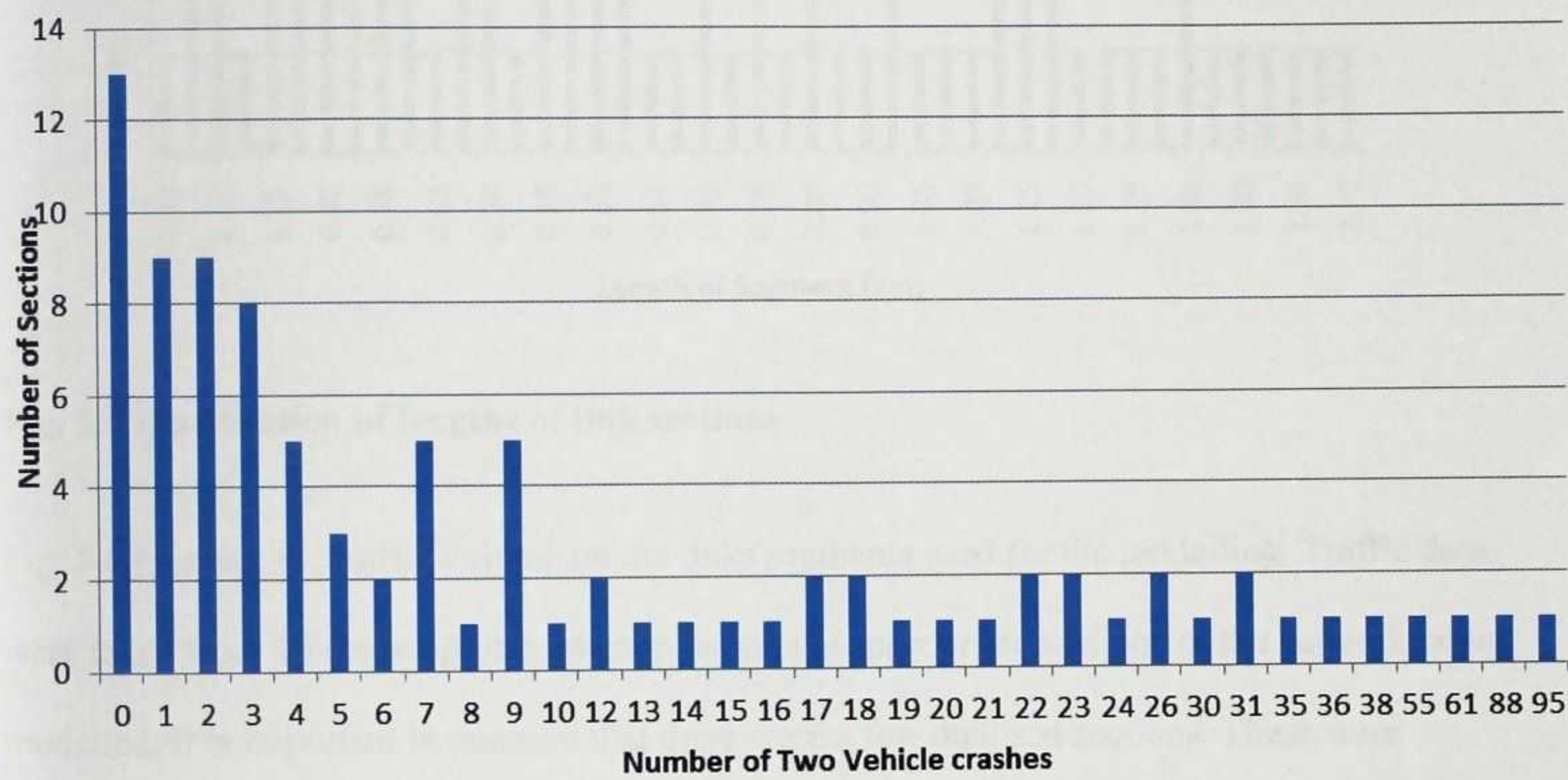


Fig. 5.4 Distribution of Two vehicle crashes on link sections

The length of sections has been severally reported to affect the data for modelling. This is true especially where small section lengths increase the number of zeros in the data set, sometimes leading to under dispersion. The lengths of the sections were assessed. As was seen earlier, only 13% of sections had zero crashes. Figure 5.5 presents the distribution of segments lengths in the data. Length of sections varied from 100 meters to 2750 meters with only some 25% having lengths of 400m. It was considered adequate to model the data without aggregating them into longer lengths because the distribution reflects what is commonly found on road networks in urban areas in Ghana.

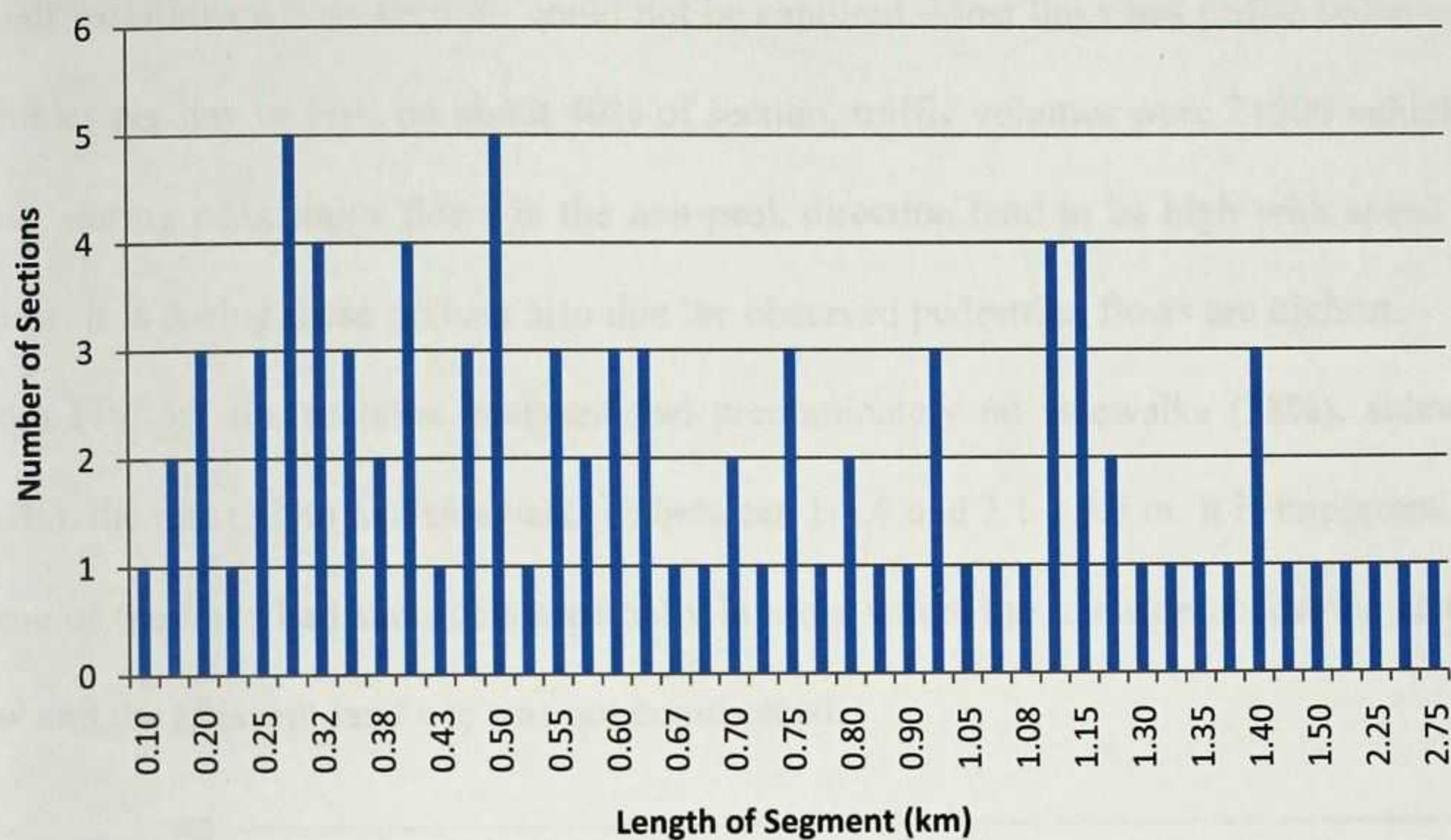


Fig. 5.5 Distribution of lengths of link sections

Fig. 5.6 presents the traffic volume on the links segments used for the modelling. Traffic data were taken from 12 census points and applied on the appropriate sections of the network being modelled. It is important to mention that there were a few dualised sections. These were considered as separate two lane roadways for each direction.

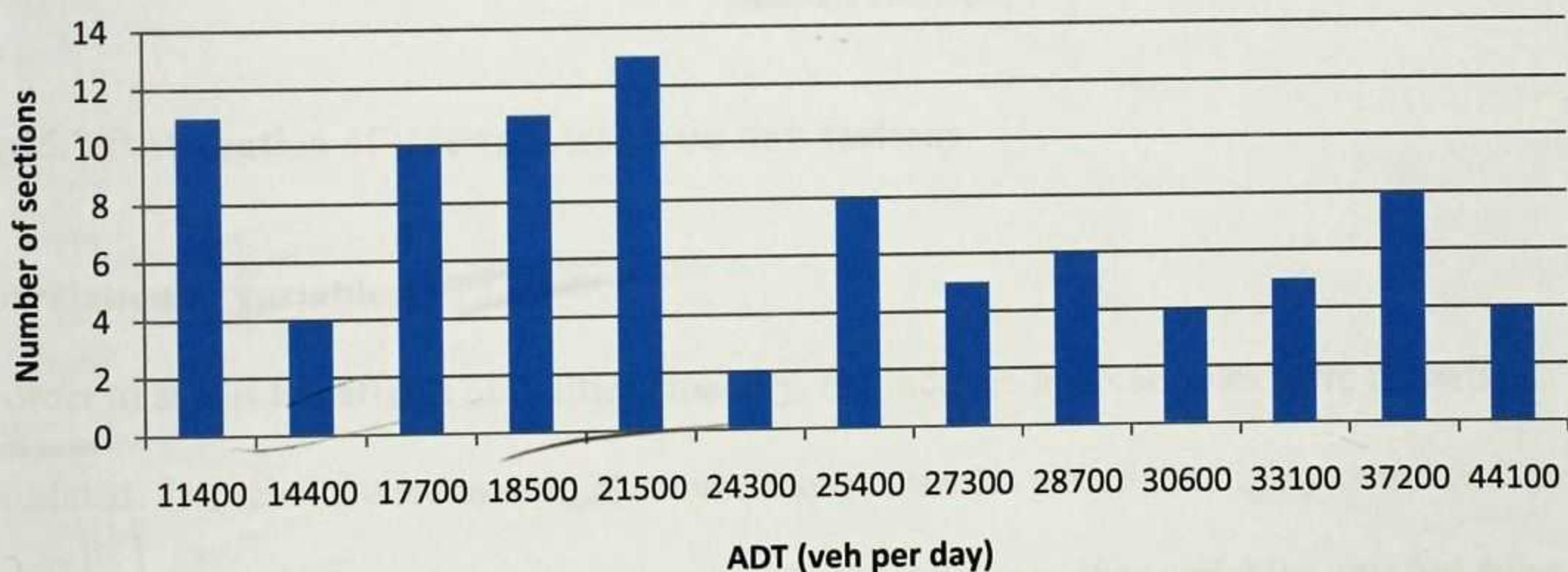


Fig. 5.6 Distribution of Traffic flow on link sections

Small variations across sections could not be captured. Most links had traffic volumes of 30,000 vehicles per day or less; on about 40% of section, traffic volumes were 21500 vehicles per day. Also, during peak times flows in the non-peak direction tend to be high with speed of over 50 km/hr. It is during these periods also that the observed pedestrian flows are highest.

From Fig. 5.7 the sections analysed had predominately no sidewalks (38%), sidewalk of 2m (30%), the rest (32%) had sidewalks of between 1-1.9 and 2.1 – 3.5 m. It is important to note that some of the links had shoulders especially in areas where the roadside pedestrian activities were low and the adjacent land use was not commercial.

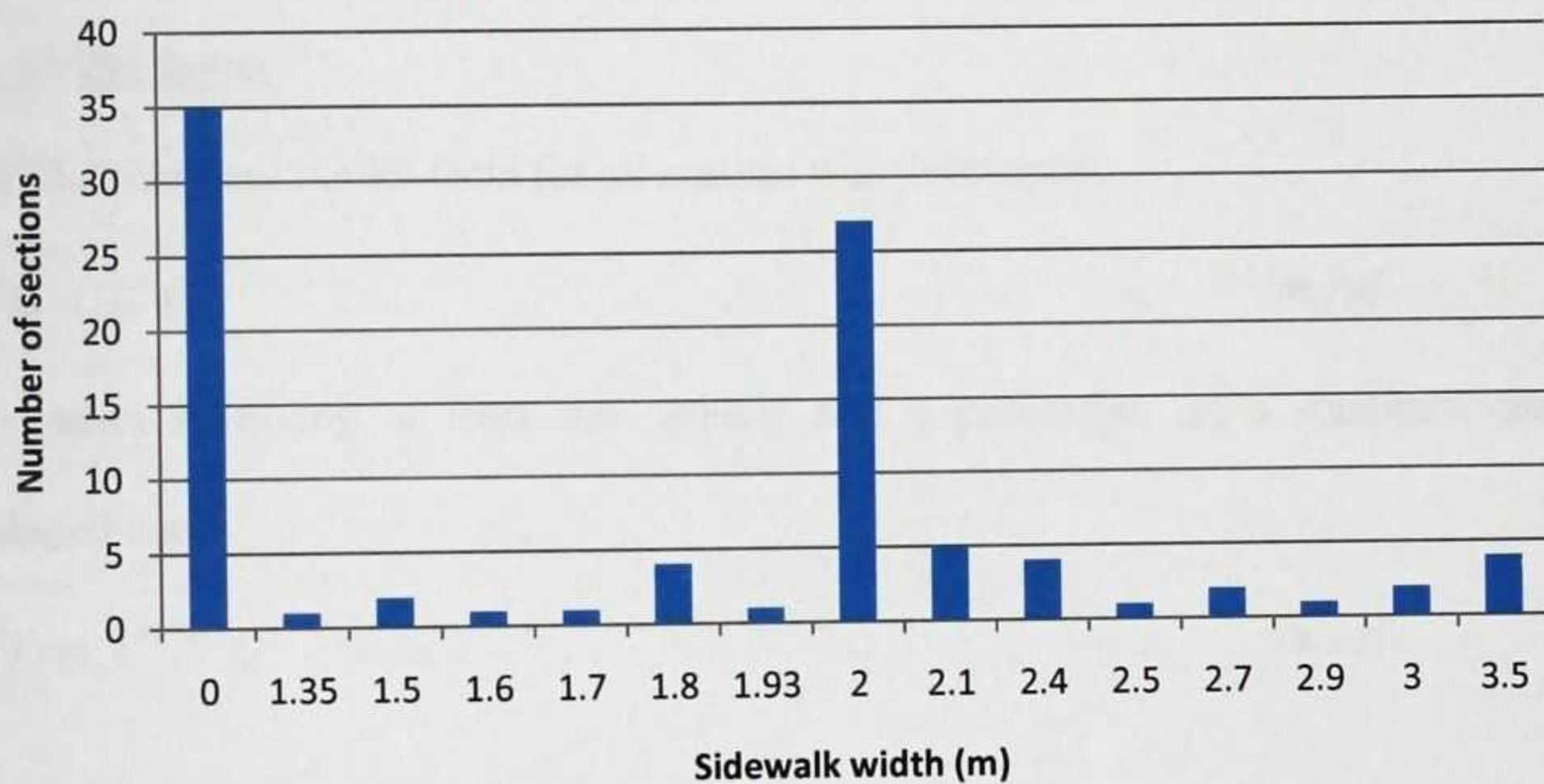


Fig. 5.7 Distribution of sidewalk width on link sections

Correlation of variables

In order to assess the effects of multicollinearity, the independent variables were pairwise correlated. The results were used to eliminate those variables which are highly correlated and whose inclusion in the model reduces the significance of some other variables, this has been discussed in Section 3.6.

CHAPTER 6: MODEL DEVELOPMENT

6.1 Functional Forms of Models

Two types of model forms were investigated for each crash type; the "Base" or "Core" model which is coarse and contains only the exposure variables Length, and Traffic Volume. The exposure variables must be present for a crash to occur; the Comprehensive model contains both exposure variables and explanatory variables. For the modelling forms used were as follows. In the case of Pedestrian crashes, a pedestrian variable was also introduced as an additional exposure variable the absence of which would mean the absence of crashes.

Base Model forms

The following base model form for all crashes was developed:

$$E(Y) = a_o L^{a1} Q^{a2} \dots \dots \dots \dots \dots (6.1a)$$

For crashes involving at least one vehicle and a pedestrian on a roadway, the model developed was

$$E(Y) = a_o L^{a1} P^{b1} Q^{a2} \dots \dots \dots \dots \dots (6.1b)$$

Full Model forms

The general forms of the Full Model for the above model types were respectively

$$E(Y) = a_o L^{a1} Q^{a2} \exp \sum c_j x_j \dots \dots \dots \dots \dots (6.2a)$$

$$E(Y) = a_o L^{a1} P^{b1} Q^{a2} \exp \sum c_j x_j \dots \dots \dots \dots \dots (6.2b)$$

Where: $E(Y)$ = mean predicted crash frequency,

L = section length (km),

Q = ADT (per day),

P = Pedestrian traffic volume

x_j = is any variable additional to L and Q , and

Exp = exponential function, $e = 2.7183$

a_0, a_1, a_2, b_1, c_j = are the model parameters

Equations (6.1a) and (6.1b) and equations (6.2a) and (6.2b) are transformed into the prediction mode using a log-link function as follows:

Base Model

$$\ln[E(Y)] = \ln(a_0) + a_1 \ln(L) + a_2 \ln(Q) \quad \dots \quad \dots \quad (6.3)$$

$$\ln[E(Y)] = \ln(a_0) + a_1 \ln(L) + a_2 \ln(Q) + b_1 \ln(P) \quad \dots \quad \dots \quad (6.4)$$

Full Model

$$\ln[E(Y)] = \ln(a_0) + a_1 \ln(L) + a_2 \ln(Q) + \sum b_j x_j \quad \dots \quad \dots \quad (6.5)$$

$$\ln[E(Y)] = \ln(a_0) + a_1 \ln(L) + a_2 \ln(Q) + b_1 \ln(P) + \sum c_j x_j \quad \dots \quad \dots \quad (6.6)$$

6.2 Modelling Procedure

The mean and variance for the crash data presented were 19.76 and 723.61 respectively which indicate that the data set was over-dispersed since the variance is greater than the mean. Initial modelling using Poisson error structure also showed that the estimated dispersion parameter (Φ) defined as:

$$\Phi = \frac{\text{Pearson } \chi^2}{(N - p)} \quad \dots \quad \dots \quad (6.7)$$

where N is the total number of sections and p is the number of parameters in the model was far greater than one (1) indicating that the data set was over-dispersed (McCullagh and Nelder (1989). That means Poisson distribution is not capable of explaining the true distribution underlying the crash frequency. Similar tests were performed for Pedestrian crashes and Two vehicle crashes data. All were found to be over dispersed and none had low sample means.

The Generalised Linear Model (GLM) was used to estimate the model coefficients using the STATA software package and assuming a Negative Binomial error structure, all consistent with earlier research works in developing these models. By specifying the dependent variable, the explanatory variables, the error structure (in this case the Negative Binomial) and the link function (in this case log), the model is fitted. Model parameters (coefficients) were estimated using maximum likelihood approach. The procedure which was adopted in the model development was the forward stepwise regression procedure in which the variables were added to the model one by one.

Robust standard errors were specified in STATA in order to deal with outliers. Initially, exposure variables were entered and the model coefficients assessed along with scaled deviance and scaled Pearson. The Akaike Information criterion (AIC) was also determined for the null model. Exposure variables were subsequently entered one at a time in a linear format and the significance of the model coefficients and the impact on scaled deviance and AIC determined. Variables that were not significant at 5% level were removed. Also variables which correlated with previously retained variables which altered the significance of the coefficients were assessed so that they could be removed for multicollinearity effects.

All 25 variables were assessed based on the impact on scaled deviance minimisation, and AIC for nested models. Final models were also examined for the engineering implication of the variables and their respective signs.

6.3 Criteria for selection variables in final models

The model with the lowest AIC and scaled deviance were preferred at every stage of the modelling, however two other criteria were used to check the correctness of the model;

- 1) Engineering judgment; variables selected into the model must have coefficients and signs that make intuitive sense and their contribution to the model can be explained logically. Throughout the modelling in this study care was taken to select candidate models to ensure they are meaningful and have the correct signs.
- 2) Significance (95%) Another criterion which was important for variable selection was the significance of the variables in the model. Models which included the exposure variables (must be in the model) and significant explanatory variables were chosen. In some cases however, a trade-off was made between engineering judgments, AIC to include some other important causal variables which were not significant at 95% but improved upon the AIC and ensured non zero coefficients at 90% CI.

Models with more explanatory variables as categorical variables which improved on model AIC and maintained the meaningful signs of all variables were also chosen.

6.3.1 Variables Included in the Model

Although a large number of variables were collected and considered for inclusion in the 'comprehensive' model development, only variables with significant estimated parameter

coefficients (p-values less than 5%) were maintained in the model. This method is similar to the one used by Vogt and Bared (1998).

The variables shown in Table 6.1 encompass those which entered the three models developed. Categorical variables were included at a two factor level. For instance side friction was initially assessed at two levels (Present or absent).

Table 6.1 Description of Variables and Symbols Used for Crash Prediction Models

No.	Variable Name	Description	Variable Type	Symbol
1	Volume	Average Daily Traffic	Continuous	WAY_AADT
2	Pedvolume	Pedestrian Volume	Continuous	PEDVOL_4HRS
3	Lengthkm	Length (km)	Continuous	LENGTH_KM
4	RoadWidth	Roadway width in (m)	Continuous	ROAD_WIDTH
5	Access Public	Number of side accesses	Continuous	ACCESS_PUB
6	Shoulder width	Width of shoulder	Continuous	SHOULDR_WDTH
7	KerbPresc	Presence of Kerbs	Categorical (1 - present, 0 - absent)	KERB_PRESC
8	Side Friction	Parked vehicles and roadside activity impeding traffic	Categorical (1 - present, 0 – absent)	SIDE_FRICTION
9	Pedestrian Crossing Presence	Presence of Pedestrian crossing points	Categorical, (1 - present, 0 –absent)	PEDX_PRESC
10	Sidewalk Presence	Presence of Sidewalk	Categorical (1 - present, 0 – absent)	SWALK_PRESC

Other variables which were not found to be significant at 95% CI were excluded or dropped from the final model. In a few cases some variables which were significant at 90% CI but improved on the AIC and scaled deviance were selected as alternative models for final analysis especially when the presence of the factor made more engineering sense to explain road environment location effects.

CHAPTER 7: MODEL RESULTS AND INTERPRETATION

7.1 Introduction

This chapter presents the results of the modelling of crashes on two lane urban roadways. Two kinds of models are presented, for Total crashes and Two vehicle crashes. In each case a base model with exposure variables and alternative comprehensive models with more explanatory variables are presented. Final proposed models for Total injury crashes, Two vehicle crashes are then compared and recommended. The effects of the model exposure and explanatory variables on road safety are also discussed. The models are tested with some observed crash data and road and traffic data. Appendix F presents some tables on parameter estimation from STATA and various models' explored during the modelling exercise.

7.2 Total Injury Crashes

7.2.1 'Base' Model

In the base model the key exposure variables are inserted and parameter estimations for the log-linear equation is made using Negative Binomial error structure. Prior to this the data was tested for Poisson error structure and the deviance and Pearson Chi-square statistics evaluated but these were found to be high. Also, due to the inequality of the mean and the variance of the data, Negative Binomial was preferred. After trial of various model forms, the base model developed is as follows:

$$E(Y) = 1.16 \times 10^{-5} \times LENGTH_KM^{0.49} \times (TWOWAY_ADT)^{1.27} \dots \dots (7.1)$$

where: $E(Y)$ = expected crashes along the road segment per year,
 $LENGTH_KM$ = length (km) of road segment and
 $TWOWAY_ADT$ = Average Daily Traffic (ADT)

The goodness-of-fit statistics for the model shows that the model fits the data reasonably well with the data. The Pearson Chi-square and deviance statistics divided by its degrees of freedom were estimated to be 1.1 and 1.2 respectively as shown in Table 7.1 below.

Table 7.1 Total injury Crashes base model coefficients and parameters

Deviance	=	108.6258929	Scale parameter =	1
Pearson	=	96.59700634	(1/df) Deviance =	1.234385
			(1/df) Pearson =	1.097693
Variance function:	$v(u) = u + (1.0941)u^2$		[Neg. Binomial]	
Link function	: $g(u) = \ln(u)$		[Log]	
Log likelihood	=	-364.8564732	AIC	= 8.084758
			BIC	= -288.3297

tot_inj_acc	Coef.	OIM Std. Err.	z	P> z	[95% Conf. Interval]	
lnlength_km	.4881389	.1679643	2.91	0.004	.1589349	.8173428
ln2wayaad	1.267355	.272232	4.66	0.000	.7337902	1.80092
_cons	-9.576786	2.774195	-3.45	0.001	-15.01411	-4.139463

From the table, both the Average Daily Traffic and section lengths were significant at 95% CI ($p < 0.05$). Both had positive estimated model parameters in the base model. This indicates that the crash frequency increases with increase in the traffic flow or section length whilst the other variables are held constant. The exponent on section length was 0.49. This also means that the more distance travelled, the higher the propensity or likelihood of the occurrence of a crash. The exponent on traffic flow (ADT) was estimated to be 1.27 which shows that traffic volume varies

almost linearly with crash occurrence. This is in consonance with some studies (Dissanayake and Ratnayake, 2006; Qin *et al.*, 2004; Vogt and Bared, 1998) emphasizing the importance of traffic flow as a major determinant of road traffic crashes.

7.2.2 Comprehensive Model for Total Injury Crashes

Several nested models were developed for predicting crashes based on the dataset. The model coefficients were checked for significance and for any nested models the AIC and scaled deviances were also assessed. Three alternative models were finally proposed due to the slight differences in the explanatory variables. The models are presented in Table 7.2.

Table 7.2 Alternative models for Total Injury crashes

VARIABLE	Model 1		Model 2		Model 3	
	Coefficient	t- value	Coefficient	t- value	coefficient	t- value
CONSTANT	-8.363	-3.31	-8.216	-3.29	-7.115	-3.07
LENGTH_KM	0.536	3.17	0.496	3.03	0.420	2.54
TWOWAY_AADT	1.032	4.12	1.014	4.09	0.934	4.03
AVE_SPEED	0.025	2.17	0.029	2.54		
SWALK_WIDTH			0.414	4.05	0.333	3.22
SWALK_PRESC	0.983	4.05				
PEDX_NUMB					0.102	3.03
AIC - Value	7.946		7.940		7.899	
Log Likelihood	-356		-356		-354.42	
Scaled Deviance	1.2685		1.272		1.274	
Scaled Pearson	1.10296		1.041		0.874	

In Model 1, the presence of sidewalk and average speed of travel are the important explanatory variables of injury crashes. Roads with sidewalk have higher injury crashes compared to those without. This may be due to the effects of endogenous variables as explained by Washington et al. (2010). From the data set roads with sidewalk simultaneously had higher pedestrian volumes, higher speeds and crash rates. Model 2 also had average speed as significant variable for

predicting crashes along with sidewalk width. Since sidewalk presence and width correlates with pedestrian volumes and presence this is indicative of how pedestrian presence in the road corridor influences crashes. The coefficients associated with the variables Sidewalk width, Sidewalk presence and Numbers of pedestrian points are all greater than that associated with the variable average speed which also is indicative of the contribution of pedestrian data compared with the average speed of travel. High pedestrian volumes usually result in low speeds and therefore lower injury crashes.

Model 3 does not have average speed as a significant variable at 5% significance level. The width of sidewalk and number of pedestrian crossing points are the significant explanatory variables. It has the lowest AIC and could be the best model which approximates the truth.

The models were compared by computing the Akaike weights and estimating the likelihood of each model as the best approximating to the ‘truth’.

The results are presented in Table 7.3.

Table 7.3 Comparison of Alternative models for Total injury crashes using Aikake weights

Model	Number of Variables	AIC	ΔAIC	$\text{Exp} (-0.5 * \Delta_i)$	w_i
Model 3	4	7.899	0	1.000	0.336
Model 2	4	7.940	0,041	0.980	0.329
Model 1	4	7.946	0.006	0.997	0.335
			Sum	2.977	

On the basis of lowest Scaled deviance and Akaike Information Criteria (AIC), Model 3 is the best of the three comprehensive models. In order to quantify the plausibility of each model as being the best approximating, we used the Akaike weights. From Table 7.3, w_i is the weight of evidence that Model i is the best approximating model. We interpret that given the data and the set of candidate models, Model 3 is the best followed by Model 1 and then Model 2 even though all three models are acceptable at 5% significance. However, from engineering judgement perspective Model 1 is better and therefore selected as the final model.

The resulting proposed comprehensive model has been determined to be as follows:

$$E(Y) = 5 \times 10^{-6} \times (LENGTH_KM)^{0.53} \times TWOWAY_ADT^{1.03} \times EXP^{(0.03 AVE_SPEED + 0.98 SWALK_PRESC)}$$

... .. (7.2)

- Where: $E(Y)$ = expected crashes along the road section per year,
- $LENGTH_KM$ = length (km) of road section and
- $TWOWAY_ADT$ = Average Daily Traffic (ADT)
- AVE_SPEED = Average Speed
- $SWALK_PRESC$ = Presence of Sidewalk (1=Yes, 0=No)
- EXP = Exponential function, $e = 2.718282$

7.3 Two vehicle crash models

Two vehicle crashes involve two vehicles without a pedestrian. Two vehicle crashes were aggregated from side swipe, rear end, head on and hit parked vehicle crashes in the data. This was done because it was found out that the collision type data had many zeros and aggregation

improved on the data. Core models were explored by entering ADT and section length as exposure variables.

7.3.1 “Base” model

In order to model Two vehicle crashes, all crashes involving two vehicles were sorted out. The results of STATA are as shown in Table 7.4 below.

Table 7.4 Total injury Crashes base model coefficients and parameters

. glm twovehicleaccident lnlength_km ln2wayaadtt , family(nbinomial ml) link(log)	
Iteration 0:	log likelihood = -323.38209
Iteration 1:	log likelihood = -321.52975
Iteration 2:	log likelihood = -321.52898
Iteration 3:	log likelihood = -321.52898
Generalized linear models	
Optimization	: ML
Deviance	= 106.329967
Pearson	= 96.1499489
Variance function:	v(u) = u+(1.1692)u^2
Link function	: g(u) = ln(u)
Log likelihood	= -321.5289825
No. of obs	= 91
Residual df	= 88
Scale parameter	= 1
(1/df) Deviance	= 1.208295
(1/df) Pearson	= 1.092613
	[Neg. Binomial]
	[Log]
AIC	= 7.132505
BIC	= -290.6257

twovehicle~t	Coef.	OIM Std. Err.	z	P> z	[95% Conf. Interval]	
lnlength_km	.4420859	.1760344	2.51	0.012	.0970647	.787107
ln2wayaadtt	1.2181	.2821113	4.32	0.000	.6651715	1.771027
_cons	-9.592244	2.876289	-3.33	0.001	-15.22967	-3.95482

The resulting ‘base’ model for two vehicle crashes has been determined to be as follows:

$$E(Y) = 1.37 \times 10^{-5} \times \text{LENGTH_KM}^{0.44} \times \text{TWOWAY_ADT}^{1.2} \dots \dots (7.3)$$

where: E(Y) = expected crashes along the road segment per year,

LENGTH_KM= length (km) of road segment and

TWOWAY_ADT = Average Daily Traffic (ADT)

Both exposure variables have positive signs and are significant ($p < 5\%$) indicating that both are good predictors of two vehicle crashes.

7.3.2 Comprehensive Model for Two vehicle Crashes

Due to multicollinearity effects the exponent on the traffic exposure variables changed slightly with the inclusion of other explanatory variables. Several alternative nested models were developed for predicting crashes based on the dataset. Several trial models were made with different variables including crash rate and traffic flow rate. In each case, the model coefficients were assessed for significance and for any nested models the AIC and scaled deviances were also assessed. Four models were finally proposed due to the differences in the explanatory variables and the AIC. The models are presented in Table 7.5.

Table 7.5 Alternative models for Two Vehicle crashes

VARIABLE	Model 1		Model 2		Model 3		Model 4	
	coefficient	t- value	coefficient t	t- value	coefficient t	t- value	coefficient	t- value
CONSTANT	-9.505	-3.33	-8.304	-3.2	-8.643	-3.29	-9.093	-3.28
LENGTH_KM	0.344	1.93	0.413	2.42	0.456	2.6	0.482	2.58
TWOWAY_AADT	1.160	4.13	0.960	3.72	0.995	3.84	1.141	4.19
AVE_SPEED	0.028	2.11	0.035	2.9	0.031	2.54	0.032	2.42
SWALK_WIDTH			0.427	4.03				
SWALK_PRESC					1.011	4.01		
SHOULDR_WDTH							-0.285	-2.46
AIC – Value	7.104		6.970		6.978		7.062	
Log Likelihood	-319		-312		-312		-316	
Scaled Deviance	1.227		1.244		1.240		1.242	
Scaled Pearson	1.228		1.130		1.133		1.165	

Average speed, Sidewalk width and presence of Sidewalk and Shoulder width are the key explanatory variables in the models. Model coefficients for Sidewalk width and the presence of Sidewalk are positive and even the presence of sidewalk in Model 3 have coefficient more than

1.0. The width of shoulder has a negative coefficient in Model 4; this indicates a reduction in crashes with increase in shoulder width. On the basis of lowest AIC and scaled deviance alone, Model 2 may be selected as the best approximating model, however, from engineering judgement, Model 4 gives the best variable which makes intuitive sense.

In order to determine the related likelihood of each of the models being selected or rejected we found how far each is from the best approximating model by comparison using the Akaike weights. Table 7.6 presents the computations for the Akaike weights for the four alternative models.

Table 7.6 Comparison of Alternative models for Two Vehicle crashes using Aikake weight

Model	Number of Variables	AIC	ΔAIC	$\text{Exp} (-0.5 * \Delta_i)$	w_i
Model 2	3	6.970	0	1.000	0.257
Model 3	4	6.978	0.008	0.996	0.256
Model 4	4	7.062	0.092	0.955	0.246
Model 1	4	7.104	0.134	0.935	0.241
			Sum	3.886	

On the basis of lowest Scaled deviance and Akaike Information Criteria AIC only, Model 2 is the best comprehensive model. When the variables were assessed Model 4 was finally confirmed as the best comprehensive model. Using the Akaike weights to determine the distance from the truth, we interpret given the data and the set of candidate models which one approximates the truth. From Table 7.6, w_i is the weight of evidence that Model i is the best approximating model, Model 2 has the highest probability of approximating the best model followed by Model 4 and

then Model 3 and Model 1. All three models are approximately predicting the truth on the basis of AIC.

The resulting comprehensive Two Vehicle model based on Model 4 has been determined to be as follows:

$$E(Y) = 2.4 \times 10^{-5} \times LENGTH_KM^{0.48} \times TWOWAYADT^{1.14} \times EXP^{(0.03 AVE_SPEED - 0.29 SHOULDR_WIDTH)} \dots \dots$$

(7.4)

Where: $E(Y)$ = expected crashes along the road segment for 3 years,

$LENGTH_KM$ = length (km) of road segment and

$TWOWAYADT$ = Average Daily Traffic (ADT)

AVE_SPEED = Average Speed

$SHOULDR_WIDTH$ = width of side walk

$EXP(x)$ = e^x

Where $e = 2.718282$

7.4 Pedestrian Crash Models on Two lane roadways

7.4.1 'Base' Model

Preliminary testing to develop a pedestrian model did not yield any good results. Several specifications of the independent variables were explored but the inclusion of pedestrian exposure variables in the base model did not produce in any good results as shown below.

hitped_acc	OIM		z	P> z	[95% Conf. Interval]	
	Coef.	Std. Err.				
lnlength_km	.6016156	.1749944	3.44	0.001	.2586329	.9445983
ln2wayaad	1.433895	.348488	4.11	0.000	.7508716	2.116919
lnpedvol_3~s	-.4045659	.9630968	-0.42	0.674	-2.292201	1.483069
_cons	-9.609596	5.75577	-1.67	0.095	-20.8907	1.671506

Various combinations of functions to include pedestrian flow variable were tried but because the results could not return zero pedestrian crashes with pedestrian absence and also the pedestrian volume was not significant ($p>0.005$) and the sign was negative, the modelling was discontinued.

CHAPTER 8: MODEL TESTING AND RISK FACTORS

8.1 Model Testing

Using data on 21 sections (28%) collected from the crash and road data survey, the models were tested for their predictive capability. The results are presented in the following sections.

8.1.1 Total injury Crash Models

Plots of the residuals (predicted-observed) against observed data is for the best choice model as discussed in Chapter 7 are presented in Figures 8.1

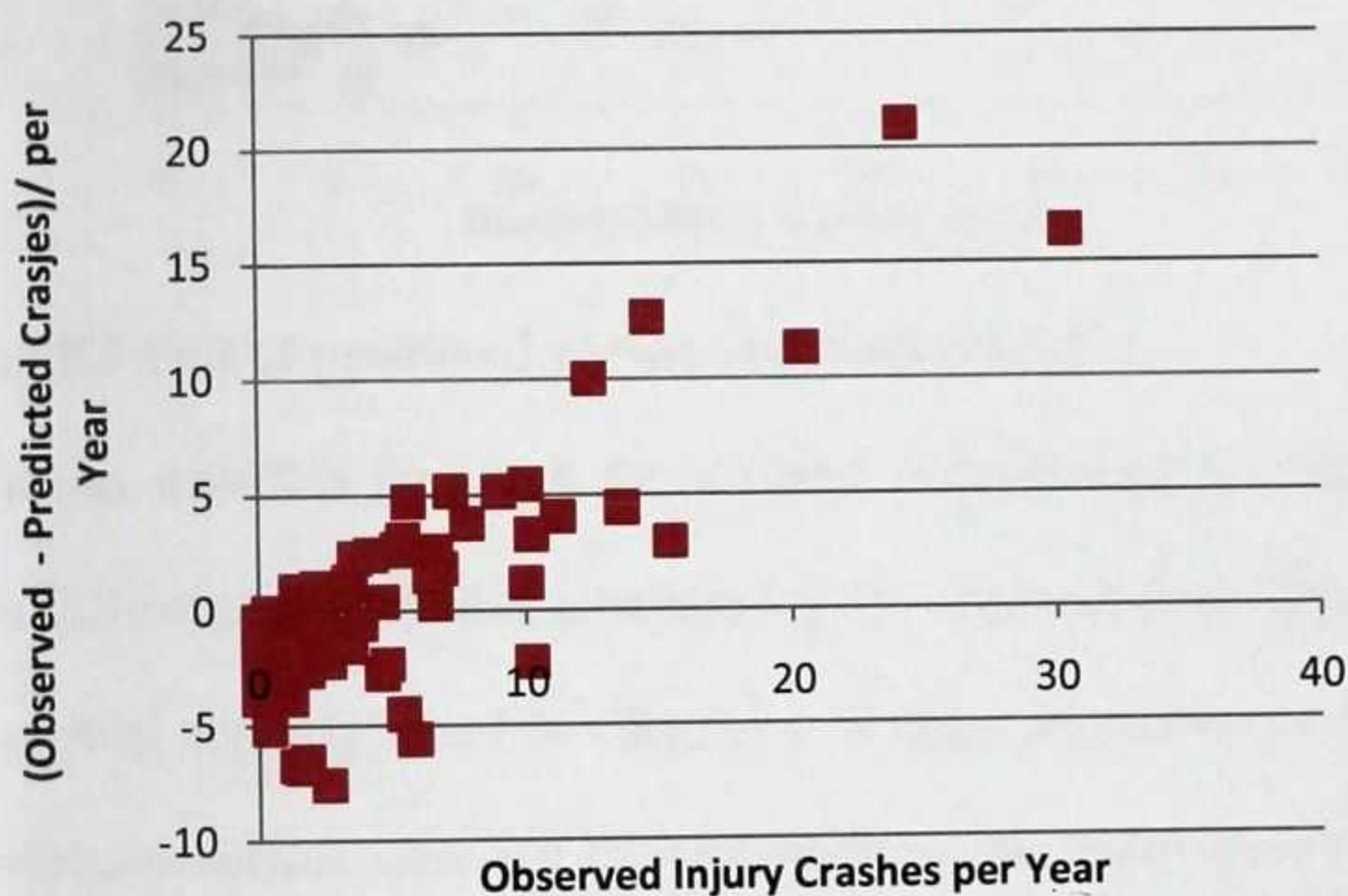


Fig. 8.1 Plot of observed crashes versus residuals for total crashes

From the plots, we observe that the predictions of the Models are very good for sections with less than 5 crashes per year for all the three model options. As the Number of crashes per year exceeds 10, the predictions seem to have a systematic error as there is consistent positive residual. We conclude that Model 4 has the best distribution of residuals plotted against the observed crashes, even though for sections having more than 5 crashes per year, the model predictions are not well distributed about the zero line but consistently above it.

Fig. 8.2 presents a plot of predicted crashes per year versus observed injury crashes per year for the three best models compared in Chapter 7. A similar picture emerges, that the model prediction are more approximate for crashes of up to 5 per year.

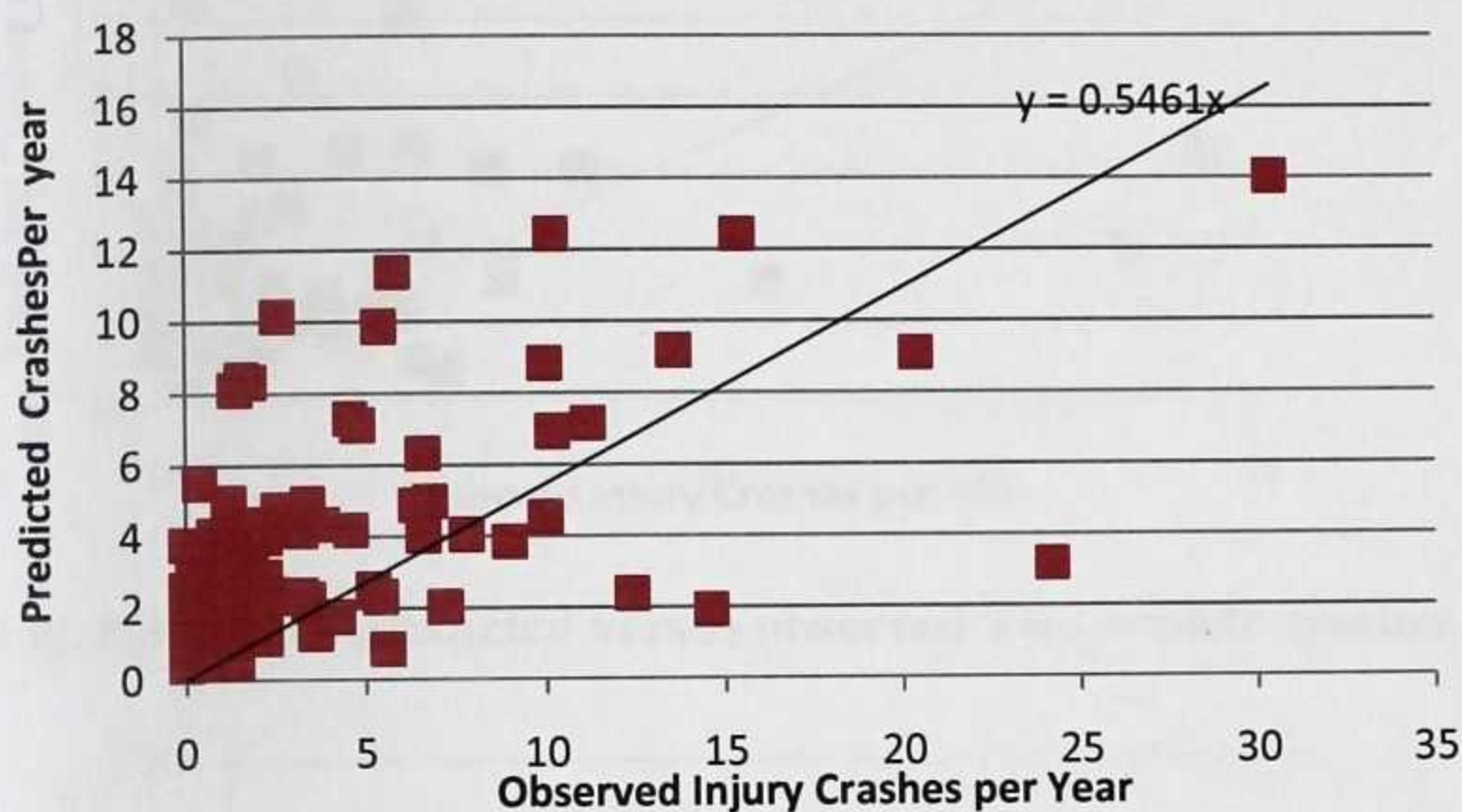


Fig. 8.2 Plot of predicted versus observed crashes.

We can establish here that for sections experiencing less than 5 crashes per year the model predictions are reasonable compared to the observed data. Regarding the general composition of the crash data explained in Chapter 4, a large proportion of crashes include pedestrians. Since pedestrian factors were not found significant for inclusion in the model this partly explains why it does not predict them well; there were very few of such sections in the database anyway. When the Freeman Turkey R^2 (coefficient of determination) a value of 0.37 was obtained. This means the model explain 37% of the systematic variation in the data.

8.1.2 Two vehicle crash Models

For two vehicle crashes, similar plots were made to test the prediction of the model and also determine how far the model prediction is from observed data. From Figure 8.3 we gather that

for sections with less than 5 crashes per year, the model predicts well and fairly closely to observed data.

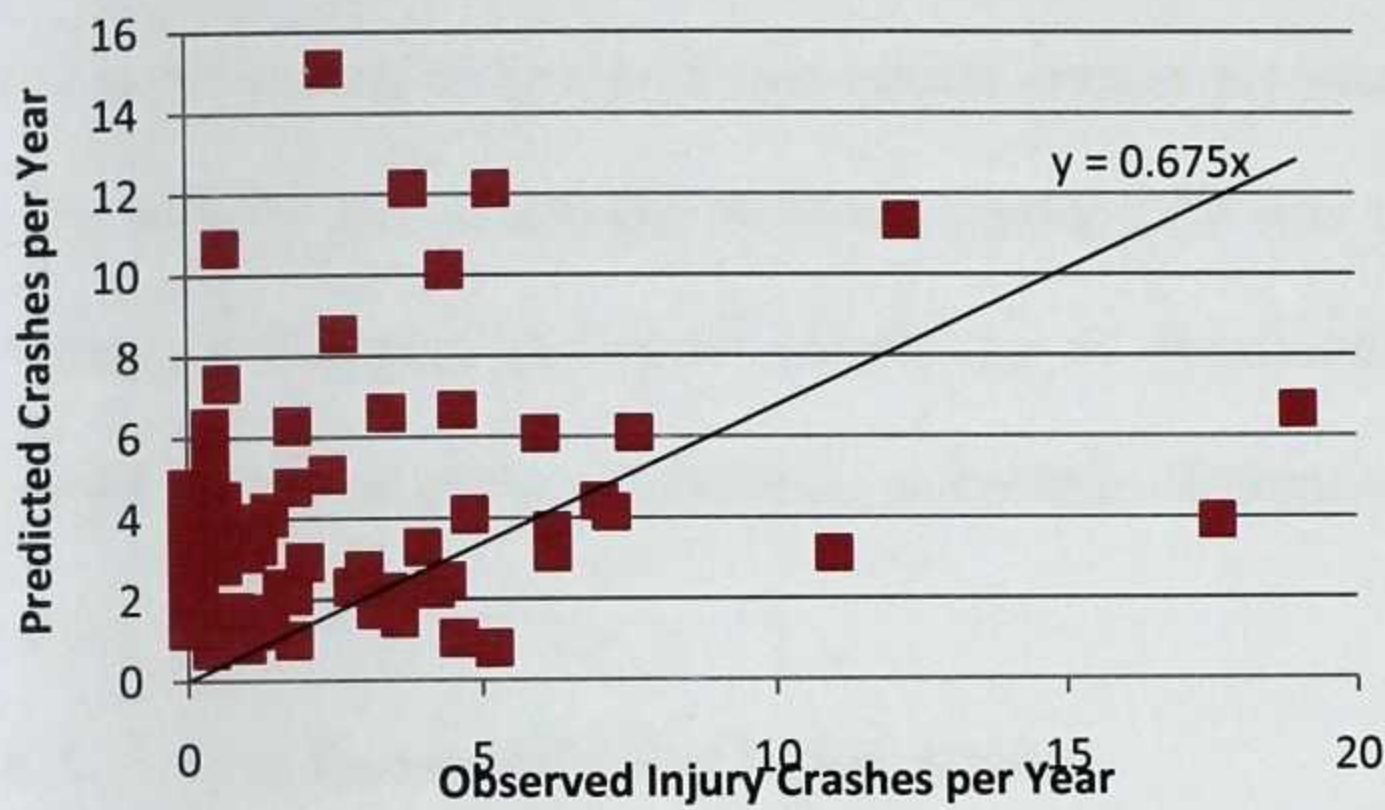


Fig. 8.3 Plot of predicted versus observed Two-vehicle crashes.

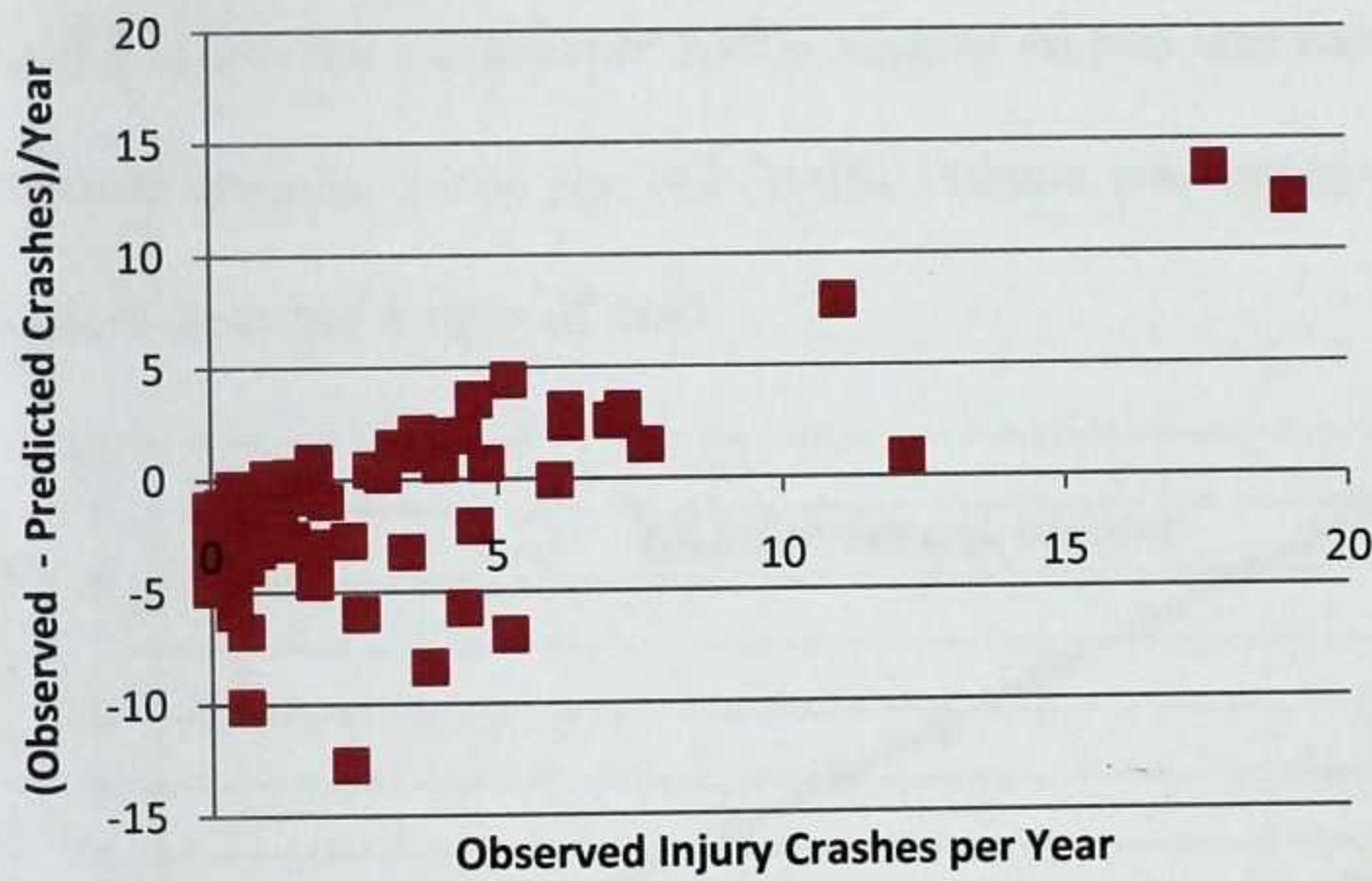


Fig. 8.4 Plot of residuals versus observed two vehicle crashes.

Figure 8.4 illustrates that the residuals for sections with less than 5 crashes per year are fairly well distributed about zero. As the number of crashes exceeds 5 per year, the prediction tends to

be less accurate as the residuals show a consistent systematic error since the difference between observed and predicted crashes are one sided and increasing.

For sections with more than 5 two-vehicle crashes per year, the model residuals are spread about zero without any systematic pattern especially for less than 10 two-vehicle crashes per year. When the Freeman Turkey R^2 (coefficient of determination) a value of 0.38 was obtained, it means the model explain 38% of the systematic variation in the data.

8.2 Risk factors affecting Injury crashes

8.2.1 Variation of Traffic Volume and Crashes

Fig. 8.5 shows the variation of traffic volume on two lane roads with injury crashes based on the proposed models. In the plot only traffic volume was varied whilst all other variables were kept constant on a unit length of road.

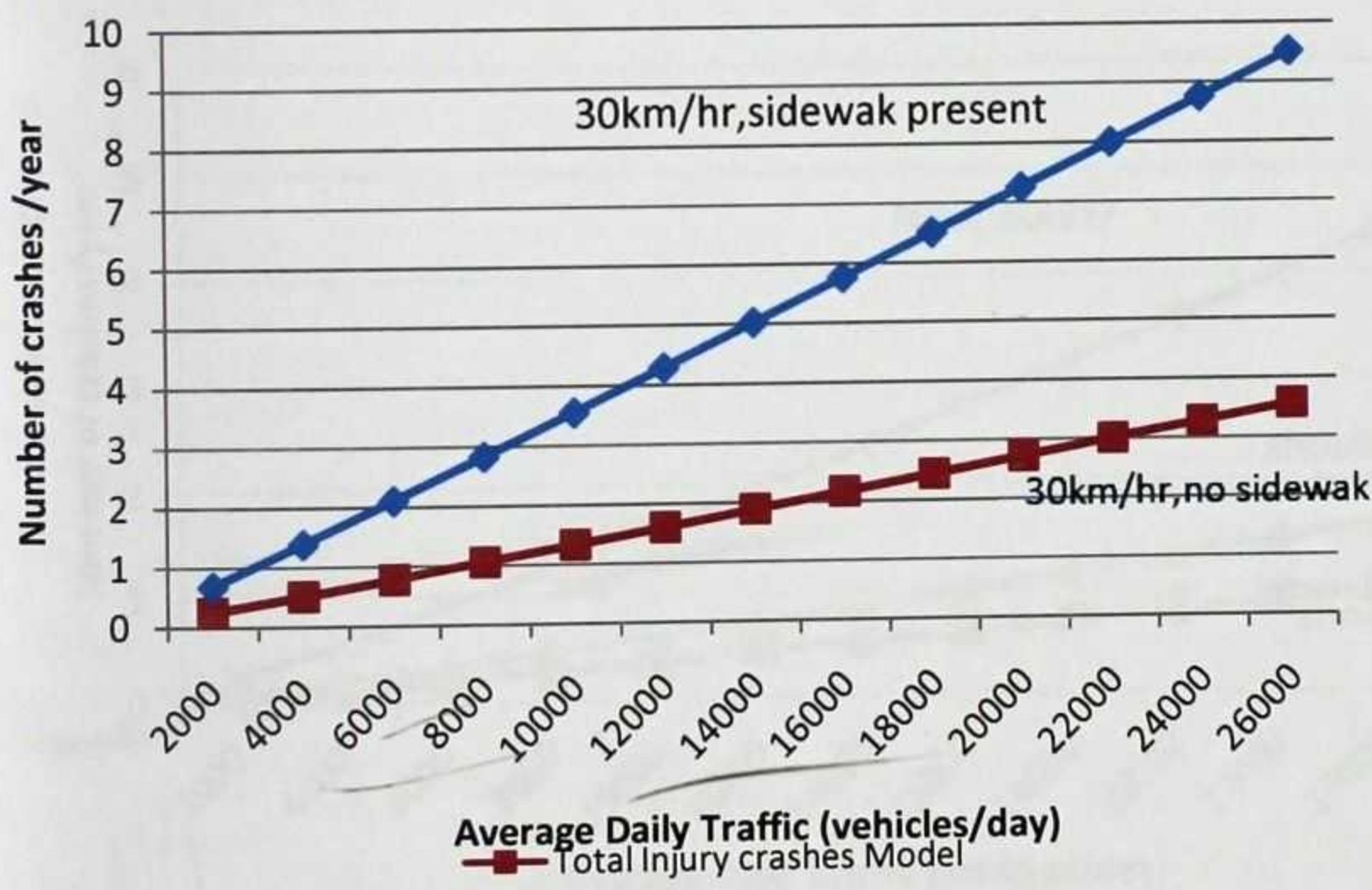


Fig. 8.5 Variation of Total Injury crashes with ADT

The exponent on the ADT in both the Total injury crash and Two vehicle models were more than 1.0 indicating that the traffic volume on the roadway is a very important predictor of crashes; this result has been corroborated by other researchers such as Beharnu (2004) who reported crash frequencies related to the AADT raised to power of 0.8–1.0 and some crash types, e.g. rear-end collision (Two Vehicle crashes) raised to power 1.23. Similar results are reported by Summersgill and Layfield (1996).

The explanatory variables of average speed and presence of sidewalk were set to values of 30km/hour and present and absence of sidewalk respectively. The presence of sidewalk on urban two-lane roadways along corridors with pedestrian is important for safety. Higher crashes were estimated on roads with sidewalks compared to those with no sidewalk for the same traffic volume and average speed. This is attributable to the presence of endogenous variable such as pedestrian flow indicated by sidewalk presence. This was reported by Washington (2010). The difference in crashes increases with increasing average daily traffic as depicted on the graphs.

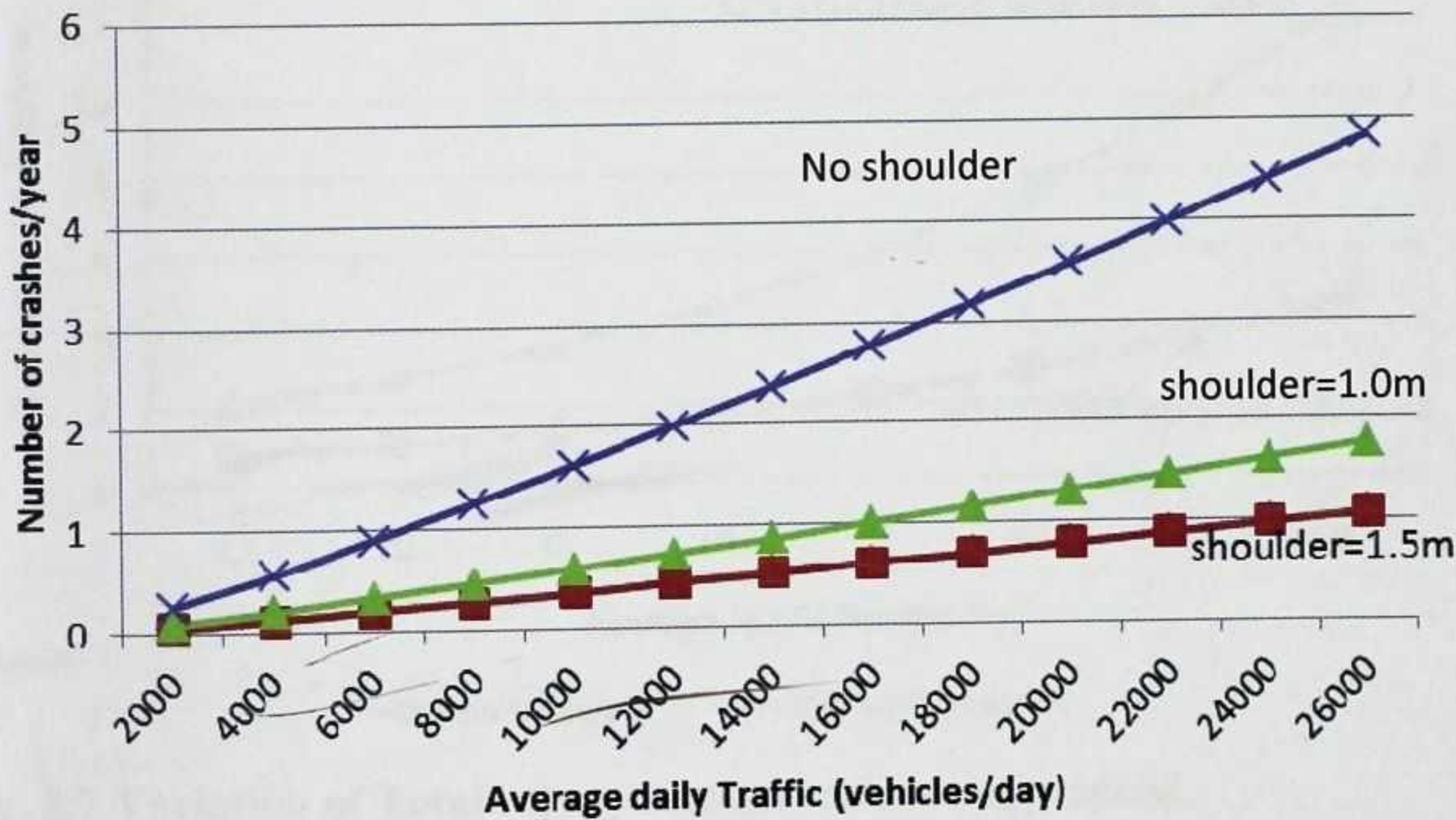


Fig. 8.6 Variation of Two vehicle crashes with ADT

For Two vehicle crashes, average speed and shoulder width were found to be significant explanatory variables for explaining the crashes. Figure 8.6 shows a plot of the variation of ADT with crashes for average speed of 30km/hour for different situations where the road has no shoulder, 1.0m shoulder and 1.5 m shoulder respectively. The presence of well-designed shoulders has an effect of drastically reducing the number of two vehicle crashes such as head-on collision, side swipe and rear end collision. Roads with no shoulders increase the frequency of two vehicle crashes.

8.2.2 Average Speed, Sidewalk, Shoulder and Crashes

Average speed is an explanatory variable in the two vehicle crashes model and also in the other models for Total injury crashes. As average speed of travel increases, the number of crashes also increases. The two plots in Figure 8.7 show two situations where the road environment has pedestrians and not much pedestrians.

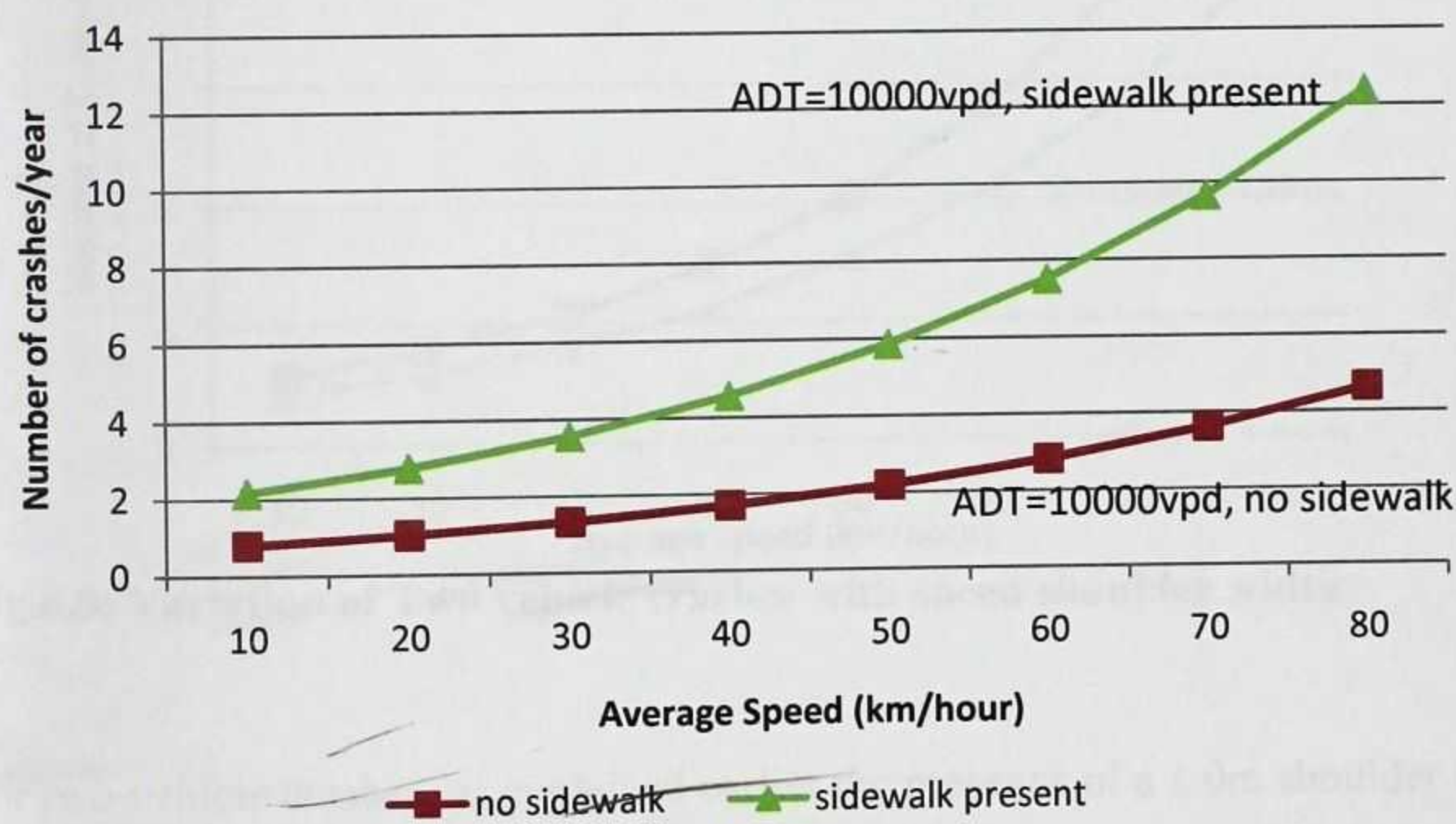


Fig. 8.7 Variation of Total injury crashes with average speed.

Whenever pedestrian volumes are high and the traffic volume and speeds are also high there is some provision of pedestrian sidewalk facility. The rate of increase in the number of crashes increases as the average speed of travel exceeds 50km/hour. This has been severally reported by many researchers how the risk of injury crashes increases with speed beyond 50km/hour. For instance Yau et al., (2006) developed models for urban motorways and reported that the model's results show speed limits and road type to be significant site factors. Higher speed limits on the road imply higher speeds of the cars on the road. Thus, it is more probable that serious traffic crashes occur on the roads with high speed limits. Vasconcellos (1999) has also reported that speed of motorized transportation was a factor in road safety on two lane roadways.

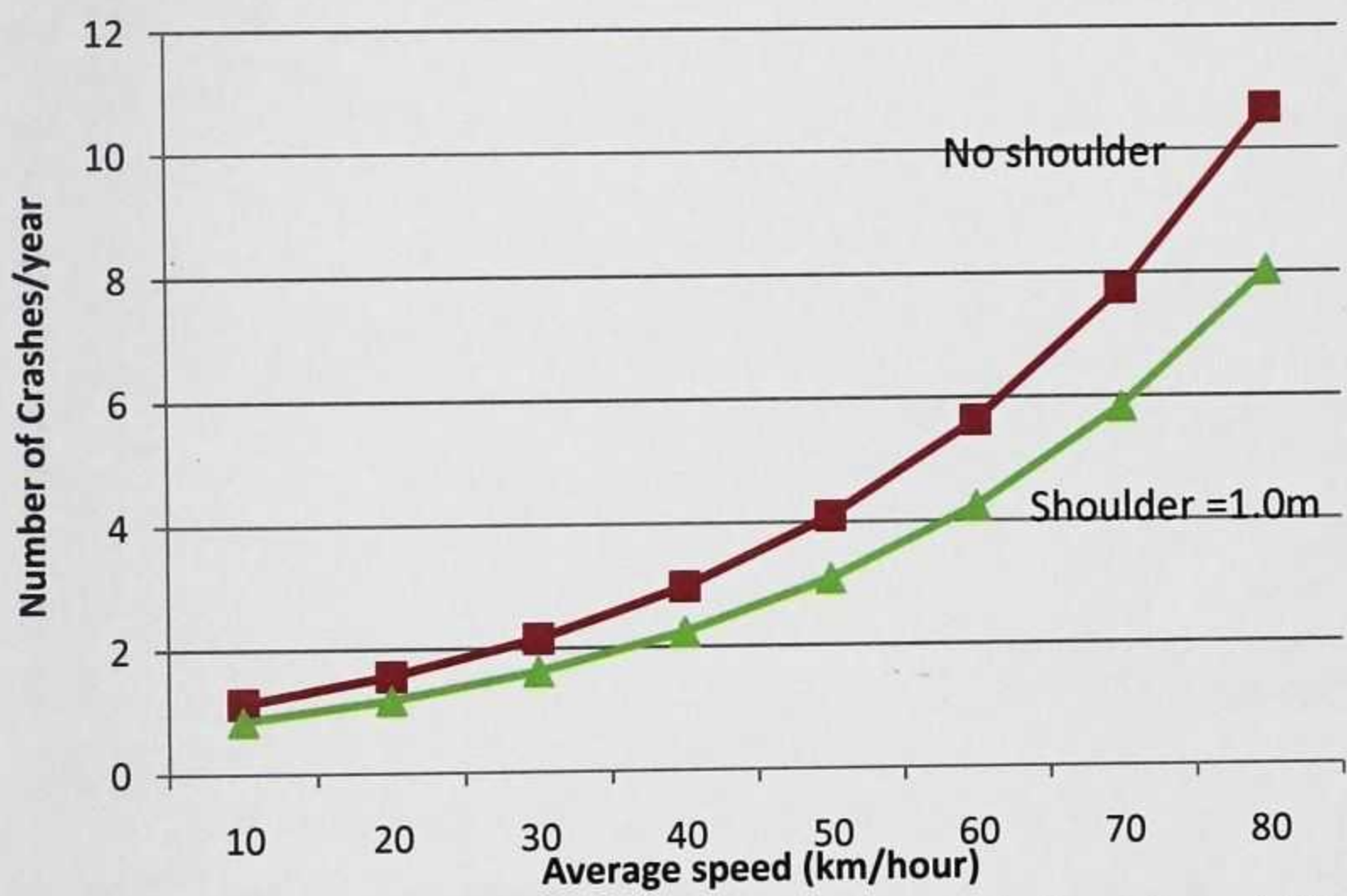


Fig.8.8: Variation of Two vehicle crashes with speed shoulder width

For two-vehicle crashes, as explained earlier the presence of a 1.0m shoulder reduces the number of expected injury crashes. Beyond a speed of 50km/hour the rate of increase in the number of crashes increases rapidly for small changes in speed.

The effect of sidewalk width on crashes is also depicted by the plots in Figure. 8.7. The presence of sidewalks on roads with speed of 30km/hour or more increases the risk of crashes especially for pedestrians. Shoulders have an effect of reducing the risk of two vehicle crashes.

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

The following conclusions have been drawn from the analysis and discussions

- The population of vehicles operating on a network is a risk factor for crashes

Models have been developed to predict Total injury crashes and two vehicle crashes.

- The main explanatory variables for injury crashes are sidewalk presence and the average speed of travel.
- For two vehicle crashes, presence of wide shoulder reduces crashes. Increase in the average speed also increases number of two vehicle crashes rapidly when speeds exceed 50km/hour.

The following risk factors were also determined from the analysis of historical data and modelling

- Vehicle population on a network
- Presence of pedestrian sidewalk
- Average speed of travel

Models have been developed which could be validated and refined for application in the World Bank highway development and management software HDM 4. These models hold promise for predicting crashes on two lane roadways in the urban environment.

9.2 Recommendation

From the analysis and models developed and subsequent discussions above, the following recommendations are made:

Road safety on two lane roadways

- Carefully designed wide shoulders can reduce crashes involving two vehicles on two lane roadways
- Sidewalks need to be carefully designed whenever volumes are high on two lane roads
- Speeds calming on urban arterials must be emphasised for the reduction of injury crashes.

9.3 Limitations of Study

The models developed in the study apply to sections of two-lane roadways in urban environments. The application of the model is considered valid for predicting only injury road traffic crashes. The data was limited to the Kumasi Metropolitan road network for which data existed. Even though the models may be applied in other urban roadway sections and links, it is the researcher's view that the models are robust only for the locations where the data was captured. For lack of funding to collect data on a wider network, traffic flow, pedestrian flows and crashes were limited to those for which data could be easily retrieved. More data on roadways may further increase model predictions and applicability.

9.4 Suggested Further Research

The study has established the relationships for predicting injury crashes on two lane roadways in urban environment. The models would need to be validated in time that is checking the predictive capacity using data that is outside the time range for which model was developed. Also in order to be able to transfer the models to predict crashes in other jurisdictions, the model would need to be validated and calibrated. Even though the crash database exists, obtaining data on urban links for validation from the MAAP software was not possible due to limitations of the

software to link crashes to Maps of the With access to traffic data for metropolitan cities, the research can be undertaken to cover more road links from several jurisdictions which will give models that reflect the differences in traffic, roadside and pedestrian characteristics across the country.

The models developed for predicting two vehicle and pedestrian crashes were not significant and could explain only small proportions of variations in the data set. Perhaps if we captured the data differently would be able to represent the variables and traffic flow variables in a form that might be significant.

9.5 Contribution to Knowledge

This study set out to determine relationships and develop statistically valid models to predict crashes on two lane urban roadways. Models have been developed which can be extended and validated for application in Ghana. Even though much work on modelling crashes has been reported in the literature in the western countries on urban two lane roadways, the literature on modelling in developing countries especially in Africa is very sparse on. The study has added to knowledge in the following areas

- Total Injury Crashes and Two Vehicle Crashes prediction models have been developed which can be validated and extended for application in Ghana.
- Risk factors for injury crashes such as presence of sidewalk and shoulder width have been identified as factors that explain crashes in Ghana.
- The Research has confirmed that average speed is important for two vehicle crashes on two lane urban roadways.

REFERENCES

- Abdel-Aty, M.A. and Radwan, A.E. (2000). Modelling Traffic Accident Occurrence and Involvement. *Accident Analysis and Prevention*. 32 pp. 633-642.
- Abdel-Aty, M., and Keller, J. (2005). Exploring the overall and specific crash severity levels at signalized intersections. *Accident Analysis and Prevention* 37 (3), 417-425.
- Afukaar, F.K. and Agyemang, W. (2006). Road Traffic Fatalities Trends in Ashanti Region of Ghana. *Bi-Annual Journal of the Building and Road Research Institute (CSIR), Ghana*. Vol 10, Jan-Dec 2006.
- Afukaar, F.K. and Debrah, E.K. (2007). Accident Prediction Models for Signalized Intersections in Ghana. Ministry of Transportation, National Accident Management Project, Final Report.
- Afukaar, F.K., Ackaah, W. and Agyemang, W. (2006). Estimation of Levels of Under-reporting of Road Traffic Crashes in Ghana. Ministry of Transportation, National Accident Management Project, Final Report.
- Afukaar, F.K., Agyemang, W., Ackaah, W. and Mosi, I. (2008). Accident Statistics 2007. Building and Road Research Institute (Council for Scientific and Industrial Research), Kumasi.
- Afukaar, F.K., Agyemang, W., Ackaah, W. (2010). Accident Statistics 2010. Building and Road Research Institute (Council for Scientific and Industrial Research), Kumasi.

Afukaar, F.K., Agyemang, W., Debrah, E.K. and Ackaah, W. (2006). Estimation of the Cost of Road Traffic Crashes in Ghana. Ministry of Transportation, National Accident Management Project, Final Report.

Agresti, A. (1996). An Introduction to Categorical Data Analysis. Wiley, New York.

Aguero-Valverde, J. and Jovanis, P.P. (2008). Analysis of road crash frequency with spatial models. Transportation Research Record 2061, 55-63.

Amis, G. (1996). An application of generalised linear modelling to the analysis of traffic crashes. Traff. Eng. Control 37 (12), 691 – 696.

Anastasopoulos, P.C. and Mannering, F.L. (2009). A note on modeling vehicle accident frequencies with random-parameters count models. Accident Analysis and Prevention 41 (1), 153-159.

Bared, J. and Vogt, A. (1998). Accident models for two-lane rural segments and intersections. Transportation Research Record: Journal of the Transportation Research Board 1635, 18–29.

Beharnu, G. (2004). Models relating traffic safety with road environment and traffic flows on arterial roads in Addis Abba. Accident Analysis and Prevention 36 (5), 697-704.

Bonneson, J.A. and Pratt M.P. (2008). Procedure for developing accident modification factors from cross-sectional data. *Transportation Research Record* 2083, 40-48.

Brüde, U. and Larsson, J. (1993). Models for predicting crashes at junctions where pedestrians and cyclists are involved. How well do they fit? *Accident Analysis and Prevention* 25 (5), 499-509.

Hadi, M.A., Aruldas, J., Chow, L.F. and Wattleworth, J.A. (1993). Estimating Safety Effects of Cross-Section Design for Various Highway Types Using Negative Binomial Regression. *Transportation Research Record*, 1500, TRB, National Research Council, 169–177.

Cameron, A.C. and Trivedi, P.K. (1998). *Regression Analysis of Count Data*. Cambridge University Press, Cambridge, UK.

(CGRS, 2008) *Making Roads Safe- A decade of Action for Road safety*, commission for Global Road safety

Damsere-Derry J., Afukaar, F.K., Donkor, P. and Mock, C. (2008). Assessment of vehicle speeds on different categories of roadways in Ghana. *International Journal of Injury Control and Safety Promotion*, 15:2, 83 – 91.

Dissanayake, S. and Ratnayake, I. (2006). Statistical Modelling of Crash Frequency on Rural Freeways and Two-lane Highways Using Negative Binomial Distribution. *Advance in Transportation Studies an International Journal*, Section B 9.

El-Basyouny, K. and Sayed, T. (2009). Accident prediction models with random corridor parameters. *Accident Analysis and Prevention* 41 (5), 1118-1123.

Fletcher, J.P., Baguley, C.J., Sexton, B. and Done, S. (2006). Road Accident Modelling for Highways Development and Management in Developing Countries. Main Report: Trials in India and Tanzania. Project Report No: PPR095.

Finch DJ et al. Speed, speed limits and accidents. Crowthorne, Transport Research Laboratory, 1994 (Project Report 58).

Fridstrøm, L., Ifver, J., Ingebrigsten, S., Kulmala, R. and Thomsen L. K. (1995). Measuring the Contribution of Randomness, Exposure, Weather, and Daylight to the Variation in the Road Accident Counts. *Accident Analysis and Prevention*, 27(1): 1-20.

Garber, N.G. and Ehrhart, A.A. (2000). Effect of speed, flow and geometric characteristics on crash frequency for two lane rural roads. *Transportation Research Record* 1717, 76–83.

Garber, N.J. and Wu, L. (2001). Stochastic Models Relating Crash Probabilities with Geometric and Corresponding Traffic Characteristics Data. Research Report No. UVACTS-5-15-74.

Ghana Highway Authority (GHA). (1991). Road Design Guide. GHA, Survey and Design Division.

Ghee, C., Silcock, D., Astrop, A. and Jacobs, G. (1997). Socio-economic aspects of road crashes in developing countries. TRL Report 247, Transport Research Laboratory, Crowthorne, Berkshire.

Greibe, P. (2003). Accident Prediction Models for Urban Roads. Accident Analysis and Prevention. 35, pp. 273-285.

Hadi, M., Aruldas, J., Chow, L. and Wattleworth, J. (1995). Estimating safety effects of cross-section design for various highway types using Negative Binomial regression. Transportation Research Record 1500, 169-177.

Hauer, E., Ng, J.C.N. and Lovell, J. (1988). Estimation of safety at signalized intersections. Transportation Research Record. 1185, 48-61.

Hauer, E. (2001). Overdispersion in modeling crashes on road sections in Empirical Bayes estimation. Accident Analysis and Prevention 33 (6), 799-808.

Hauer, E. (2004). Statistical road safety modeling. Transportation Research Record: Journal of the Transportation Research Board 1897, 81-87.

Hauer, E. (1994). On Two Uses of Exposure. Paper Presented at the Transportation Research Board Annual Meeting, Washington D.C.

Hauer, E. and Bamfo, J. (1997). Two tools for finding what function links the dependent variable to the explanatory variables. In: Proceedings of ICTCT 97 Conference, Lund, Sweden. Israel,

G.D. (1992). Determining sample size. University of Florida. Fact Sheet PEOD-6.

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

Haydecker, B.G. and Wu, J. (2001). Identification of sites for road accident remedial work by Bayesian statistical methods: an example of uncertain inference. *Advances in Engineering Software* 32 (10), 859-869.

Ivan, J.N. and O'Mara, P.J. (1997). Prediction of Traffic Accident Rates Using Poisson Regression, Presented in the 1997. Transportation Research Board Meeting, Washington, DC.

Johansson, P. (1996). Speed limitation and motorway casualties: a time series count data regression approach. *Accident Analysis and Prevention* 28 (1), 73-87.

Jones, I.S. and Whitfield, R.A. (1991). Predicting injury risk with new car assessment program crashworthiness ratings. *Accident Analysis and Prevention* 6 (20), 411-419.

Joshua, S.C. and Garber, N.J. (1990). Estimating truck accident rate and involvement using linear and poisson regression models. *Transportation Planning and Technology* 15, 41-58.

Jovanis, P.P. and Chang, H.L. (1986). Modeling the relationship of crashes to miles travelled. *Transportation Research Record* 1068, 42-51.

Karlaftis, M.G. and Tarko, A. (1998). Heterogeneity considerations in accident modeling. *Accident Analysis and Prevention* 30 (4), 425-433.

Kelvin K.W. Yau , H.P. Lo, Sherrice H.H. Fung (2006), Multiple-vehicle traffic accidents in Hong Kong, *Accident Analysis and Prevention* 38 1157–1161

Kim, S.H., Chung, S.B., Song, K.H. and Chong, K.S. (2005). Developing of an Accident Prediction Model Using GLIM (Generalized Log-linear Model) and EB method: A case of Seoul. *Journal of the Eastern Asia Society for Transportation Studies*, Vol. 6, pp.3669-3682.

Kim, D. and Washington, S. (2006). The significance of endogeneity problems in crash models: an examination of left-turn lanes in intersection crash models. *Accident Analysis and Prevention* 38 (6), 1094-1100.

Knuiman, M., Council, F. and Reinfurt, D. (1993). The effect of median width on highway accident rates. *Transportation Research Record* 1401, 70-80.

Kumala, R. (1995). Safety at Rural Three- and Four- arm Junctions: Development and Applications of Accident Prediction Models, vol. 233. VTT Publications, Technical Research Centre of Finland, Espoo, Finland.

Kumara, S.S.P. and Chin, H.C. (2003). Modeling accident occurrence at signalized tee intersections with special emphasis on excess zeros. *Traffic Injury Prevention* 3 (4), 53-57.

Kumara, S.S.P. and Chin, H.C. (2005). Application of Poisson underreporting model to examine crash frequencies at signalized three-legged intersections. *Transportation Research Record* 1908, 46-50.

Lambert, D. (1992). Zero-inflated Poisson regression, with an application to defects in manufacturing. *Technometrics* 34 (1), 1-14.

Lave, C. (1985). Speeding, coordination, and the 55 MPH limit. *The American Economic Review*, 75, 1159-1164.

Lee, J. and Mannering, F. (2002). Impact of roadside features on the frequency and severity of run-off-roadway crashes: an empirical analysis. *Accident Analysis and Prevention* 34 (2), 149-161.

Lerman, S.R. and Gonzales, S.L. (1980). Poisson regression analysis under alternate sampling strategies. *Transportation Science* 14 (4), 346-364.

Lord, D. and Persaud, B. (2000). Accident prediction models with and without trend: application of the generalized estimating equations procedure. *Transportation Research Record* 1717, 102-108.

Lord, D., Washington, S.P. and Ivan, J.N. (2004a). Poisson, Poisson-Gamma and Zero-Inflated Regression Models of Motor Vehicle Crashes: Balancing Statistical Fit and Theory. Paper AA&P 03225.

Lord, D., Washington, S.P. and Ivan, J.N. (2005b). Poisson, Poisson-Gamma and Zero Inflated Regression Models of Motor Vehicle Crashes: Balancing Statistical Fit and Theory. *Accident Analysis and Prevention* 37 (1), 35-46.

Lord, D., Manar, A. and Vizioli, A. (2005). Modeling crash-flow-density and crash-flow-v/c ratio for rural and urban freeway segments. *Accident Analysis and Prevention* 37 (1), 185-199.

Lord, D. (2006). Modeling motor vehicle crashes using Poisson-gamma models: examining the effects of low sample mean values and small sample size on the Estimation of the fixed dispersion parameter. *Accident Analysis and Prevention* 38 (4), 751-766.

Lord, D., Washington, S.P. and Ivan, J.N. (2007). Further notes on the application of zero inflated models in highway safety. *Accident Analysis and Prevention* 39 (1), 53-57.

Lord, D. and Miranda-Moreno, L.F. (2008). Effects of low sample mean values and small sample size on the estimation of the fixed dispersion parameter of Poisson-gamma models for modeling motor vehicle crashes: a Bayesian perspective. *Safety Science* 46 (5), 751-770.

Ma, J. (2009). Bayesian analysis of underreporting Poisson regression model with an application to traffic crashes on two-lane highways. Paper #09-3192. Presented at the 88th Annual Meeting of the Transportation Research Board, Washington, DC.

Maher M.J. and Summersgill, I. (1996). A comprehensive methodology for the fitting predictive accident models. *Accident Analysis and Prevention* 28 (3), 281-296.

Maycock, G. and Hall, R. D. (1984). Crashes at 4-arm Roundabouts. Transport and Road Research Report 1120.

Miaou, S. and Lum, H. (1993). Modelling vehicle accident and highway geometric design relationship. Accident Analysis & Prevention 25, 689–709.

McCullar, P. and Nelder, J.A. (1989). Generalized Linear Models, Chapman and Hall, London.

McGee, H., Hughes, W. and Daily, K. (1995). Effect of Highway Standards on Safety. NCHRP Report 374, Transportation Research Board.

Miaou, S.-P. (1994). The Relationship Between Truck Crashes and Geometric Design of Road Sections: Poisson versus Negative Binomial Regressions. Accident Analysis and Prevention. Vol. 26, No. 4 pp. 471-482.

Miaou, S.P., Hu, P.S., Wright, T., Rathi, A.K. and Davis, S.C. (1992). Relationship between truck crashes and highway geometric design: a poisson regression approach. Transportation Research Record 1376, 10–18.

Miaou, S.-P. (1996). Measuring the Goodness-of-Fit of Accident Prediction Models. FHWA-RD-96-040, Federal Highway Administration, Washington, D.C.

Miaou, S.-P. and Lum, H. (1993). Modelling Vehicle Crashes and Highway Geometric Design Relationships. *Accident Analysis and Prevention*. Vol. 25, No. 6 pp. 689-703.

Miaou, S.-P. and Lord, D. (2003). Modeling traffic crash-flow relationships for intersections: dispersion parameter, functional form, and Bayes versus Empirical Bayes. *Transportation Research Record* 1840, 31-40.

Miaou, S.-P., Song, J.J. and Mallick, B.K. (2003). Roadway traffic crash mapping: a space-time

modeling approach. *Journal of Transportation and Statistics* 6 (1), 33-57.

Miaou, S.-P., Song, J.J. and Mallick, B.K. (2003). Roadway traffic crash mapping: a space-time

Miaou, S.-P. and Song, J.J. (2005). Bayesian ranking of sites for engineering safety improvements: decision parameter, treatability concept, statistical criterion and spatial dependence. *Accident Analysis and Prevention* 37 (4), 699-720.

Miaou, S.-P., Song, J.J. and Mallick, B.K. (2003). Roadway traffic crash mapping: a space-time

Miaou, S.-P., Hu, P.S., Wright, T., Davis S.C. and Rathi A.K. (1993). Development of Relationship between Truck Crashes and Geometric Design: Phase I. Publication No. FHWA-RD-91-124.

Milton, J. and Mannering, F. (1996). The Relationship Between Highway Geometrics, Traffic Related Elements and Motor Vehicle. Washington State Dept. of Transportation.

Milton, J. and Mannering, F. (1996). The Relationship Between Highway Geometrics, Traffic Related Elements and Motor Vehicle

Milton, J. and Mannering, F. (1998). The relationship among highway geometrics, traffic-related elements and motor-vehicle accident frequencies. *Transportation*, 25(4), 395-413.

Mohamedshah, Y.M., Paniati, J.F. and Hobeika, A.G. (1993). Truck accident models for interstate and two-lane rural roads. *Transportation Research Record* 1407, 35–41.

Mountain, L., Fawaz, B. and Jarrett, D. (1996). Accident prediction models for roads with minor junctions. *Accident Analysis and Prevention* 28 (6), 695 – 707.

Mountain, L., Maher M.J. and Fawaz B. (1998). The influence of Trend on estimates of Crashes at Junctions, *Accident Analysis & Prevention*, Vol 30, No. 5, pp. 641-49.

Oh, J., Washington, S.P. and Nam, D. (2006). Accident prediction model for railway-highway interfaces. *Accident Analysis and Prevention* 38 (2), 346-356.

Park, E.S. and Lord, D. (2007). Multivariate Poisson-lognormal models for jointly modeling crash frequency by severity. *Transportation Research Record* 2019, 1–6.

Pasupathy, R., Ivan, J. and Ossenbruggen, P. (2000). Single and multi-vehicle prediction models for two-lane roadways. Final Report, Project UCN9-8, United States Department of Transportation, Washington, D.C.

Pardillo, J.M. and Llamas, R. (2003). Relevant variables for crash rate prediction in Spain's two lane rural roads. In: *TRB 82nd Annual Meeting Compendium of Papers*, CD-ROM, TRB. National Research Council, Washington, DC.

Qin, X., Ivan, J.N. and Ravishanker, N. (2004). Selecting Exposure Measures in Crash Rate Prediction for Two-lane Highway Segments. *Accident Analysis and Prevention* 36, 183-191.

Salifu, M. (2003). Development of Safety Performance Charts for Unsignalised Urban Junctions. Journal of the Ghana Institution of Engineers. Vol. 1, No 1. pp 50-55.

Salifu, M. (2004). Accident Prediction Models for Unsignalised Urban Junctions in Ghana. IATSS Research Vol. 28 No. 1.

Salifu, M., Mosi, I., Addae-Bofah, K. and Sarpong, K. (2006). Accident Statistics 2005. Building and Road Research Institute (Council for Scientific and Industrial Research), Kumasi.

Sawalha, Z. and Sayed, T. (2001). Evaluating Safety of Urban Arterial Roadways. Journal of Transportation Engineering, 127 (2), 151-158.

Sawalha, Z. and Sayed, T. (2006). Traffic Accident Modeling: Some Statistical Issues. Can. J. Civ. Eng. 33: 1115-1124.

Shankar, V., Mannering, F., and Barfield, W. (1995). Effect of roadway geometrics and environmental factors on rural freeway accident frequencies. Accident Analysis and Prevention, 27(3), 371-389.

Shankar, V., Albin, R., Milton, J. and Mannering, F. (1998). Evaluating median cross-over likelihoods with clustered accident counts: an empirical inquiry using the random effects Negative Binomial model. Transportation Research Board 1635, 44-48.

Shankar, V.N., Ulfarsson, G.F., Pendyala, R.M. and Nebergall, M.B. (2003). Modeling crashes involving pedestrians and motorized traffic. *Safety Science* 41 (7), 627-640.

Smeed R. Some statistical aspects of road safety research. *Journal of the Royal Statistical Society*, 1949, 112

Summersgill, I., Kennedy, J.V. and Baynes, D. (1996). Crashes at three-arm priority junctions on urban single-carriageway roads, TRL Report 184, Transport Research Laboratory, Crowthorne, pp132. (132).

Tarko, A.P., Sinha, K.C. and Farooq, O. (1996). A Methodology for Identifying Highway Safety Problem Areas, Presented in the 1997. Transportation Research Board Meeting, Washington, DC.

Vasconcellos, E. A. (1999) Urban development and traffic accidents in Brazil, *Accident Analysis and Prevention* 31 (1999) 319–328

Vogt, A. and Bared, J.G. (1998). Accident Models for Two-Lane Rural Roads: Segments and Intersections. Publication No. FHWA-RD-98-133.

Washington, S.P., Karlaftis, M.G. and Mannering, F.L. (2003). Statistical and Econometric Methods for Transportation Data Analysis. Chapman Hall/CRC, Boca Raton, FL.

Washington, S.P., Karlaftis, M.G. and Mannering, F.L. (2010). Statistical and Econometric Methods for Transportation Data Analysis, second ed. Chapman Hall/CRC, Boca Raton, FL.

Washington, S., Lord, D. and Persaud, B. (2009). Use of expert panels in highway safety: critique. *Transportation Research Record: Journal of the Transportation Research Board* 2102, 101–107.

WHO. (2004). World Report on Road Traffic Injury Prevention: Summary. World Health Organization.

Wood, G.R. (2002). Generalised linear accident models and goodness of fit testing. *Accident Analysis and Prevention* 34 (4), 417-427.

Zhang, C. and Ivan, J.N. (2005). Effects of geometric characteristics on head-on crash incidence on two-lane roads in Connecticut. *Transportation Research Record* 1908, 159–164.

Zeeger, C.V., Deen, R.C. and Mayes, J.G. (1981). "Effect of Lane and Shoulder Width on Accident Reduction on Rural, Two-Lane Roads," *Transportation Research Record* 806, Transportation Research Board.

Zeeger, C.V., Reinfurt, D.W., Hummer J., Herf, L. and Hunter, W. (1988). "Safety Effects of Cross-Section Design for Two-Lane Roads," *Transportation Research Record* 1195, Transportation Research Board.

APPENDICES

- A LISTING OF ROAD TRAFFIC CRASH CHARACTERISTICS FOR SECTIONS, ROAD GEOMETRY CHARACTERISTICS, TRAFFIC FLOW AND CRASH DATA FOR ROAD SECTIONS
- B VEHICLE REGISTRATION IN GHANA
- C CRASHES DATA FOR 2000 – 2009
- D PICTURE LEGEND FOR DATA COLLECTION
- E CORRELATION OF MODELLING VARIABLES TO CHECK FOR MULTICOLLINEARITY
- F PARAMETER ESTIMATION MODELLING IN STATA

**APPENDIX A:
LISTING OF
ROAD TRAFFIC CRASH CHARACTERISTICS FOR SECTIONS,
ROAD GEOMETRY CHARACTERISTICS,
TRAFFIC FLOW AND CRASH DATA FOR ROAD SECTIONS**

APPENDIX A- LIST OF SECTIONS

NO.	Road section/ Segment	Total Inlkury Accidents	Hit Pedestrian HTHPED_ACC	Pedestrian Volume (\$ Hours)	Length of Section (m)	Length of Section (km)	Total flow per km/100mil vehicles(Q)
1	Tafo Market - Suame New Rd	73	43	2158	1625	1.625	0.6
2	Suame New Rd - Magazine New Rd Link Int.	0	0	2158	375	0.375	0.1
3	Magazine New Rd Link Int. - Tafo Nhyaeso Rd Int.	18	7	2158	525	0.525	0.2
4	Tafo Nhyaeso Rd Int. - Suame R/A	36	13	2158	1075	1.075	0.4
5	Suame R/A - Kotoko Rd Int.	121	9	2158	300	0.3	0.1
6	Kotoko Rd Int. - Kejetia T Lite	23	4	2158	1050	1.05	0.4
7	Siloam Hosp. Jn - Agric. Rd Int.	3	2	1600	900	0.9	0.4
8	Agric. Rd Int. - Siloam/ 2 Brigade Rd Int.	5	2	1600	400	0.4	0.2
9	Siloam/ 2 Brigade Rd Int. - Sofo line R/A	1	0	1600	550	0.55	0.3
10	Sofo line R/A - North Suntreso Rd Int.	9	3	1600	950	0.95	0.5
11	North Suntreso Rd Int. - Bekwai R/A	26	7	1600	500	0.5	0.2
12	Atonsus Terminal - Gyenyasi Int.	6	3	1600	1060	1.06	0.5
13	Gyenyasi Int. - Kaase Rd Int.	16	9	1600	1250	1.25	0.6
14	Kaase Rd Int. - Southern By-pass Int.	4	2	1600	670	0.67	0.3
15	Southern By-pass Int. - Hudson Rd Int.	4	1	1600	230	0.23	0.1
16	Hudson Rd Int. - Dadiesoaba Rd Int	4	0	1600	450	0.45	0.2
17	Dadiesoaba Rd Int - Maxwell Rd Int	5	2	1600	850	0.85	0.4
18	Maxwell Rd Int - Prempeh I Street Int	9	1	1921	1250	1.25	0.6
19	Prempeh I Street Int - UTC T Lite	17	2	1921	100	0.1	0
20	Dr. Mensah - Odumase Rd Int.	8	3	1582	150	0.15	0.1
21	Odumase Rd Int. - Kotoko Rd Int.	6	1	1582	250	0.25	0.1
22	Kotoko Rd Int. - Kejetia T Lite	2	2	1582	650	0.65	0.3
23	Manhyia R/A - Burma Rd Int	5	1	1582	300	0.3	0.1
24	Burma Rd Int - Dichenso Rd Int	11	2	1582	300	0.3	0.1
25	Dichenso Rd Int - Airport R/A	13	2	1582	1100	1.1	0.4
26	Airport R/A - Buokrom	50	20	1582	2750	2.75	1.1
27	KNUST Jn - Bomso Jn	6	1	1629	550	0.55	0.4
28	Bomso Jn - STC T Lite	13	2	1629	1500	1.5	1

NO.	Road section/ Segment	Total Inkury Accidents	Hit Pedestrian HITPED_ACC	Pedestrian Volume (\$ Hours)	Length of Section (m)	Length of Section (km)	Total flow per km/100mil vehicles(Q)
29	STC T Lite - Anloga Jn	56	13	1629	600	0.6	0.4
30	Anloga Jn - Stadium Jn	68	21	1629	950	0.95	0.6
31	Stadium Jn - Amakom T Lite	33	6	1629	350	0.35	0.2
32	Amakom T Lite - Labour R/A	51	14	1629	700	0.7	0.5
33	Labour R/A - Asafo Market R/A	34	11	1629	450	0.45	0.3
34	Asafo Market R/A - UTC T Lite	33	7	1629	250	0.25	0.2
35	Ahodwo R/A - Pine Avenue Int	9	3	1200	1425	1.425	0.5
36	Pine Avenue Int - Prempeh I Street Int	11	1	1200	800	0.8	0.3
37	Prempeh I Street Int - UTC T Lite	12	3	1200	300	0.3	0.1
38	Starlets 91 Ave Int - Amakom Int	7	4	1200	650	0.65	0.1
39	Amakom Int - Old Ejisu Rd Int	28	4	1200	200	0.2	0
40	Old Ejisu Rd Int - 5th Street Int	2	0	1200	300	0.3	0.1
41	5th Street Int - Keneako Rd Int	7	3	1200	325	0.325	0.1
42	Keneako Rd Int - Burma Rd Int	8	3	1200	400	0.4	0.1
43	Abrepo Jn - North Suntreso Rd Int.	45	9	1678	600	0.6	0.3
44	North Suntreso Rd Int. - Bekwai R/A	16	8	1678	750	0.75	0.3
45	Brenan Jn - Suame New Rd Int	23	10	1678	700	0.7	0.6
46	Suame New Rd Int - Anomangye Jn	39	11	1678	1150	1.15	0.9
47	Anomangye Jn - 1st Suame Street Int	27	7	1678	750	0.75	0.6
48	1st Suame Street Int - Suame R/A	29	8	1678	650	0.65	0.5
49	Antoa Rd Int - Kejetia Link int	3	1	1678	350	0.35	0.1
50	Kejetia Link int - Kotoko Rd Int.	2	1	1678	775	0.775	0.3
51	Kotoko Rd Int. - Kejetia T Lite	3	0	1678	325	0.325	0.1
52	Ampabame Rd - Abrepo Jn	17	5	1678	1150	1.15	0.4
53	Lake Rd Int - Ahodwo R/A	7	2	1200	1350	1.35	0.4
54	Ahodwo R/A - Pine Avenue Int	6	0	1200	1400	1.4	0.5
55	Adiembra Rd Int - TUC Jn	0	0	1200	600	0.6	0.2
56	TUC Jn - Santasi R/A	11	0	1200	800	0.8	0.3

APPENDIX A- LIST OF SECTIONS

NO.	Road section/ Segment	Total Inlkury Accidents	Hit Pedestrian HITPED_ACC	Pedestrian Volume (\$ Hours)	Length of Section (m)	Length of Section (km)	Total flow per km/100mil vehicles(Q)
57	Santasi R/A - Estate Rd Int	4	1	1200	325	0.325	0.2
58	Estate Rd Int - Edwenase Rd Int	5	4	1200	1150	1.15	0.6
59	Edwenase Rd Int - Kwadaso Estate Rd Int	7	5	1200	1325	1.325	0.7
60	Kwadaso Estate Rd Int - Sofo line R/A	0	0	1200	575	0.575	0.3
61	Sofo line R/A - Abrepo Jn	7	1	1200	1375	1.375	0.7
62	Abrepo Jn - Suame R/A	102	26	1200	575	0.575	0.3
63	24th Feb int - Starlets 91 Ave. Int	11	5	1200	500	0.5	0.2
64	Starlets 91 Ave. Int - 6th Street Int	3	0	1200	500	0.5	0.2
65	6th Street Int - Lake Rd Int	32	11	1200	1300	1.3	0.4
66	Lake Rd Int - Asafo Cement R/A	1	0	1200	500	0.5	0.2
67	Asafo Cement R/A - Labour R/A	6	3	1200	675	0.675	0.2
68	Labour R/A - 5th Street Int	62	26	1200	425	0.425	0.1
69	5th Street Int - Zongo Rd Int	0	0	1200	400	0.4	0.1
70	Gee R/A - Bekwai R/A	27	4	1220	750	0.75	0.4
71	Bekwai R/A - Ceedar Ave. Int	2	1	1220	2450	2.45	1.4
72	Ceedar Ave. Int - Santasi R/A	2	0	1220	200	0.2	0.1
73	Santasi R/A - Bekwai R/A	8	4	1220	550	0.55	0.3
74	Bekwai R/A - Cedar Rd Int	19	5	1220	1150	1.15	0.2
75	Cedar Rd Int - Rain tree Ave. Int	17	2	1200	450	0.45	0.1
76	Rain tree Ave. Int - Residency Link Int	0	0	1200	250	0.25	0.1
77	Residency Link Int - Harper Rd Int	0	0	1200	400	0.4	0.1
78	Odumase Rd Int. - Kotoko Rd Int.	0	0	1200	200	0.2	0.1
79	Kotoko Rd Int. - St. Anns Rd int	0	0	1200	150	0.15	0
80	St. Anns Rd int - 1st Krofrom Street Int	0	0	1200	725	0.725	0.2
81	1st Krofrom Street Int - Krofrom T Lite	0	0	1200	375	0.375	0.1
82	Anloga Jn - Adukrom Jn	50	18	1500	1100	1.1	0.7
83	Adukrom Jn - Kumaca Jn	24	11	1500	500	0.5	0.3
84	Kumaca Jn - Airport R/A	51	8	1500	1100	1.1	0.7

NO.	Road section/ Segment	Total Inkury Accidents	Hit Pedestrian HITPED_ACC	Pedestrian Volume (\$ Hours)	Length of Section (m)	Length of Section (km)	Total flow per km/100mil vehicles(Q)
85	Airport R/A - Krofrom T Lite	152	44	1500	2250	2.25	1.4
86	Krofrom T Lite - Suame R/A	77	14	1500	1400	1.4	0.8
87	Ahodwo R/A - 1st Ahodwo Street Int	16	4	1500	1100	1.1	0.4
88	1st Ahodwo Street Int - 2nd Ahodwo Street int	0	0	1500	350	0.35	0.1
89	2nd Ahodwo Street int - Sir Max Hotel Jn	0	0	1500	325	0.325	0.1
90	Pine Rd Int - Cedar Link Int	21	4	1500	950	0.95	0.2
91	Cedar Link Int - New Bekwai Rd	11	2	1500	1400	1.4	0.3

APPENDIX A- LIST OF SECTIONS

NO.	Road section/ Segment	Two Way Volume 2WAY_ AADT (veh/day)	Number of Lanes NUMB_LANES	Average Speed on Section AVE_SPEED (km/hr)	Speed Limit SPEED_LMT (km/hr)	Side Friction SIDE_FRIC TION	Presence of Pedestrian Crossing in Section PEDX PRES
1	Tafo Market - Suame New Rd	21500	2	2.7	50	1	1
2	Suame New Rd - Magazine New Rd Link Int.	21500	2	3.1	50	1	1
3	Magazine New Rd Link Int. - Tafo Nhyiaeso Rd Int.	21500	2	11.3	50	0	0
4	Tafo Nhyiaeso Rd Int. - Suame R/A	21500	2	13.7	50	0	1
5	Suame R/A - Kotoko Rd Int.	21500	4	19.8	50	0	1
6	Kotoko Rd Int. - Kejeta T Lite	21500	4	4.1	50	1	1
7	Siloam Hosp. Jn - Agric. Rd Int.	27300	2	4.3	50	1	1
8	Agric. Rd Int. - Siloam/ 2 Brigade Rd Int.	27300	2	4.4	50	0	1
9	Siloam/ 2 Brigade Rd Int. - Sofo line R/A	27300	2	10.1	50	0	1
10	Sofo line R/A - North Suntreso Rd Int.	27300	2	22.8	50	0	1
11	North Suntreso Rd Int. - Bekwai R/A	27300	2	29.5	50	0	0
12	Atonsu Terminal - Gyenyasi Int.	25400	2	3.9	50	1	1
13	Gyenyasi Int. - Kaase Rd Int.	25400	2	10	50	1	1
14	Kaase Rd Int. - Southern By-pass Int.	25400	2	5.5	50	1	0
15	Southern By-pass Int. - Hudson Rd Int.	25400	2	13	50	0	0
16	Hudson Rd Int. - Dadiesoaba Rd Int	25400	2	11.5	50	0	1
17	Dadiesoaba Rd Int - Maxwell Rd Int	25400	2	29.3	50	0	1
18	Maxwell Rd Int - Prempeh I Street Int	25400	2	20.9	50	0	0
19	Prempeh I Street Int - UTC T Lite	25400	2	23	50	0	0
20	Dr. Mensah - Odumase Rd Int.	21500	1	3.7	50	1	0
21	Odumase Rd Int. - Kotoko Rd Int.	21500	2	4.6	50	1	0
22	Kotoko Rd Int. - Kejeta T Lite	21500	2	6.9	50	1	1
23	Manhyia R/A - Burma Rd Int	21500	2	2	50	0	0
24	Burma Rd Int - Dichemso Rd Int	21500	2	13.2	50	0	1
25	Dichemso Rd Int - Airport R/A	21500	2	8.3	50	0	1
26	Airport R/A - Buokrom	21500	2	13.2	50	0	1
27	KNUST Jn - Bomso Jn	37200	4	7.6	50	1	1
28	Bomso Jn - STC T Lite	37200	4	9.2	50	0	1

NO.	Road section/ Segment	Two Way Volume 2W AY_ AADT (veh/day)	Number of Lanes NUMB_LANES	Average Speed on Section AVE_SPEED (km/hr)	Speed Limit SPEED_LMT (km/hr)	Side Friction SIDE_FRIC TION	Presence of Pedestrian Crossing in Section PEDX PRES
29	STC T Lite - Anloga Jn	37200	4	14.8	50	0	1
30	Anloga Jn - Stadium Jn	37200	4	14.9	50	1	1
31	Stadium Jn - Amakom T Lite	37200	4	21.4	50	1	0
32	Amakom T Lite - Labour R/A	37200	4	10.2	50	1	1
33	Labour R/A - Asafo Market R/A	37200	4	6.5	50	1	1
34	Asafo Market R/A - UTC T Lite	37200	2	10.7	50	0	0
35	Ahodwo R/A - Pine Avenue Int	17700	2	7.2	50	0	1
36	Pine Avenue Int - Prempeh I Street Int	17700	2	16	50	0	0
37	Prempeh I Street Int - UTC T Lite	17700	2	16.5	50	0	0
38	Starlets 91 Ave Int - Amakom Int	11400	2	5.8	50	0	0
39	Amakom Int - Old Ejisu Rd Int	11400	2	2.5	50	0	1
40	Old Ejisu Rd Int - 5th Street Int	11400	2	8.5	50	0	1
41	5th Street Int - Keneako Rd Int	11400	2	9.7	50	0	1
42	Keneako Rd Int - Burma Rd Int	11400	2	2.8	50	0	1
43	Abrepo Jn - North Suntreso Rd Int.	24300	2	7.5	50	1	1
44	North Suntreso Rd Int. - Bekwai R/A	24300	2	6.1	50	1	1
45	Breman Jn - Suame New Rd Int	44100	2	5.3	50	0	0
46	Suame New Rd Int - Anomangye Jn	44100	4	10.3	50	1	0
47	Anomangye Jn - 1st Suame Street Int	44100	4	15.9	50	1	0
48	1st Suame Street Int - Suame R/A	44100	4	24.7	50	1	1
49	Antoa Rd Int - Kejetia Link int	18500	2	9.4	50	1	0
50	Kejetia Link int - Kotoko Rd Int.	18500	2	12	50	1	1
51	Kotoko Rd Int. - Kejetia T Lite	18500	2	3.7	50	1	0
52	Ampabame Rd - Abrepo Jn	18500	2	14.9	50	0	1
53	Lake Rd Int - Ahodwo R/A	17700	2	9.1	50	0	0
54	Ahodwo R/A - Pine Avenue Int	17700	2	25.7	50	0	1
55	Adiembra Rd Int - TUC Jn	17700	2	10	50	0	0
56	TUC Jn - Santasi R/A	17700	2	6.1	50	0	1

APPENDIX A- LIST OF SECTIONS

NO.	Road section/ Segment	Two Way Volume 2WAY_ AADT (veh/day)	Number of Lanes NUMB_LANES	Average Speed on Section AVE_SPEED (km/hr)	Speed Limit SPEED_LMT (km/hr)	Side Friction SIDE_FRIC TION	Presence of Pedestrian Crossing in Section PEDX PRES
57	Santasi R/A - Estate Rd Int	28700	2	17.7	50	0	1
58	Estate Rd Int - Edwenase Rd Int	28700	2	13.9	50	0	1
59	Edwenase Rd Int - Kwadaso Estate Rd Int	28700	2	13.2	50	0	1
60	Kwadaso Estate Rd Int - Sofo line R/A	28700	2	15.6	50	0	0
61	Sofo line R/A - Abrepo Jn	28700	4	12.8	50	0	1
62	Abrepo Jn - Suame R/A	28700	4	36	50	1	1
63	24th Feb int - Starlets 91 Ave. Int	18500	2	11.3	50	1	1
64	Starlets 91 Ave. Int - 6th Street Int	18500	2	18.5	50	1	1
65	6th Street Int - Lake Rd Int	18500	2	11.8	50	0	1
66	Lake Rd Int - Asafo Cement R/A	18500	2	11.7	50	1	1
67	Asafo Cement R/A - Labour R/A	18500	2	11.3	50	1	1
68	Labour R/A - 5th Street Int	18500	2	6.9	50	1	1
69	5th Street Int - Zongo Rd Int	18500	2	10.9	50	1	1
70	Gee R/A - Bekwai R/A	30600	2	12.3	50	1	1
71	Bekwai R/A - Ceedar Ave. Int	30600	2	21.6	50	0	1
72	Ceedar Ave. Int - Santasi R/A	30600	2	24.2	50	0	0
73	Santasi R/A - Bekwai R/A	30600	4	31.2	50	0	0
74	Bekwai R/A - Cedar Rd Int	11400	2	29.8	50	0	0
75	Cedar Rd Int - Rain tree Ave. Int	11400	2	20.8	50	0	0
76	Rain tree Ave. Int - Residency Link Int	11400	2	7.1	50	0	0
77	Residency Link Int - Harper Rd Int	11400	2	8.7	50	0	0
78	Odumase Rd Int. - Kotoko Rd Int.	14400	2	15.6	50	1	0
79	Kotoko Rd Int. - St. Anns Rd int	14400	2	13.4	50	1	1
80	St. Anns Rd int - 1st Krofrom Street Int	14400	2	24.5	50	0	1
81	1st Krofrom Street Int - Krofrom T Lite	14400	2	11.2	50	0	1
82	Anloga Jn - Adukrom Jn	33100	4	27.6	50	1	1
83	Adukrom Jn - Kumaca Jn	33100	4	23.4	50	1	1
84	Kumaca Jn - Airport R/A	33100	4	28.8	50	1	1

NO.	Road section/ Segment	Two Way Volume 2WAY_ AADT (veh/day)	Number of Lanes NUMB_LANES	Average Speed on Section AVE_SPEED (km/hr)	Speed Limit SPEED_LMT (km/hr)	Side Friction SIDE_FRIC TION	Presence of Pedestrian Crossing in Section PEDX PRES
85	Airport R/A - Krofrom T Lite	33100	4	18.2	50	1	1
86	Krofrom T Lite - Suame R/A	33100	4	23.6	50	1	1
87	Ahodwo R/A - 1st Ahodwo Street Int	17700	2	26.6	50	1	1
88	1st Ahodwo Street Int - 2nd Ahodwo Street int	17700	2	15.5	50	1	1
89	2nd Ahodwo Street int - Sir Max Hotel Jn	17700	2	24.6	50	1	1
90	Pine Rd Int - Cedar Link Int	11400	2	37	50	0	0
91	Cedar Link Int - New Bekwai Rd	11400	2	22.3	50	0	1

NO.	Road section/ Segment	Number of Pedestrian crossing Points PEDX NUM	Width of Pedestrian Sidewalk SWALK_WIDT H (m)	Presence of sidewalk SWALK_PRES C Yes=1, No =0	Width of Median MEDIAN_WID TH (m)	Presence of Median Breaks MEDIAN_BRE AK Yes=1, No =0	Number of road Signs in section ROADSIGNS NUMB
1	Tafo Market - Suame New Rd	2	0	0	0	0	8
2	Suame New Rd - Magazine New Rd Link Int.	3	0	0	0	0	1
3	Magazine New Rd Link Int. - Tafo Nhyiaeso Rd Int.	0	0	0	0	0	3
4	Tafo Nhyiaeso Rd Int. - Suame R/A	2	0	0	0	0	3
5	Suame R/A - Kotoko Rd Int.	1	2	1	0.8	1	0
6	Kotoko Rd Int. - Kejetia T Lite	3	2	1	3.2	1	2
7	Siloam Hosp. Jn - Agric. Rd Int.	2	0	0	0	0	1
8	Agric. Rd Int. - Siloam/ 2 Brigade Rd Int.	1	0	0	0	0	0
9	Siloam/ 2 Brigade Rd Int. - Sofo line R/A	1	0	0	0	0	0
10	Sofo line R/A - North Suntreso Rd Int.	3	0	0	0	0	0
11	North Suntreso Rd Int. - Bekwai R/A	0	0	0	0	0	0
12	Atonsu Terminal - Gyenyasi Int.	4	2.1	1	0	0	1
13	Gyenyasi Int. - Kaase Rd Int.	2	0	0	0	0	3
14	Kaase Rd Int. - Southern By-pass Int.	0	2	1	0	0	0
15	Southern By-pass Int. - Hudson Rd Int.	0	0	0	0	0	0
16	Hudson Rd Int. - Dadiesoaba Rd Int	1	2	1	0	0	1
17	Dadiesoaba Rd Int - Maxwell Rd Int	1	0	0	0	0	2
18	Maxwell Rd Int - Prempeh I Street Int	0	2	1	0	0	3
19	Prempeh I Street Int - UTC T Lite	0	2	1	0	0	6
20	Dr. Mensah - Odumase Rd Int.	0	2	1	0	0	1
21	Odumase Rd Int. - Kotoko Rd Int.	0	1.5	1	0	0	2
22	Kotoko Rd Int. - Kejetia T Lite	2	2	1	0	0	1
23	Manhyia R/A - Burma Rd Int	0	2.4	1	0	0	0
24	Burma Rd Int - Dichemso Rd Int	2	2	1	0	0	0
25	Dichemso Rd Int - Airport R/A	4	2.4	1	0	0	1
26	Airport R/A - Buokrom	3	1.5	1	0	0	2
27	KNUST Jn - Bomso Jn	2	0	0	4	1	9
28	Bomso Jn - STC T Lite	3	2	1	4	1	3

NO.	Road section/ Segment	Number of Pedestrian crossing Points PEDX NUM	Width of Pedestrian Sidewalk SWALK_WIDT H (m)	Presence of sidewalk SWALK_PRES C Yes=1, No=0	Width of Median MEDIAN_WID TH (m)	Presence of Median Breaks MEDIAN_BRE AK Yes=1, No =0	Number of road Signs in section ROADSIGNS NUMB
29	STC T Lite - Anloga Jn	2	2	1	2	1	1
30	Anloga Jn - Stadium Jn	3	2	1	2	1	0
31	Stadium Jn - Amakom T Lite	0	2	1	2	0	2
32	Amakom T Lite - Labour R/A	1	1.93	1	2	1	4
33	Labour R/A - Asafo Market R/A	1	3.5	1	2	1	1
34	Asafo Market R/A - UTC T Lite	0	2.5	1	0.6	1	11
35	Ahodwo R/A - Pine Avenue Int	3	2.4	1	0	0	16
36	Pine Avenue Int - Prempeh I Street Int	0	1.6	1	0	0	0
37	Prempeh I Street Int - UTC T Lite	0	1.8	1	0	0	3
38	Starlets 91 Ave Int - Amakom Int	0	2.1	1	0	0	0
39	Amakom Int - Old Ejisu Rd Int	2	2	1	0	0	0
40	Old Ejisu Rd Int - 5th Street Int	1	0	0	0	0	2
41	5th Street Int - Keneako Rd Int	1	0	0	0	0	4
42	Keneako Rd Int - Burma Rd Int	1	2.4	1	0	0	0
43	Abrepo Jn - North Suntreso Rd Int.	3	2.1	1	0	0	5
44	North Suntreso Rd Int. - Bekwai R/A	6	1.35	1	0	0	0
45	Breman Jn - Suame New Rd Int	0	2	1	3.5	1	0
46	Suame New Rd Int - Anomangye Jn	0	0	0	2	1	3
47	Anomangye Jn - 1st Suame Street Int	0	2	1	2	1	1
48	1st Suame Street Int - Suame R/A	1	2	1	2	1	2
49	Antoa Rd Int - Kejetia Link int	0	2	1	0	0	2
50	Kejetia Link int - Kotoko Rd Int.	5	2	1	0	0	2
51	Kotoko Rd Int. - Kejetia T Lite	0	2	1	0	0	4
52	Ampabame Rd - Abrepo Jn	1	2.1	1	0	0	5
53	Lake Rd Int - Ahodwo R/A	0	0	0	0	0	14
54	Ahodwo R/A - Pine Avenue Int	1	0	0	0	0	3
55	Adiembra Rd Int - TUC Jn	0	0	0	0	0	3
56	TUC Jn - Santasi R/A	1	0	0	0	0	1

APPENDIX A- LIST OF SECTIONS

NO.	Road section/ Segment	Number of Pedestrian crossing Points PEDX NUM	Width of Pedestrian Sidewalk SWALK_WIDT H (m)	Presence of sidewalk SWALK_PRES C Yes=1, No =0	Width of Median MEDIAN_WID TH (m)	Presence of Median Breaks MEDIAN_BRE AK Yes=1, No =0	Number of road Signs in section ROADSIGNS NUMB
57	Santasi R/A - Estate Rd Int	1	0	0	0	0	3
58	Estate Rd Int - Edwenase Rd Int	3	0	0	0	0	5
59	Edwenase Rd Int - Kwadaso Estate Rd Int	2	0	0	0	0	7
60	Kwadaso Estate Rd Int - Sofo line R/A	0	0	0	0	0	0
61	Sofo line R/A - Abrepo Jn	9	2	1	4.5	1	31
62	Abrepo Jn - Suame R/A	11	1.8	1	4.5	1	7
63	24th Feb int - Starlets 91 Ave. Int	1	2	1	0	0	0
64	Starlets 91 Ave. Int - 6th Street Int	2	2	1	0	0	4
65	6th Street Int - Lake Rd Int	2	2	1	0	0	6
66	Lake Rd Int - Asafo Cement R/A	1	2	1	0	0	26
67	Asafo Cement R/A - Labour R/A	2	3.5	1	0	0	8
68	Labour R/A - 5th Street Int	2	3.5	1	0	0	3
69	5th Street Int - Zongo Rd Int	2	3.5	1	0	0	1
70	Gee R/A - Bekwai R/A	3	0	0	0	0	11
71	Bekwai R/A - Ceedar Ave. Int	1	0	0	0	0	15
72	Ceedar Ave. Int - Santasi R/A	0	0	0	0	0	2
73	Santasi R/A - Bekwai R/A	0	1.7	1	4.3	1	2
74	Bekwai R/A - Cedar Rd Int	0	1.8	1	0	0	4
75	Cedar Rd Int - Rain tree Ave. Int	0	1.8	1	0	0	4
76	Rain tree Ave. Int - Residency Link Int	0	0	0	0	0	0
77	Residency Link Int - Harper Rd Int	0	0	0	0	0	0
78	Odumase Rd Int. - Kotoko Rd Int.	0	2	1	0	0	0
79	Kotoko Rd Int. - St. Anns Rd int	0	2.1	1	0	0	3
80	St. Anns Rd int - 1st Krofrom Street Int	1	3	1	0	0	0
81	1st Krofrom Street Int - Krofrom T Lite	0	3	1	0	0	0
82	Anloga Jn - Adukrom Jn	11	0	0	3.2	1	7
83	Adukrom Jn - Kumaca Jn	5	2	1	1.8	0	8
84	Kumaca Jn - Airport R/A	8	2.9	1	3	1	5

NO.	Road section/ Segment	Number of Pedestrian crossing Points PEDX NUM	Width of Pedestrian Sidewalk SWALK_WIDT H (m)	Presence of sidewalk SWALK_PRES C Yes=1, No =0	Width of Median MEDIAN_WID TH (m)	Presence of Median Breaks MEDIAN_BRE AK Yes=1, No =0	Number of road Signs in section ROADSIGNS NUMB
85	Airport R/A - Krofrom T Lite	11	2.7	1	1	1	8
86	Krofrom T Lite - Suame R/A	3	2.7	1	1	0	2
87	Ahodwo R/A - 1st Ahodwo Street Int	1	0	0	0	0	3
88	1st Ahodwo Street Int - 2nd Ahodwo Street int	1	0	0	0	0	4
89	2nd Ahodwo Street int - Sir Max Hotel Jn	1	0	0	0	0	2
90	Pine Rd Int - Cedar Link Int	0	0	0	0	0	0
91	Cedar Link Int - New Bekwai Rd	1	0	0	0	0	6

APPENDIX A- LIST OF SECTIONS

NO.	Road section/ Segment	Road Marking condition ROADMARKNG_ COND Good =1, Poor =0	Width of shoulder SHOULDR_WID TH (m)	Carriageway Width ROAD_WIDT H (m)	number of Bus stops in Section BUSTOP_NU MB	Presence of Kerbs KERB_PRESC Yes =1, No =0
1	Tafo Market - Suame New Rd	1	2.7	8.2	3	0
2	Suame New Rd - Magazine New Rd Link Int.	0	3	8.2	2	0
3	Magazine New Rd Link Int. - Tafo Nhyiaeso Rd Int.	0	2	11.2	4	0
4	Tafo Nhyiaeso Rd Int. - Suame R/A	0	2.3	11.2	4	0
5	Suame R/A - Kotoko Rd Int.	1	0	15	2	1
6	Kotoko Rd Int. - Kejetia T Lite	1	0	15	2	1
7	Siloam Hosp. Jn - Agric. Rd Int.	0	2.9	7	0	0
8	Agric. Rd Int. - Siloam/ 2 Brigade Rd Int.	0	1.2	6.9	0	0
9	Siloam/ 2 Brigade Rd Int. - Sofo line R/A	0	1.2	7.2	1	0
10	Sofo line R/A - North Suntreso Rd Int.	0	1.2	7.2	0	0
11	North Suntreso Rd Int. - Bekwai R/A	1	1.2	7	0	0
12	Atonsu Terminal - Gyenyasi Int.	0	2.1	8.4	6	0
13	Gyenyasi Int. - Kaase Rd Int.	0	3	7.8	5	0
14	Kaase Rd Int. - Southern By-pass Int.	0	0	9.2	1	1
15	Southern By-pass Int. - Hudson Rd Int.	0	0	7	1	0
16	Hudson Rd Int. - Dadiesoaba Rd Int	0	2	8.2	3	1
17	Dadiesoaba Rd Int - Maxwell Rd Int	1	1.8	7	0	1
18	Maxwell Rd Int - Prempeh I Street Int	1	0	11.4	0	0
19	Prempeh I Street Int - UTC T Lite	1	0	12	0	1
20	Dr. Mensah - Odumase Rd Int.	0	0	13.4	0	1
21	Odumase Rd Int. - Kotoko Rd Int.	0	0	8.5	0	1
22	Kotoko Rd Int. - Kejetia T Lite	1	0	9	0	1
23	Manhyia R/A - Burma Rd Int	0	0	7	0	1
24	Burma Rd Int - Dichemso Rd Int	1	1	7	1	1
25	Dichemso Rd Int - Airport R/A	1	2	7	5	1
26	Airport R/A - Buokrom	1	2	7.4	2	1
27	KNUST Jn - Bomso Jn	1	2	14	4	1
28	Bomso Jn - STC T Lite	1	2	14	2	1

NO.	Road section/ Segment	Road Marking condition ROADMARKNG_ COND Good =1, Poor =0	Width of shoulder SHOULDR_WID TH (m)	Carriageway Width ROAD_WIDT H (m)	number of Bus stops in Section BUSSTOP_NU MB	Presence of Kerbs KERB_PRESC Yes =1, No =0
29	STC T Lite - Anloga Jn	1	1.9	14	1	1
30	Anloga Jn - Stadium Jn	1	0	14	2	1
31	Stadium Jn - Amakom T Lite	1	0	14	2	1
32	Amakom T Lite - Labour R/A	1	0	14	0	1
33	Labour R/A - Asafo Market R/A	1	0	15	1	1
34	Asafo Market R/A - UTC T Lite	1	0	7	0	1
35	Ahodwo R/A - Pine Avenue Int	1	0	9.7	0	1
36	Pine Avenue Int - Prempeh I Street Int	1	0	9.5	0	1
37	Prempeh I Street Int - UTC T Lite	1	0	8.7	0	1
38	Starlets 91 Ave Int - Amakom Int	1	2.1	7.3	0	0
39	Amakom Int - Old Ejisu Rd Int	1	0	8.2	0	1
40	Old Ejisu Rd Int - 5th Street Int	0	2.1	7.2	0	0
41	5th Street Int - Keneako Rd Int	0	2.1	6.9	0	0
42	Keneako Rd Int - Burma Rd Int	0	0	7	0	1
43	Abrepo Jn - North Suntreso Rd Int.	1	0	7.2	1	1
44	North Suntreso Rd Int. - Bekwai R/A	1	0	7.2	1	1
45	Breman Jn - Suame New Rd Int	0	0	14	4	1
46	Suame New Rd Int - Anomangye Jn	0	2	14	2	1
47	Anomangye Jn - 1st Suame Street Int	0	0	15	2	1
48	1st Suame Street Int - Suame R/A	1	0	14	1	1
49	Antoa Rd Int - Kejetia Link int	1	0	6.9	1	1
50	Kejetia Link int - Kotoko Rd Int.	1	0	6.9	0	1
51	Kotoko Rd Int. - Kejetia T Lite	0	0	9	0	1
52	Ampabame Rd - Abrepo Jn	0	3.2	7.2	1	1
53	Lake Rd Int - Ahodwo R/A	1	1.8	7.9	2	0
54	Ahodwo R/A - Pine Avenue Int	1	2	7.9	2	0
55	Adiembra Rd Int - TUC Jn	1	1.8	7.8	1	0
56	TUC Jn - Santasi R/A	1	1.8	7.8	0	0

APPENDIX A- LIST OF SECTIONS

NO.	Road section/ Segment	Road Marking condition ROADMARKNG_ COND Good =1, Poor =0	Width of shoulder SHOULDR_WID TH (m)	Carriageway Width ROAD_WIDT H (m)	number of Bus stops in Section BUSSTOP_NU MB	Presence of Kerbs KERB_PRESC Yes =1, No =0
57	Santasi R/A - Estate Rd Int	1	2	7.5	1	0
58	Estate Rd Int - Edwenase Rd Int	1	2.2	7	5	0
59	Edwenase Rd Int - Kwadaso Estate Rd Int	1	1.5	6.7	1	0
60	Kwadaso Estate Rd Int - Sofo line R/A	0	1.2	7	1	0
61	Sofo line R/A - Abrepo Jn	1	0	15	1	1
62	Abrepo Jn - Suame R/A	1	0	15	0	1
63	24th Feb int - Starlets 91 Ave. Int	1	0	7.2	1	1
64	Starlets 91 Ave. Int - 6th Street Int	1	0	7.3	2	1
65	6th Street Int - Lake Rd Int	1	0	7.3	3	1
66	Lake Rd Int - Asafo Cement R/A	1	0	7.3	2	0
67	Asafo Cement R/A - Labour R/A	1	0	6.7	2	0
68	Labour R/A - 5th Street Int	1	0	6.7	1	1
69	5th Street Int - Zongo Rd Int	1	0	8.9	2	1
70	Gee R/A - Bekwai R/A	1	2.5	9.8	2	0
71	Bekwai R/A - Ceedar Ave. Int	1	2.8	7.8	2	0
72	Ceedar Ave. Int - Santasi R/A	1	2.8	7.8	2	0
73	Santasi R/A - Bekwai R/A	1	0	15	2	1
74	Bekwai R/A - Cedar Rd Int	1	0	7	0	1
75	Cedar Rd Int - Rain tree Ave. Int	1	0	7	0	1
76	Rain tree Ave. Int - Residency Link Int	1	1.5	6	0	0
77	Residency Link Int - Harper Rd Int	1	1.5	6	0	0
78	Odumase Rd Int. - Kotoko Rd Int.	1	0	6	0	0
79	Kotoko Rd Int. - St. Anns Rd int	1	0	7.5	0	1
80	St. Anns Rd int - 1st Krofrom Street Int	0	0	8.2	0	0
81	1st Krofrom Street Int - Krofrom T Lite	0	0	8.2	0	0
82	Anloga Jn - Adukrom Jn	1	2.1	15	1	1
83	Adukrom Jn - Kumaca Jn	1	2.2	14	1	1
84	Kumaca Jn - Airport R/A	1	2.2	15.2	3	1

NO.	Road section/ Segment	Road Marking condition ROADMARKNG_ COND Good =1, Poor =0	Width of shoulder SHOULDR_WID TH (m)	Carriageway Width ROAD_WIDT H (m)	number of Bus stops in Section BUSSTOP_NU MB	Presence of Kerbs KERB_PRESC Yes =1, No =0
85	Airport R/A - Krofrom T Lite	0	0	14	4	1
86	Krofrom T Lite - Suame R/A	1	2.2	14	0	1
87	Ahodwo R/A - 1st Ahodwo Street Int	0	1.8	7.2	2	0
88	1st Ahodwo Street Int - 2nd Ahodwo Street int	0	2	7.2	1	0
89	2nd Ahodwo Street int - Sir Max Hotel Jn	0	2	7.3	0	0
90	Pine Rd Int - Cedar Link Int	1	2.1	6	0	0
91	Cedar Link Int - New Bekwai Rd	1	2.1	6	1	0

NO.	Road section/ Segment	Number of Public accesses in Section ACCESS_PUB	Number of Two vehicle accident	Single Vehicle accidents without ped	Rate of single vehicle accident without ped	Total single vehicle accidents	Hit pedestrian accident rate
29	STC T Lite - Anloga Jn	2	35	3	7.36	16	31.91
30	Anloga Jn - Stadium Jn	3	38	5	7.75	26	32.56
31	Stadium Jn - Amakom T Lite	3	26	1	4.21	7	25.25
32	Amakom T Lite - Labour R/A	3	30	2	4.21	16	29.46
33	Labour R/A - Asafo Market R/A	1	23	0	0	11	36.01
34	Asafo Market R/A - UTC T Lite	0	22	2	11.78	9	41.24
35	Ahodwo R/A - Pine Avenue Int	7	6	0	0	3	6.52
36	Pine Avenue Int - Prempeh I Street Int	0	10	0	0	1	3.87
37	Prempeh I Street Int - UTC T Lite	2	9	0	0	3	30.96
38	Starlets 91 Ave Int - Amakom Int	0	2	0	0	4	29.58
39	Amakom Int - Old Ejisu Rd Int	1	21	1	24.03	5	96.13
40	Old Ejisu Rd Int - 5th Street Int	3	2	0	0	0	0
41	5th Street Int - Keneako Rd Int	4	3	1	14.79	4	44.37
42	Keneako Rd Int - Burma Rd Int	0	4	1	12.02	4	36.05
43	Abrepo Jn - North Suntreso Rd Int.	9	31	2	7.52	11	33.82
44	North Suntreso Rd Int. - Bekwai R/A	9	5	2	6.01	10	24.05
45	Breman Jn - Suame New Rd Int	4	9	3	5.33	13	17.75
46	Suame New Rd Int - Anomangye Jn	4	20	4	4.32	15	11.88
47	Anomangye Jn - 1st Suame Street Int	3	13	1	1.66	8	11.6
48	1st Suame Street Int - Suame R/A	3	19	0	0	8	15.29
49	Antoa Rd Int - Kejetia Link int	2	1	0	0	1	8.46
50	Kejetia Link int - Kotoko Rd Int.	3	1	0	0	1	3.82
51	Kotoko Rd Int. - Kejetia T Lite	4	3	0	0	0	0
52	Ampabame Rd - Abrepo Jn	11	9	3	7.73	8	12.88
53	Lake Rd Int - Ahodwo R/A	4	5	0	0	2	4.59
54	Ahodwo R/A - Pine Avenue Int	3	4	1	2.21	1	0
55	Adiembra Rd Int - TUC Jn	1	0	0	0	0	0
56	TUC Jn - Santasi R/A	4	7	2	7.74	2	0

APPENDIX A- LIST OF SECTIONS

NO.	Road section/ Segment	Number of Public accesses in Section ACCESS_PUB	Number of Two vehicle accident	Single Vehicle accidents without ped	Rate of single vehicle accident without ped	Total single vehicle accidents	Hit pedestrian accident rate
57	Santasi R/A - Estate Rd Int	3	2	1	5.87	2	5.87
58	Estate Rd Int - Edwenase Rd Int	6	1	0	0	4	6.64
59	Edwenase Rd Int - Kwadaso Estate Rd Int	5	1	0	0	5	7.2
60	Kwadaso Estate Rd Int - Sofo line R/A	3	0	0	0	0	0
61	Sofo line R/A - Abrepo Jn	4	4	1	1.39	2	1.39
62	Abrepo Jn - Suame R/A	3	61	4	13.28	30	86.33
63	24th Feb int - Starlets 91 Ave. Int	4	6	0	0	5	29.62
64	Starlets 91 Ave. Int - 6th Street Int	3	2	0	0	0	0
65	6th Street Int - Lake Rd Int	4	18	1	2.28	12	25.06
66	Lake Rd Int - Asafo Cement R/A	4	1	0	0	0	0
67	Asafo Cement R/A - Labour R/A	8	1	1	4.39	4	13.16
68	Labour R/A - 5th Street Int	6	31	3	20.91	29	181.2
69	5th Street Int - Zongo Rd Int	6	0	0	0	0	0
70	Gee R/A - Bekwai R/A	3	22	0	0	4	9.55
71	Bekwai R/A - Ceedar Ave. Int	3	1	0	0	1	0.73
72	Ceedar Ave. Int - Santasi R/A	6	2	0	0	0	0
73	Santasi R/A - Bekwai R/A	3	3	1	3.26	5	13.02
74	Bekwai R/A - Cedar Rd Int	3	14	0	0	5	20.9
75	Cedar Rd Int - Rain tree Ave. Int	2	15	0	0	2	21.36
76	Rain tree Ave. Int - Residency Link Int	0	0	0	0	0	0
77	Residency Link Int - Harper Rd Int	0	0	0	0	0	0
78	Odumase Rd Int. - Kotoko Rd Int.	0	0	0	0	0	0
79	Kotoko Rd Int. - St. Anns Rd int	4	0	0	0	0	0
80	St. Anns Rd int - 1st Krofrom Street Int	4	0	0	0	0	0
81	1st Krofrom Street Int - Krofrom T Lite	6	0	0	0	0	0
82	Anloga Jn - Adukrom Jn	4	24	5	7.52	23	27.09
83	Adukrom Jn - Kumaca Jn	2	12	1	3.31	12	36.42
84	Kumaca Jn - Airport R/A	3	36	5	7.52	13	12.04

NO.	Road section/ Segment	Number of Public accesses in Section ACCESS_PUB	Number of Two vehicle accident	Single Vehicle accidents without ped	Rate of single vehicle accident without ped	Total single vehicle accidents	Hit pedestrian accident rate
85	Airport R/A - Krofrom T Lite	9	88	4	2.94	48	32.37
86	Krofrom T Lite - Suame R/A	1	55	5	5.91	19	16.55
87	Ahodwo R/A - 1st Ahodwo Street Int	3	9	2	5.63	6	11.26
88	1st Ahodwo Street Int - 2nd Ahodwo Street int	2	0	0	0	0	0
89	2nd Ahodwo Street int - Sir Max Hotel Jn	3	0	0	0	0	0
90	Pine Rd Int - Cedar Link Int	6	16	0	0	4	20.24
91	Cedar Link Int - New Bekwai Rd	12	5	1	3.43	3	6.87

VEHICLE REGISTRATION IN GHANA

APPENDIX B:

Table B 1- NUMBER OF REGISTERED VEHICLES IN GHANA (DVLA 2010 DATA)

YEAR	MOTOR CYCLE	PTE MV UPTO 2000CC	COMM MV UPTO 2000CC	MV ABOVE 2000CC	BUSES AND COACHES	R/C TRUCKS UPTO 16 TON	R/C TRUCKS FROM 16-22 TON	R/C TRUCKS ABOVE 22 TON	ART TRUCKS UPTO 24 TONS	ART TRUCKS ABOVE 24-32 TONS
1995	4908	17248	2941	6	10387	5130	1387	104	686	176
1996	29551	112991	36475	1067	42501	13794	5189	1421	2243	1403
1997	7930	24134	5490	26	9114	2546	981	487	531	388
1998	6064	22693	4869	71	11443	3770	1085	669	396	319
1999	6623	24434	12004	6249	9843	3454	590	292	196	291
2000	6440	27552	5104	5196	5469	1428	395	229	120	305
2001	6058	17953	5568	5343	2676	861	367	234	136	251
2002	6430	18512	6015	7143	2601	1044	300	281	138	201
2003	8777	20564	5110	7778	2916	914	292	326	116	447
2004	14462	20333	7642	7189	4882	2065	603	442	447	376
2005	15136	22949	6686	8715	5585	2457	420	543	551	374
2006	18051	23806	7249	11127	7399	2747	475	1024	269	188
2007	20320	29633	7757	15296	9791	3586	669	1240	160	342
2008	25475	31628	7040	17374	11737	3997	861	1303	89	284
2009	27581	25128	7868	17414	8810	3130	933	1120	134	414
TOTAL	203806	439558	127818	109994	145154	50923	14547	9715	6212	5759

Table B 2- CUMULATIVE NUMBER OF VEHICLES IN GHANA

YEAR	MOTOR CYCLE	PTE MV UPTO 2000CC	COMM MV UPTO 2000CC	MV ABOVE 2000CC	BUSES AND COACHES	R/C TRUCKS UPTO 16 TON	R/C TRUCKS FROM 16-22 TON	R/C TRUCKS ABOVE 22 TON	ART TRUCKS UPTO 24 TONS	ART TRUCKS ABOVE 24-32 TONS	TOTAL VEHICLES
1995	4908	17248	2941	6	10387	5130	1387	104	686	176	42973
1996	34459	130239	39416	1073	52888	18924	6576	1525	2929	1579	289608
1997	42389	154373	44906	1099	62002	21470	7557	2012	3460	1967	341235
1998	48453	177066	49775	1170	73445	25240	8642	2681	3856	2286	392614
1999	55076	201500	61779	7419	83288	28694	9232	2973	4052	2577	456590
2000	61516	229052	66883	12615	88757	30122	9627	3202	4172	2882	508828
2001	67574	247005	72451	17958	91433	30983	9994	3436	4308	3133	548275
2002	74004	265517	78466	25101	94034	32027	10294	3717	4446	3334	590940
2003	82781	286081	83576	32879	96950	32941	10586	4043	4562	3781	638180
2004	97243	306414	91218	40068	101832	35006	11189	4485	5009	4157	696621
2005	112379	329363	97904	48783	107417	37463	11609	5028	5560	4531	760037
2006	130430	353169	105153	59910	114816	40210	12084	6052	5829	4719	832372
2007	150750	382802	112910	75206	124607	43796	12753	7292	5989	5061	921166
2008	176225	414430	119950	92580	136344	47793	13614	8595	6078	5345	1020954
2009	203806	439558	127818	109994	145154	50923	14547	9715	6212	5759	1113486
TOTAL	1341993	3933817	1155146	525861	1383354	480722	149691	64860	67148	51287	

APPENDIX C:

CRASHES DATA FOR 2000 – 2009

APPENDIX C

Trend in Accidents by Region

Year	Region										Total
	Ashanti	Brong Ahafo	Central	Eastern	Greater Accra	Northern	Upper East	Upper W	Volta	Western	
2000	1818	630	918	1421	5234	188	169	103	509	724	11714
2001	1680	494	955	1397	5003	225	173	86	594	684	11291
2002	1774	588	831	1469	4230	193	209	66	546	809	10715
2003	1917	562	907	1383	4110	203	225	64	517	756	10644
2004	2037	691	1026	1703	4624	323	209	72	682	800	12167
2005	1680	655	916	1445	4983	224	181	82	567	595	11328
2006	1706	621	883	1351	5454	266	125	62	522	678	11668
2007	1975	541	709	1349	5936	255	136	73	495	569	12038
2008	1779	691	756	1295	5044	257	155	79	503	655	11214
2009	1971	693	917	1340	5588	220	119	61	554	836	12299
Total	18337	6166	8818	14153	50206	2354	1701	748	5489	7106	115078
%	15.9	5.4	7.7	12.3	43.6	2.0	1.5	0.6	4.8	6.2	100.0

Trend in All Fatal Accidents by Region

Year	Region										Total
	Ashanti	Brong Ahafo	Central	Eastern	Greater Accra	Northern	Upper East	Upper W	Volta	Western	
2000	247	107	134	201	214	44	47	16	79	110	1199
2001	263	87	156	205	220	54	32	14	112	114	1257
2002	251	157	141	226	150	47	39	18	108	108	1245
2003	306	109	148	196	207	76	47	22	114	120	1345
2004	377	151	176	240	253	96	54	21	111	121	1600
2005	249	130	156	236	259	71	63	21	90	116	1391
2006	257	172	138	174	305	76	45	21	129	102	1419
2007	332	163	146	218	363	80	63	25	118	114	1622
2008	343	136	150	238	351	77	54	33	131	134	1647
2009	388	168	181	261	385	63	52	33	117	142	1790
Total	3013	1380	1526	2195	2707	684	496	224	1109	1181	14515
%	20.8	9.5	10.5	15.1	18.6	4.7	3.4	1.5	7.6	8.1	100.0

Annual Distribution of Traffic Fatalities by Region

Year	Region										Total
	Ashanti	Brong Ahafo	Central	Eastern	Greater Accra	Northern	Upper East	Upper We	Volta	Western	
2000	332	141	199	272	237	60	85	18	89	145	1578
2001	379	152	206	279	240	66	34	17	152	135	1660
2002	359	190	215	346	169	71	44	20	130	121	1665
2003	377	140	188	263	232	138	53	35	152	138	1716
2004	577	202	234	325	299	131	68	24	167	158	2185
2005	315	192	183	299	313	97	79	30	122	154	1784
2006	388	244	184	216	335	112	44	21	169	143	1856
2007	463	207	190	280	407	105	69	27	145	150	2043
2008	416	155	150	294	385	95	59	36	179	169	1938
2009	469	259	246	343	429	113	54	40	140	144	2237
Total	4075	1882	1995	2917	3046	988	589	268	1445	1457	18662
%	21.8	10.1	10.7	15.6	16.3	5.3	3.2	1.4	7.7	7.8	100.0

Annual Distribution of Traffic Casualties by Region

Year	Region										Total
	Ashanti	Brong Ahafo	Central	Eastern	Greater Accra	Northern	Upper East	Upper We	Volta	Western	
2000	2608	920	2101	2899	3295	335	312	198	905	1091	14664
2001	2386	952	1681	3013	3420	439	339	185	1325	1093	14833
2002	2482	1168	1991	3185	2798	473	304	121	1187	1365	15074
2003	3548	1039	2193	2882	3136	623	323	133	1226	1211	16314
2004	3676	1451	1943	3148	3782	806	322	134	1828	1346	18436
2005	2913	1346	1602	2995	3566	448	291	187	1445	1045	15838
2006	2604	1261	1170	2501	3880	594	144	86	1189	1063	14492
2007	3243	1121	1324	2662	4857	615	245	117	1056	1176	16416
2008	2856	1512	1438	2749	4267	745	241	174	1271	1216	16469
2009	3663	1538	1862	2897	4971	524	199	144	1155	1543	18496
Total	29979	12308	17305	28931	37972	5602	2720	1479	12587	12149	161032
%	18.6	7.6	10.7	18.0	23.6	3.5	1.7	0.9	7.8	7.5	100.0

Ashanti Region (2000-2009)

Ashanti Region (2000-2009)											
Year	Accidents	Casualties									
	Total	Index	Fatal	Index	Injury	Index	Total	Index	Persons Killed	Index	Persons Injured
2000	1818	100.0	247	100.0	1357	100.0	2608	100.0	332	100.0	2276
2001	1680	92.4	263	106.5	1131	83.3	2389	91.6	379	114.2	2010
2002	1774	97.6	251	101.6	874	64.4	2482	95.2	359	108.1	2123
2003	1917	105.4	306	123.9	1060	78.1	3548	136.0	365	109.9	3183
2004	2036	112.0	377	152.6	1066	78.6	3676	141.0	577	173.8	3099
2005	1680	92.4	249	100.8	939	69.2	2913	111.7	315	94.9	2598
2006	1706	93.8	257	104.0	1206	88.9	2992	114.7	388	116.9	2604
2007	1975	108.6	332	134.4	1417	104.4	3243	124.3	463	139.5	2780
2008	1779	97.9	343	138.9	960	70.7	2856	109.5	416	125.3	2440
2009	1971	108.4	388	157.1	1117	82.3	3663	140.5	469	141.3	3194

Regional Distribution of Accidents and Casualties

Description	Ashanti	Brong Ahafo	Central	Eastern	Greater Accra	Northern	Upper East	Upper West	Volta	Western	Total
All Accidents	18337	6166	8818	14153	50206	2354	1701	748	5489	7106	115078
% Accidents	15.9	5.4	7.7	12.3	43.6	2.0	1.5	0.6	4.8	6.2	100.0
All Fatal Accidents	3013	1380	1526	2195	2707	684	496	224	1109	1181	14515
%	20.8	9.5	10.5	15.1	18.6	4.7	3.4	1.5	7.6	8.1	100.0
Killed	4075	1882	1995	2917	3046	988	589	268	1445	1457	18662
% killed	21.8	10.1	10.7	15.6	16.3	5.3	3.2	1.4	7.7	7.8	100.0
Casualties	29979	12308	17305	28931	37972	5602	2720	1479	12587	12149	161032
% Casualties	18.6	7.6	10.7	18.0	23.6	3.5	1.7	0.9	7.8	7.5	100.0

APPENDIX C Road User Class

Year	Pedestrian	Car	HGV	Tract	Bus	Minibus	Motor Cycle	Pickup	Bicycle	Other	Unknown	Total
2000	2839	2283	712	28	1587	37	335	416	338	49	43	8667
2001	3094	2334	754	46	1675	13	369	410	377	81	19	9172
2002	2863	2316	954	34	1671	21	336	348	384	18	26	8971
2003	2918	2335	1057	40	1732	35	414	354	436	42	39	9402
2004	3330	2814	1179	75	2036	17	566	430	506	26	30	11009
2005	3025	2388	979	40	744	935	592	441	441	19	12	9616
2006	3202	2361	1079	43	664	1033	584	395	452	18	13	9844
2007	3284	2659	1078	39	882	957	763	460	405	23	13	10563
2008	2981	2707	1189	37	775	923	885	433	391	21	19	10361
2009	3326	3245	1255	42	757	1274	996	519	319	16	10	11759
Total	18525	15749	6483	260	5470	5136	4313	2616	2465	122	67	61206
	30	26	11	0	9	8	7	4	4	0	0	100

Distribution of Injury Accidents by Road Environment

Year	Environment of Accident							All Injury Accidents	% Killed or Serious Injury
	Urban		Rural		Village		other		
	Number	% Fatal	Number	% Fatal	Number	% Fatal			
2000	3782	10.8	949	24.9	1690	26.3	5	6426	57.6
2001	3850	12.3	1026	27.2	1939	25.9	14	6829	54.9
2002	3772	12.1	893	29.3	1920	27.2	7	6592	57.7
2003	3691	12.4	1060	26.9	2093	27.9	2	6846	58.5
2004	4234	12.9	1058	26.8	2653	28.9	4	7949	55.9
2005	3869	12.6	918	30.4	2243	28.1	0	7030	55.5
2006	4100	13.2	672	32.6	2361	27.7	3	7136	59.0
2007	4598	14.7	671	34.7	2261	31.5	0	7530	60.1
2008	3752	15.0	797	35.4	2758	29.1	1	7308	58.9
2009	4430	14.6	684	30.6	3074	30.4	0	8188	56.3
Total	24273	21.6	4591	55.9	14880	44.1	8	43752	69.5

Distribution of Personal Injury Accidents by Road Environment

Year	Road Environment			APPENDIX C Total
	Urban	Rural	Village	
			?	
2000	3782	949	1690	6426
2001	3850	1026	1939	6829
2002	3772	893	1920	6592
2003	3691	1060	2093	6846
2004	4234	1058	2653	7949
2005	3869	918	2243	7030
2006	4100	672	2361	7136
2007	4598	671	2261	7530
2008	3752	797	2758	7308
2009	4430	684	3074	8188
Total	24273	4591	14880	43752
55.5				10.5
				34.0

Distribution of Fatalities by road user class

Distribution of Fatalities by road user class												Total
Year	Road User Class											
	Pedestrian	Car	HGV	Tract	Bus	Minibus	Motor Cycle	Pickup	Bicycle	Other	Unknown	
2000	553	216	175	8	239	12	37	56	51	15	6	1368
2001	685	220	194	11	235	3	42	50	59	28	4	1531
2002	613	252	273	13	268	3	47	55	71	8	4	1607
2003	656	243	304	13	273	6	45	56	93	9	8	1706
2004	792	294	347	23	345	3	99	64	107	4	7	2085
2005	718	250	263	8	116	124	108	82	98	4	3	1774
2006	736	223	311	12	120	145	105	50	102	2	4	1810
2007	842	284	304	16	168	131	187	61	95	5	3	2096
2008	820	337	323	13	126	163	189	70	114	1	7	2163
2009	896	387	323	19	142	222	206	70	101	2	2	2370
Total	7311	2706	2817	136	2032	812	1065	614	891	78	48	18510
%	39.5	14.6	15.2	0.7	11.0	4.4	5.8	3.3	4.8	0.4	0.3	100

Distribution of Serious Injury casualties by Road User Class

APPENDIX C Road User Class													Total
Year													
	Pedestrian	Car	HGV	Tract	Bus	Minibus	Motor Cycle	Pickup	Bicycle	Other	Unknown		
2000	1259	779	248	11	646	10	127	155	126	12	9	5382	
2001	1243	675	236	20	562	6	150	130	128	24	5	3179	
2002	1179	743	332	11	636	8	144	135	151	4	8	3351	
2003	1253	700	352	21	667	11	189	127	173	15	9	3517	
2004	1330	811	376	23	638	4	219	137	172	12	8	3730	
2005	1157	711	295	17	258	331	247	144	157	5	2	3324	
2006	1406	799	359	15	223	332	248	139	187	4	4	3716	
2007	1388	867	373	15	284	378	327	180	151	8	4	3975	
2008	1231	823	364	8	258	289	372	138	143	9	6	3641	
2009	1332	868	385	10	221	360	413	148	121	4	0	3862	
Total	12778	7776	3320	151	4393	1729	2436	1433	1509	97	55	35677	
%	35.8	21.8	9.3	0.4	12.3	4.8	6.8	4.0	4.2	0.3	0.2	100.0	

Distribution of Fatal and Serious Accidents Casualties by Road User Class

Year	Road User Class											Total
	Pedestrian	Car	HGV	Tract	Bus	Minibus	Motor Cycle	Pickup	Bicycle	Other	Unknown	
2000	1812	995	423	19	885	22	164	211	177	27	15	6750
2001	1928	895	430	31	797	9	192	180	187	52	9	4710
2002	1792	995	605	24	904	11	191	190	222	12	12	4958
2003	1909	943	656	34	940	17	234	183	266	24	17	5223
2004	2122	1105	723	46	983	7	318	201	279	16	15	5815
2005	1875	961	558	25	374	455	355	226	255	9	5	5098
2006	2142	1022	670	27	343	477	353	189	289	6	8	5526
2007	2230	1151	677	31	452	509	514	241	246	13	7	6071
2008	2051	1160	687	21	384	452	561	208	257	10	13	5804
2009	2228	1255	708	29	363	582	619	218	222	6	2	6232
Total	20089	10482	6137	287	6425	2541	3501	2047	2400	175	103	56187
%	35.8	18.7	10.9	0.5	11.4	4.5	6.2	3.6	4.3	0.3	0.2	100.0

Annual Distribution of Fatalities by Sex

APPENDIX C

Annual Distribution of Fatal Accidents by Road Environment

Year	Road Environment			Total
	Urban	Rural	Village	
2000	409	236	445	1092
2001	472	279	503	1257
2002	458	262	522	1245
2003	457	285	583	1327
2004	547	284	768	1600
2005	486	279	631	1396
2006	543	219	655	1417
2007	674	233	713	1620
2008	561	282	803	1646
2009	645	209	936	1790
Total	5252	2568	6559	14390

Year	Sex		Total
	Male	Female	
2000	1091	441	1532
2001	1193	441	1634
2002	1175	480	1655
2003	1280	437	1717
2004	1568	587	2155
2005	1292	463	1755
2006	1348	492	1840
2007	1554	489	2043
2008	1448	490	1938
2009	1655	582	2237
Total	13604	4902	18506
%	73.5	26.5	100.0

Annual Distribution of Serious Accidents by Road Environment

Year	Road Environment			Total
	Urban	Rural	Village	
2000	1491	412	705	2608
2001	1322	393	771	2490
2002	1378	345	833	2559
2003	1333	425	918	2676
2004	1396	395	1046	2840
2005	1320	309	880	2509
2006	1584	236	974	2796
2007	1711	238	960	2909
2008	1366	246	1044	2656
2009	1502	254	1061	2817
Total	8633	1588	5782	16008

Annual Distribution of Fatal and Serious Accidents by Road Environment

Year	Road Environment	Total
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	Urban	Rural	Village	?	
2000	1900	648	1150	2	3700
2001	1794	672	1274	7	3747
2002	1836	607	1355	6	3804
2003	1790	710	1501	2	4003
2004	1943	679	1814	4	4440
2005	1806	588	1511	0	3905
2006	2127	455	1629	2	4213
2007	2385	471	1673	0	4529
2008	1927	528	1847	0	4302
2009	2147	463	1997	0	4607
Total	13885	4156	12341	16	30398

Vehicles involvement in collision types for injury All Crashes (2003-2007)												
Year	Collision Type	Vehicle Type involved in injury crashes										Total
		Car	HGV	Tract	Bus	Mimbus	Motor Cycle	Pickup	Bicycle	Other	Unknown	
	Head On	5306	1470	29	1925	921	1038	676	577	31	20	11993
	Rear End	5826	2108	131	2508	1135	1344	829	1001	87	76	15045
	Right Ang	4534	754	36	1291	667	1427	627	968	40	21	10365
	Side Swip	3950	1619	75	1670	777	1281	620	1186	53	61	11292
	Ran Off R	1968	1471	41	1718	1044	237	585	39	12	4	7119
	Hit Object	192	88	4	100	47	24	33	14	3	0	505
	Hit Object	814	309	3	377	157	47	140	7	6	3	1863
	Hit Parked	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
	Hit Pedest	15155	2392	71	6167	2898	1686	1637	707	112	592	31417
	Other	2085	1277	57	2393	60	249	466	169	61	21	6838
	animal	20	10	0	3	12	12	6	0	1	0	64
	Total	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!

Collision Types vrs Vehicle Types for Injury Accidents		
Year	Collision	Vehicle Type
		Total

Year	Collision Type	Vehicle Type involved in Injury crashes										
		Car	HGV	Tract	Bus	Mimibus	Motor Cycle	Pickup	Bicycle	Other	Unknown	Total
	Head On	5306	1470	29	1925	921	1038	676	577	31	20	11993
	Rear End	5826	2108	131	2508	1135	1344	829	1001	87	76	15045
	Right Ang	4534	754	36	1291	667	1427	627	968	40	21	10365
	Side Swip	3950	1619	75	1670	777	1281	620	1186	53	61	11292
	Ran Off R	1968	1471	41	1718	1044	237	585	39	12	4	7119
	Hit Object	192	88	4	100	47	24	33	14	3	0	505
	Hit Object	814	309	3	377	157	47	140	7	6	3	1863
	Hit Parked	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
	Hit Pedest	15155	2392	71	6167	2898	1686	1637	707	112	592	31417
	Other	2085	1277	57	2393	60	249	466	169	61	21	6838
	animal	20	10	0	3	12	12	6	0	1	0	64
	Total	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
Collision Types vrs Vehicle Types for Injury Accidents												
Year	Collision	Vehicle Type										Total

APPENDIX C

	Type	Car	HGV	Tractor	Bus	Motorcycle	Pickup	Cycle	Other	Unknown	
2000	Head On	481	111	3	252	9	62	57	6	6	1052
2000	Rear End	550	154	6	319	6	89	82	14	16	1305
2000	Right Ang	393	51	4	180	3	79	70	4	3	841
2000	Slide Swip	283	100	2	170	6	67	85	5	6	777
2000	Overturme	91	46	2	137	0	3	1	3	0	310
2000	Hit Object	23	3	0	16	0	2	3	2	0	53
2000	Hit Object	86	24	0	63	0	1	1	2	3	196
2000	Hit Parked	53	34	4	32	3	4	5	1	2	146
2000	Hit Pedest	1436	177	8	829	7	119	72	19	77	2889
2000	Other	323	189	7	418	10	28	33	12	5	1145
2000	Total	3719	889	36	2416	44	454	409	68	118	8714
2001	Head On	438	76	3	229	0	54	54	11	1	921
2001	Rear End	453	123	12	317	2	79	70	25	3	1151
2001	Right Ang	380	65	2	155	2	66	65	2	1	797
2001	Side Swip	353	113	8	210	1	70	119	15	8	963
2001	Overturme	87	39	2	116	0	4	5	0	1	274
2001	Hit Object	14	12	0	12	0	5	0	0	0	49
2001	Hit Object	64	27	0	35	1	2	1	1	0	141
2001	Hit Parked	73	45	2	48	1	6	2	1	1	188
2001	Hit Pedest	1560	185	8	943	12	106	76	31	71	3168
2001	Other	471	254	17	551	6	82	61	26	4	1590
2001	Total	3893	939	54	2616	25	474	453	112	90	9242
2002	Head On	531	146	3	287	3	56	61	3	0	1145
2002	Rear End	506	171	12	297	3	74	75	4	6	1220
2002	Right Ang	448	86	4	159	1	69	108	1	3	929
2002	Side Swip	339	156	2	206	1	95	120	3	10	984
2002	Overturme	91	67	2	170	3	4	4	1	1	361
2002	Hit Object	12	9	0	13	0	2	3	1	0	40

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2002	Hit Object	70	25	1	43	2	12	1	0	0	156
2002	Hit Parked	50	40	3	43	4	7	1	1	2	152
2002	Hit Pedest	1501	206	8	810	92	138	70	9	89	2926
2002	Other	267	254	7	453	29	82	10	4	4	1117
2002	Total	3815	1160	42	2481	427	486	453	27	115	9030
2003	Head On	501	156	1	278	66	71	66	2	6	1151
2003	Rear End	502	208	11	308	86	70	97	7	12	1305
2003	Right Ang	420	57	4	167	109	48	98	10	3	919
2003	Side Swip	359	169	10	241	87	51	133	7	13	1079
2003	Overtur	103	99	3	167	6	28	2	2	1	414
2003	Hit Object	16	13	1	13	2	3	1	0	0	49
2003	Hit Object	68	31	0	52	1	14	1	0	0	167
2003	Hit Parked	31	35	0	29	4	0	3	1	0	104
2003	Hit Pedest	1411	237	13	832	142	149	98	9	68	2969
2003	Other	335	289	10	477	53	68	35	13	4	1295
2003	Total	3746	1294	53	2564	556	502	534	51	107	9452
2004	Head On	645	174	7	331	81	68	72	3	3	1387
2004	Rear End	518	221	25	360	120	74	93	6	13	1432
2004	Right Ang	531	88	10	218	162	66	166	4	1	1249
2004	Side Swip	468	205	13	269	137	64	138	6	7	1309
2004	Overtur	127	106	4	233	14	54	4	0	0	542
2004	Hit Object	18	6	0	11	2	5	0	0	0	43
2004	Hit Object	83	31	0	66	3	22	0	0	0	205
2004	Hit Parked	82	68	1	57	5	8	3	2	0	227
2004	Hit Pedest	1658	247	10	959	164	177	91	7	78	3400
2004	Other	340	280	15	490	41	69	28	5	4	1277
2004	Total	4470	1426	85	2994	729	607	595	33	106	11071
2005	Head On	474	129	5	103	93	79	42	2	0	1079

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2005	Rear End	495	173	8	145	173	146	66	111	6	4	1327
2005	Right Ang	426	70	3	85	108	138	59	108	5	1	1003
2005	Side Swip	428	186	9	110	152	131	62	152	2	4	1236
2005	Ran Off R	236	154	2	167	177	15	89	2	1	0	843
2005	Hit Object	23	12	0	5	10	5	4	1	0	0	60
2005	Hit Object	79	32	0	16	29	6	12	0	0	0	174
2005	Hit Parked	75	49	3	16	25	5	7	1	0	0	181
2005	Hit Pedest	1454	242	5	338	570	164	166	76	7	46	3068
2005	Animal	14	1	1	1	9	4	3	2	0	0	35
2005	Other	137	173	9	96	99	48	60	21	3	3	649
2005	Total	3841	1221	45	1082	1504	755	607	516	26	58	9655
2006	Head On	475	163	3	99	179	113	67	59	0	0	1158
2006	Rear End	602	225	16	153	236	137	83	156	5	3	1616
2006	Right Ang	480	84	3	76	143	169	69	116	4	3	1147
2006	Side Swip	319	157	6	96	134	109	48	102	5	4	980
2006	Ran Off R	259	233	4	165	207	19	72	4	1	0	964
2006	Hit Object	17	11	0	7	11	1	7	0	0	0	54
2006	Hit Object	74	43	1	22	32	9	11	1	0	0	193
2006	Hit Parked	78	62	3	12	21	10	15	2	0	1	204
2006	Hit Pedest	1548	253	5	365	589	176	174	70	6	32	3218
2006	Animal	7	0	0	0	3	3	1	0	0	0	14
2006	Other	50	101	7	34	67	14	22	12	3	2	312
2006	Total	3909	1332	48	1029	1622	760	569	522	24	45	9860
2007	Head On	502	158	0	127	181	126	72	56	2	1	1225
2007	Rear End	700	256	17	224	230	197	110	136	8	4	1882
2007	Right Ang	450	85	2	80	104	183	68	81	3	3	1059
2007	Side Swip	453	174	7	147	149	157	69	113	2	5	1276
2007	Ran Off R	271	199	7	192	188	50	95	7	2	0	1011
2007	Hit Object	22	4	0	7	5	2	1	1	0	0	42

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2007	Hit Object	94	33	0	36	31	11	17	2	1	0	225
2007	Hit Parked	73	83	1	24	29	12	7	1	0	0	230
2007	Hit Pedest	1552	294	6	442	553	212	178	65	9	30	3341
2007	Animal	10	3	0	2	4	3	1	0	0	0	23
2007	Other	84	83	5	43	36	22	20	8	5	0	306
2007	Total	4211	1372	45	1324	1510	975	638	470	32	43	10620
2008	Head On	587	170	3	101	165	185	65	68	1	1	1346
2008	Rear End	644	265	9	193	194	202	94	107	7	12	1727
2008	Right Ang	474	79	2	79	139	226	74	89	3	2	1167
2008	Side Swip	417	175	13	113	126	178	67	111	5	2	1207
2008	Ran Off R	312	265	3	194	182	57	86	0	0	0	1099
2008	Hit Object	23	9	2	7	9	1	2	4	0	0	57
2008	Hit Object	93	31	1	23	30	6	11	0	2	0	197
2008	Hit Parked	100	93	0	29	38	14	16	3	0	1	294
2008	Hit Pedest	1418	280	5	342	488	238	157	46	12	58	3044
2008	Animal	2	4	0	1	1	5	1	0	1	0	15
2008	Other	55	98	4	35	39	11	17	9	2	1	271
2008	Total	4125	1469	42	1117	1411	1123	590	437	33	77	10424
2009	Head On	672	187	1	118	225	202	79	42	1	2	1529
2009	Rear End	856	312	15	192	285	214	124	74	5	3	2080
2009	Right Ang	532	89	2	92	161	226	80	67	4	1	1254
2009	Side Swip	531	184	5	108	197	250	88	113	3	2	1481
2009	Ran Off R	391	263	12	177	284	65	96	10	2	1	1301
2009	Hit Object	24	9	1	9	11	2	1	1	0	0	58
2009	Hit Object	103	32	0	21	32	6	15	0	0	0	209
2009	Hit Parked	112	90	1	27	42	21	16	6	0	1	316
2009	Hit Pedest	1617	271	3	307	657	273	177	43	3	43	3394
2009	Animal	1	3	0	0	4	1	3	0	0	0	12
2009	Other	23	86	5	13	33	9	17	6	1	0	193

2009	Total	4862	1526	45	1064	1931	1269	696	362	19	53	11827
Total		20948	6920	225	5616	7978	4882	3100	2307	134	276	52386

Collision Types vrs Accident Severity in Ghana

Year	Collision Type	Accident Severity				Total
		Fatal	Hospitalised	Not-Hospitalised	Damage Only	
2000	Head On	97	231	192	384	904
2000	Rear End	57	212	342	1711	2322
2000	Right Angl	31	122	262	705	1120
2000	Side Swipe	46	119	214	960	1339
2000	Overtuned	80	135	86	65	366
2000	Hit Object	7	22	17	57	103
2000	Hit Object	25	80	86	202	393
2000	Hit Parked	12	23	39	94	168
2000	Hit Pedestr	553	1259	1027	0	2839
2000	Other	184	406	459	478	1527
2000	Total	1092	2609	2724	4656	11081
2001	Head On	106	150	202	276	734
2001	Rear End	44	148	340	1490	2022
2001	Right Angl	30	111	251	668	1060
2001	Side Swipe	27	144	287	991	1449
2001	Overtuned	75	99	91	55	320
2001	Hit Object	3	20	18	64	105
2001	Hit Object	21	49	67	163	300
2001	Hit Parked	14	28	55	131	228
2001	Hit Pedestr	685	1243	1166	0	3094
2001	Other	251	497	603	623	1974
2001	Total	1256	2489	3080	4461	11286
2002	Head On	121	244	198	293	856

2002	Rear End	68	145	351	1441	2005
2002	Right Angl	49	137	270	604	1060
2002	Side Swipe	67	175	235	1011	1488
2002	Overtuned	69	180	106	97	452
2002	Hit Object	3	13	16	80	112
2002	Hit Object	26	53	75	157	311
2002	Hit Parked	17	25	35	96	173
2002	Hit Pedestr	613	1179	1071	0	2863
2002	Other	212	407	430	343	1392
2002	Total	1245	2558	2787	4122	10712
2003	Head On	140	211	204	229	784
2003	Rear End	63	171	371	1279	1884
2003	Right Angl	45	154	250	533	982
2003	Side Swipe	51	162	305	890	1408
2003	Overtuned	95	193	114	73	475
2003	Hit Object	5	9	22	56	92
2003	Hit Object	24	54	83	170	331
2003	Hit Parked	14	17	24	67	122
2003	Hit Pedestr	656	1253	1009	0	2918
2003	Other	234	452	460	394	1540
2003	Total	1327	2676	2842	3691	10536
Total		4920	10332	11433	16930	43615

2004	Head On					
2004	Rear End					
2004	Right Angle					
2004	Side Swipe					
2004	Overtuned					
2004	Hit Object On Road					
2004	Hit Object Off Road					
2004	Hit Parked Vehicle					
2004	Hit Pedestrian					
2004	Other					
2005	Head On	138	193	206	228	765

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2005	Rear End	80	177	369	1383	2009
2005	Right Angl	65	159	267	560	1051
2005	Side Swipe	43	212	346	1184	1785
2005	Ran Off Rd	129	289	412	271	1101
2005	Hit Object	7	15	30	52	104
2005	Hit Object	32	60	81	194	367
2005	Hit Parked	11	27	55	111	204
2005	Hit Pedestr	718	1157	1150	35	3060
2005	Animal	4	12	15	22	53
2005	Other	169	206	193	259	827
2005	?	1	1	1	0	3
2005	Total	1397	2508	3125	4299	11329
2006	Head On	126	220	221	224	791
2006	Rear End	98	243	410	1587	2338
2006	Right Angl	71	197	298	593	1159
2006	Side Swipe	46	159	269	1179	1653
2006	Ran Off Rd	189	345	419	376	1329
2006	Hit Object	3	18	22	44	87
2006	Hit Object	32	77	73	208	390
2006	Hit Parked	20	41	44	139	244
2006	Hit Pedestr	736	1406	1060	25	3227
2006	Animal	2	7	5	37	51
2006	Other	95	84	102	125	406
2006	Total	1418	2797	2923	4537	11675
2007	Head On	147	240	221	306	914
2007	Rear End	121	295	457	1632	2505
2007	Right Angl	69	174	277	526	1046
2007	Side Swipe	70	208	330	1095	1703
2007	Ran Off Rd	205	394	394	349	1342
2007	Hit Object	9	11	14	32	66
2007	Hit Object	42	76	99	243	460

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2007	Hit Parked	23	50	38	156	267
2007	Hit Pedestr	842	1388	1054	8	3292
2007	Animal	5	6	10	34	55
2007	Other	89	67	108	121	385
2007	Total	1622	2909	3002	4502	12035
2008	Head On	182	232	251	241	906
2008	Rear End	105	247	445	1360	2157
2008	Right Angl	77	199	294	446	1016
2008	Side Swipe	71	181	324	974	1550
2008	Ran Off Rd	225	374	482	346	1427
2008	Hit Object	12	13	20	28	73
2008	Hit Object	36	67	92	187	382
2008	Hit Parked	35	39	63	201	338
2008	Hit Pedestr	820	1231	930	6	2987
2008	Animal	5	2	6	24	37
2008	Other	78	71	99	92	340
2008	Total	1646	2656	3006	3905	11213
2009	Head On	222	244	284	197	947
2009	Rear End	114	241	596	1467	2418
2009	Right Angl	65	180	371	563	1179
2009	Side Swipe	85	229	391	1057	1762
2009	Ran Off Rd	266	422	568	327	1583
2009	Hit Object	9	12	24	28	73
2009	Hit Object	29	54	123	187	393
2009	Hit Parked	28	49	75	198	350
2009	Hit Pedestr	896	1332	1098	6	3332
2009	Animal	2	4	6	26	38
2009	Other	74	50	45	54	223
2009	Total	1790	2817	3581	4110	12298
Total		7873	13687	15637	21353	58550

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Accident Location vrs Accident Severity for Urban Environment in Ghana

Year	Location Type	Accident Severity				Total
		Fatal	Hospitalised	Not-Hospitalised	Damage Only	
2000	Not at Junction	296	1046	1183	1876	4401
2000	Crossroads	30	98	173	557	858
2000	T/Junction	63	273	396	1001	1733
2000	Staggered	4	17	30	47	98
2000	Y/Junction	1	12	13	32	58
2000	Roundabout	1	20	33	222	276
2000	Railway	1	0	3	8	12
2000	Other	13	18	42	108	181
2000	?	0	7	9	12	28
2000	Total	409	1491	1882	3863	7645
2001	Not at Junction	333	886	1285	1663	4167
2001	Crossroads	17	99	224	506	846
2001	T/Junction	98	262	391	957	1708
2001	Staggered	5	14	20	28	67
2001	Y/Junction	3	12	18	35	68
2001	Roundabout	5	19	53	193	270
2001	Railway	0	0	0	4	4
2001	Other	11	26	55	142	234
2001	?	0	4	10	15	29
2001	Total	472	1322	2056	3543	7393
2002	Not at Junction	341	954	1246	1601	4142
2002	Crossroads	17	98	183	483	781
2002	T/Junction	74	257	391	919	1641
2002	Staggered	7	17	15	25	64
2002	Y/Junction	4	15	9	28	56
2002	Roundabout	4	16	34	199	253
2002	Railway	0	0	2	8	10

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2002	Other	10	19	50	125	204
2002	?	1	2	6	3	12
2002	Total	458	1378	1936	3391	7163
2003	Not at Junction	332	930	1204	1410	3876
2003	Crossroads	30	85	180	421	716
2003	T/Junction	68	273	391	775	1507
2003	Staggered Crossroads	2	8	23	24	57
2003	Y/Junction	2	2	12	21	37
2003	Roundabouts	11	8	34	174	227
2003	Railway	1	2	5	7	15
2003	Other	10	19	42	102	173
2003	?	1	6	10	11	28
2003	Total	457	1333	1901	2945	6636
2004	Not at Junction					
2004	Crossroads					
2004	T/Junction					
2004	Staggered Crossroads					
2004	Y/Junction					
2004	Roundabouts					
2004	Railway					
2004	Other					
2005	Not at Junction	352	925	1313	1748	4338
2005	Crossroads	25	93	209	468	795
2005	T/Junction	75	217	354	828	1474
2005	Staggered Crossroads	3	15	25	27	70
2005	Y/Junction	5	14	11	25	55
2005	Roundabouts	11	12	35	149	207
2005	Railway	1	2	2	3	8
2005	Other	13	36	99	178	326
2005	?	0	4	11	22	37
2005	Total	485	1318	2059	3448	7310
2006	Not at Junction	401	1111	1280	1825	4617
2006	Crossroads	26	107	165	479	777

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2006	T/Junction	85	285	391	931	1692
2006	Staggered	4	15	26	53	98
2006	Y/Junction	7	9	14	30	60
2006	Roundabout	3	18	27	167	215
2006	Railway	0	4	6	10	20
2006	Other	17	34	64	158	273
2006	?	0	0	0	2	2
2006	Total	543	1583	1973	3655	7754
2007	Not at Junc	485	1145	1333	1857	4820
2007	Crossroads	36	116	245	520	917
2007	T/Junction	111	362	484	1091	2048
2007	Staggered	11	20	24	37	92
2007	Y/Junction	0	10	18	35	63
2007	Roundabout	14	22	49	142	227
2007	Railway	0	3	3	8	14
2007	Other	17	33	57	122	229
2007	Total	674	1711	2213	3812	8410
2008	Not at Junc	391	927	1099	1489	3906
2008	Crossroads	25	92	184	383	684
2008	T/Junction	110	253	411	770	1544
2008	Staggered	9	19	21	31	80
2008	Y/Junction	3	15	7	28	53
2008	Roundabout	10	34	43	122	209
2008	Railway	0	1	1	2	4
2008	Other	13	25	59	123	220
2008	Total	561	1366	1825	2948	6700
2009	Not at Junc	504	1089	1448	1708	4749
2009	Crossroads	27	76	239	424	766
2009	T/Junction	87	269	461	864	1681
2009	Staggered	7	21	28	37	93
2009	Y/Junction	3	11	14	19	47
2009	Roundabout	8	16	37	125	186
2009	Railway	1	0	2	3	6

2009	Other	7	20	51	105	183
2009	?	0	0	1	0	1
2009	Total	644	1502	2281	3285	7712
Total		2907	7480	10351	17148	37886

Accident Location vrs Accident Severity for Village Environment in Ghana

Year	Location Type	Accident Severity				Total
		Fatal	Hospitalised	Not-Hospitalised	Damage Only	
2000	Not at Junc	389	620	466	418	1893
2000	Crossroads	7	11	10	8	36
2000	T/Junction	45	66	54	57	222
2000	Staggered	2	2	3	3	10
2000	Y/Junction	1	3	1	3	8
2000	Roundabout	0	0	1	1	2
2000	Railway	0	0	2	0	2
2000	Other	0	2	2	6	10
2000	?	1	1	1	2	5
2000	Total	445	705	540	498	2188
2001	Not at Junc	439	665	572	458	2134
2001	Crossroads	9	12	10	13	44
2001	T/Junction	45	82	66	103	296
2001	Staggered	3	5	7	7	22
2001	Y/Junction	1	2	4	2	9
2001	Roundabout	1	1	1	1	4
2001	Railway	1	1	2	1	5
2001	Other	4	3	2	4	13
2001	?	0	0	1	1	2
2001	Total	503	771	665	590	2529
2002	Not at Junc	454	698	485	412	2049
2002	Crossroads	6	16	13	6	41
2002	T/Junction	54	102	55	61	272
2002	Staggered	2	4	5	2	13
2002	Y/Junction	3	6	3	5	17

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2002	Roundabout	0	0	1	1	2
2002	Railway	0	2	0	1	3
2002	Other	3	5	3	3	14
2002	?	0	0	0	1	1
2002	Total	522	833	565	492	2412
2003	Not at Junction	525	812	516	429	2282
2003	Crossroads	7	19	10	2	38
2003	T/Junction	47	70	56	56	229
2003	Staggered Crossroads	3	6	2	1	12
2003	Y/Junction	0	3	1	1	5
2003	Roundabout	0	3	0	1	4
2003	Railway	0	0	1	2	3
2003	Other	1	3	3	4	11
2003	?	0	2	3	1	6
2003	Total	583	918	592	497	2590
2004	Not at Junction					
2004	Crossroads					
2004	T/Junction					
2004	Staggered Crossroads					

2004	Y/Junction					
2004	Roundabout					
2004	Railway					
2004	Other					
2004	?					
2005	Not at Junction	543	752	622	496	2413
2005	Crossroads	10	11	11	15	47
2005	T/Junction	63	85	81	86	315
2005	Staggered Crossroads	7	5	1	0	13
2005	Y/Junction	0	5	1	0	6
2005	Roundabout	3	1	3	6	13
2005	Railway	0	0	1	1	2
2005	Other	5	21	12	17	55
2005	?	0	0	0	1	1

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2005	Total	631	880	732	622	2865
2006	Not at Junc	555	809	589	548	2501
2006	Crossroads	12	22	29	32	95
2006	T/Junction	73	111	89	100	373
2006	Staggered	8	9	3	3	23
2006	Y/Junction	2	5	3	2	12
2006	Roundabout	1	5	4	7	17
2006	Railway	0	1	0	2	3
2006	Other	4	12	15	10	41
2006	Total	655	974	732	704	3065
2007	Not at Junc	627	833	498	413	2371
2007	Crossroads	9	12	6	8	35
2007	T/Junction	71	94	68	68	301
2007	Staggered	1	7	3	3	14
2007	Y/Junction	2	2	4	4	12
2007	Roundabout	1	2	4	1	8
2007	Railway	1	1	0	2	4
2007	Other	1	9	5	9	24
2007	Total	713	960	588	508	2769
2008	Not at Junc	684	869	718	588	2859
2008	Crossroads	8	12	20	20	60
2008	T/Junction	85	131	133	144	493
2008	Staggered	9	11	8	4	32
2008	Y/Junction	1	5	6	1	13
2008	Roundabout	9	6	6	4	25
2008	Railway	0	0	0	1	1
2008	Other	7	10	20	24	61
2008	Total	803	1044	911	786	3544
2009	Not at Junc	826	929	898	525	3178
2009	Crossroads	12	11	21	18	62
2009	T/Junction	76	88	131	101	396
2009	Staggered	3	10	7	2	22

APPENDIX C					
2009	Y/Junction	0	7	1	1
2009	Roundabout	5	7	5	2
2009	Railway	0	1	0	1
2009	Other	11	8	13	9
2009	?	0	0	1	0
2009	Total	933	1061	1077	659
Total		3735	4919	4040	3279

Accident Location vrs Accident Severity for Rural Environment in Ghana

Year	Location Type	Accident Severity				Total
		Fatal	Hospitalised	Not-Hospitalised	Damage Only	
2000	Not at Junction	224	393	289	283	1189
2000	Crossroads	1	0	1	0	2
2000	T/Junction	10	13	9	10	42
2000	Staggered	1	0	1	0	2
2000	Y/Junction	0	4	0	1	5
2000	Railway	0	1	1	0	2
2000	Other	0	1	0	2	3
2000	Total	236	412	301	296	1245
2001	Not at Junction	273	373	334	295	1275
2001	Crossroads	0	1	2	3	6
2001	T/Junction	4	16	13	20	53
2001	Staggered	1	0	0	3	4
2001	Y/Junction	0	2	1	0	3
2001	Roundabout	0	0	1	0	1
2001	Railway	0	0	2	3	5
2001	Other	0	1	1	1	3
2001	?	1	0	0	0	1
2001	Total	279	393	354	325	1351
2002	Not at Junction	258	328	272	222	1080
2002	Crossroads	0	2	2	1	5
2002	T/Junction	2	12	9	14	37
2002	Y/Junction	2	1	2	0	5

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2002	Other	0	2	1	2	5
2002	Total	262	345	286	239	1132
2003	Not at Junc	271	405	338	239	1253
2003	Crossroads	4	3	3	0	10
2003	T/Junction	7	13	6	10	36
2003	Y/Junction	0	1	1	0	2
2003	Roundabout	1	0	0	0	1
2003	Other	2	2	0	0	4
2003	?	0	1	2	1	4
2003	Total	285	425	350	250	1310
2004	Not at Junction					
2004	Crossroads					
2004	T/Junction					
2004	Y/Junction					
2004	Roundabout					
2004	Other					
2004	?					
2005	Not at Junc	275	301	312	203	1091
2005	Crossroads	0	1	2	0	3
2005	T/Junction	2	2	12	5	21
2005	Staggered	0	1	0	0	1
2005	Y/Junction	0	0	1	0	1
2005	Roundabout	0	0	0	1	1
2005	Railway	0	0	1	0	1
2005	Other	2	4	2	0	8
2005	Total	279	309	330	209	1127
2006	Not at Junc	207	220	207	169	803
2006	Crossroads	2	4	1	0	7
2006	T/Junction	8	8	7	6	29
2006	Roundabout	0	1	0	0	1
2006	Other	2	3	2	1	8
2006	Total	219	236	217	176	848
2007	Not at Junc	223	229	195	176	823

APPENDIX C					
2007	Crossroads	1	0	0	0
2007	T/Junction	8	6	3	3
2007	Staggered	0	1	0	1
2007	Y/Junction	0	0	0	1
2007	Roundabout	1	0	2	1
2007	Other	0	2	0	0
2007	Total	233	238	200	182
2008	Not at Junc	267	229	255	157
2008	Crossroads	2	3	0	2
2008	T/Junction	7	9	7	8
2008	Staggered	1	0	0	0
2008	Y/Junction	0	2	0	0
2008	Roundabout	1	2	1	2
2008	Railway	1	0	0	0
2008	Other	3	1	6	2
2008	Total	282	246	269	171
2009	Not at Junc	199	245	208	157
2009	Crossroads	0	1	1	0
2009	T/Junction	5	7	11	5
2009	Y/Junction	1	0	0	3
2009	Roundabout	3	1	1	1
2009	Other	1	0	0	1
2009	Total	209	254	221	167
Total		1222	1283	1237	905
					4647

APPENDIX C

[illegible]

APPENDIX C

APPENDIX C										
2004	Injured Not-H									
	Damage Only									
	Total									
2005	Fatal	9	213	26	27	2	2	85	0	364
2005	Hospitalise	14	585	99	84	0	21	80	4	887
2005	Injured Not	19	686	102	112	10	6	144	5	1084
2005	Damage Or	0	12	3	1	0	0	3	0	19
2005	Total	42	1496	230	224	12	29	312	9	2354
2006	Fatal	13	281	13	33	2	4	84	0	430
2006	Hospitalise	16	723	75	104	26	11	144	2	1101
	Injured Not- Hospitalis									
2006	ed	25	594	90	136	1	11	152	2	1011
2006	Damage Or	0	12	1	1	0	0	1	0	15
2006	Total	54	1610	179	274	29	26	381	4	2557
2007	Fatal	6	347	28	71	4	9	80	0	545
2007	Hospitalise	11	751	67	111	2	22	146	0	1110
	Injured Not- Hospitalis									
2007	ed	8	619	103	121	5	20	161	0	1037
2007	Damage Or	0	5	0	0	0	0	3	0	8
2007	Total	25	1722	198	303	11	51	390	0	2700
2008	Fatal	1	269	41	41	6	11	73	0	442
2008	Hospitalise	8	582	58	102	2	23	137	0	912
	Injured Not- Hospitalis									
2008	ed	2	455	109	118	3	19	136	0	842

APPENDIX C									
2008	Damage On	1	3	1	0	1	1	0	7
2008	Total	12	1309	209	261	11	54	0	2203
2009	Fatal	16	323	24	26	7	3	0	499
2009	Hospitalise	37	615	109	110	1	10	0	1001
2009	Injured Not-Hospitalis								
2009	ed	51	531	132	93	5	15	0	993
2009	Damage On	0	2	1	1	0	0	0	5
2009	Total	104	1471	266	230	13	28	0	2498

Pedestrian Action vrs Crash Severity for Village Environment in Ghana

Pedestrian Action vrs Crash Severity for Village Environment in Ghana											
Year	Accident Severity	Pedestrian Action							Total		
		No Action	Crossing Road	Walking Along Road	Walking along Edge	Playing On Road	On Footpath	Other		Unknown	
2000	Fatal	1	180	15	58	0	7	40	5	306	
2000	Hospitalise	0	230	26	45	0	1	49	7	358	
	Injured Not-Hospitalis										
	2000	ed	0	70	11	10	2	5	51	12	161
	2000	Total	1	480	52	113	2	13	140	24	825
2001	Fatal	2	204	14	40	5	6	132	5	408	
2001	Hospitalise	1	299	34	25	2	7	62	4	434	
	Injured Not-Hospitalis										
	2001	ed	2	115	9	31	0	7	37	3	204
	2001	Total	5	618	57	96	7	20	231	12	1046
2002	Fatal	2	206	23	23	1	4	88	5	352	
2002	Hospitalise	3	262	29	26	5	3	63	1	392	

APPENDIX C

APPENDIX C										
	Injured Not-Hospitalised									
2002	2	79	13	22	1	5	34	2	158	
2002	Total	547	65	71	7	12	185	8	902	
2003	Fatal	217	9	33	1	3	95	13	372	
2003	Hospitalised	3	23	17	3	0	84	8	431	
	Injured Not-Hospitalised									
2003	ed	0	7	10	1	1	51	2	171	
2003	Total	4	39	60	5	4	230	23	974	
2004	Fatal									
2004	Hospitalised									
	Injured Not-Hospitalised									
2004	ed									
2005	Fatal	5	41	31	2	1	65	1	436	
2005	Hospitalised	16	46	31	3	2	70	0	487	
2005	Injured Not-Hospitalised	1	23	24	0	0	67	0	230	
2005	Damage Origin	0	0	1	0	0	0	0	1	
2005	Total	22	110	87	5	3	202	1	1154	
2006	Fatal	3	25	34	1	8	71	0	426	
2006	Hospitalised	5	29	64	5	20	84	0	560	
	Injured Not-Hospitalised									
2006	ed	4	15	41	1	5	35	0	219	
2006	Damage Origin	0	0	8	0	0	0	0	10	
2006	Total	12	69	147	7	33	190	0	1215	

APPENDIX C

2007	Fatal	4	320	57	32	1	2	58	0	474
2007	Hospitalise	4	347	31	43	0	12	50	0	487
	Injured Not-Hospitalis									
2007	ed	2	96	15	25	2	7	26	0	173
2007	Damage Or	0	1	0	0	0	0	1	0	2
2007	Total	10	764	103	100	3	21	135	0	1136
2008	Fatal	3	324	21	29	6	11	89	0	483
2008	Hospitalise	4	340	60	69	1	19	71	0	564
	Injured Not-Hospitalis									
2008	ed	2	138	34	37	9	3	51	0	274
2008	Damage Or	0	1	0	0	0	0	0	0	1
2008	Total	9	803	115	135	16	33	211	0	1322
2009	Fatal	23	331	41	83	3	3	102	0	586
2009	Hospitalise	27	376	34	57	7	0	83	0	584
	Injured Not-Hospitalis									
2009	ed	14	163	27	45	0	2	42	0	293
2009	Total	64	870	102	185	10	5	227	0	1463
Total		117	3918	499	654	41	95	965	1	6290

Pedestrian Action vrs Crash Severity for Rural Environment in Ghana

Pedestrian Action vrs Crash Severity for Rural Environment in Ghana										
Year	Accident Severity	Pedestrian Action							Total	
		No Action	Crossing Road	Walking Along Road	Walking along Edge	Playing On Road	On Footpath	Other		Unknown
2000	Fatal	0	35	1	15	0	1	16	3	71
2000	Hospitalise	0	35	3	12	3	1	9	3	66

APPENDIX D:

PICTURE LEGEND FOR DATA COLLECTION

APPENDIX D - PICTURE LEGEND FOR DATA COLLECTION

	
Patches /potholes(yes=1)	Absence of patches/potholes(No=0)
	
Curb Parking(yes=1)	Absence of curb parking(No=0)
	
Pedestrian presence (yes=1)	Pedestrian absence(No=0)
	
Road marking (yes=1)	No road marking(No=0)

APPENDIX D - PICTURE LEGEND FOR DATA COLLECTION

	
Side friction(yes=1)	No side friction(No=0)
	
Kerb presence (yes=1)	Kerb absence(No=0)
	
Presence of side walk(Yes=1)	Absence of side walk(No=0)
	
Horizontal curves(count)	Vertical curves(count)

APPENDIX D - PICTURE LEGEND FOR DATA COLLECTION

	
Access road(count)	Bus stops(counts)

APPENDIX E - CORRELATION OF MODELLING VARIABLES TO CHECK FOR MULTICOLLINEARITY

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
TOT INJ ACC	1																					
LENGTH KM	0.2655*	1.00																				
WAY AADT	0.3482*	0.2068*	1.00																			
NUMB LANES	0.5682*	0.2250*	0.6524*	1.00																		
AVE SPEED	0.2187*	0.16	0.12	0.2685*																		
SIDE FRICT-N	0.2219*	-0.03	0.2492*	0.3003*	1.00																	
PEDX_PRES	0.2015*	0.3337*	0.03	0.16	0.2122	1.00																
PEDX_NUMB	0.5054*	0.3999*	0.2407*	0.4425*	0.3022	0.5125	1.00															
SWALK WIDTH	0.2454*	-0.11	0.05	0.2361*	0.2427	0.06	0.14	1.00														
SWALK PRES	0.2300*	-0.11	0.05	0.2419*	0.2165	-0.03	0.13	0.9400*	1.00													
MEDIAN WIDTH	0.3442*	0.1834*	0.6229*	0.8391*	0.2009	0.07	0.4487*	0.1900*	0.2282*	1.00												
ROADSIGNS-B	0.05	0.2847*	0.09	0.13	0.04	0.1752	0.3378*	0.01	0.01	0.227*	0.15	1.00										
ROADSIGNS PE-M	-0.04	-0.2971*	0.05	-0.02	0.07	-0.06	0.02	0.10	0.12	0.05	0.05	0.631	1.00									
ROADSIGNS PE-M	-0.04	-0.2971*	0.05	-0.02	0.07	-0.06	0.02	0.10	0.12	0.05	0.05	0.631	1.0001	1.00								
ROADMARKING-D	0.15	0.11	0.00	0.2185*	-0.02	0.06	0.14	0.1853*	0.2144*	0.1803	0.13	0.257	0.199	0.199	1.00							
SHOULDR WIDTH	-0.10	0.3296*	0.04	-0.08	-0.15	0.2328	0.06	-0.6428*	-0.6815	-0.12	-0.12	0.01	-0.14	-0.14	-0.14	1.00						
SHOULDR WD-P	-0.02	0.2460*	0.03	-0.01	0.00	0.2790	0.1766*	-0.3560*	-0.3803	-0.02	-0.12	0.06	-0.03	-0.03	-0.12	0.813*	1.00					
ROAD WIDTH-h	0.5276*	0.14	0.6794*	0.8561*	0.2840	0.03	0.3778*	0.2911*	0.3168*	0.8231	0.800	0.14	0.06	0.06	0.09	-0.16	-0.04	1.00				
ROAD WIDTH-P	0.1959*	0.04	0.3816*	0.3672*	0.1738	-0.04	0.00	0.14	0.13	0.2931	0.312	-0.02	0.00	0.00	0.01	0.02	0.07	0.6083*	1.00			
BUSSTOP NUMB	0.1889*	0.3974*	0.3223*	0.15	0.13	0.2125	0.2373*	-0.06	-0.09	0.179*	0.190	0.12	-0.07	-0.07	-0.10	0.320*	0.3876*	0.2081*	0.249*	1.00		
KERB PRES	0.3505*	-0.06	0.2930*	0.4416*	0.2487	0.01	0.2453*	0.6407*	0.7303*	0.4361	0.444	-0.01	0.08	0.08	0.242	-0.508	-0.3132	0.4839*	0.178*	-0.06	-0.04	1.00
ACCESS PUB	0.2197*	0.4753*	-0.05	-0.08	0.1780	0.3683	0.2657*	0.05	0.03	-0.09	-0.08	0.181	-0.08	-0.08	0.01	0.220*	0.3051*	-0.13	0.01	0.3389	0.276	-0.02

APPENDIX F: PARAMETER ESTIMATION FOR EXPLANATORY VARIABLES AS ESTIMATED BY STATA STATISTICAL SOFTWARE

```
. glm HITPED_ACC LnLENGTH_KM Ln2WAYAADT lnPEDVOL_3HRS SWALK_WIDTH PEDX_PRESC, family(nbinomial 1) link(log)rob
> ust
```

```
Iteration 0: log pseudolikelihood = -232.95764
Iteration 1: log pseudolikelihood = -230.33224
Iteration 2: log pseudolikelihood = -230.32791
Iteration 3: log pseudolikelihood = -230.32791
```

```
Generalized linear models
Optimization      : ML
```

```
No. of obs      =      91
Residual df      =      85
Scale parameter  =      1
(1/df) Deviance  =  1.116263
(1/df) Pearson   =  1.088438
```

```
Deviance      =  94.88239749
Pearson       =  92.51725532
```

```
Variance function: V(u) = u+(1)u^2
Link function      : g(u) = ln(u)
```

```
[Neg. Binomial]
[Log]
```

```
Log pseudolikelihood = -230.3279148
```

```
AIC      =  5.19402
BIC      = -288.5407
```

HITPED_ACC	Coef.	Robust Std. Err.	z	P> z	[95% Conf. Interval]	
LnLENGTH_KM	.7445513	.1683812	4.42	0.000	.4145303	1.074572
Ln2WAYAADT	.7801906	.3108386	2.51	0.012	.1709583	1.389423
lnPEDVOL_3~S	1.546766	.7497998	2.06	0.039	.0771855	3.016347
SWALK_WIDTH	.3469364	.119204	2.91	0.004	.113301	.5805719
PEDX_PRESC	.2978673	.2386449	1.25	0.212	-.1698681	.7656028
_cons	-17.99495	4.496993	-4.00	0.000	-26.80889	-9.181003