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Comparative Model Analysis of Road Traffic Accidents in Ghana

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Abstract Road traffic accidents of varying degrees that have occurred in Ghana both in the past and present have resulted in several road fatalities. These has led to the loss of lives, property, broken homes, and as well as leaving behind shattered families and communities, among others despite the indispensable role the road transport sector plays in the economy. This paper sort to explore the most parsimonious and robust linear model for the estimation and forecasting road traffic accidents statistically. This was achieved through the examination of the relationship between road traffic accidents, human and vehicular population in Ghana using linear regression models. Empirical results showed the existence of significant positive relationship between road traffic accidents, vehicle population and human population, with respective correlation coefficients as R1=0.855, R2=0.853, and R3=0.855 indicating a very strong positive association between them. The simple linear regression model between road traffic accidents and vehicle population was adjudged the most robust and parsimonious model based on model diagnostics (residual analysis with plots) coupled with tests of hypothesis. The paper therefore concludes that vehicular population is a very key variable that should not be left out in the policy formulation that would deal with curbing road traffic accidents in Ghana based on available statistics and results.

Keywords Robust, Parsimonious, Model, Regression model, Correlation coefficient

1. Introduction

The road transport sector plays a key role in the socio-economic development of every economy. Not only does it facilitate the smooth transportation humans, goods and services from source(s) to respective destination(s), but also serve as a huge source of employment which is a critical economic indicator to development. The sector has been bedevilled with quite a number of goring tendencies through the occurrence of traffic accidents in Ghana. The spate increase in these forms of road traffic accidents has therefore become a worrying and growing concern to most Ghanaians in recent times. This is as a result of the tremendous negative effects of road traffic accidents on human lives, properties and the environment. The National Road Safety Commission (NRSC) was therefore established by an Act of Parliament (Act 567) in 1999 with the mission of promoting best road safety practices for all categories of road users through the vision of making Ghana a country with the safest road transportation system in Africa.

Despite the existence of these powerful institutions and other regulatory bodies globally, statistics relating to road traffic accidents are very disheartening.

WHO (2010), available statistics shows that at least 1.3 million people are killed every year through road crashes, with some 20-50 million suffering from various forms of disability; 90% of these road casualties are in low and middle income countries; at current rates, it is estimated that road traffic crashes will be the 3rd leading cause of death worldwide by the year 2020 if rigorous actions are not taken.

Furthermore, 1,800 lives are lost in Ghana annually through road crashes with 14,000 injuries from an average of 11,000 road traffic crashes; road traffic crashes cost the nation 1.6% of GDP which translates to US$ 165 million in 2006 and US$ 288 million in 2009; 42% of these crash victims are pedestrians; 60% of all crash victims are people within the productive age group (NRSC, 2010).

According to a World Health Organization (WHO) & World Bank (1999) report on "The Global Burden of Disease", deaths from non-communicable diseases are expected to climb from 28.1 million a year in 1990 to 49.7 million by 2020 (an increase in absolute numbers of 77%). Road traffic crashes will contribute significantly to this rise. According to the report, road traffic injuries are expected to move from ninth place to take third place in the rank order of disease burden by the year 2020.

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In assessing the magnitude of the problem of road traffic crashes, according to WHO, 1.2 million people die through road traffic crashes annually. On the average, in the industrialized countries, and also in many developing countries, one out of every ten hospital beds is occupied by a road traffic crash accident victim (NRSC 2010).

The 1999 WHO publication on "Injury: A Leading Cause of the Global Burden of Disease," reports that road traffic crashes are the major cause of severe injuries in most countries and the leading injury-related cause of death among people aged 15-44 years. Globally, the WHO reports that 38,848,625 people were injured through motor vehicle crashes in 1998. Out of the 5.8 million people who died of injuries, 1,170,694 (20%) died as a direct result of injuries sustained in motor vehicle crashes.

The above facts reveal unacceptable levels of road traffic accidents and casualties and therefore have global, national, social and economic burden, especially in Ghana as quite a substantial amount of the nation's GDP is channelled into the management of road traffic accidents rather than real investments and development.

To best of our knowledge, enough work has been done on road traffic accidents globally and as well as in Ghana, however, a comprehensive database about the menace especially regarding other variables which affect road traffic accidents such as the road network, educational or qualification status of drivers type of vehicles used and involved in traffic accidents, among others are currently not existence. This therefore makes it impossible for the need for interventions and strategies to be put in place based on empirical research outcomes to deal with the menace especially by reducing it by 50% by the end of 2020 as recommended in the United Nations (UN) Global Plan for the Decade of Action for Road Safety 2011- 2020.

This paper therefore attempts to further explore available statistics through a continuation of the works of Boakye, A. etal (2013 and 2014) on ''Regression Analysis of Road Traffic Accidents and Population Growth in Ghana'' and ''Modelling the Relationship between Road Traffic Accidents and Vehicle Population; Empirical Evidence from Ghana'' respectively.

The main objective of this paper was to explore the most parsimonious and robust linear model for the estimation and forecasting road traffic accidents statistically based on three quantitative variables namely the road traffic accidents, vehicular population and as well as the human population.

2. Methodology

2.1. Type and Source of Data

The type of data used in this research was purely quantitative obtained from secondary sources. The data specifically relates the set of observations on the three main variables that are being studied. These are road traffic accidents, human population or simply population and vehicular population in Ghana covering a twenty (20) year period from 1991 to 2010, with road traffic accidents being the predictor or dependent variable whilst the remaining two being the explanatory or independent variables.

Fay (1997), concluded that the key point of secondary data is that it should be relevant, accurate and available. For this reason and purpose, the time series data relating to road traffic accidents, the population and vehicular population covering the period 1991 to 2010 were collected from National Road Safety Commission of Ghana for the analysis.

2.2. Method of Data Analysis

Exploratory data analysis, descriptive and inferential data analysis were performed. The data was first explored through the use of graphical displays to help identify and analyse trends and patterns in the data. These included line graphs and frequency polygons. Where the two or more variables were looked at concurrently, scatter plots was used to establish the relationship between them.

With respect to the descriptive analysis, correlation coefficients, standard errors, have also been computed and interpreted. Linear regression model which attempts to model the relationship between the variables by fitting both the simple and multiple linear regression equations to the observed data was subsequently developed. In addition to linear regression analysis, multivariate times series analyses were also performed since the data was also viewed as a time series data. Finally, with regard to the inferential analysis, hypothesis tests were performed using the computed p-values in which decisions and conclusions were arrived at.

2.3. Assumptions and Model Formulation

In order to use any model in statistics, the model must first of all be found to have been fitted well and as well as statistically significant. In this regression and multivariate time analysis, it became imperative to go beyond the fitting of an equation to data and making inferences about the population from which the data were drawn. There are some underlying conditions that must be satisfied, at least approximately, before any statistical inference can be considered reasonable. These conditions listed below were therefore verified:

1. In the underlying population, the relationship between the response variable, Y, and the predictor variable of X is or must be linear. That is $Y = \beta_0 + \beta_X$.
2. For each value of X, there is a group of Y values, and these Y values are normally distributed.
3. The Y-values are statistically independent. That is, the Y values chosen for a population value of X do not depend on the Y values for any other value of X.
4. For each value of X, the variance, σ^2 of Y about the regression line (i.e. the amount of variation in the population of Y values) is the same.
5. For time series analysis stationary is a critical assumption of time series analysis, stipulating that statistical descriptors of the time series are invariant for

different ranges of the series.

6. Again, the residual vector must follow a multivariate white noise, i.e. E(εt) = 0
7. No outliers. As in other forms of regression, outliers may affect conclusions strongly and misleadingly.
8. Random shocks. If shocks are present in the time series, they are assumed to be randomly distributed with a mean of 0 and a constant variance.

2.4. Model Adequacy Checking (diagnostics)

The model diagnostics is done using graphical displays of the residuals described as follows. The probability plot of the residuals is used to verify the assumption of normality. In this case it is expected that the individual probabilities of the residuals are normally distributed if all the points are near or closer to one another with the plotted points forming an approximately straight line. Any points that tend to deviate from this pattern may be termed as an outlier.

A plot of the residuals verses the fitted values must clearly show that the residuals appear to be randomly scattered about zero, thereby satisfying the assumption of constant variance. Again, the time plot of the residuals is used to check the assumption of statistical independence of the dependent variable. The residuals must appear to be randomly distributed without showing any clear visible pattern. As well as the histogram plot of the residuals is also used to check the same normality assumption in which the histogram plot of the residuals must appear to be normal in order to satisfy the normality assumption. However, a slight deviation from normality is allowed.

Finally, with regard to the multivariate time series model, the residuals or errors are therefore conceived of as an independently and identically distributed (i.i.d) sequence with a constant variance and a zero mean. The ACF plot of the residuals must show no evidence of a significant spike in the ACF plot (the spikes are within the confidence limits) indicating that the residuals seem to be uncorrelated. The probability plot of the residuals should also indicate that the individual probabilities of the residual are greater than or above 0.05 (red line).

3. Analysis and Results

3.1. Exploratory Data Analyses

The plot of the trend of road traffic accident data from 1991 to 2010. It can be seen from the figure that the accident situation over the period has not remained constant but rather varied from year to year. Some years saw significantly high occurrences whilst others saw low growths or occurrences. 1993 and 1994 recorded the least occurrences and has since been steadily increasing over the period. (Refer to Appendix I, Figure 3.1)

It is clear from Figure 3.2 Appendix I that the vehicular population or the number of registered vehicles has continuously increased over the period, except during the year 2008 a marginal decrease and increased thereafter. This shows that the vehicle population has been growing and will continue to grow over time of course with gradual or minor fluctuations expected.

Figure 3.3 (Appendix I) also on the other hand displays the plot of the trend of population of Ghana from 1991 to 2010. The trend in the population is not different from that of road traffic accidents and vehicle population as displayed in Figures 3.1 and 3.2 respectively. It clearly shows that population of the country has continuously increased over the period. This shows that the population has been growing and will continue to grow over time of course with gradual or minor fluctuations expected based on implementation of population programs.

3.2. Model Development and Analysis of Relationship

Table 3.1. Summary of Model statistics

Statistic	Value
R	0.855
R-Square	0.731 (73.1%)
R-Square (adj)	0.716 (71.6%)
Standard error	1022.94

Predictors: Constant, Vehicle population
Dependent variable: Road Traffic Accidents

Table 3.1 above presents summary of model statistics which is used to assess the exact nature of the relationship between the road traffic accidents and the vehicular population through the use of correlation coefficients. Specifically, the R which represents the correlation coefficient of value 0.855 shows a strong positive relationship between road traffic accidents and vehicle population. The coefficient of determination (R-square) which is a measure of the explanatory power of the model indicate that vehicular population or number of registered vehicles is able to account for or explain 73.1% of the changes in the number of road traffic accidents in Ghana. This also imply that there are other variables or factors that have effect on road traffic accidents which of course are not included in this model in the neighbourhood of about 26.902%.

Table 3.2. Summary of Regression coefficients

Predictor	Coeff	SE Coef	T	P
Constant	7166.331	469.517	15.2632	
Vehicle (X_1)	0.005	0.001	6.9935	0.000

Predictors: (Constant), VEHICLE POPULATION
Dependent Variable: ROAD TRAFFIC ACCIDENTS

The Table 3.2 above report the regression coefficients and other vital statistics such standard errors of the coefficients, the t values and the p values. The regression model, which establishes the relationship between total yearly accidents and number of registered vehicles is thus given as $Y = 7166.33 + 0.005X_1$, where Y is the total number of accidents in a year and X_1 being the total number of registered vehicles in a year.

From the regression model obtained, the value of 7166.331 is interpreted to be the total number of yearly accidents when the total number of registered vehicles is set to zero and all other factors are held constant, whilst the coefficient of X_1 of 0.005 is the rate or magnitude of change in the number of accidents as a result of a unit change in the number of registered vehicles. Its positive sign is an indication of the fact that there is a positive association between road traffic accidents.

Again, the errors associated with these coefficients are minimal as displayed by the standard errors of the coefficients. The p-values indicate that the constant term, as well as that of the predictor variable (X_1) are statistically significant since it is less than the chosen alpha level of 0.05.

Table 3.3. Analysis of Variance

Source	Df	SS	MS	F	P
Regression	1	5.118E7	5.118E7	48.910	0.000
Residual Err	18	1.884E7	1046405.493		
Total	19	7.001E7			

Predictors: (Constant), VEHICLE POPULATION
Dependent Variable: ROAD TRAFFIC ACCIDENTS

The analysis of variance table is used here to test the hypothesis for the study:

Null Hypothesis (Ho): There is no significant relationship between road traffic accidents and vehicle population growth in Ghana.

Alternative Hypothesis (H_1): There is a significant relationship between road traffic accidents and vehicle population growth in Ghana.

The p-value of 0.000 as reported in the analysis of variance table indicates that the test is significant at 0.05. Therefore, we fail to accept the null hypothesis and conclude that indeed there is a significant relationship between road traffic accidents and vehicle population growth in Ghana as stated alternatively.

Table 3.4. Summary of Model statistics

Statistic	Value
R	0.854
R-Square	0.729 (72.9%)
R-Square (adj)	0.713 (71.3%)
Standard error	1027.611

Predictors: (Constant), VEHICLE POPULATION
Dependent Variable: ROAD TRAFFIC ACCIDENTS

Again, examining the relationship between road traffic accidents and population, it can be seen from the results presented in Table 3.4 above that there exists a strong positive correlation between them. This is reported by the correlation coefficient value of 0.854, with a corresponding coefficient of determination (R-sq) of 72.9% indicating that for the period under study based on the available data, population is able to account for 72.9% of the changes in accidents in the country with only 27.1% not being explained by population but rather by other variables which were not included in the study.

Table 3.5. Summary of Regression Coefficients

Predictor	Coeff	SE Coef	P
Constant	-263.213	1499.310	0.863
Vehicle (X_1)	0.005	0.001	0.000

Predictors: (Constant), VEHICLE POPULATION
Dependent Variable: ROAD TRAFFIC ACCIDENTS

Haven established the fact that there exist a strong positive relationship between road traffic accidents and population as shown in the Table 3.4 above, it is imperative to derive the exact mathematical model of this relationship. This is achieved with the aid of the regression coefficients as summarized in the Table 3.5.

The regression model, which establishes the relationship between total yearly accidents and population is thus given as $Y = - 263.213 + 0.001X_2$, where Y is the total number of accidents in a year and X_2 being the total yearly population.

The value of -263.213 is interpreted in absolute terms to be the total number of yearly accidents when the total population is set to zero with all other factors held constant, whilst the coefficient of X_2 of 0.001 is the rate or magnitude of change in the number of accidents as a result of a change in the population. Its positive sign is an indication of the fact that there is a positive association between road traffic accidents and the population as already established by analysis of the correlation coefficients above.

Again, the p-value indicates that the predictor variable (X_2) of 0.000 shows a highly significant even though it quite smaller, with approximately 0 standard error associated with it.

Table 3.6. Analysis of Variance

Source	Df	SS	MS	F	P
Regression	1	5.101E7	5.101E7	48.303	0.000
Residual Err	18	1.901E7	1055984.180		
Total	19	7.001E7			

Predictors: (Constant), POPULATION
Dependent Variable: ROAD TRAFFIC ACCIDENTS

The analysis of variance table is used here to test the hypothesis for the overall significance of the model.

Null Hypothesis (Ho): There is no significant relationship between road traffic accidents and population in Ghana.

Alternative Hypothesis (H_1): There is a significant relationship between road traffic accidents and population in Ghana.

The p-value of 0.000 as reported in the analysis of variance table indicates that the test is significant at 0.05. Therefore, we fail to accept the null hypothesis and conclude that indeed there is a significant relationship between road traffic accidents and the population in Ghana.

Table 3.7. Summary of Model statistics

Statistic	Value
R	0.855
R-Square	0.731 (73.1%)
R-Square (adj)	0.700 (70.0%)
Standard error	1051.942

Predictors: (Constant), POPULATION GROWTH, VEHICLE POPULATION
Dependent Variable: ROAD TRAFFIC ACCIDENTS

The final aspect of the analysis is development of the third and final model of this study. This model seeks to incorporate the two independent variable namely vehicle population and population of Ghana as already used in the two models above. This leads to the development of multiple regression model since it involves more than one independent variable.

The results in Table 3.7 above reveals a strong positive correlation between the dependent and the independent variables, with the independent variables accounting for 73.1% of the variations or change in the dependent variable as recorded by the values of the correlation and coefficient of determination respectively.

Table 3.8. Summary of Regression Coefficients

Predictor	Coeff	SE Coef	P
Constant	5248.588	13191.690	0.696
Vehicle (X_1)	0.004	0.009	0.679
Pop (X_2)	0.001	0.001	0.886

Predictors: (Constant), VEHICLE POPULATION
Dependent Variable: ROAD TRAFFIC ACCIDENTS

Since it has already been established the fact that there exist a strong positive relationship between road traffic accidents, vehicle population and population of Ghana as shown in the Table 3.7 above, the exact mathematical model of this relationship is thus given as $Y = 5249 + 0.00387X_1 + 0.000137X_2$, where X_1, X_2 and Y denote their usual meanings and the model interpreted similarly. Interestingly, the p-values in the model reveal that the individual parameters in the model are not significant since they all tend to be higher than the 0.05 level of significance chosen.

Table 3.9. Analysis of Variance

Source	Df	SS	MS	F	P
Regression	2	5.120E7	2.560E7	23.135	0.000
Residual Err	17	1.881E7	1106581.242		
Total	19	7.001E7			

Predictors: (Constant), POPULATION GROWTH, VEHICLE POPULATION
Dependent Variable: ROAD TRAFFIC ACCIDENTS

The analysis of variance table is used here to test the hypothesis for the overall significance of the model.

Null hypothesis (Ho): $\beta_1 = \beta_1 = 0$

Alternative hypothesis (H_1): $\beta_1 \neq \beta_1 \neq 0$

The level of significance given is $\alpha = 0.05$

The test statistic is the significant F (P-value) = 0.00

The decision rule is that do not reject the null hypothesis if the $\alpha <$ P-value

From the ANOVA table in the output the p-value is 0.000 which is less than the $\alpha = 0.05$. Therefore, from the decision rule we fail to accept the null hypothesis and conclude that at least one of the coefficients is not zero and as a result the model is significant.

3.3. Multivariate time Series Model Development and Analysis

Table 3.10. Final Estimates of Parameters for VARMA (1,1)

Type	Coef	SE Coef	T	P
Constant	242.341	949.565	0.255	0.803
AR 1 (Lag 1)	-0.343	0.296	-1.159	0.267
MA 1 (Lag 1)	0.986	5.619	0.175	0.863

The research further sought to build multivariate time series model based on the fact that the study intends to model and explain the interactions and comovements among a group of time series variables. As a result, since the data contained one dependent variable and two independent variables, vector autoregression (VAR) model was built with the results presented in the Table 3.10 above. The exact model is thus given as

$$Y_t = 242.341 - 0.343X_1t + 0.986X_2t$$.

The result as displayed in the Table 3.10 below with regard to the T and P-values indicates that the parameter coefficients are statistically insignificant at alpha levels of ($\alpha = 0.01, 0.05$). As a result the model is discarded.

The Table 3.11 above summarizes the fitness of the model in terms of Stationary R-squared, R-squared, Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE), among others.

Basically, Stationary R-squared which is a measure that compares the stationary part of the model to a simple mean model which of course was preferable to ordinary R-squared due to the non-stationary nature of the data with a value of 0.633 means that the model under consideration is better than the baseline model.

R-squared which an estimate of the proportion of the total variation in the series that is explained by the model is most useful after the series is stationary. Therefore R-squared value of -0.066 means that only small or insignificant proportion of the total variation is accounted for by the model. Its negative value implies that the model under consideration is worse than the baseline model.

The other statistics are interpreted similarly and based on the values corroborate the fact that the model is insignificant and therefore should be discarded for a better model to be fitted.

Table 3.11. Model Summary

Fit Statistic	Mean	Minimum	Maximum	50	75	90
Stationary R-squared	.633	.633	.633	.633	.633	.633
R-squared	-.066	-.066	-.066	-.066	-.066	-.066
RMSE	1349.547	1349.547	1349.547	1349.547	1349.547	1349.547
MAPE	199.824	199.824	199.824	199.824	199.824	199.824
MaxAPE	717.339	717.339	717.339	717.339	717.339	717.339
MAE	1014.673	1014.673	1014.673	1014.673	1014.673	1014.673
MaxAE	2280.076	2280.076	2280.076	2280.076	2280.076	2280.076
Normalized BIC	15.218	15.218	15.218	15.218	15.218	15.218

4. Findings and Conclusions

4.1. Findings

The findings of the study include the following:

Firstly, the study revealed that the road traffic accidents in Ghana over the period under study had a strong positive correlation with population and as well as vehicle population with a correlation coefficient value of 0.855, but at the same time implying that 14.5% of the changes in road traffic accidents being accounted for by other variables which were not included in the study.

Specifically, the independent variables accounted for 73.1% of the variations or change in the dependent variable as recorded by the values of the coefficient of determination. However, in terms of the time seires model, R-squared value of -0.066 means that only small or insignificant proportion of the total variation is accounted for by the model. Its negative value implies that the model under consideration is worse than the baseline model.

Secondly, the linear regression models obtained are respectively:

$Y = 7166.33 + 0.005X_1$; … … … …Model 1

$Y = - 263.213 + 0.001X_2$; … … … …Model 2

$Y = 5249 + 0.00387X_1 + 0.000137X_2$; and, … …Model 3

$Y_t = 242.341 - 0.343X_1t + 0.986X_2t$ … …Model 4

Where Y is the number of accidents

X_1 is number of registered vehicles or vehicle population

X_2 is the population growth

Furthermore, the study revealed that all the above models were found to be statistically significant from the tests of hypothesis both in individual parameter coefficient and overall model terms except the third and fourth models which were not statistically significant in terms of the individual parameters coefficients.

The model that is best at explaining and predicting road traffic accidents in Ghana should be the one with the highest r, r-square and found to be statistically significant as well.

Finally, it was found out that models 1and 3 had the same values in terms of r, r-square and were statistically significant in overall model terms except in individual parameter coefficient terms that the model 3 was found not to be statistically significant and as such model 1 could be preferred to 3.

4.2. Conclusions

Based on the findings, the study conclude that model 1 that is the model which seeks to establish a relation between road traffic accidents and vehicle population is selected as the best model. It is also adjudged the more robust and parsimonious since it has fewer numbers of explanatory variable(s) in this case only one.

Finally, the model thus chosen therefore can be used for estimation and forecasting purposes and should subsequently form the basis of decision and policy formulation regarding road traffic accident management in Ghana. The forth model was discarded outright since all the parameter coefficients were found to be statistically insignificant.

Appendix I

Road traffic accident, vehicle population and human population data for Ghana

Year	Accidents (Y)	Vehicle Population (X1)	Human Population (X2)
1991	8370	132051	14821000
1992	6922	137966	15222000
1993	6467	157782	15634000
1994	6584	193198	16056000
1995	8313	234962	16491000
1996	8488	297475	16937000
1997	9918	340913	17295000
1998	10996	393255	17865000
1999	8763	458182	18349000
2000	11087	511063	18845000
2001	11293	567780	19328000
2002	10715	613153	19811000
2003	10542	643824	20506000
2004	12175	703372	21093000
2005	11320	767067	21693000
2006	11668	841314	22294000
2007	12038	922748	22911000
2008	11214	942000	23544000
2009	12299	1030000	24196000
2010	11506	1122700	24233000

Source: NRSC, 2010.

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