# 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 counties, 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:

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

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 Aruldhas (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. Hierchachal 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 $\chi 2$-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 $\chi^2$ 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).

Maher 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 Poison 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 $\lambda$ for all values of p. Then as $N \to \infty$

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

where, n = 0,1,2,…,N and $\lambda$ 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,

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

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), $\lambda$ can be estimated using the formulation,

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



where, X is a vector of explanatory variables and $\beta$ 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 ki = EXP(bXi + ei) where EXP(ei) 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 VAR [yi] = E[yi][1 + aE[yi]] = E[yi]+ aE[yi]$^2$. 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 EXP (ei) 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,

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

where $\kappa$ 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 ($\Delta_i$), is a measure of each model relative to the best model, and is calculated as

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

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 (wi ) provide another measure of the strength of evidence for each model, and represent the ratio of delta AIC ($\Delta_i$) values for each model relative to the whole set of *R* candidate models:

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



In effect, we are simply changing the scale of the $\Delta_i$*'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

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

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 multcollinearity 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.




**Figure 3.1 Maps of Ghana roads network (Left hand side) and The Kumasi road network (Right hand side)**

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 | Dompoase Junction - UTC T'lite | 5.86 | 8 |
| Antoa Rd | Arterial | Dr Mensah - Boukrom Int | 5.50 | 7 |
| 24th February Rd NB | Arterial | Femusua - UTC T'lite | 5.40 | 8 |
| 24th February Rd SB | Arterial | Femusua - UTC T'lite | 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 juntion | 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× (number of years of crashes) × (sum of all motorized vehicle flow) × (length of road km)/$10^8$.

R= (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:



$$AIC = -2 \ln (L) + 2k \ldots \quad \ldots \qquad (3.1)$$

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.

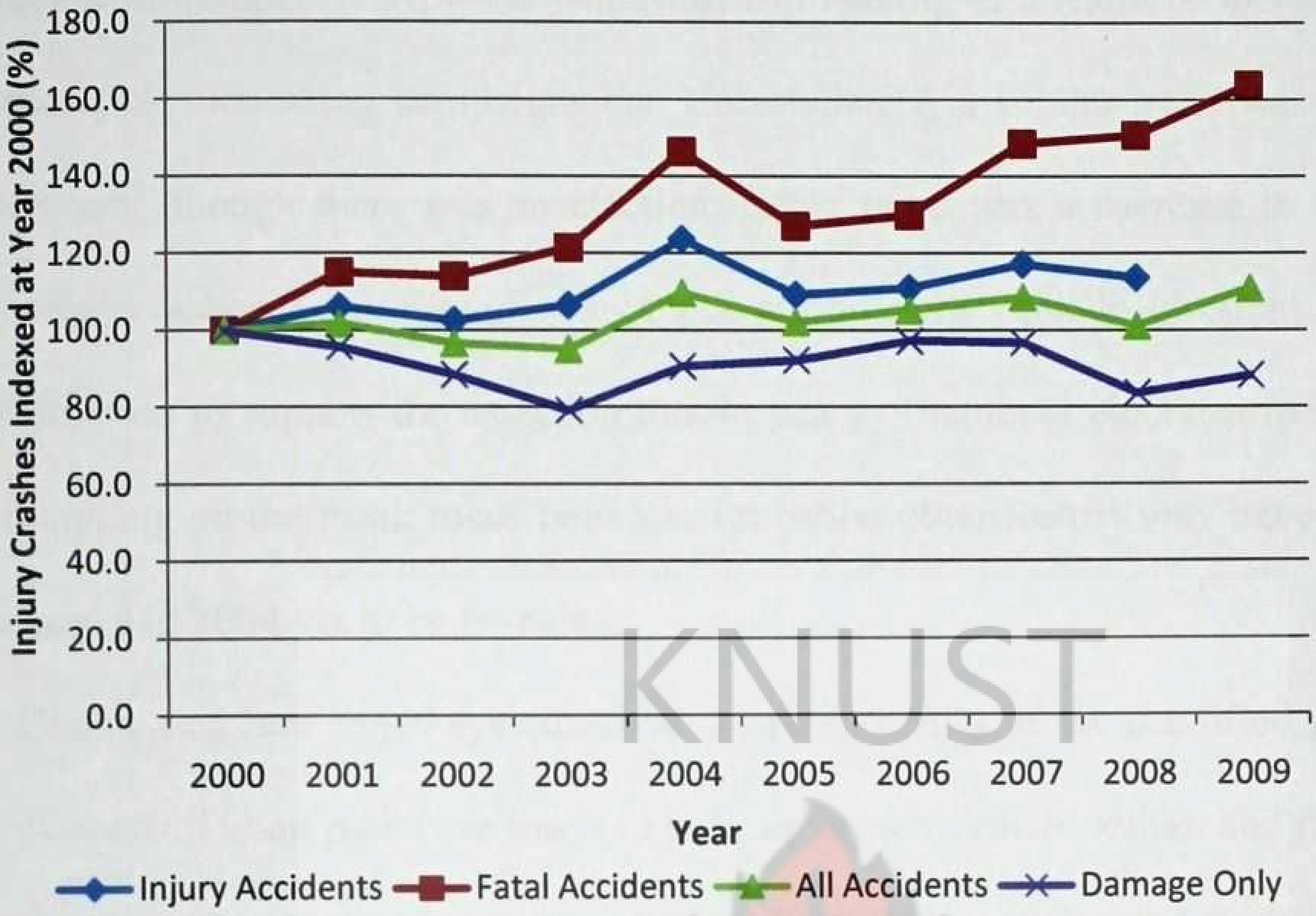


**Fig. 4.1 National Trends in Injury Traffic Crashes (source: Authors analysis of data)**

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.

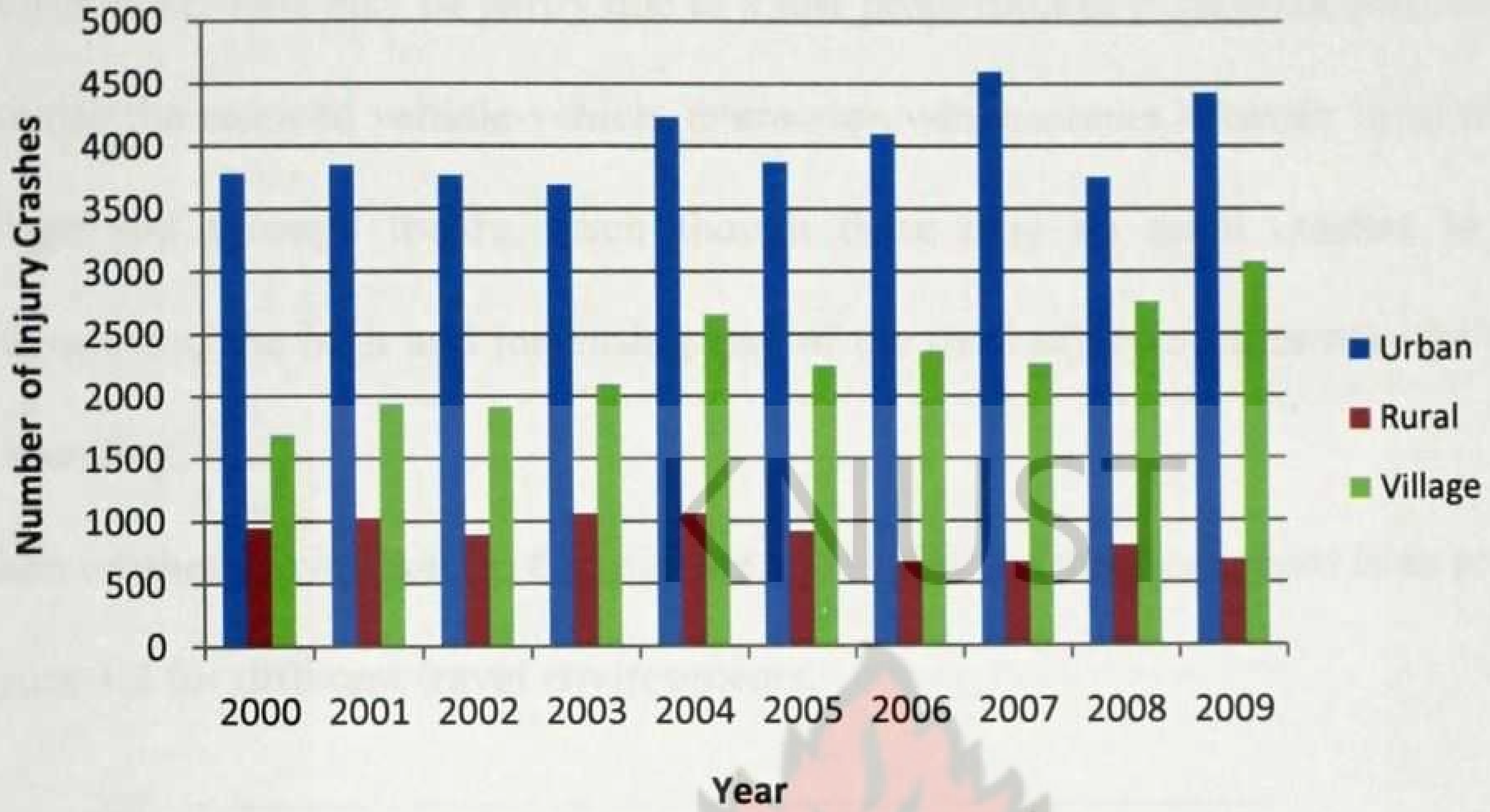


**Fig. 4.2 Trends in injury crashes for different road environments (source Author data analysis)**

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.

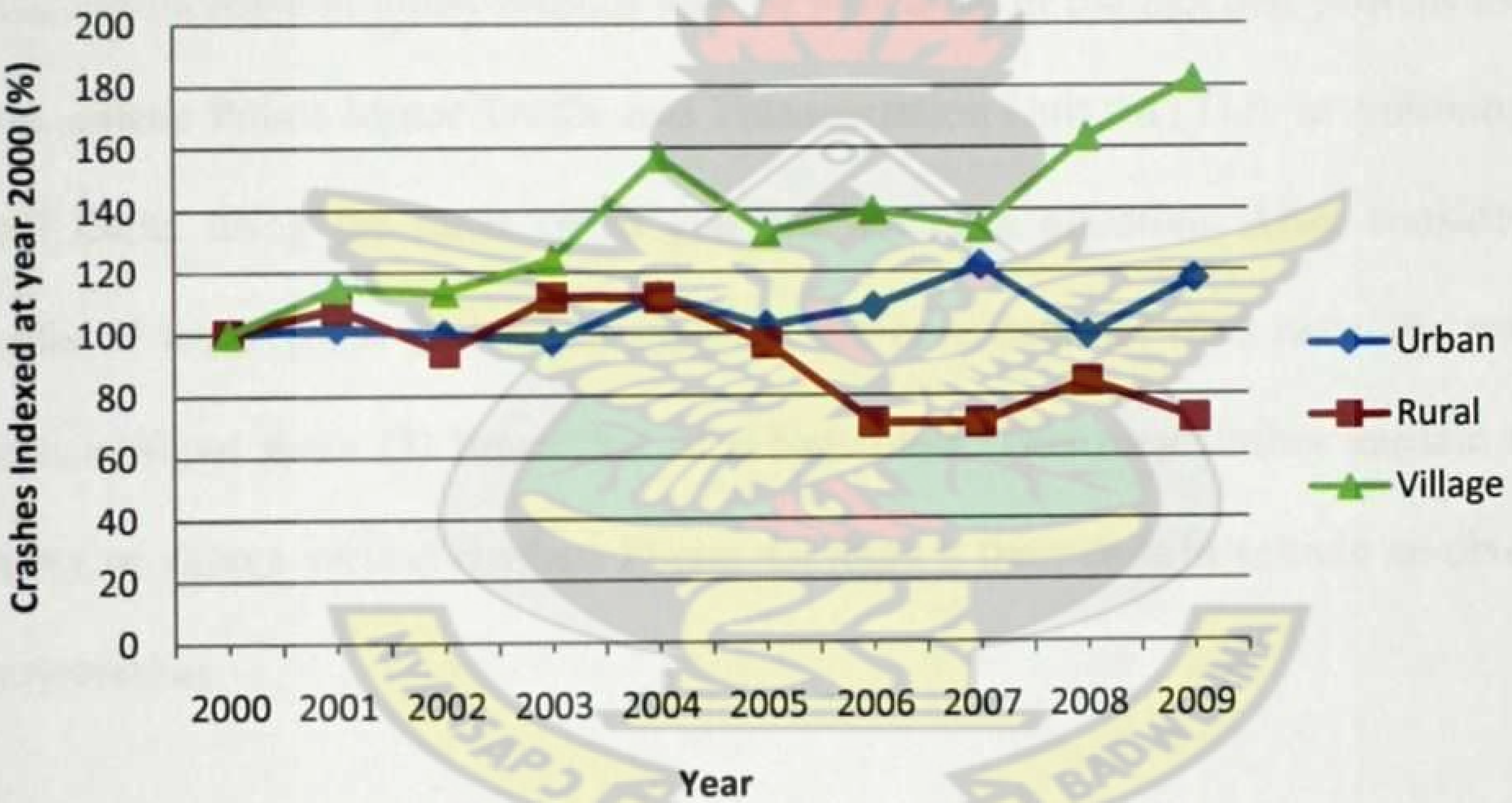


**Fig. 4.3 Injury crashes trends indexed at year 2000 as baseline (source: Author analysed data)**

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.

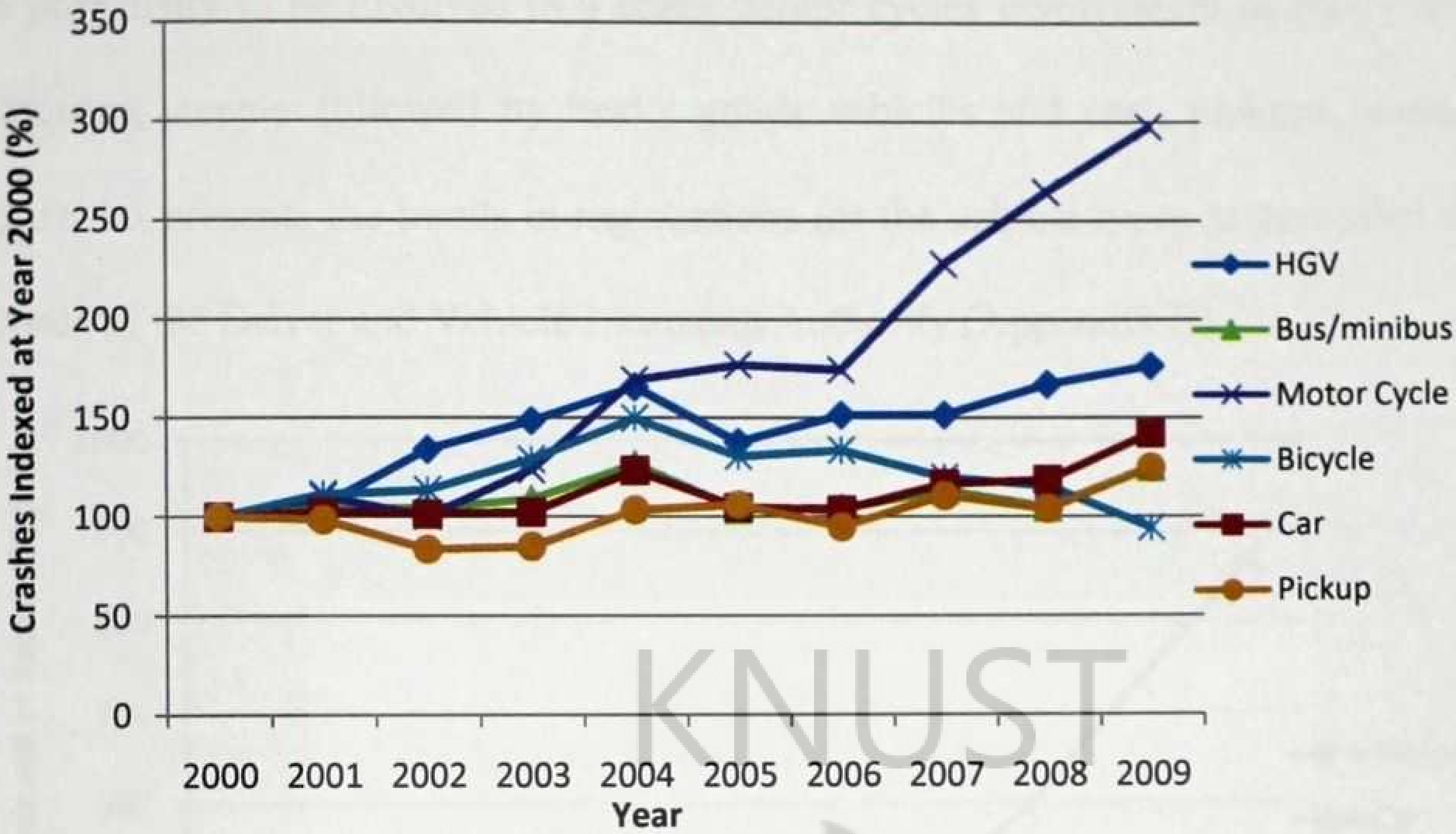


**Fig. 4.4 Road user involvement in injury crashes**

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).

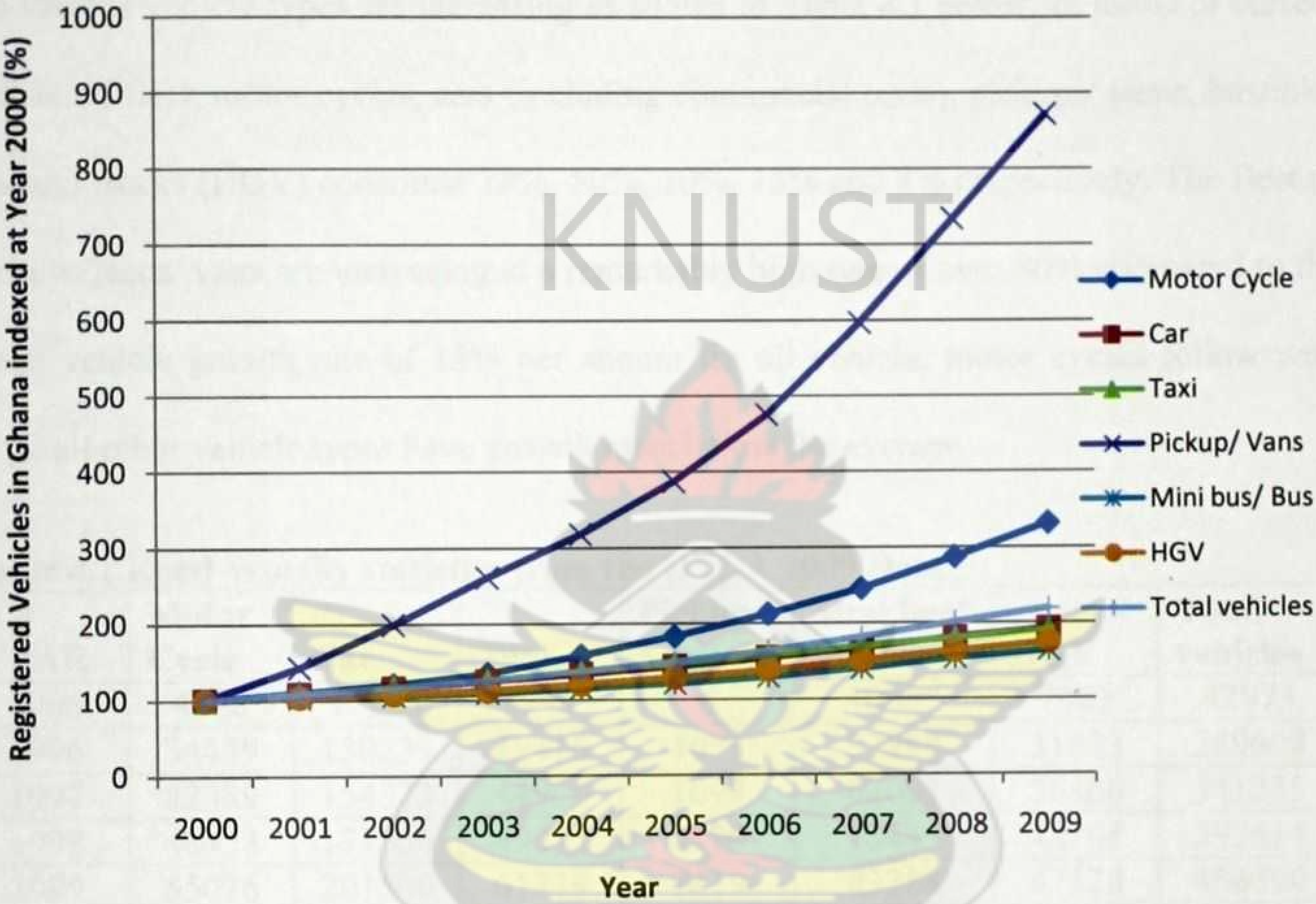


**Fig. 4.5 Vehicle registration trends for the different vehicle types**

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 theses 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**

| | Regional Characteristics | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Description | Ashanti | Brong Ahafo | Central | Eastern | Greater Accra | Northern | Upper East | Upper West | Volta | Western | Total |
| 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)

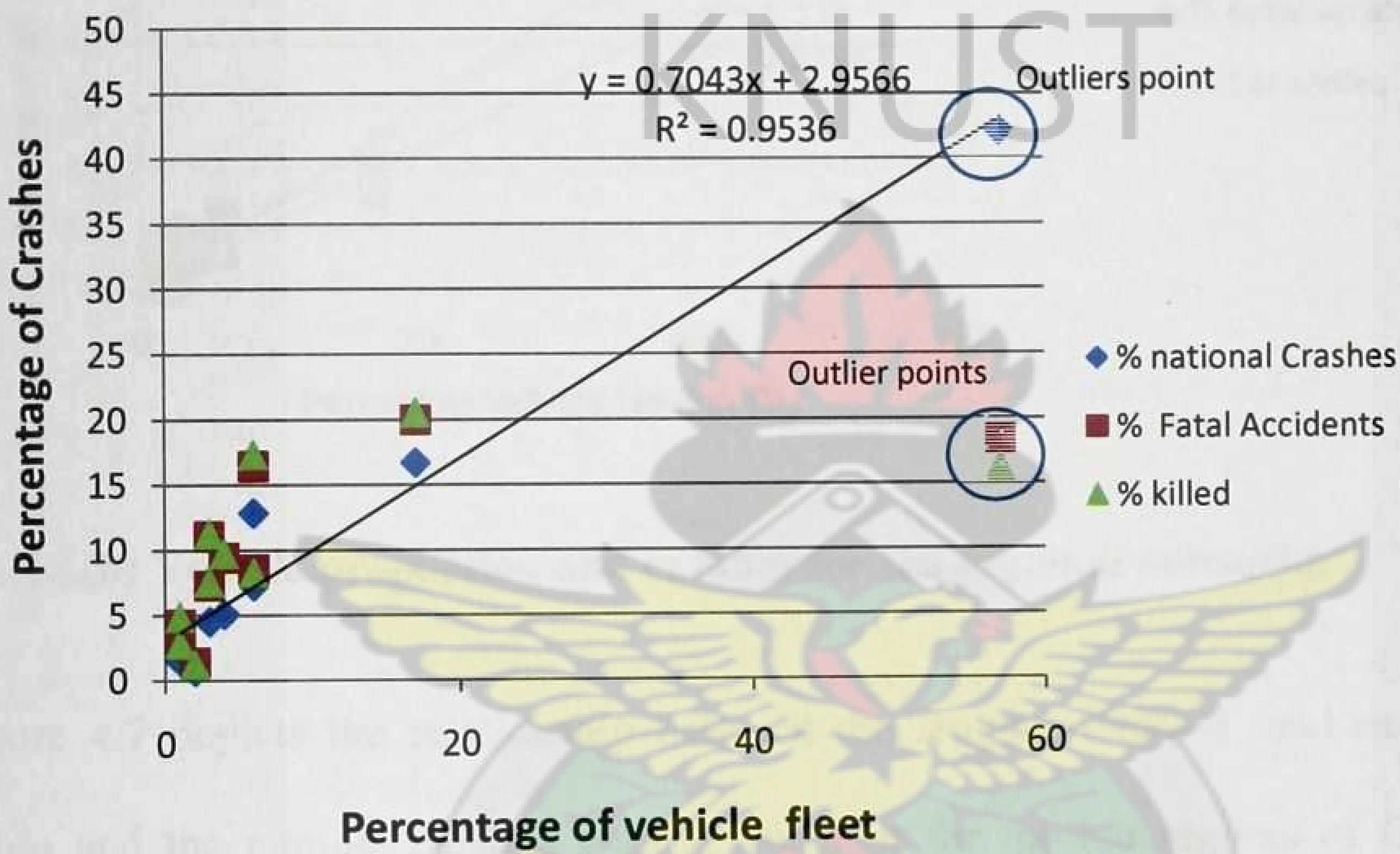


**Fig. 4.6(a) Vehicle proportion and crashes for ten regional networks**

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.

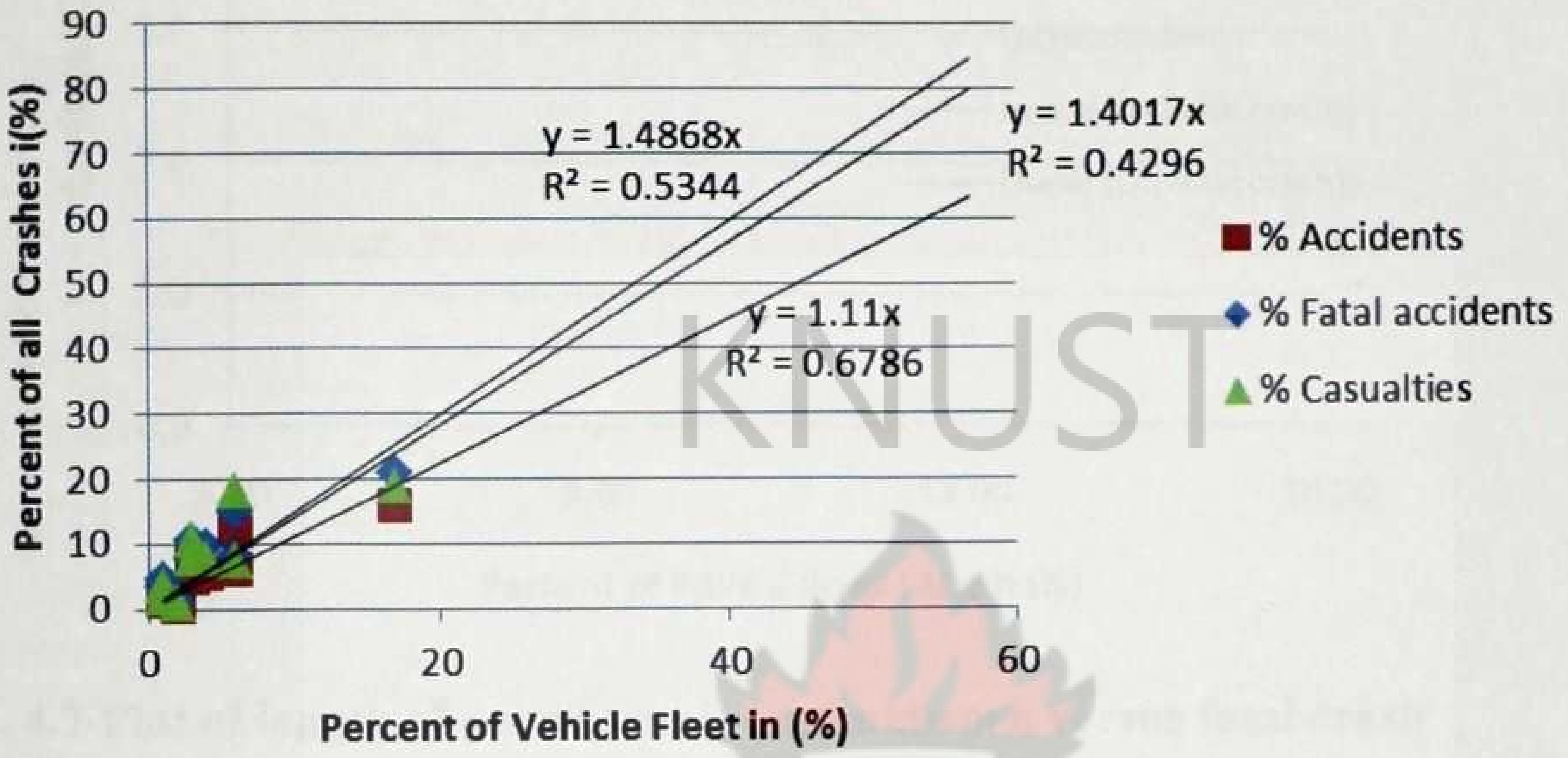


**Fig. 4.6(b) Vehicle proportion and crashes for ten regional networks**

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.

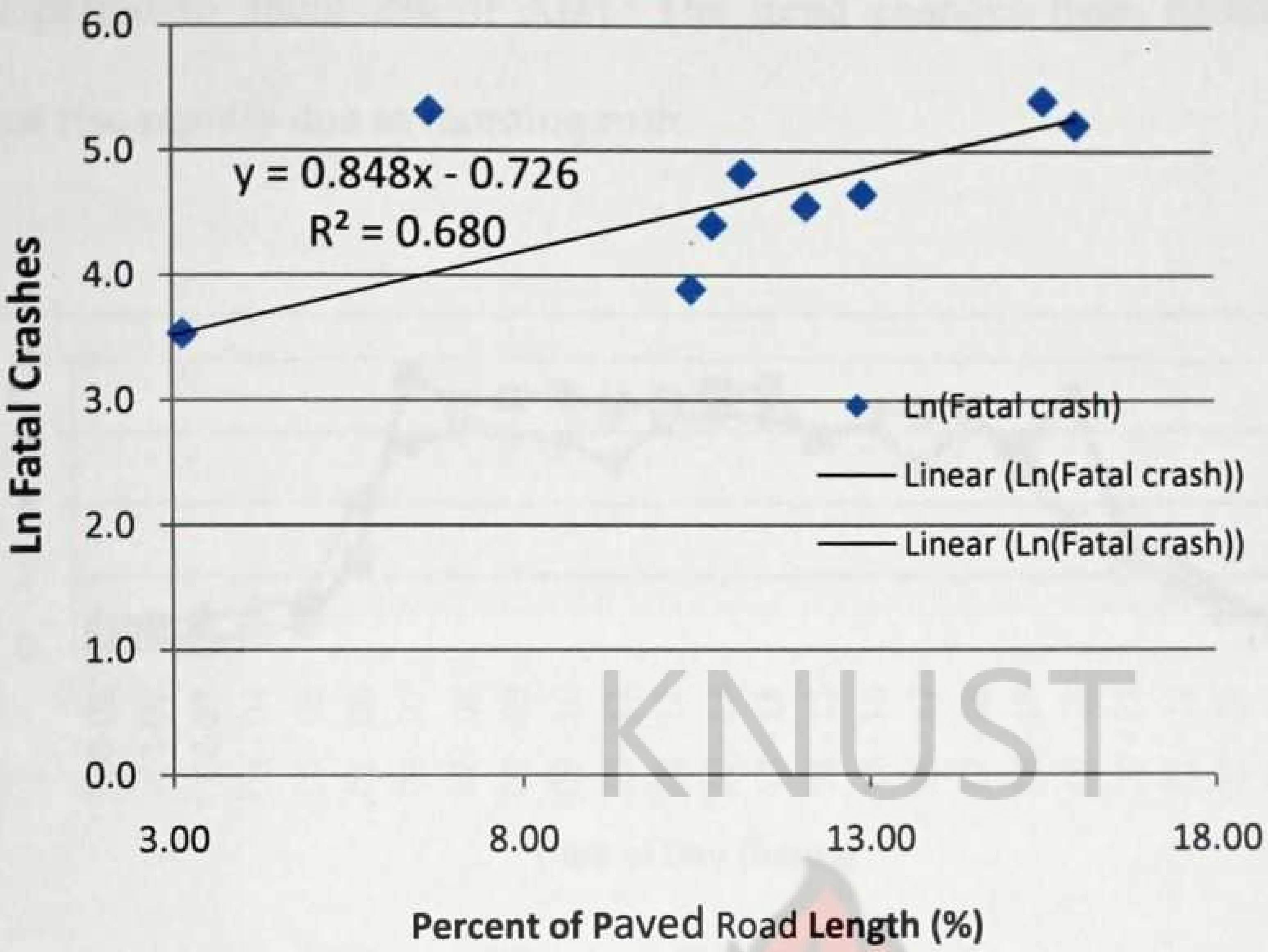


**Fig. 4.7 Plot of length of paved trunk road network versus fatal crash**

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.

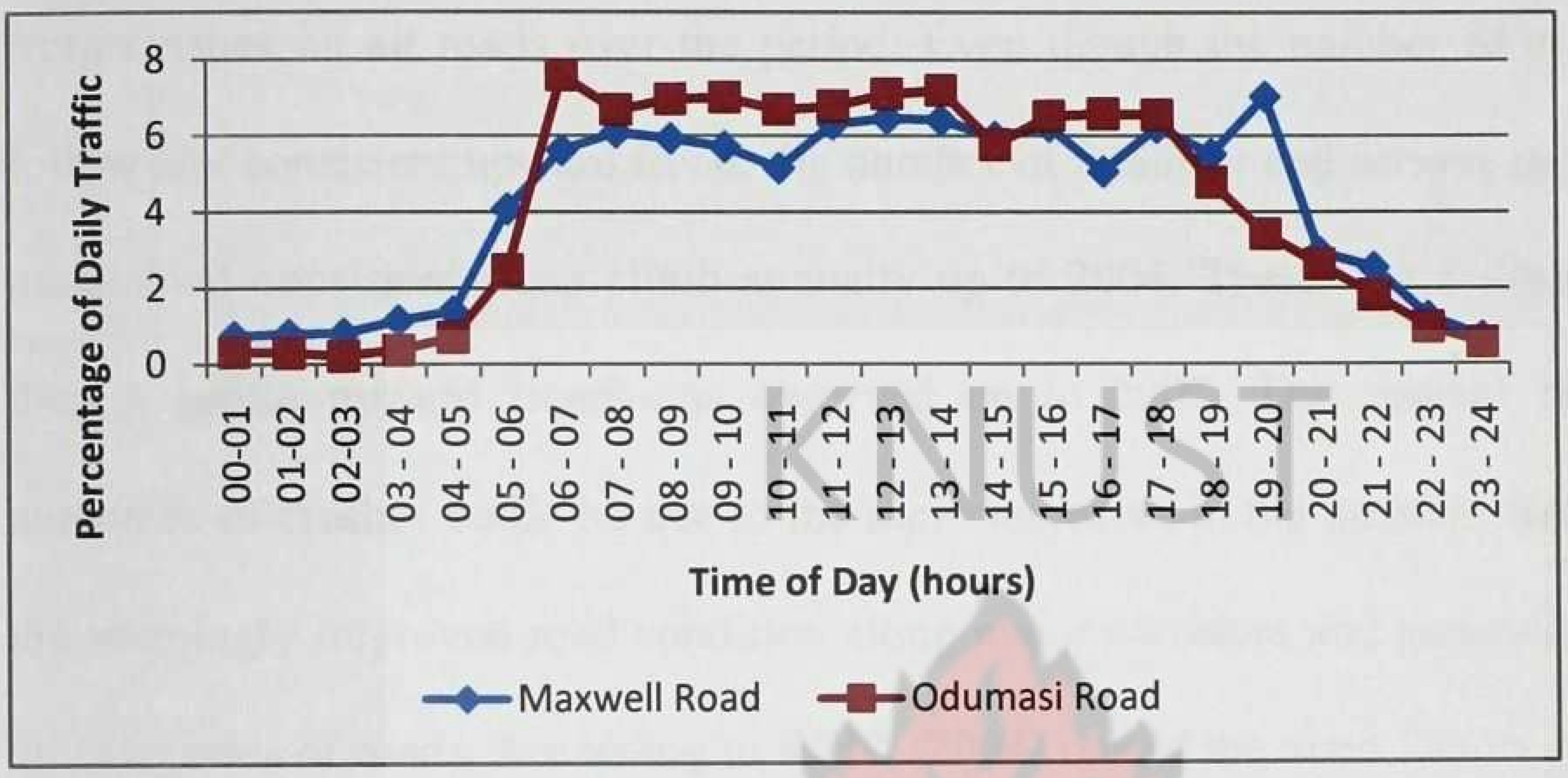


**Fig. 4.8 Hourly variation of daily traffic on selected roads in Kumasi**

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.

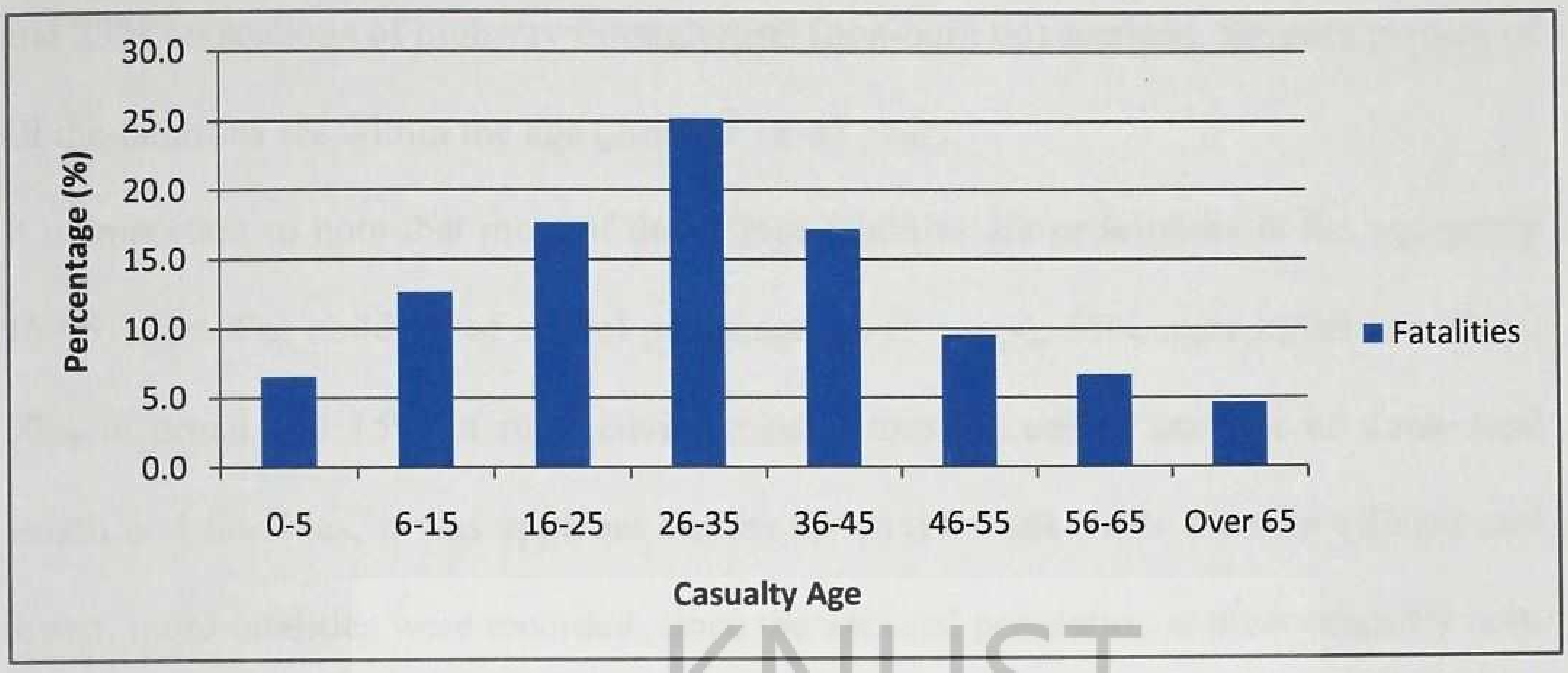




**Fig. 4.9 Distribution of fatalities by age group**

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)**

| | Age of Persons killed (years) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Total killed | 1 - 5 | 6- 15 | 16 - 30 | 31 - 45 | 46 - 60 | 61 - 70 | 71 - 80 | 81+ | Total |
| 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 rage (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 | 27.1 | 13 | 124 | 111 |
| 2001 | 19.3 | 567780 | 6831 | 35.3 | NA | 11293 | 1660 | 13178 | 8.6 | 29.2 | 29.4 | 15 | 131 | 117 |
| 2002 | 19.8 | 613153 | 6593 | 33.3 | NA | 10715 | 1665 | 13412 | 8.4 | 27.2 | 31.0 | 16 | 141 | 125 |
| 2003 | 20.5 | 643824 | 6849 | 33.4 | NA | 10542 | 1716 | 14469 | 8.4 | 26.7 | 31.4 | 16 | 154 | 137 |
| 2004 | 21.1 | 703372 | 7952 | 37.7 | NA | 12175 | 2186 | 16259 | 10.4 | 31.1 | 33.3 | 18 | 151 | 134 |
| 2005 | 21.7 | 767067 | 7025 | 32.4 | NA | 11320 | 1779 | 14034 | 8.2 | 23.2 | 35.4 | 16 | 140 | 124 |
| 2006 | 22.3 | 841314 | 7137 | 32.0 | NA | 11668 | 1856 | 14492 | 8.3 | 22.1 | 37.7 | 16 | 140 | 124 |
| 2007 | 22.9 | 922748 | 7533 | 32.9 | NA | 12038 | 2043 | 14373 | 8.9 | 22.1 | 40.3 | 17 | 136 | 119 |
| 2008 | 23.5 | 942000 | 7309 | 31.0 | NA | 11214 | 1938 | 14531 | 8.2 | 20.6 | 40.0 | 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).

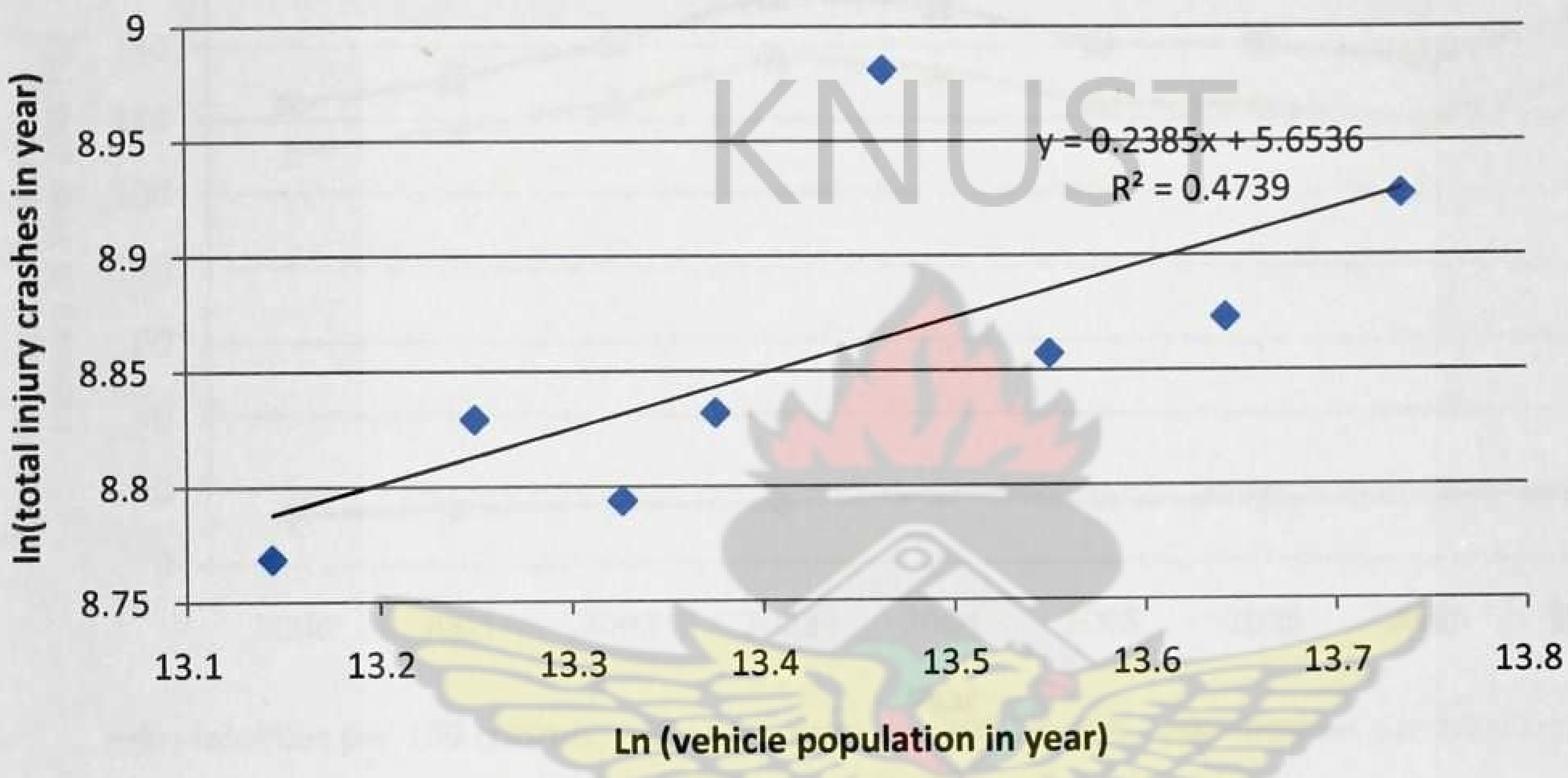


**Fig. 4.10 Injury crashes versus vehicle population**

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.

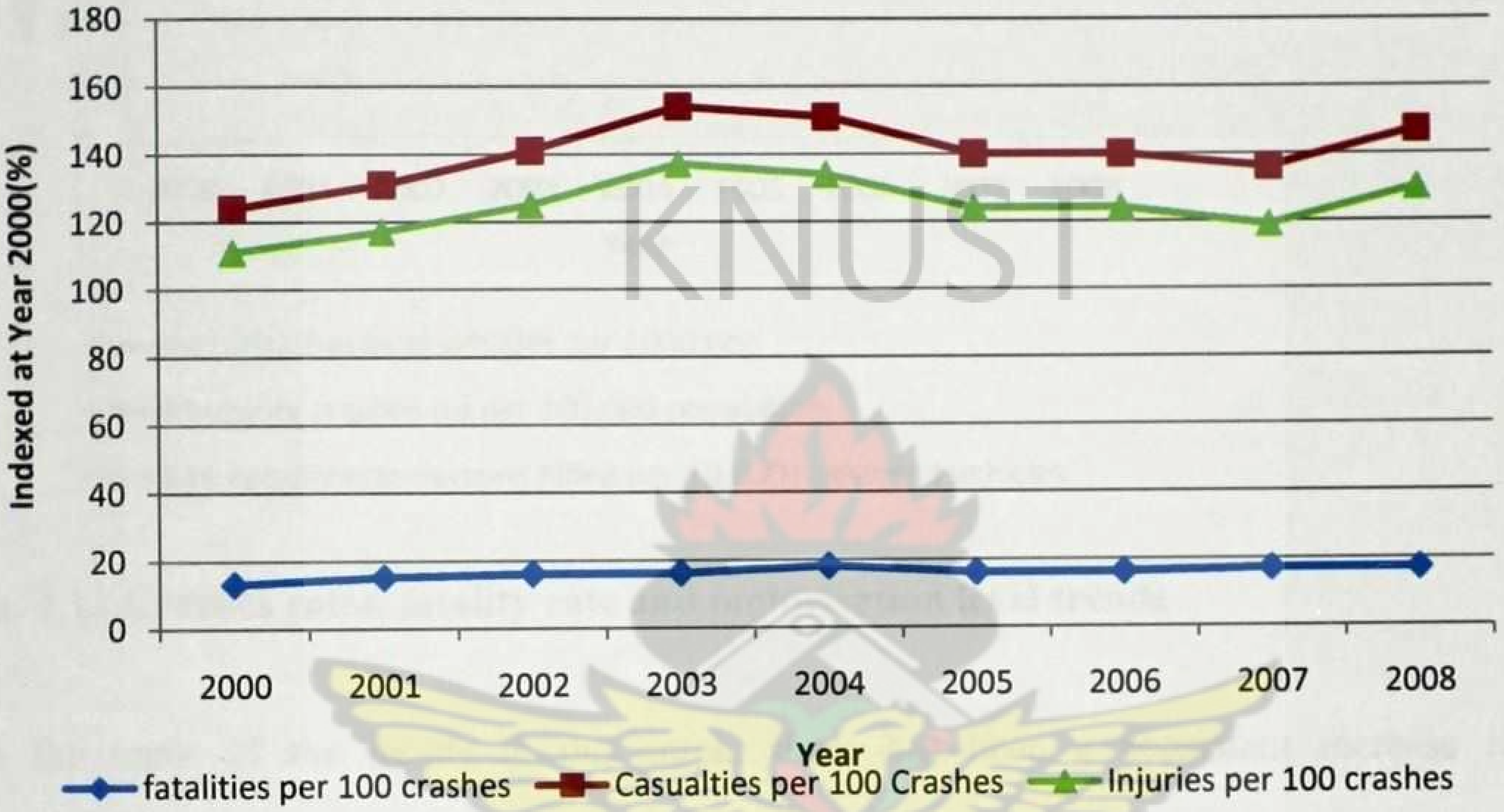


**Fig. 4.11 Casualty indices per 100 crashes**

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.

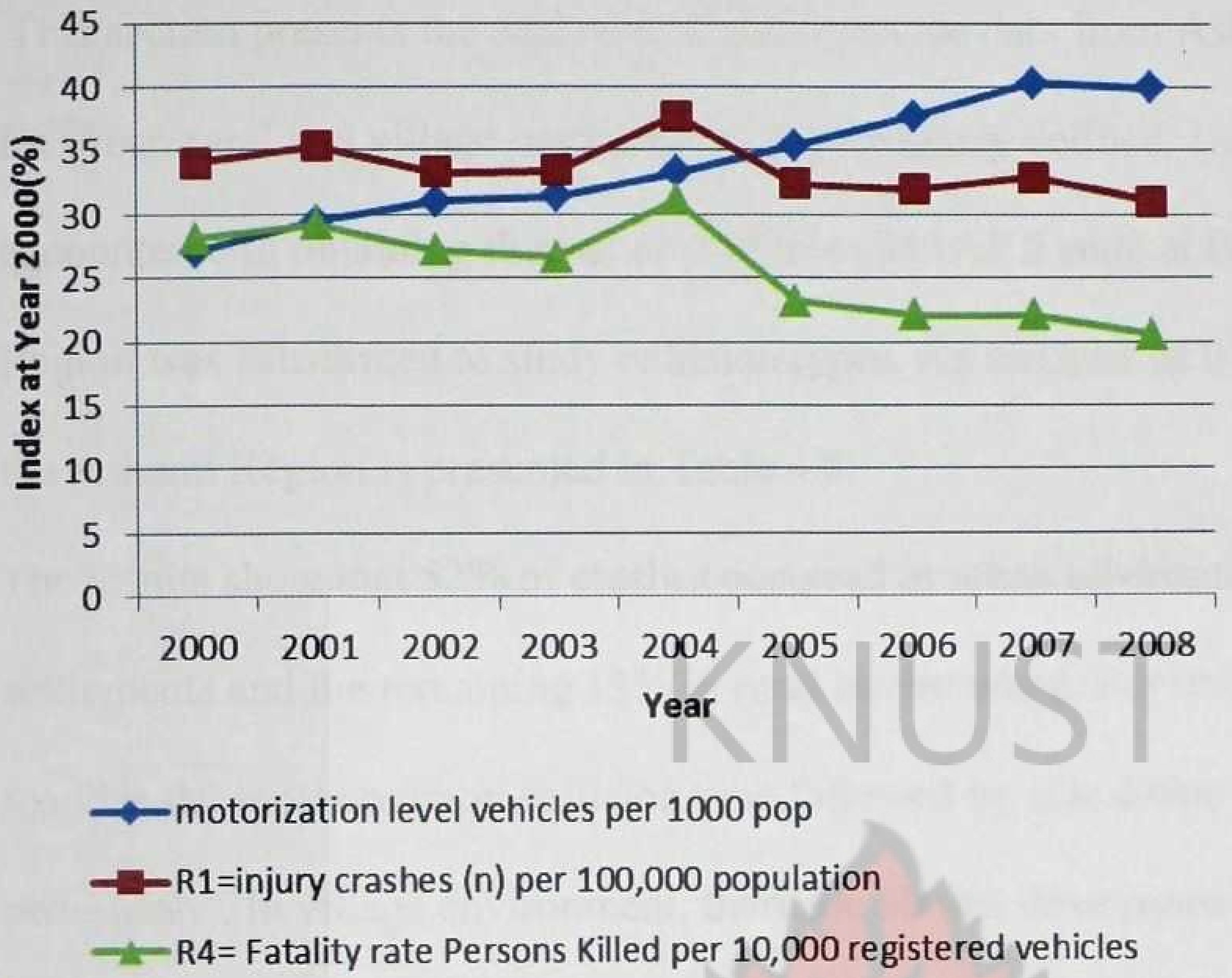


**Fig. 4.12 Crashes rates, fatality rate and motorisation level trends**

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.

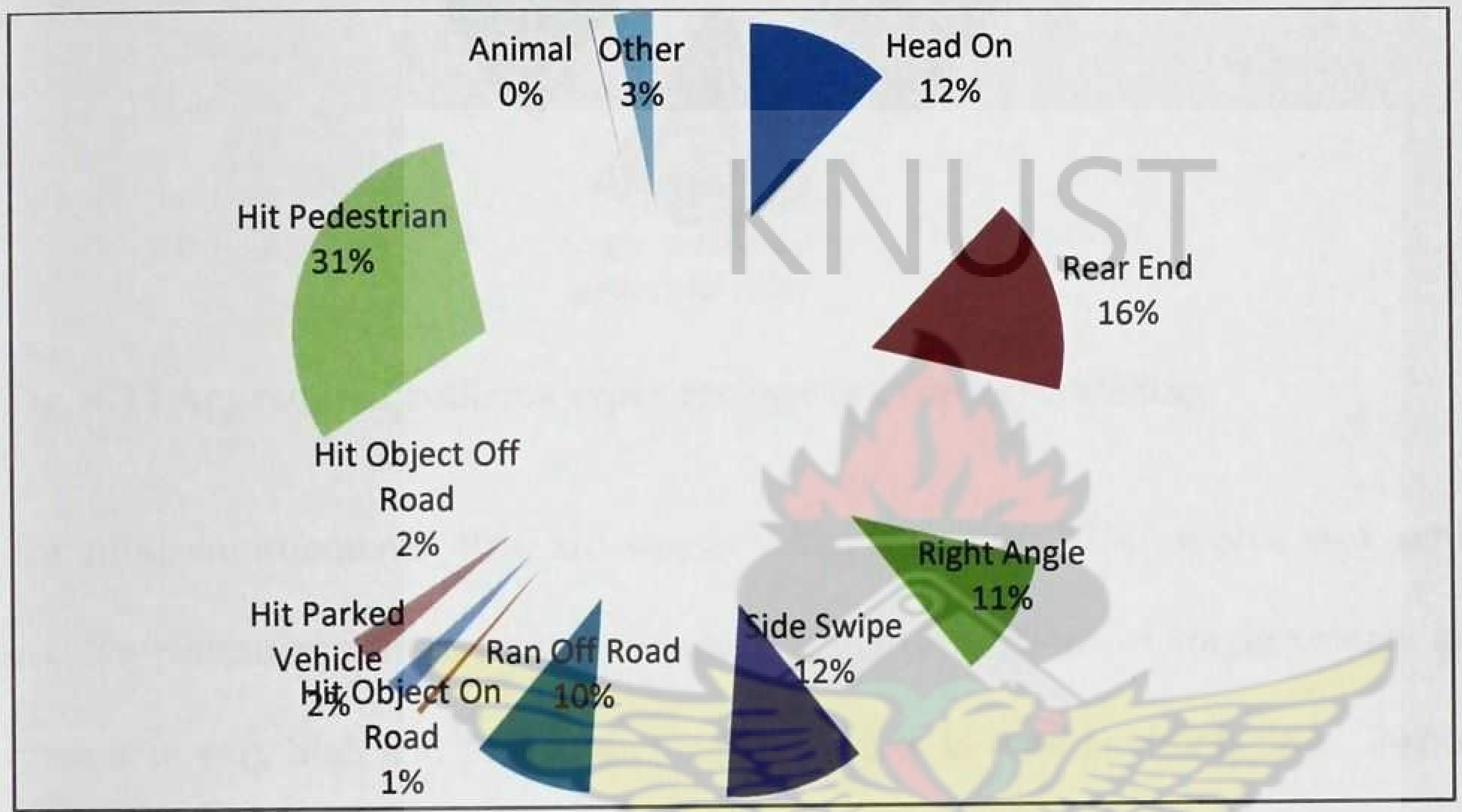


**Fig. 4.13 Collision types for injury crashes**

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.

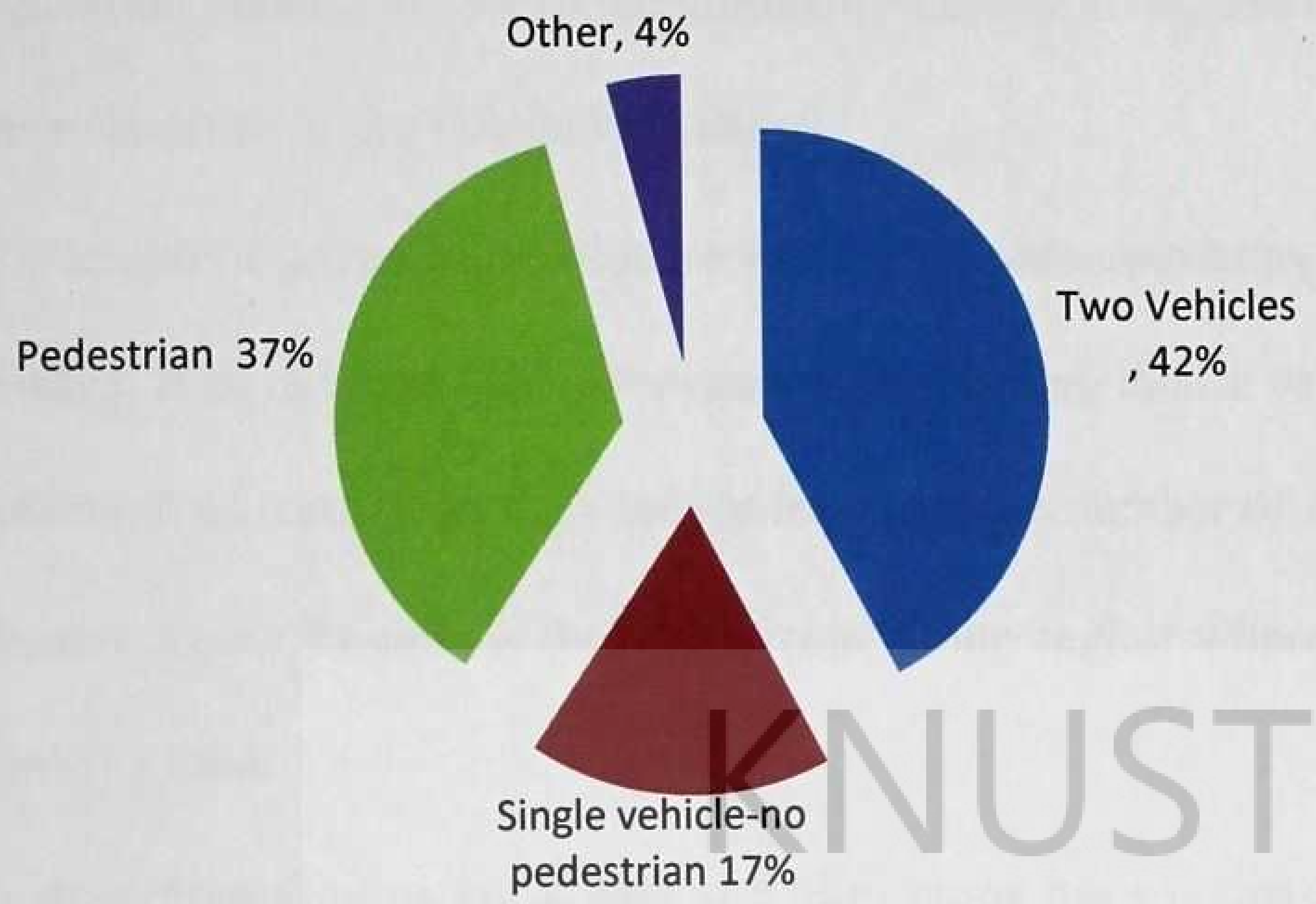


**Fig. 4.14 Aggregated collision types for injury crashes modelling**

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.



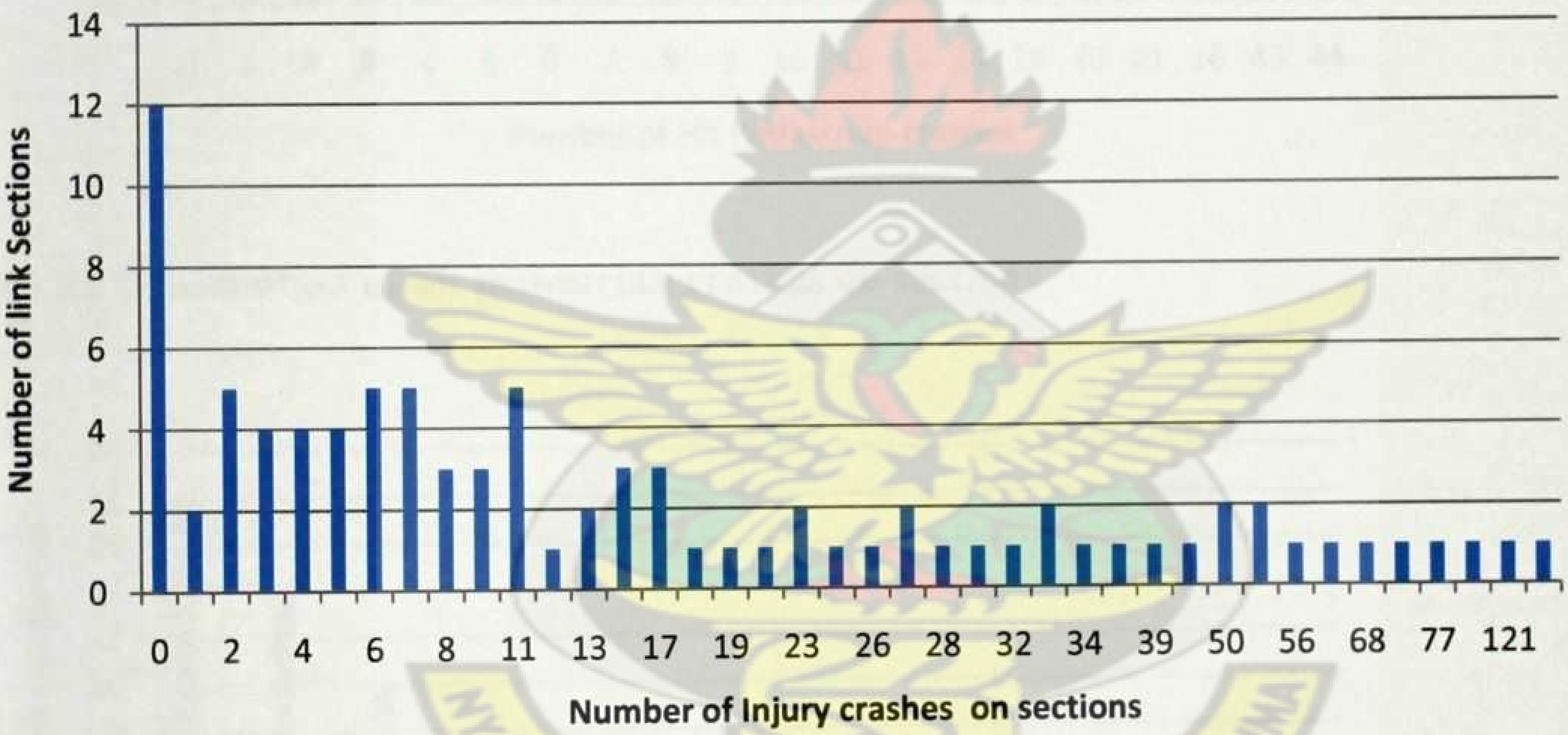


**Fig. 5.1 Distribution of injury crashes on link sections**

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.

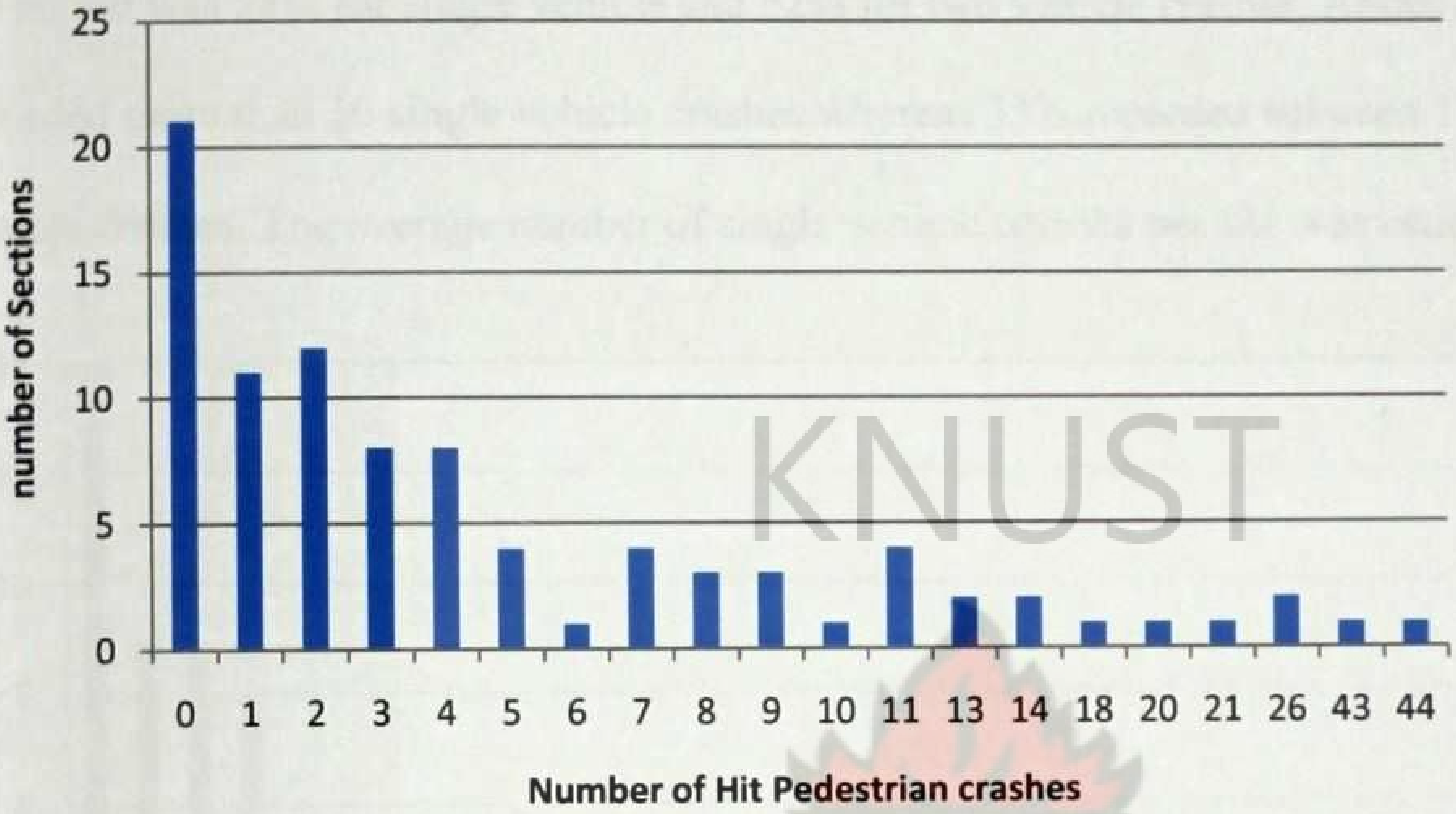


**Fig. 5.2 Distribution of hit pedestrian crashes on sections**

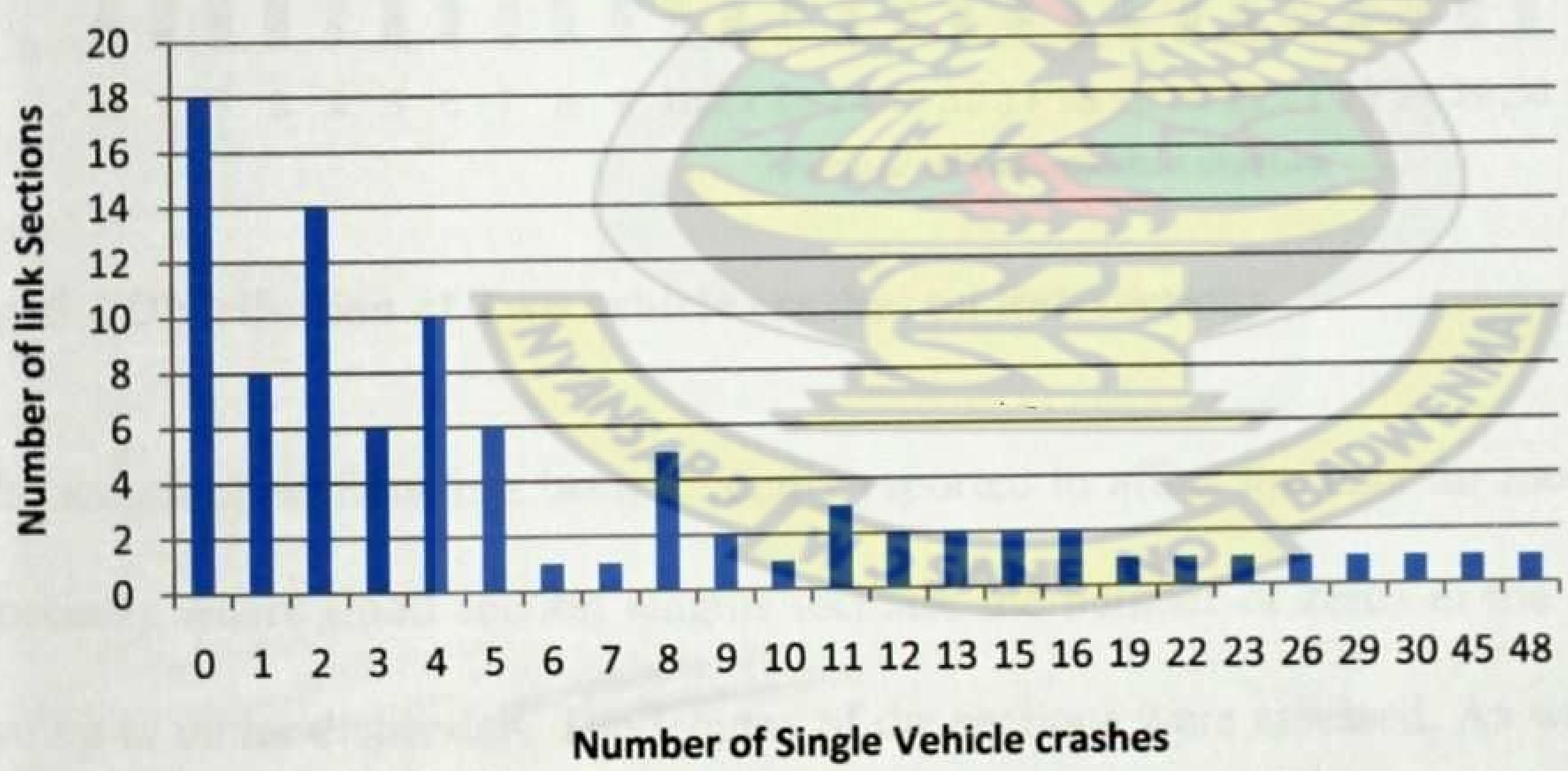


**Fig. 5.3 Distribution of Single Vehicle crashes on sections**

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).

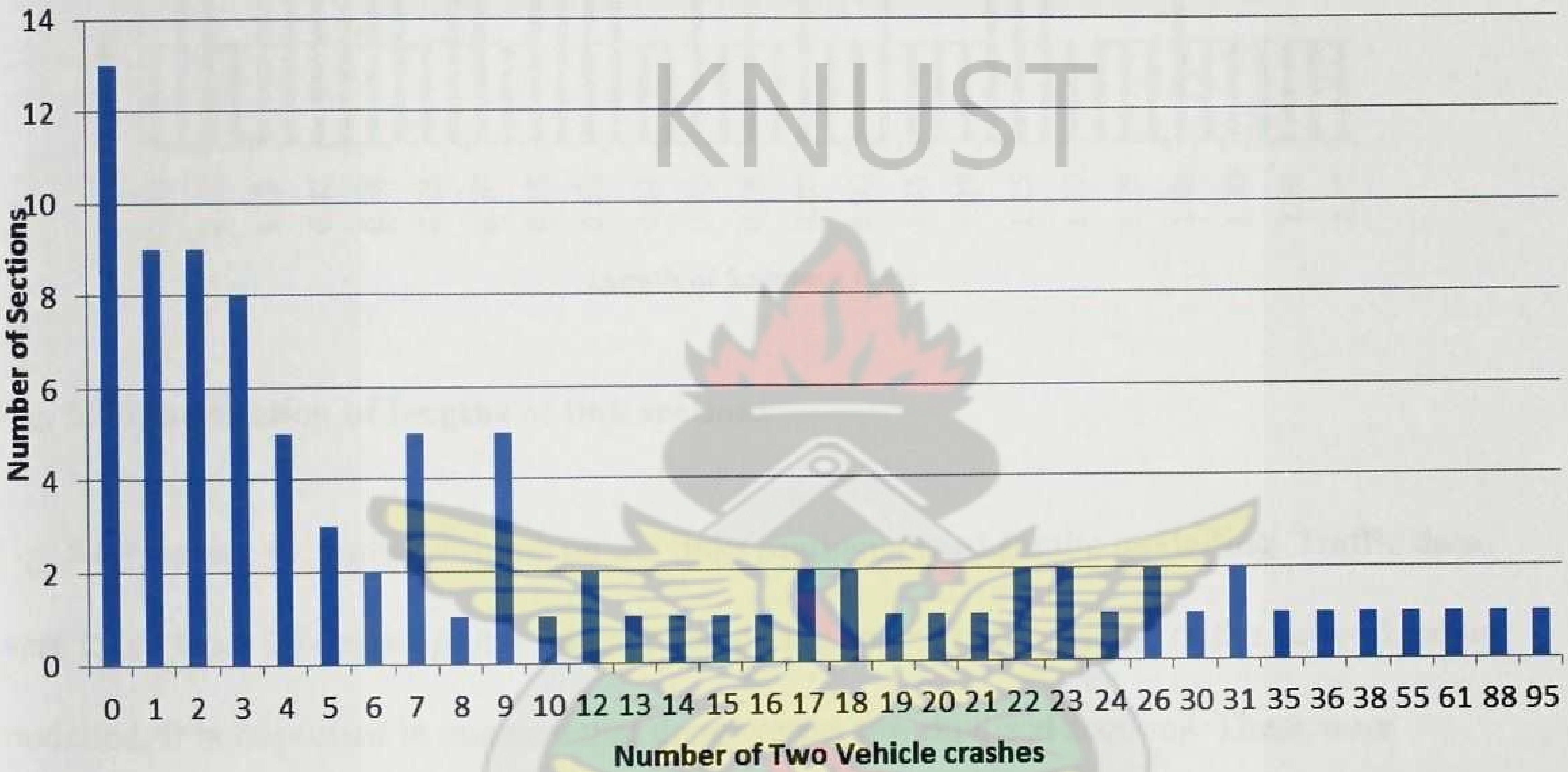


**Fig. 5.4 Distribution of Two vehicle crashes on link sections**

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.

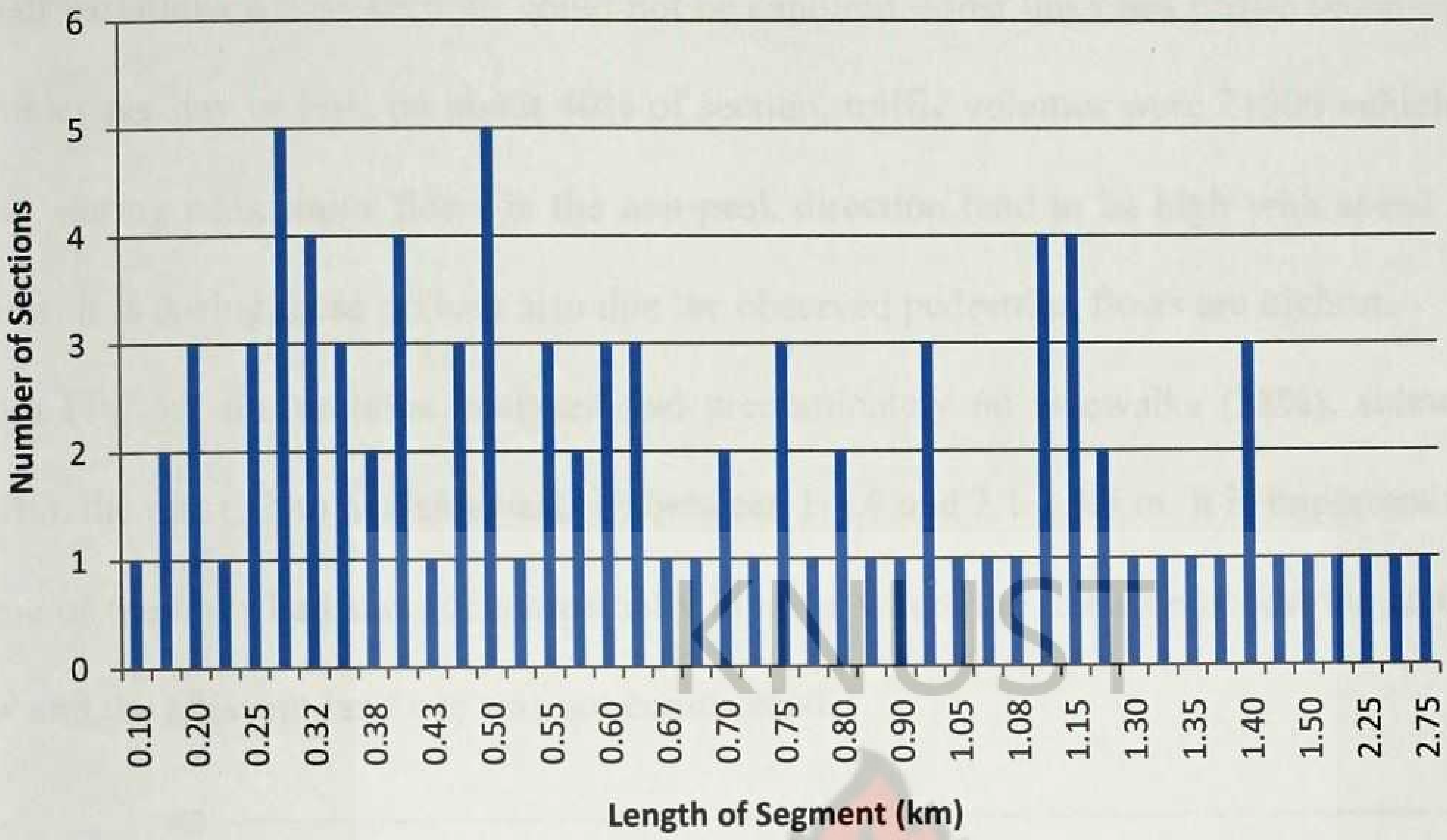


**Fig. 5.5 Distribution of lengths of link sections**

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.

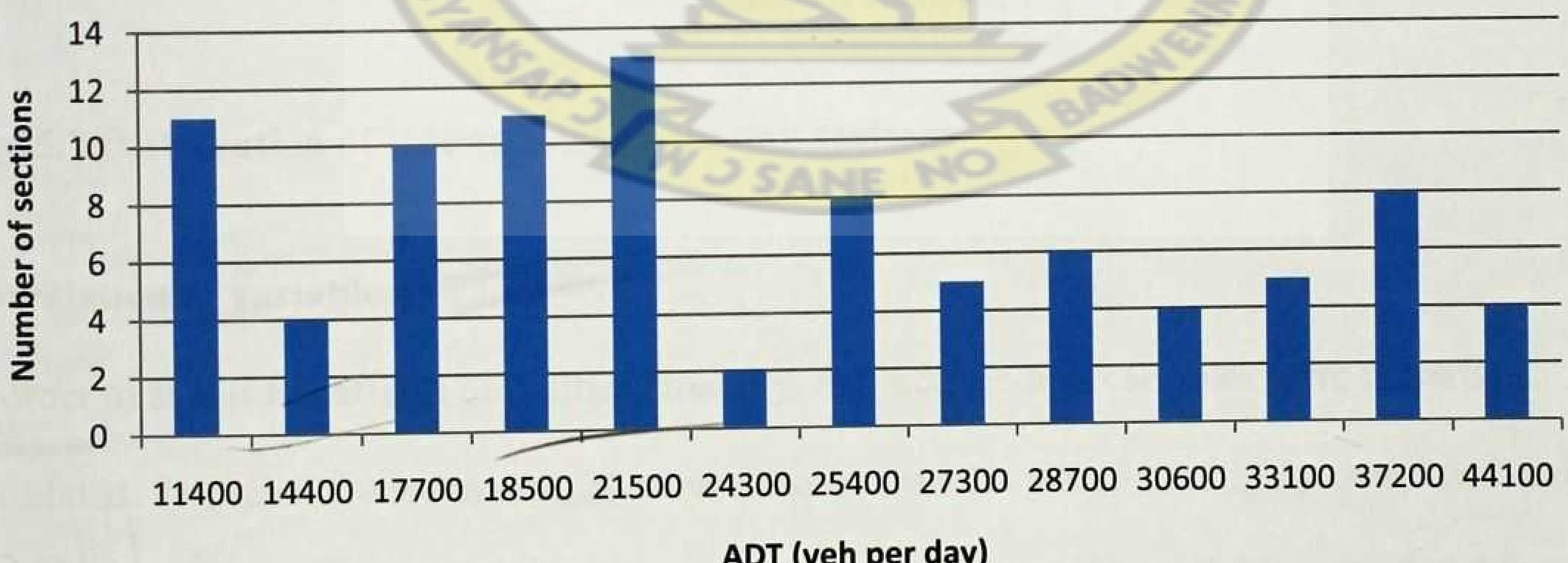


**Fig. 5.6 Distribution of Traffic flow on link sections**

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.

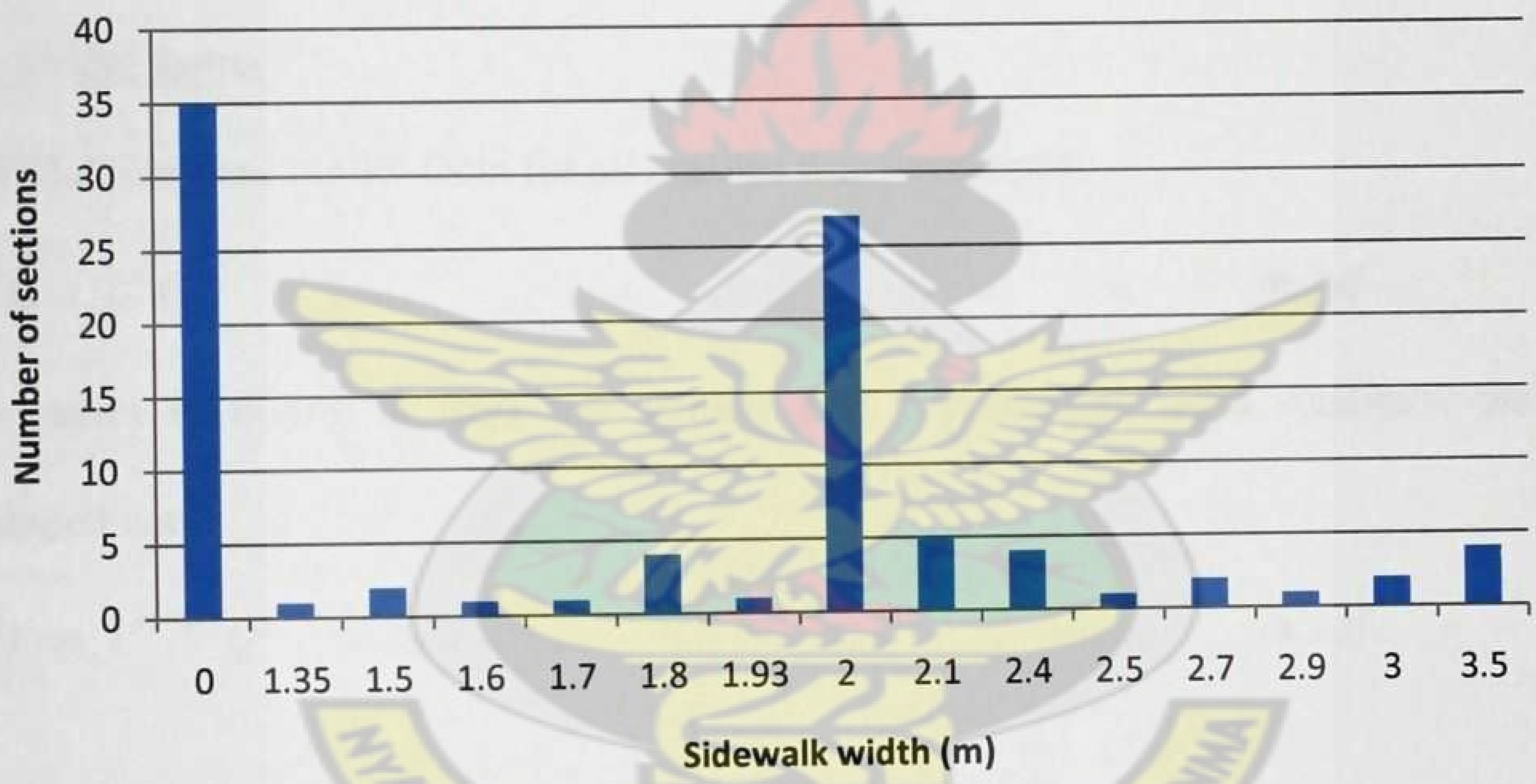


**Fig. 5.7 Distribution of sidewalk width on link sections**

**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:

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

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

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

Full Model forms

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

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

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

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

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

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

Full Model

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

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

## 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 ($\Phi$) defined as:

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

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 Publc | 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:

$$E(Y) = 1.16 \times 10^{-5}. \times LENGTH\_KM^{0.49} \times (TWOWAY\_ADT)^{1.27} \quad \ldots \quad \ldots \qquad (7.1)$$

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**

```
                                                   Scale parameter =         1
Deviance          =  108.6258929                   (1/df) Deviance =  1.234385
Pearson           =  96.59700634                   (1/df) Pearson  =  1.097693

Variance function: V(u) = u+(1.0941)u^2            [Neg. Binomial]
Link function    : g(u) = ln(u)                    [Log]

                                                   AIC             =  8.084758
Log likelihood    = -364.8564732                   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 |
| ln2wayaadt | 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 | 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, wi 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:

$$E(Y) = 5x10^{-6} \times (LENGTH\_KM)^{0.53} \times TWOWAY\_ADT^{1.03} \times EXP^{(0.03 AVE\_SPEED + 0.98 SWALK\_PRESC)} \quad \ldots \ldots \quad (7.2)$$

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  ln2wayaadt       , 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                          No. of obs      =         91
Optimization     : ML                              Residual df     =         88
                                                   Scale parameter =          1
Deviance         =   106.329967                    (1/df) Deviance =   1.208295
Pearson          =   96.1499489                    (1/df) Pearson  =   1.092613

Variance function: V(u) = u+(1.1692)u^2            [Neg. Binomial]
Link function    : g(u) = ln(u)                    [Log]

                                                   AIC             =   7.132505
Log likelihood   = -321.5289825                    BIC             =  -290.6257

------------------------------------------------------------------------------
             |                 OIM
twovehicle~t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 lnlength_km |   .4420859   .1760344     2.51   0.012     .0970647     .787107
  ln2wayaadt |     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:

$$E(Y) = 1.37 \times 10^{-5} \times LENGTH\_KM^{0.44} \times TWOWAY\_ADT^{1.2} \ldots \quad \ldots \quad (7.3)$$

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- value | coefficient | 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 | 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, wi 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:

$$E(Y) = 2.4x10^{-5} \times LENGTH\_KM^{0.48} \times TWOWAYADT^{1.14} \times EXP^{(0.03 AVESPEED - 0.29 SHOULDR\_WDTH)} \ldots \quad \ldots \quad (7.4)$$

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_WDTH* = 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 | Coef. | OIM Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lnlength_km | .6016156 | .1749944 | 3.44 | 0.001 | .2586329 | .9445983 |
| ln2wayaadt | 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



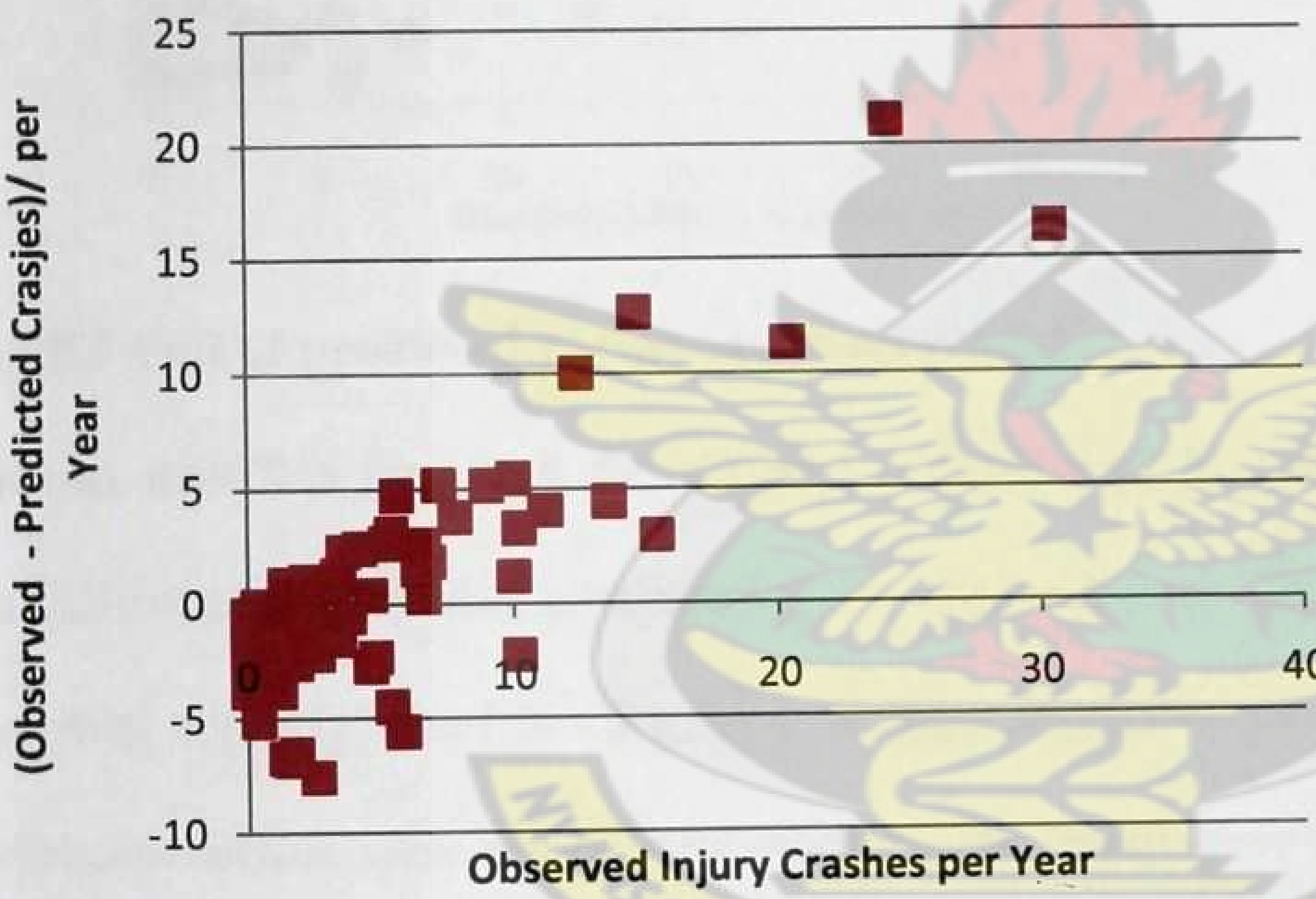


**Fig. 8.1 Plot of observed crashes versus residuals for total crashes**

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.

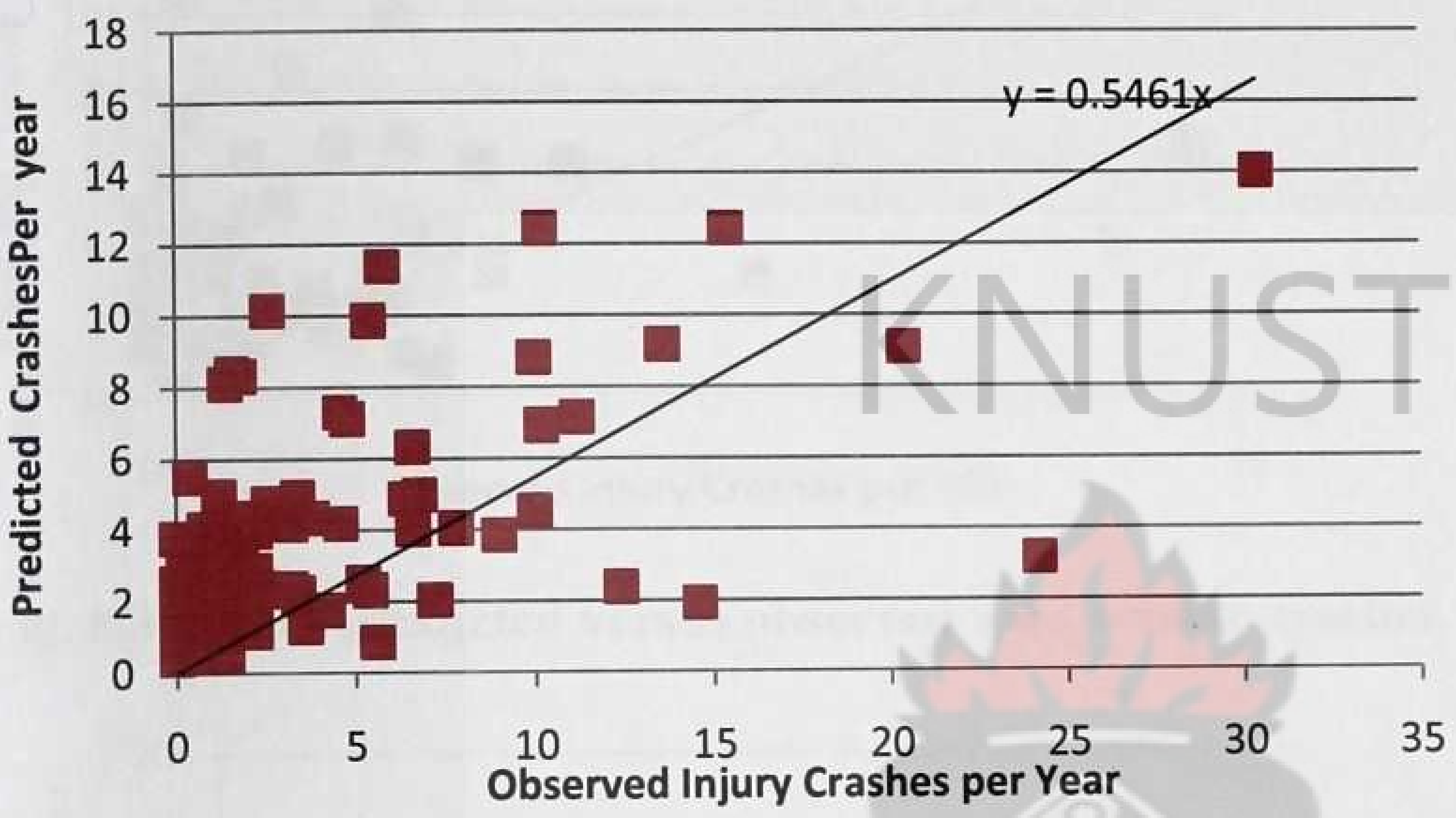


**Fig. 8.2 Plot of predicted versus observed crashes.**

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.

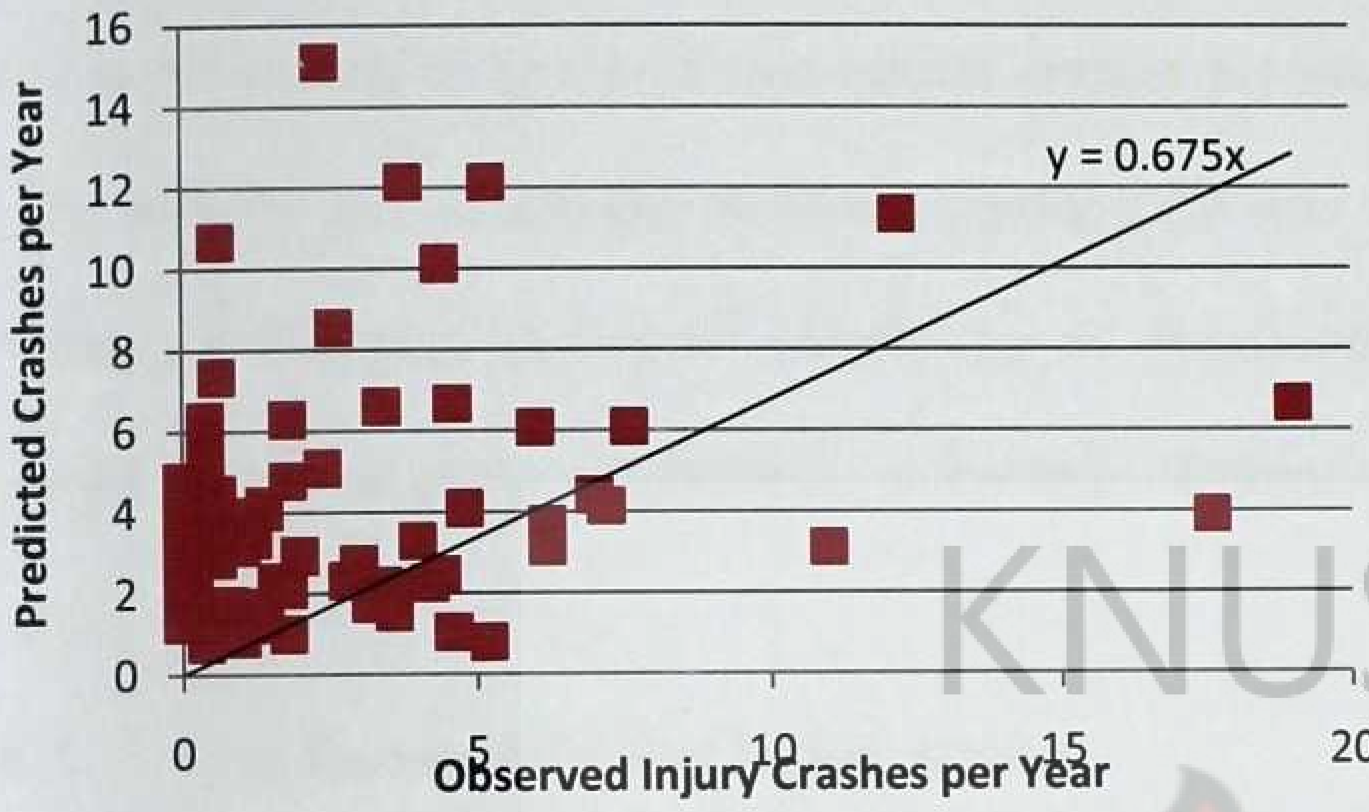


**Fig. 8.3 Plot of predicted versus observed Two-vehicle crashes.**

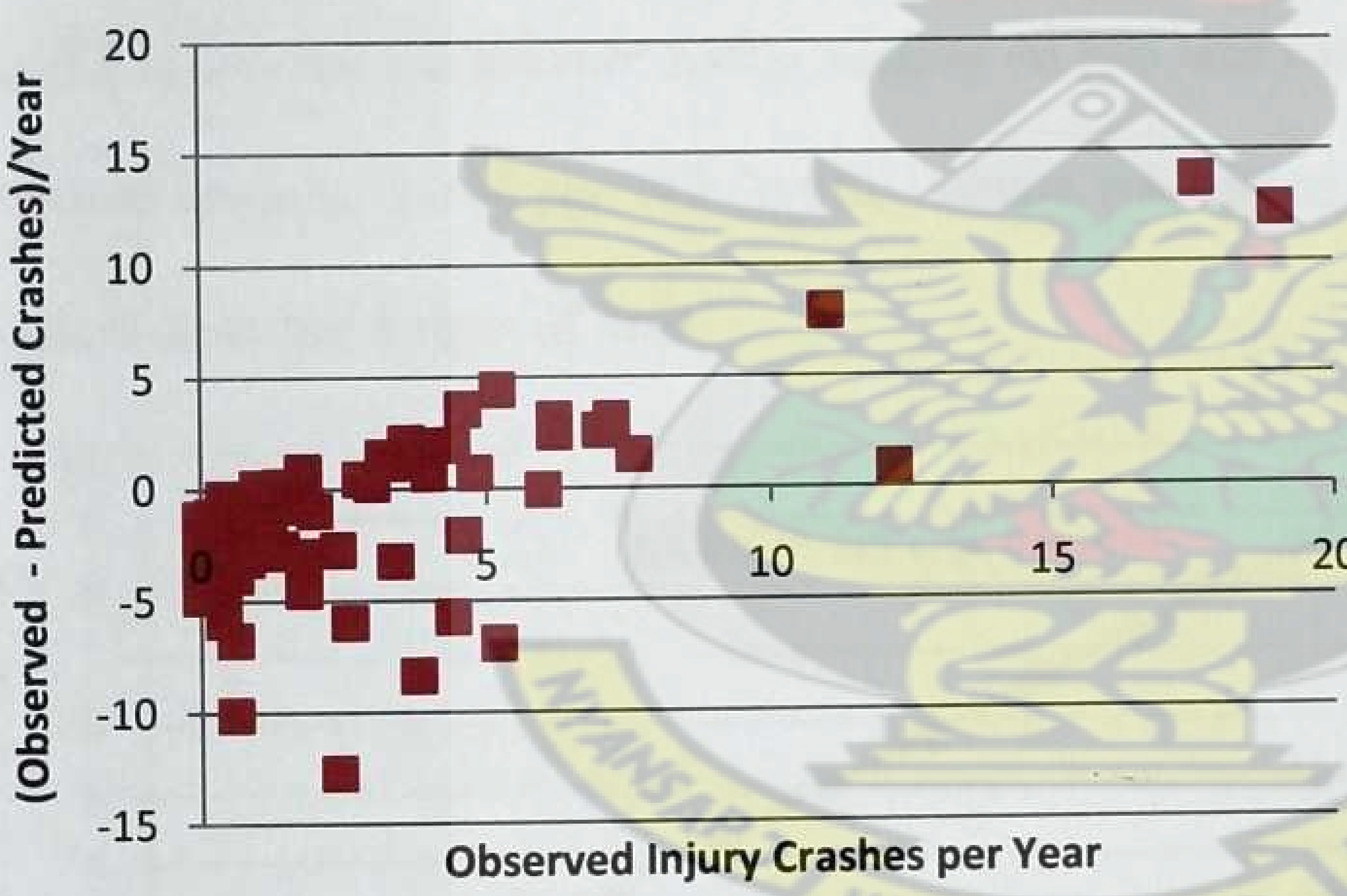


**Fig. 8.4 Plot of residuals versus observed two vehicle crashes.**

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.

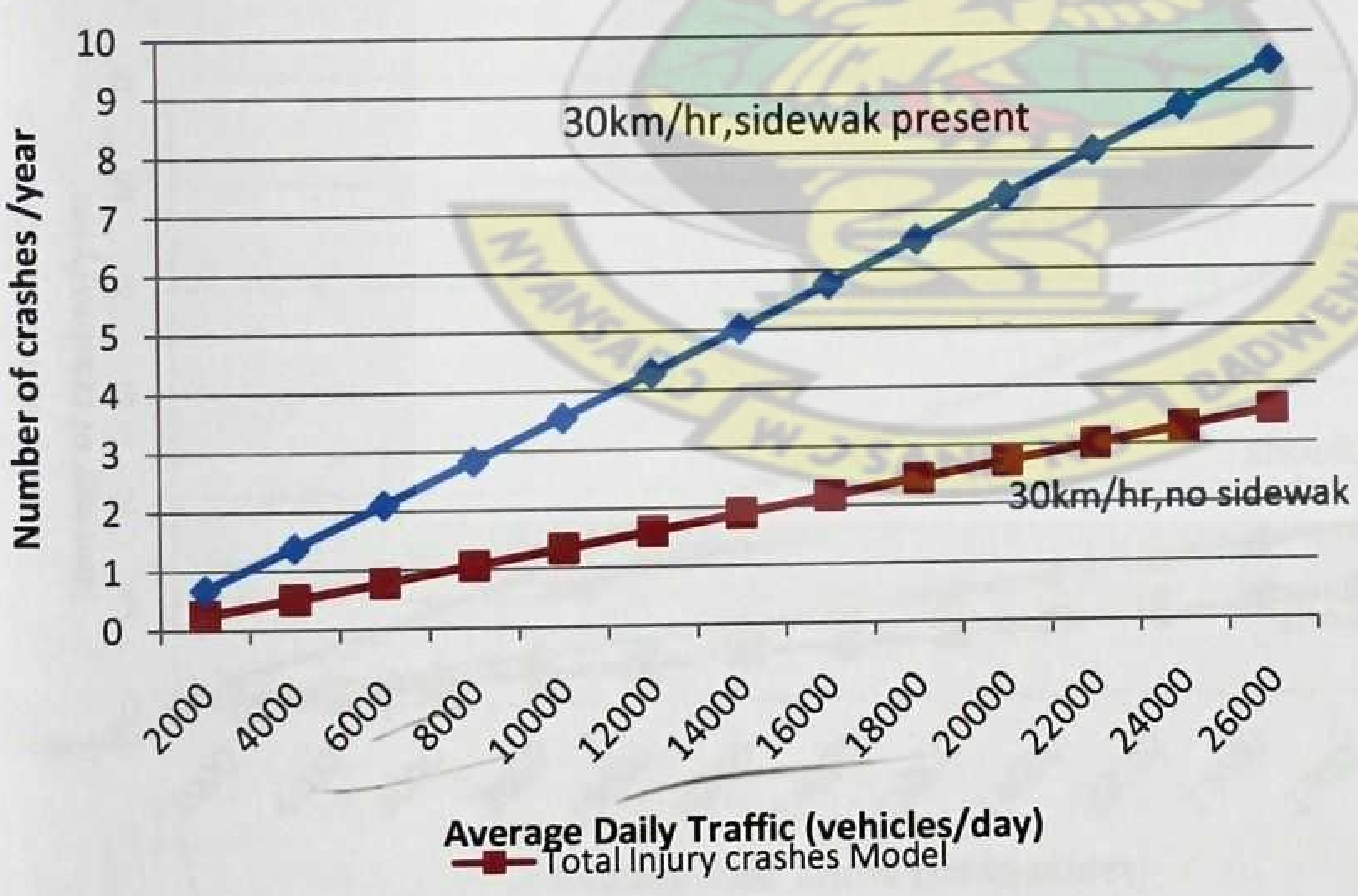


**Fig. 8.5 Variation of Total Injury crashes with ADT**

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.

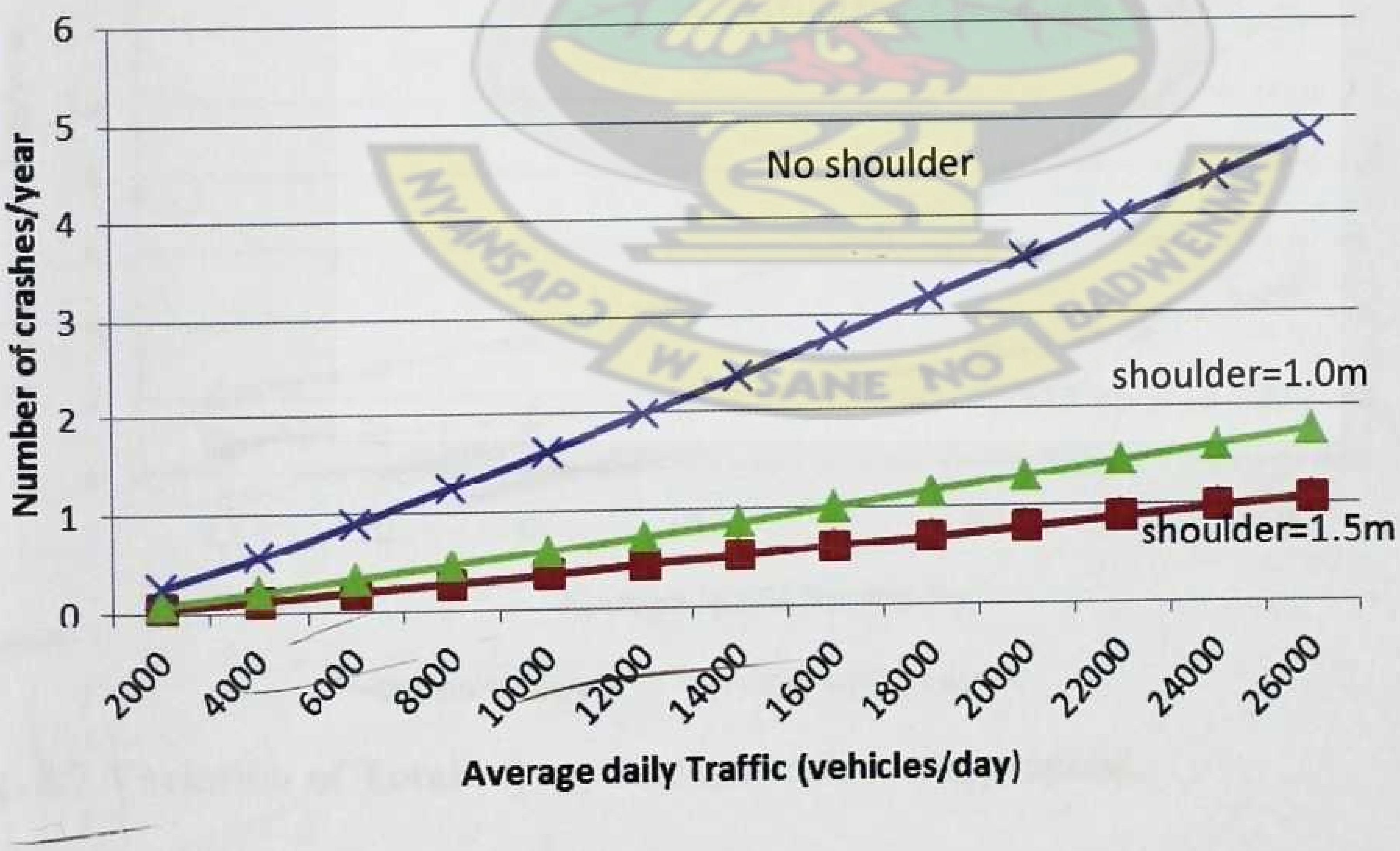


**Fig. 8.6 Variation of Two vehicle crashes with ADT**

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.

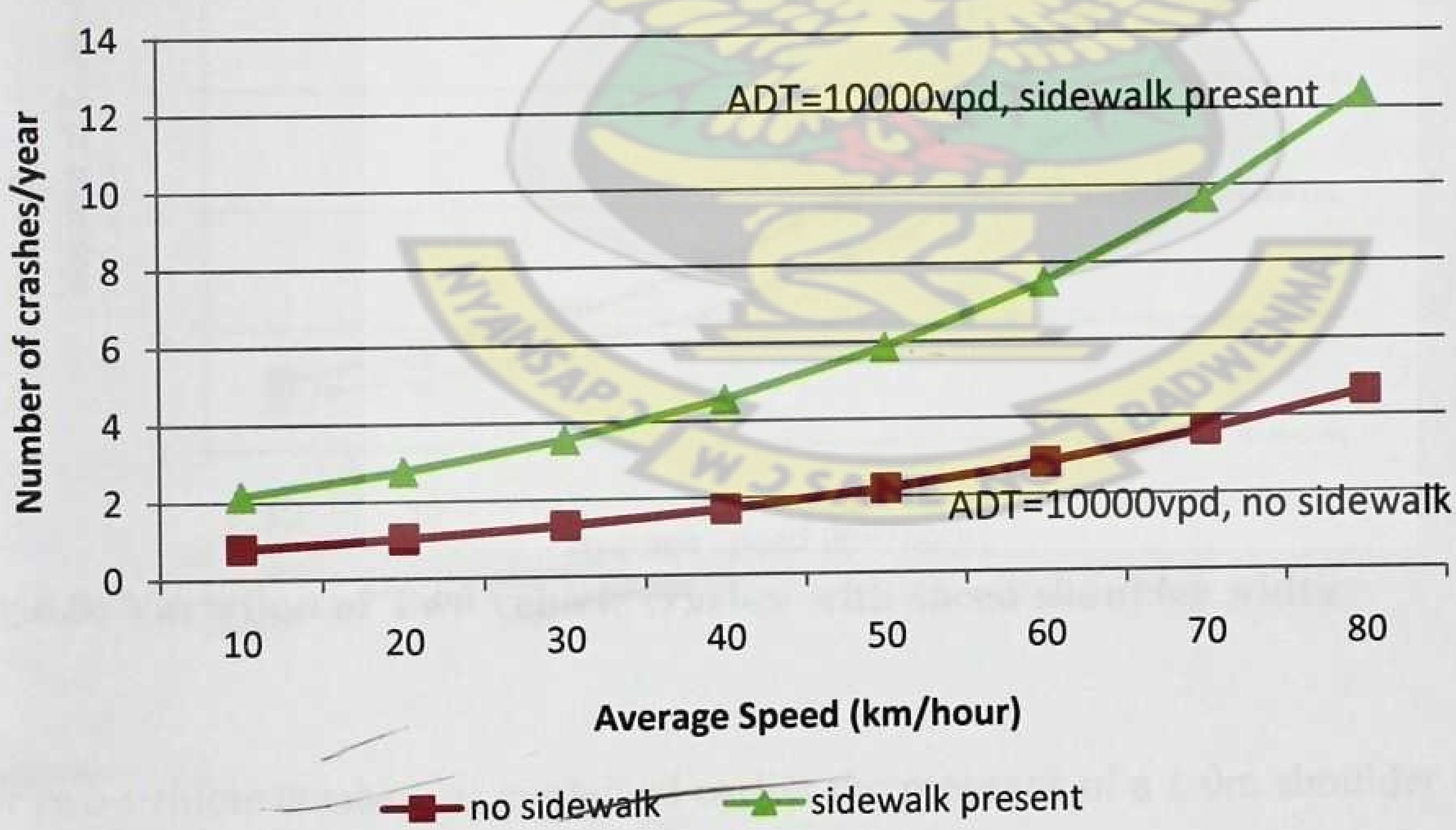


**Fig. 8.7 Variation of Total injury crashes with average speed.**

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.

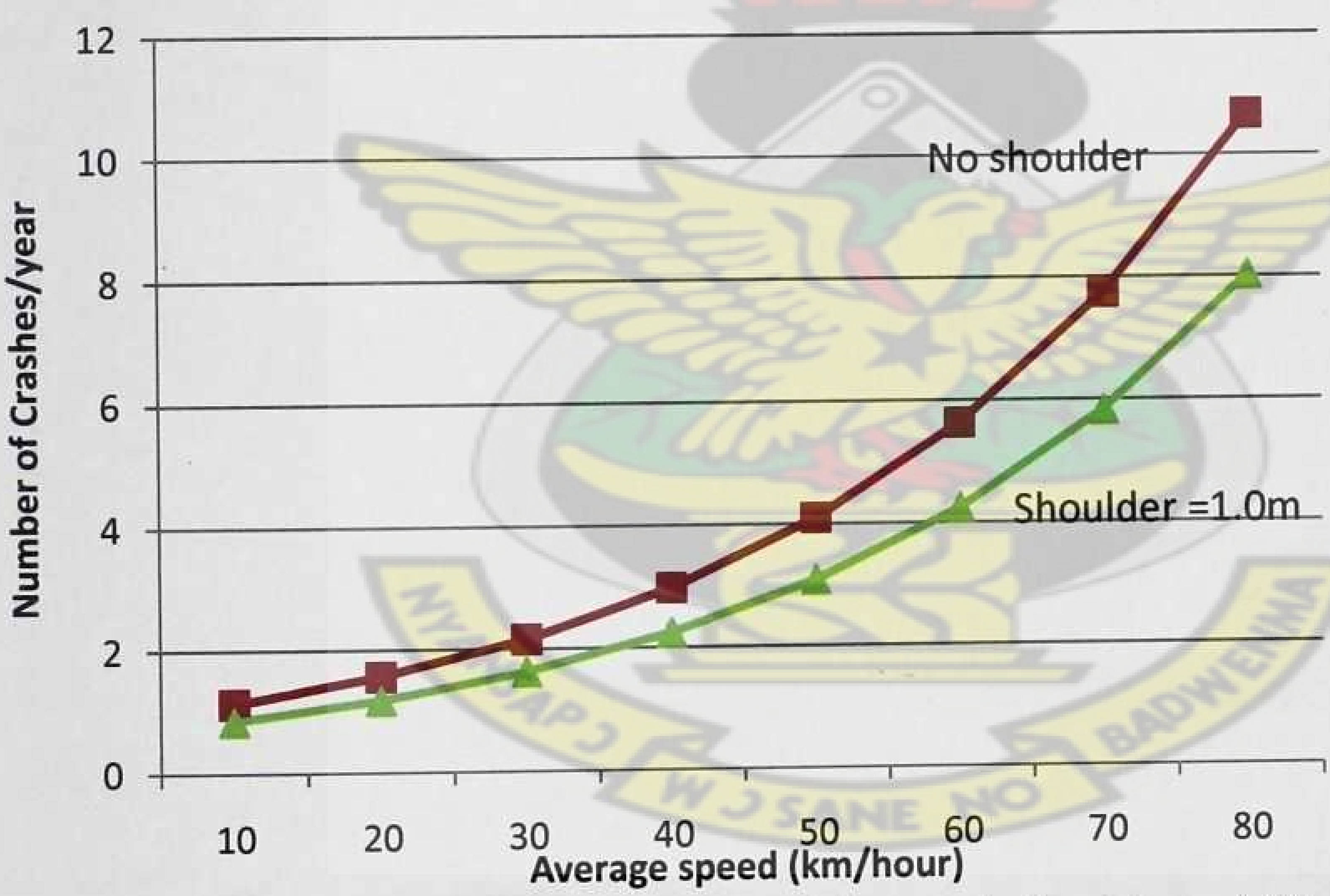


**Fig.8.8: Variation of Two vehicle crashes with speed shoulder width**

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.

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# 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 Inkury Accidents | Hit Pedestrian HITPED_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 Nhyiaeso Rd Int. | 18 | 7 | 2158 | 525 | 0.525 | 0.2 |
| 4 | Tafo Nhyiaeso 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 | Atonsu 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 - Dichemso Rd Int | 11 | 2 | 1582 | 300 | 0.3 | 0.1 |
| 25 | Dichemso 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 | Breman 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 Inkury 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 - Kwadaaso Estate Rd Int | 7 | 5 | 1200 | 1325 | 1.325 | 0.7 |
| 60 | Kwadaaso 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. - Kejetia 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. - Kejetia 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 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_FRICTION | 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 - Kwadaaso Estate Rd Int | 28700 | 2 | 13.2 | 50 | 0 | 1 |
| 60 | Kwadaaso 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 |

# APPENDIX A- LIST OF SECTIONS

| NO. | Road section/ Segment | Number of Pedestrian crossing Points PEDX_NUM | Width of Pedestrian Sidewalk SWALK_WIDTH (m) | Presence of sidewalk SWALK_PRESC Yes=1, No =0 | Width of Median MEDIAN_WIDTH (m) | Presence of Median Breaks MEDIAN_BREAK 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_WIDTH (m) | Presence of sidewalk SWALK_PRESC Yes=1, No =0 | Width of Median MEDIAN_WIDTH (m) | Presence of Median Breaks MEDIAN_BREAK 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 | 1 |
| 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 | 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_WIDTH (m) | Presence of sidewalk SWALK_PRESC Yes=1, No =0 | Width of Median MEDIAN_WIDTH (m) | Presence of Median Breaks MEDIAN_BREAK 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 - Kwadaaso Estate Rd Int | 2 | 0 | 0 | 0 | 0 | 7 |
| 60 | Kwadaaso 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_WIDTH (m) | Presence of sidewalk SWALK_PRESC Yes=1, No =0 | Width of Median MEDIAN_WIDTH (m) | Presence of Median Breaks MEDIAN_BREAK 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_WIDTH (m) | Carriageway Width ROAD_WIDTH (m) | number of Bus stops in Section BUSSTOP_NUMB | 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_WIDTH (m) | Carriageway Width ROAD_WIDTH (m) | number of Bus stops in Section BUSSTOP_NUMB | 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_WIDTH (m) | Carriageway Width ROAD_WIDTH (m) | number of Bus stops in Section BUSSTOP_NUMB | 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 - Kwadaaso Estate Rd Int | 1 | 1.5 | 6.7 | 1 | 0 |
| 60 | Kwadaaso 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_WIDTH (m) | Carriageway Width ROAD_WIDTH (m) | number of Bus stops in Section BUSSTOP_NUMB | 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 pedetrian 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 pedetrian 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 - Kwadaaso Estate Rd Int | 5 | 1 | 0 | 0 | 5 | 7.2 |
| 60 | Kwadaaso 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 pedetrian 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 |

## APPENDIX B:

## 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 |

## APPENDIX B

**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 |

# APPENDIX C

**Annual Distribution of Traffic Fatalities by Region**

| Year | Region | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ashanti | Brong Ahafo | Central | Eastern | Greater Accra | Northern | Upper East | Upper We | Volta | Western | Total |
| 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 |

# APPENDIX C

**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

| Year | Road User Class | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pedestrian | Car | HGV | Tract | Bus | Minibus | Motor Cycle | Pickup | Bicycle | Other | Unknown | |
| 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**

# APPENDIX C

| Year | Road Environment | | | | Total |
|---|---|---|---|---|---|
| | Urban | Rural | Village | ? | |
| 2000 | 3782 | 949 | 1690 | 5 | 6426 |
| 2001 | 3850 | 1026 | 1939 | 14 | 6829 |
| 2002 | 3772 | 893 | 1920 | 7 | 6592 |
| 2003 | 3691 | 1060 | 2093 | 2 | 6846 |
| 2004 | 4234 | 1058 | 2653 | 4 | 7949 |
| 2005 | 3869 | 918 | 2243 | 0 | 7030 |
| 2006 | 4100 | 672 | 2361 | 3 | 7136 |
| 2007 | 4598 | 671 | 2261 | 0 | 7530 |
| 2008 | 3752 | 797 | 2758 | 1 | 7308 |
| 2009 | 4430 | 684 | 3074 | 0 | 8188 |
| Total | 24273 | 4591 | 14880 | 8 | 43752 |
| | **55.5** | **10.5** | **34.0** | | |

**Distribution of Fatalities by road user class**

| Year | Road User Class | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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

| Year | Road User Class | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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 | 2 | 1092 |
| 2001 | 472 | 279 | 503 | 3 | 1257 |
| 2002 | 458 | 262 | 522 | 3 | 1245 |
| 2003 | 457 | 285 | 583 | 2 | 1327 |
| 2004 | 547 | 284 | 768 | 1 | 1600 |
| 2005 | 486 | 279 | 631 | 0 | 1396 |
| 2006 | 543 | 219 | 655 | 0 | 1417 |
| 2007 | 674 | 233 | 713 | 0 | 1620 |
| 2008 | 561 | 282 | 803 | 0 | 1646 |
| 2009 | 645 | 209 | 936 | 0 | 1790 |
| Total | 5252 | 2568 | 6559 | 11 | 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 | 0 | 2608 |
| 2001 | 1322 | 393 | 771 | 4 | 2490 |
| 2002 | 1378 | 345 | 833 | 3 | 2559 |
| 2003 | 1333 | 425 | 918 | 0 | 2676 |
| 2004 | 1396 | 395 | 1046 | 3 | 2840 |
| 2005 | 1320 | 309 | 880 | 0 | 2509 |
| 2006 | 1584 | 236 | 974 | 2 | 2796 |
| 2007 | 1711 | 238 | 960 | 0 | 2909 |
| 2008 | 1366 | 246 | 1044 | 0 | 2656 |
| 2009 | 1502 | 254 | 1061 | 0 | 2817 |
| Total | 8633 | 1588 | 5782 | 5 | 16008 |

**Annual Distribution of Fatal and Serious Accidents by Road Environment**

| Year | Road Environment | Total |
|---|---|---|

## APPENDIX C

| | 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 (2005-2009)**

| Year | Collision Type | Vehicle Type involved in injury crashes | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Car | HGV | Tract | Bus | Minibus | 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 | Tract | Bus | Trotro | M/Cyc | PickU | Cycle | Other | Unknown | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | Head On | 481 | 111 | 3 | 252 | 9 | 62 | 65 | 57 | 6 | 6 | 1052 |
| 2000 | Rear End | 550 | 154 | 6 | 319 | 6 | 89 | 69 | 82 | 14 | 16 | 1305 |
| 2000 | Right Ang | 393 | 51 | 4 | 180 | 3 | 79 | 54 | 70 | 4 | 3 | 841 |
| 2000 | Side Swip | 283 | 100 | 2 | 170 | 6 | 67 | 53 | 85 | 5 | 6 | 777 |
| 2000 | Overturne | 91 | 46 | 2 | 137 | 0 | 3 | 27 | 1 | 3 | 0 | 310 |
| 2000 | Hit Object | 23 | 3 | 0 | 16 | 0 | 2 | 4 | 3 | 2 | 0 | 53 |
| 2000 | Hit Object | 86 | 24 | 0 | 63 | 0 | 1 | 16 | 1 | 2 | 3 | 196 |
| 2000 | Hit Parked | 53 | 34 | 4 | 32 | 3 | 4 | 8 | 5 | 1 | 2 | 146 |
| 2000 | Hit Pedest | 1436 | 177 | 8 | 829 | 7 | 119 | 145 | 72 | 19 | 77 | 2889 |
| 2000 | Other | 323 | 189 | 7 | 418 | 10 | 28 | 120 | 33 | 12 | 5 | 1145 |
| **2000** | **Total** | **3719** | **889** | **36** | **2416** | **44** | **454** | **561** | **409** | **68** | **118** | **8714** |
| | | | | | | | | | | | | |
| 2001 | Head On | 438 | 76 | 3 | 229 | 0 | 54 | 55 | 54 | 11 | 1 | 921 |
| 2001 | Rear End | 453 | 123 | 12 | 317 | 2 | 79 | 67 | 70 | 25 | 3 | 1151 |
| 2001 | Right Ang | 380 | 65 | 2 | 155 | 2 | 66 | 59 | 65 | 2 | 1 | 797 |
| 2001 | Side Swip | 353 | 113 | 8 | 210 | 1 | 70 | 66 | 119 | 15 | 8 | 963 |
| 2001 | Overturne | 87 | 39 | 2 | 116 | 0 | 4 | 20 | 5 | 0 | 1 | 274 |
| 2001 | Hit Object | 14 | 12 | 0 | 12 | 0 | 5 | 6 | 0 | 0 | 0 | 49 |
| 2001 | Hit Object | 64 | 27 | 0 | 35 | 1 | 2 | 10 | 1 | 1 | 0 | 141 |
| 2001 | Hit Parked | 73 | 45 | 2 | 48 | 1 | 6 | 9 | 2 | 1 | 1 | 188 |
| 2001 | Hit Pedest | 1560 | 185 | 8 | 943 | 12 | 106 | 176 | 76 | 31 | 71 | 3168 |
| 2001 | Other | 471 | 254 | 17 | 551 | 6 | 82 | 118 | 61 | 26 | 4 | 1590 |
| **2001** | **Total** | **3893** | **939** | **54** | **2616** | **25** | **474** | **586** | **453** | **112** | **90** | **9242** |
| | | | | | | | | | | | | |
| 2002 | Head On | 531 | 146 | 3 | 287 | 3 | 56 | 55 | 61 | 3 | 0 | 1145 |
| 2002 | Rear End | 506 | 171 | 12 | 297 | 3 | 74 | 72 | 75 | 4 | 6 | 1220 |
| 2002 | Right Ang | 448 | 86 | 4 | 159 | 1 | 69 | 50 | 108 | 1 | 3 | 929 |
| 2002 | Side Swip | 339 | 156 | 2 | 206 | 1 | 95 | 52 | 120 | 3 | 10 | 984 |
| 2002 | Overturne | 91 | 67 | 2 | 170 | 3 | 4 | 18 | 4 | 1 | 1 | 361 |
| 2002 | Hit Object | 12 | 9 | 0 | 13 | 0 | 2 | 0 | 3 | 1 | 0 | 40 |

## APPENDIX C

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2002 | Hit Object | 70 | 25 | 1 | 43 | 2 | 2 | 12 | 1 | 0 | 0 | 156 |
| 2002 | Hit Parked | 50 | 40 | 3 | 43 | 1 | 4 | 7 | 1 | 1 | 2 | 152 |
| 2002 | Hit Pedest | 1501 | 206 | 8 | 810 | 3 | 92 | 138 | 70 | 9 | 89 | 2926 |
| 2002 | Other | 267 | 254 | 7 | 453 | 7 | 29 | 82 | 10 | 4 | 4 | 1117 |
| **2002** | **Total** | **3815** | **1160** | **42** | **2481** | **24** | **427** | **486** | **453** | **27** | **115** | **9030** |
| | | | | | | | | | | | | |
| 2003 | Head On | 501 | 156 | 1 | 278 | 4 | 66 | 71 | 66 | 2 | 6 | 1151 |
| 2003 | Rear End | 502 | 208 | 11 | 308 | 4 | 86 | 70 | 97 | 7 | 12 | 1305 |
| 2003 | Right Ang | 420 | 57 | 4 | 167 | 3 | 109 | 48 | 98 | 10 | 3 | 919 |
| 2003 | Side Swip | 359 | 169 | 10 | 241 | 9 | 87 | 51 | 133 | 7 | 13 | 1079 |
| 2003 | Overturne | 103 | 99 | 3 | 167 | 3 | 6 | 28 | 2 | 2 | 1 | 414 |
| 2003 | Hit Object | 16 | 13 | 1 | 13 | 0 | 2 | 3 | 1 | 0 | 0 | 49 |
| 2003 | Hit Object | 68 | 31 | 0 | 52 | 0 | 1 | 14 | 1 | 0 | 0 | 167 |
| 2003 | Hit Parked | 31 | 35 | 0 | 29 | 1 | 4 | 0 | 3 | 1 | 0 | 104 |
| 2003 | Hit Pedest | 1411 | 237 | 13 | 832 | 10 | 142 | 149 | 98 | 9 | 68 | 2969 |
| 2003 | Other | 335 | 289 | 10 | 477 | 11 | 53 | 68 | 35 | 13 | 4 | 1295 |
| **2003** | **Total** | **3746** | **1294** | **53** | **2564** | **45** | **556** | **502** | **534** | **51** | **107** | **9452** |
| | | | | | | | | | | | | |
| 2004 | Head On | 645 | 174 | 7 | 331 | 3 | 81 | 68 | 72 | 3 | 3 | 1387 |
| 2004 | Rear End | 518 | 221 | 25 | 360 | 2 | 120 | 74 | 93 | 6 | 13 | 1432 |
| 2004 | Right Ang | 531 | 88 | 10 | 218 | 3 | 162 | 66 | 166 | 4 | 1 | 1249 |
| 2004 | Side Swip | 468 | 205 | 13 | 269 | 2 | 137 | 64 | 138 | 6 | 7 | 1309 |
| 2004 | Overturne | 127 | 106 | 4 | 233 | 0 | 14 | 54 | 4 | 0 | 0 | 542 |
| 2004 | Hit Object | 18 | 6 | 0 | 11 | 1 | 2 | 5 | 0 | 0 | 0 | 43 |
| 2004 | Hit Object | 83 | 31 | 0 | 66 | 0 | 3 | 22 | 0 | 0 | 0 | 205 |
| 2004 | Hit Parked | 82 | 68 | 1 | 57 | 1 | 5 | 8 | 3 | 2 | 0 | 227 |
| 2004 | Hit Pedest | 1658 | 247 | 10 | 959 | 9 | 164 | 177 | 91 | 7 | 78 | 3400 |
| 2004 | Other | 340 | 280 | 15 | 490 | 5 | 41 | 69 | 28 | 5 | 4 | 1277 |
| **2004** | **Total** | **4470** | **1426** | **85** | **2994** | **26** | **729** | **607** | **595** | **33** | **106** | **11071** |
| | | | | | | | | | | | | |
| 2005 | Head On | 474 | 129 | 5 | 103 | 152 | 93 | 79 | 42 | 2 | 0 | 1079 |

## APPENDIX C

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |

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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **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 | ed Not-Hospit | 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 | Overturned | 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 | Overturned | 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 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| 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 | Overturned | 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 | Overturned | 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** | Overturned | | | | | |
| **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 Rc | 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 Rc | 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 | ed Not-Hospit | Damage Only | |
| 2000 | Not at Junc | 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 | Roundabou | 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 Junc | 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 | Roundabou | 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 Junc | 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 | Roundabou | 4 | 16 | 34 | 199 | 253 |
| 2002 | Railway | 0 | 0 | 2 | 8 | 10 |

## APPENDIX C

| | | | | | | |
|---|---|---|---|---|---|---|
| 2002 | Other | 10 | 19 | 50 | 125 | 204 |
| 2002 | ? | 1 | 2 | 6 | 3 | 12 |
| **2002** | **Total** | **458** | **1378** | **1936** | **3391** | **7163** |
| 2003 | Not at Junc | 332 | 930 | 1204 | 1410 | 3876 |
| 2003 | Crossroads | 30 | 85 | 180 | 421 | 716 |
| 2003 | T/Junction | 68 | 273 | 391 | 775 | 1507 |
| 2003 | Staggered C | 2 | 8 | 23 | 24 | 57 |
| 2003 | Y/Junction | 2 | 2 | 12 | 21 | 37 |
| 2003 | Roundabou | 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** | Roundabout | | | | | |
| **2004** | Railway | | | | | |
| **2004** | Other | | | | | |
| 2005 | Not at Junc | 352 | 925 | 1313 | 1748 | 4338 |
| 2005 | Crossroads | 25 | 93 | 209 | 468 | 795 |
| 2005 | T/Junction | 75 | 217 | 354 | 828 | 1474 |
| 2005 | Staggered C | 3 | 15 | 25 | 27 | 70 |
| 2005 | Y/Junction | 5 | 14 | 11 | 25 | 55 |
| 2005 | Roundabou | 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 Junc | 401 | 1111 | 1280 | 1825 | 4617 |
| 2006 | Crossroads | 26 | 107 | 165 | 479 | 777 |

## APPENDIX C

| | | | | | | |
|---|---|---|---|---|---|---|
| 2006 | T/Junction | 85 | 285 | 391 | 931 | 1692 |
| 2006 | Staggered ( | 4 | 15 | 26 | 53 | 98 |
| 2006 | Y/Junction | 7 | 9 | 14 | 30 | 60 |
| 2006 | Roundabou | 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 | Roundabou | 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 | Roundabou | 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 | Roundabou | 8 | 16 | 37 | 125 | 186 |
| 2009 | Railway | 1 | 0 | 2 | 3 | 6 |

## APPENDIX C

| | | | | | | |
|---|---|---|---|---|---|---|
| 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 | ed Not-Hospit | 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 | Roundabou | 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 | Roundabou | 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 |

APPENDIX C

| | | | | | | |
|---|---|---|---|---|---|---|
| 2002 | Roundabou | 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 Junc | 525 | 812 | 516 | 429 | 2282 |
| 2003 | Crossroads | 7 | 19 | 10 | 2 | 38 |
| 2003 | T/Junction | 47 | 70 | 56 | 56 | 229 |
| 2003 | Staggered C | 3 | 6 | 2 | 1 | 12 |
| 2003 | Y/Junction | 0 | 3 | 1 | 1 | 5 |
| 2003 | Roundabou | 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 Junc | 543 | 752 | 622 | 496 | 2413 |
| 2005 | Crossroads | 10 | 11 | 11 | 15 | 47 |
| 2005 | T/Junction | 63 | 85 | 81 | 86 | 315 |
| 2005 | Staggered C | 7 | 5 | 1 | 0 | 13 |
| 2005 | Y/Junction | 0 | 5 | 1 | 0 | 6 |
| 2005 | Roundabou | 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 |

## APPENDIX C

| | | | | | | |
|---|---|---|---|---|---|---|
| 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 | Roundabou | 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 | Roundabou | 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 | Roundabou | 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 | 9 |
| 2009 | Roundabou | 5 | 7 | 5 | 2 | 19 |
| 2009 | Railway | 0 | 1 | 0 | 1 | 2 |
| 2009 | Other | 11 | 8 | 13 | 9 | 41 |
| 2009 | ? | 0 | 0 | 1 | 0 | 1 |
| 2009 | Total | 933 | 1061 | 1077 | 659 | 3730 |
| Total | | 3735 | 4919 | 4040 | 3279 | 15973 |

**Accident Location vrs Accident Severity for Rural Environment in Ghana**

| Year | Location | Accident Severity | | | | Total |
|---|---|---|---|---|---|---|
| | Type | Fatal | Hospitalised | ed Not-Hospit | Damage Only | |
| 2000 | Not at Junc | 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 Junc | 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 | Roundabou | 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 Junc | 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 |

## APPENDIX C

| | | | | | | |
|---|---|---|---|---|---|---|
| 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 | Roundabou | 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 C | 0 | 1 | 0 | 0 | 1 |
| 2005 | Y/Junction | 0 | 0 | 1 | 0 | 1 |
| 2005 | Roundabou | 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 | Roundabou | 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 | 1 |
| 2007 | T/Junction | 8 | 6 | 3 | 3 | 20 |
| 2007 | Staggered ( | 0 | 1 | 0 | 1 | 2 |
| 2007 | Y/Junction | 0 | 0 | 0 | 1 | 1 |
| 2007 | Roundabou | 1 | 0 | 2 | 1 | 4 |
| 2007 | Other | 0 | 2 | 0 | 0 | 2 |
| 2007 | Total | 233 | 238 | 200 | 182 | 853 |
| 2008 | Not at Junc | 267 | 229 | 255 | 157 | 908 |
| 2008 | Crossroads | 2 | 3 | 0 | 2 | 7 |
| 2008 | T/Junction | 7 | 9 | 7 | 8 | 31 |
| 2008 | Staggered ( | 1 | 0 | 0 | 0 | 1 |
| 2008 | Y/Junction | 0 | 2 | 0 | 0 | 2 |
| 2008 | Roundabou | 1 | 2 | 1 | 2 | 6 |
| 2008 | Railway | 1 | 0 | 0 | 0 | 1 |
| 2008 | Other | 3 | 1 | 6 | 2 | 12 |
| 2008 | Total | 282 | 246 | 269 | 171 | 968 |
| 2009 | Not at Junc | 199 | 245 | 208 | 157 | 809 |
| 2009 | Crossroads | 0 | 1 | 1 | 0 | 2 |
| 2009 | T/Junction | 5 | 7 | 11 | 5 | 28 |
| 2009 | Y/Junction | 1 | 0 | 0 | 3 | 4 |
| 2009 | Roundabou | 3 | 1 | 1 | 1 | 6 |
| 2009 | Other | 1 | 0 | 0 | 1 | 2 |
| 2009 | Total | 209 | 254 | 221 | 167 | 851 |
| Total | | 1222 | 1283 | 1237 | 905 | 4647 |

# APPENDIX C

| 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 | 229 | 18 | 28 | 2 | 3 | 48 | 14 | 343 |
| 2000 | Hospitalise | 3 | 732 | 79 | 74 | 4 | 11 | 114 | 35 | 1052 |
| 2000 | Injured Not-Hospitalised | 6 | 616 | 80 | 88 | 5 | 9 | 161 | 47 | 1012 |
| **2000** | **Total** | **10** | **1577** | **177** | **190** | **11** | **23** | **323** | **96** | **2407** |
| 2001 | Fatal | 0 | 266 | 12 | 45 | 2 | 0 | 57 | 8 | 390 |
| 2001 | Hospitalise | 3 | 662 | 28 | 65 | 1 | 11 | 109 | 20 | 899 |
| 2001 | Injured Not-Hospitalised | 5 | 717 | 71 | 96 | 4 | 10 | 171 | 36 | 1110 |
| **2001** | **Total** | **8** | **1645** | **111** | **206** | **7** | **21** | **337** | **64** | **2399** |
| 2002 | Fatal | 0 | 218 | 14 | 36 | 7 | 4 | 71 | 8 | 358 |
| 2002 | Hospitalise | 2 | 670 | 55 | 44 | 4 | 3 | 178 | 5 | 961 |
| 2002 | Injured Not-Hospitalised | 5 | 662 | 72 | 84 | 14 | 3 | 178 | 21 | 1039 |
| **2002** | **Total** | **7** | **1550** | **141** | **164** | **25** | **10** | **427** | **34** | **2358** |
| 2003 | Fatal | 0 | 227 | 19 | 19 | 2 | 6 | 91 | 7 | 371 |
| 2003 | Hospitalise | 1 | 638 | 57 | 61 | 6 | 3 | 176 | 8 | 950 |
| 2003 | Injured Not-Hospitalised | 3 | 586 | 61 | 68 | 1 | 8 | 203 | 17 | 947 |
| **2003** | **Total** | **4** | **1451** | **137** | **148** | **9** | **17** | **470** | **32** | **2268** |
| **2004** | Fatal | | | | | | | | | |
| **2004** | Hospitalised | | | | | | | | | |

## 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 On | 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 |
| 2006 | Injured Not-Hospitalised | 25 | 594 | 90 | 136 | 1 | 11 | 152 | 2 | 1011 |
| 2006 | Damage On | 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 |
| 2007 | Injured Not-Hospitalised | 8 | 619 | 103 | 121 | 5 | 20 | 161 | 0 | 1037 |
| 2007 | Damage On | 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 |
| 2008 | Injured Not-Hospitalised | 2 | 455 | 109 | 118 | 3 | 19 | 136 | 0 | 842 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2008 | Damage Or | 1 | 3 | 1 | 0 | 0 | 1 | 1 | 0 | 7 |
| 2008 | Total | 12 | 1309 | 209 | 261 | 11 | 54 | 347 | 0 | 2203 |
| | | | | | | | | | | |
| 2009 | Fatal | 16 | 323 | 24 | 26 | 7 | 3 | 100 | 0 | 499 |
| 2009 | Hospitalise | 37 | 615 | 109 | 110 | 1 | 10 | 119 | 0 | 1001 |
| 2009 | Injured Not-Hospitalised | 51 | 531 | 132 | 93 | 5 | 15 | 166 | 0 | 993 |
| 2009 | Damage Or | 0 | 2 | 1 | 1 | 0 | 0 | 1 | 0 | 5 |
| 2009 | Total | 104 | 1471 | 266 | 230 | 13 | 28 | 386 | 0 | 2498 |

**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 |
| 2000 | Injured Not-Hospitalised | 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 |
| 2001 | Injured Not-Hospitalised | 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 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2002 | Injured Not-Hospitalised | 2 | 79 | 13 | 22 | 1 | 5 | 34 | 2 | 158 |
| **2002** | **Total** | **7** | **547** | **65** | **71** | **7** | **12** | **185** | **8** | **902** |
| 2003 | Fatal | 1 | 217 | 9 | 33 | 1 | 3 | 95 | 13 | 372 |
| 2003 | Hospitalise | 3 | 293 | 23 | 17 | 3 | 0 | 84 | 8 | 431 |
| 2003 | Injured Not-Hospitalised | 0 | 99 | 7 | 10 | 1 | 1 | 51 | 2 | 171 |
| **2003** | **Total** | **4** | **609** | **39** | **60** | **5** | **4** | **230** | **23** | **974** |
| **2004** | Fatal | | | | | | | | | |
| **2004** | Hospitalised | | | | | | | | | |
| **2004** | Injured Not-Hospitalised | | | | | | | | | |
| 2005 | Fatal | 5 | 290 | 41 | 31 | 2 | 1 | 65 | 1 | 436 |
| 2005 | Hospitalise | 16 | 319 | 46 | 31 | 3 | 2 | 70 | 0 | 487 |
| 2005 | Injured Not | 1 | 115 | 23 | 24 | 0 | 0 | 67 | 0 | 230 |
| 2005 | Damage Or | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 2005 | Total | 22 | 724 | 110 | 87 | 5 | 3 | 202 | 1 | 1154 |
| | | | | | | | | | | |
| 2006 | Fatal | 3 | 284 | 25 | 34 | 1 | 8 | 71 | 0 | 426 |
| 2006 | Hospitalise | 5 | 353 | 29 | 64 | 5 | 20 | 84 | 0 | 560 |
| 2006 | Injured Not-Hospitalised | 4 | 118 | 15 | 41 | 1 | 5 | 35 | 0 | 219 |
| 2006 | Damage Or | 0 | 2 | 0 | 8 | 0 | 0 | 0 | 0 | 10 |
| 2006 | Total | 12 | 757 | 69 | 147 | 7 | 33 | 190 | 0 | 1215 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | Fatal | 4 | 320 | 57 | 32 | 1 | 2 | 58 | 0 | 474 |
| 2007 | Hospitalise | 4 | 347 | 31 | 43 | 0 | 12 | 50 | 0 | 487 |
| 2007 | Injured Not-Hospitalised | 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 |
| 2008 | Injured Not-Hospitalised | 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 |
| 2009 | Injured Not-Hospitalised | 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**

| 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)

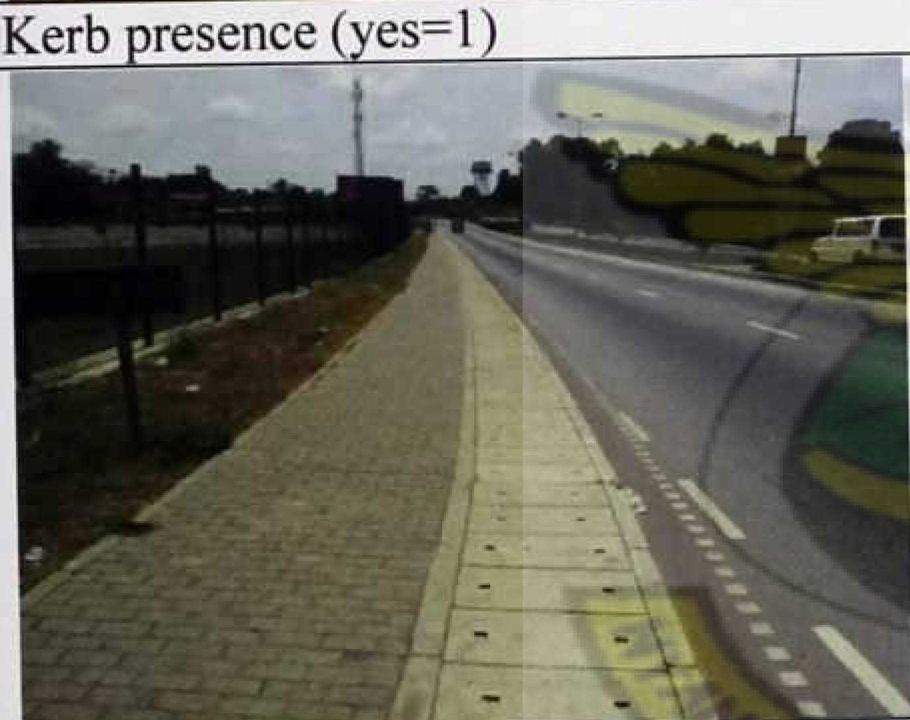
# APPENDIX D - PICTURE LEGEND FOR DATA COLLECTION

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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | TOT INJ ACC | 1 | | | | | | | | | | | | | | | | | | | | | |
| 3 | LnLENGTH KM | 0.2655* | 1.00 | | | | | | | | | | | | | | | | | | | | |
| 4 | WAY AADT | 0.3482* | 0.2068* | 1.00 | | | | | | | | | | | | | | | | | | | |
| 5 | NUMB LANES | 0.5682* | 0.2250* | 0.6524' | 1.00 | | | | | | | | | | | | | | | | | | |
| 6 | AVE SPEED | 0.2187* | 0.16 | 0.12 | 0.2685* | | | | | | | | | | | | | | | | | | |
| 7 | SIDE FRICT-N | 0.2219* | -0.03 | 0.2492* | 0.3003* | 1.00 | | | | | | | | | | | | | | | | | |
| 8 | PEDX_PRESC | 0.2015* | 0.3337* | 0.03 | 0.16 | 0.2122 | 1.00 | | | | | | | | | | | | | | | | |
| 9 | PEDX NUMB | 0.5054* | 0.3999* | 0.2407' | 0.4425* | 0.3022 | 0.5125 | 1.00 | | | | | | | | | | | | | | | |
| 10 | SWALK WIDTH | 0.2454* | -0.11 | 0.05 | 0.2361* | 0.2427 | 0.06 | 0.14 | 1.00 | | | | | | | | | | | | | | |
| 11 | SWALK PRESC | 0.2300* | -0.11 | 0.05 | 0.2419* | 0.2165 | -0.03 | 0.13 | 0.9400* | 1.00 | | | | | | | | | | | | | |
| 12 | MEDIAN WDTH | 0.3442* | 0.1834* | 0.6229' | 0.8391* | 0.2009 | 0.07 | 0.4487" | 0.1900* | 0.2282' | 1.00 | | | | | | | | | | | | |
| 13 | 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 | | | | | | | | | | |
| 14 | RDSIGNS 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 | | | | | | | | | |
| 15 | RDSIGNS 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 | | | | | | | | |
| 16 | ROADMARKNG~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 | | | | | | | |
| 17 | SHOULDR WDTH | -0.10 | 0.3296* | 0.04 | -0.08 | -0.15 | 0.2328 | 0.06 | -0.6428* | -0.6815 | -0.12 | -0.182 | 0.01 | -0.14 | -0.14 | -0.14 | 1.00 | | | | | | |
| 18 | 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 | | | | | |
| 19 | ROAD WIDTH~h | 0.5276* | 0.14 | 0.6794' | 0.8561* | 0.2840 | 0.03 | 0.3778" | 0.2911* | 0.3168' | 0.823! | 0.800 | 0.14 | 0.06 | 0.06 | 0.09 | -0.16 | -0.04 | 1.00 | | | | |
| 20 | 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 | | | |
| 21 | 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 | | |
| 22 | KERB PRESC | 0.3505* | -0.06 | 0.2930' | 0.4416* | 0.2487 | 0.01 | 0.2453' | 0.6407* | 0.7303' | 0.436! | 0.444 | -0.01 | 0.08 | 0.08 | 0.242 | -0.508 | -0.3132 | 0.4839* | 0.178; | -0.06 | -0.04 | 1.00 |
| 23 | ACCESS PUB | 0.2197* | 0.4753* | -0.05 | -0.08 | 0.1780* | 0.3683 | 0.2657" | 0.05 | 0.03 | -0.09 | -0.08 | 0.1810* | -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                         No. of obs      =         91
Optimization     : ML                             Residual df     =         85
                                                  Scale parameter =          1
Deviance         =  94.88239749                   (1/df) Deviance =   1.116263
Pearson          =  92.51725532                   (1/df) Pearson  =   1.088438

Variance function: V(u) = u+(1)u^2                [Neg. Binomial]
Link function    : g(u) = ln(u)                   [Log]

                                                  AIC             =    5.19402
Log pseudolikelihood = -230.3279148               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 |