Mathematical Modeling of the Correlation between Frequency of Road Traffic Accidents and Contributing Factors

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Abstract

The study investigated the causes and contributing factors of a road traffic accident. In order to achieve the stated objective, the total number of 532 road crash records for a period of six years (2011 - 2016) was collected from secondary sources (traffic police records and transport office database) throughout the entire road. A questionnaire survey, field measurement, and observations were also carried out to collect the required data for accident analyses. Based on statistical analysis, the significant variables with strong prediction ability for model development were selected among three categorized contributing factors. The mathematical models were developed using partial least square regression and multiple nonlinear regression techniques. In order to determine the interactive effect of individual variables on the model, the Monte Carlo approach was employed with the 10,000 times repeated simulation of samples within the probability density functions of the input data. The results revealed that the education level of driver and driving experience has a high contribution to traffic accident in relation to the human factors, with an absolute value of 55.47% and 18.01%. In the road geometric factors, the gradient, sight distance, and horizontal curve were highly correlated with accident frequency and have a correlation coefficient of 0.692, -0.529, and -0.426 respectively. In addition, vehicular factors like the service period of a vehicle, type of vehicle, and volume has a significant effect on the road traffic accident.

Keywords - Mathematical Modeling, Road Traffic Accident, Black Spot, Accident Frequency, Monte Carlo Simulation.

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1. Introduction

The road transportation with appropriate road safety measures promotes efficient movement of goods and services within and between countries. In the context of Ethiopia, the road transportation is the common- mode used for the movement of both peoples and goods. Therefore road transportation has a direct impact on people's daily activities. The lack of an appropriate road network and related problems contributes to a road traffic accident (RTA) in Ethiopia now a day. RTA's currently estimated to be the ninth leading cause of death across all age groups globally, and is predicted to become the seventh leading cause of death by 2030 (WHO, 2015). Ethiopia is one of the countries where the road traffic accident regarded as a serious problem. The number of death rate due to a traffic accident is reported to be amongst the highest in the world with the estimated road traffic fatality rate of 17.6 per 100,000 population (WHO, 2013).Therefore an in-depth investigation of causes and contributing factors to a traffic accident was an essential part of this study. It is common to state that the cause of a traffic accident is not a singular (AASHTO, 2009). Instead, crashes are the result of a convergence of a series of events that are influenced by a number of contributing factors. In general, there are three categories of crash contributing factors. These are: human factors, vehicle factors, and roadway and environmental factors. Under this category, human factor has a large percentage share over the other factors. As shown in Figure 1 below, 93% of the accident causes are human factors but only 3% of road crashes are due to roadway factors, whereas 34% of road crashes are a combination of roadway factors & human factors and the other 3% is related to vehicle factors.

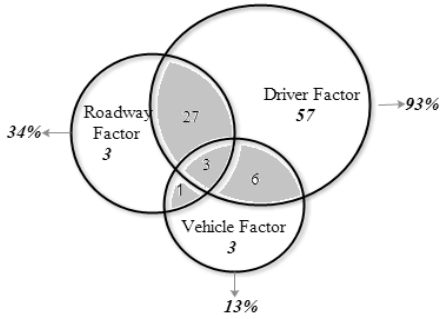


Figure 1. Contributing factors to vehicle crash (Source: HSM, 20)

1.1 Problem Statement

Previously published studies focused on the study area employed several types of causes and contributing factors to a traffic accident. However, conventional methods like; simple chart, and tables were used to analyze the factors contributing to road traffic accident rather than clear measurement and model of the related features. Therefore, this study fills those gaps by carrying out a clear analysis and model by using new statistical approaches like principal component analysis, partial least square method, and other advanced techniques for the sound full decision.

1.2 Research Objective

General objective

The main aim of this study was to model the correlation between frequency of road traffic accident and major contributing factors.

Specific objectives

1) To evaluate the feature of road traffic accident on the proposed road segment.
2) To determine the major contributing factors to a road traffic accidents.
3) To develop a model that describe the correlation between contributing factors and frequency of accident.

2. Literature review

The Ethiopian government proposed to establish a ten-year successive plan for the period 2010-2020 based on experiences gained from industrialized countries, under the Road Safety Vision 2020: ''**Making Ethiopian Roads Safer for Every One**''. The target of the Road Safety Vision 2020 was to reduce the fatality rate to 25 fatalities per 10,000 vehicles by 2020 from the base year rate (136 per 10,000 vehicles in 2002) (UNECA, 2009). However, road traffic accident still without due consideration and remains to be a serious problem of the road transport of Ethiopia.

2.1 Causes of Road Traffic Accident

Traffic crash is the result of multiplicity of factors and it is often the interaction of more than one variable that leads to the occurrence of crash

(Samson, 2006). RTA results from a combination of factors related to the components of the system including roads, location, vehicles, road users, and the way they interact. The identification of the risk factors that contribute to road traffic crashes is important to propose relevant interventions that can reduce the risks and other associated factors.

2.1.1 Human related factors of road traffic accident

Previous studies on traffic safety explicitly indicated human error as a primary cause of traffic accidents. As stated by several researchers, accident caused by road users (human factors), especially driver and pedestrian, accounts between 65 to 96% of total accidents (Samson, 2006; UNECA, 2009; Gebremeskel, 2014). The human factors comprises many specific factors, including driver careless action (speeding, traffic violations etc.), driver error or negative reaction (loss of control, failure to keep safe distances, not giving priority for pedestrian sudden braking etc.), behavior or inexperience (aggressive driving, tension, uncertainty etc.), driver distraction or impairment (eating, drinking, smoking, talking with passengers, alcohol, fatigue, mobile phone use etc.) and pedestrian errors.

2.1.2 Road and its environment related factors of road traffic accident

Actually, it is difficult to estimate and determine how much the geometric factors contribute to the likelihood of accident occurrence because there is no valid, practical and simple instrument for traffic polices to examine effects of each individual factor on accidents. Hence, the relationship between geometric designs elements and accident rates is complex and not fully understood (Mohammed, 2013; Divya , et al. 2016). However, everyone agrees that there exists a relationship between traffic safety and geometric design consistency. Some of the primary geometric design elements that can affect traffic accidents are carriageway, grade, horizontal curvature, shoulder, median, vertical curve, super elevation and sight distance (Mohammed, 2013).

2.1.3 Vehicle related facors of road traffic accident

The safety, periodic inspection and maintenance of the vehicle are all considered to be an important factors in the safety of the driving efforts. Several researchers investigated a number of vehicular factors causes to the road traffic accident. The vehicle related factors refers to the design or mechanical faults of the vehicle, which mainly includes lack of maintenance, burst tire, faulty light, and faulty brakes (Gebremeskel, 2014;Bahiru, 2015; Divya , et al., 2016). Zewude & Ashine, (2016) investigated determinants of traffic fatalities and injuries related to vehicular factors, and concluded that vehicle type, and vehicle age as the main factors cause to RTA.

3. Methodology

3.1 Description of the Study Area

The study area Halaba - Sodo road is located in southern Ethiopia about 309 km distance from Addis Ababa and has a total length of 72 Kilometer. According to Ethiopian Roads Authority (2013) classification, the road section is classified as trunk road under the category A-7 (A-7-4). The road connects the capital Addis Ababa city with the southern parts of the country. The road was constructed by DS4 (design standard four) with the ERA standard and having the following characteristics. Existing road segment is paved road with carriageway width of 7.0m, and AADT of 849. The base course and sub base thickness of existing road is 16cm and 20cm respectively. The roughness measurement of a road segment shows that 60% of the road segment is in poor or bad condition and 40% is in good or fair condition. The average international roughness index (IRI) of the road segment is 6.43. Therefore, the road is recommended for periodic maintenance (over lay) to bring the road in to better good condition.

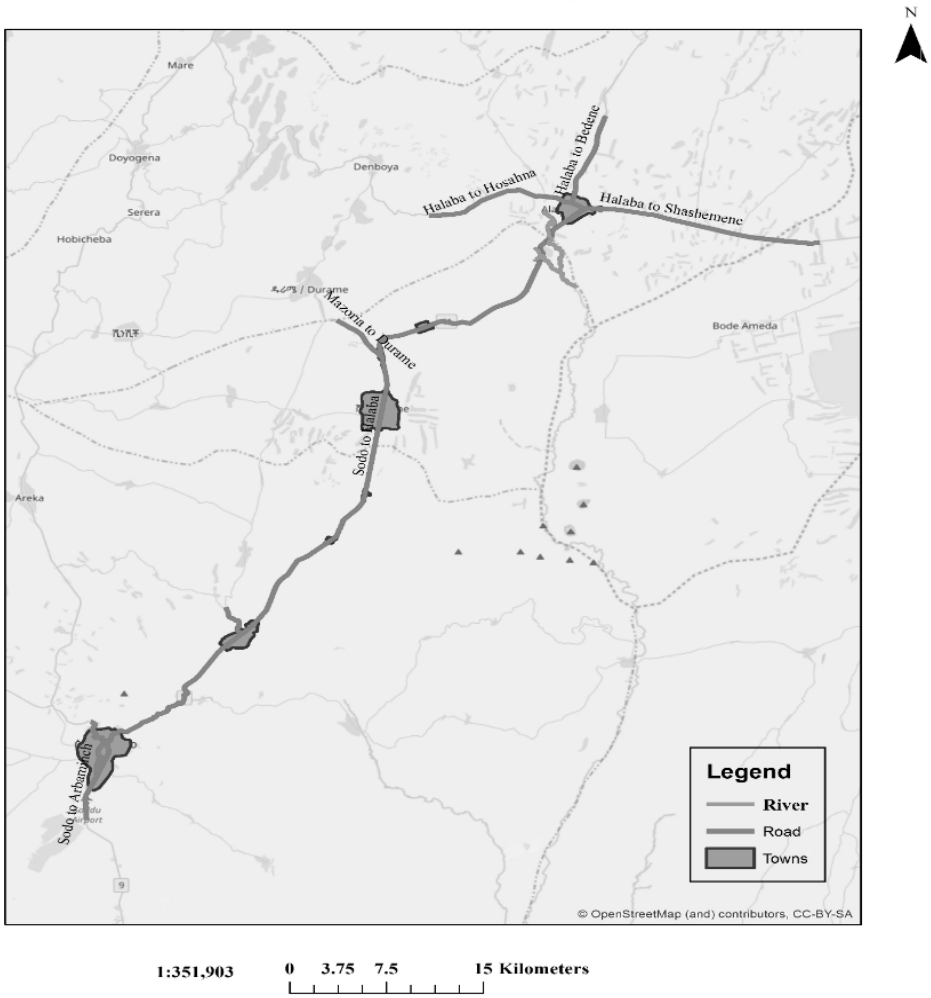


Figure 2 the study area map

3.2 Methods of Data Collection

Based on the strategy and necessity of data, both primary and secondary data were collected in this study. The primary data obtained through measurement and questionnaire survey through interviews of traffic police officers with longtime experiences. On the other hand, the secondary data collected from traffic police records, transport office database, and ERA Wolaita Sodo district office.

3.3 Method of Data Analysis

Data collected from both primary and secondary sources were processed and analyzed by using a statistical technique known as principal component analysis (PCA). The main aim of PCA was to ensure the significance of the variables by reducing the dimension (Paul, et al., 2013). Eigenvalues, eigenvectors, squared cosines, contributions, correlation matrix, and Correlation circles are the features used to select significant variables among the others. In addition, the redundant variables are also removed based on this result. Partial least square and multiple non–linear regressions used to develop a model for three categorized accident contributing factors. The statistical analysis was performed with XLSTAT tool (version 2015.5.01.22537).

3.3.1 Method used for the simulation

Simulation of the correlation between frequency of traffic accident and contributing factors to the accident was performed by Monte Carlo (MC) simulation method. MC simulations performed using XLSTAT software add-ins in Microsoft ® Excel. Once after the simulation was processed, the correlation between frequency of traffic accident and its contributing factors was analyzed using histogram, correlation matrix, sensitivity and scatter plots of 10, 000 number times repeated simulation and the result was used in the discussion section.

3.4 Black spot identification

In order to get a black spot in this particular road, six years accident data record was distributed along the road to give a rough location of accidents. Then, a dangerous site was selected based on priority value (P), was selected based on priority value (P), calculated using the following formula similar to (Segni, 2007):

$$P = \frac{(1 + \mathrm{W} + 2 * X + 3 * Y + 5 * Z)}{D}, where$$

P = prioritization weight, W = total number of property damage, X = total number of light injuries, Y = total number of serious injuries, Z = total umber of deadly injuries, D = distance of black spot section in km.

4. Results and Discussion

4.1 Evaluation of Road Traffic Accident Feature

The accidents database of the study area contains all accidents reported during the period of six-years between 2011 and 2016. The distribution of total number road traffic accidents by the major contributing factors are presented in Figure 4.1. The number of accidents varies or shows non-uniform distribution throughout the study period.

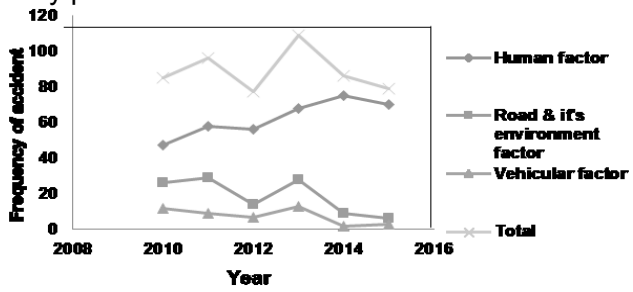


Figure 4.1 Trends in police reported accident for the year 2009 to 2016

4.2 Variations based on time periods (monthly, and daily)

***Variations on a monthly basis**:* The total number of traffic accident distributed in the months of the year is shown in Figure 4.2. The months of September and August recorded the largest number of accidents compared to the other months throughout the study period. This could be due to multiple reasons including the increase in traffic and pedestrian flow and weather related environment effects. Likewise, accident occurrence also depends upon the seasonal effects.

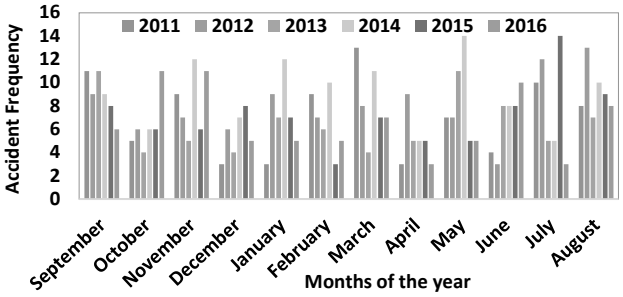


Figure 4.2 Number of accident by the month of the year

***Variations in weekday's basis**:* Accident on the day of a week also depends upon the activity and movement of road users from one place to the other place. The variation of traffic accident for the days of the week is presented in Figure 4.3 below.

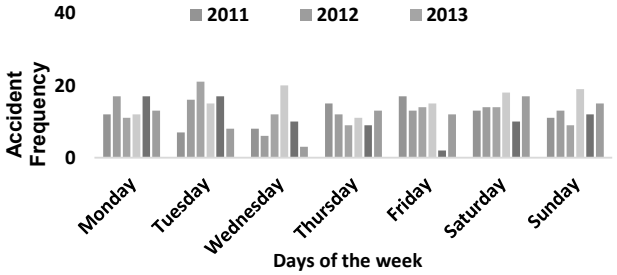


Figure 4.3 Frequency of accident by the days of the week

The two days of the week, Tuesday and Saturday, experienced higher accident frequency and to some extent the lowest frequency was registered on Wednesdays. The total number of accidents occurred during six-year specifically on these two weekdays (Tuesday and Saturday) were scored above 80 and below 60 on Wednesday. The main reason for the increased traffic accident on those two weekdays might be due to the fact that the days are regarded as market days for entire local area. In addition, accident also varies by the hours of the day. About 74% of the accidents occurred during the daytime. Which indicates that in the morning (the beginning of the working day) and evening (the end of the working day) the roads are typically busy with more traffic flows. More number of crashes were reported during the morning peak in the intervals of 8:00 – 12:00 hours and in the afternoon during 2:00 - 5:00 hours. Around the midnight accident rate relatively lower than that of day time. This was due to the fact that traffic and pedestrian movement decreased significantly during the night time. However, the severity of the

accidents was high in night time rather than daytime due to the perception time of driver might be affected by the visibility of the object. Among total accident occurred, 29.1 %, 11.5%, 27.6%, and 31.8% were recorded under fatal, injury, minor, and property damage respectively.

4.3 Black Spot Identification

Following the criteria developed in chapter three for black spot identification, 24 road sections were defined and grouped for identification of black spots. Based on their priority value of each location not more than 1.4km, those recording values greater than or equal to 13 were selected as black spots as shown on the map below. On this base the following locations; Kawo Shapa, Bortuwa Shapa (River), Shone Adilo River, Dalbo Wogene Village, Kokate Maracare, Dalbo St. Gebriel church (300m to Sodo), Halaba Bilate River, In front of LEWI International Hotel, Dalbo Wogene Abatuna Limat, and Kokate Forest Cooperative Nursery (River) were identified as black spot. Beyond locations listed, there are also a number of spots which experienced in traffic accident frequently. But, the causes and contributing factors beyond them is not related to the road geometry according to the traffic police record. Here are some of the places experienced with frequent traffic accident due to human factors and road environment like; rural village, market, school, and church areas, on Mazoria, Shone, Buge, Gacheno, and Boditi town sections specifically as shown on the map below.

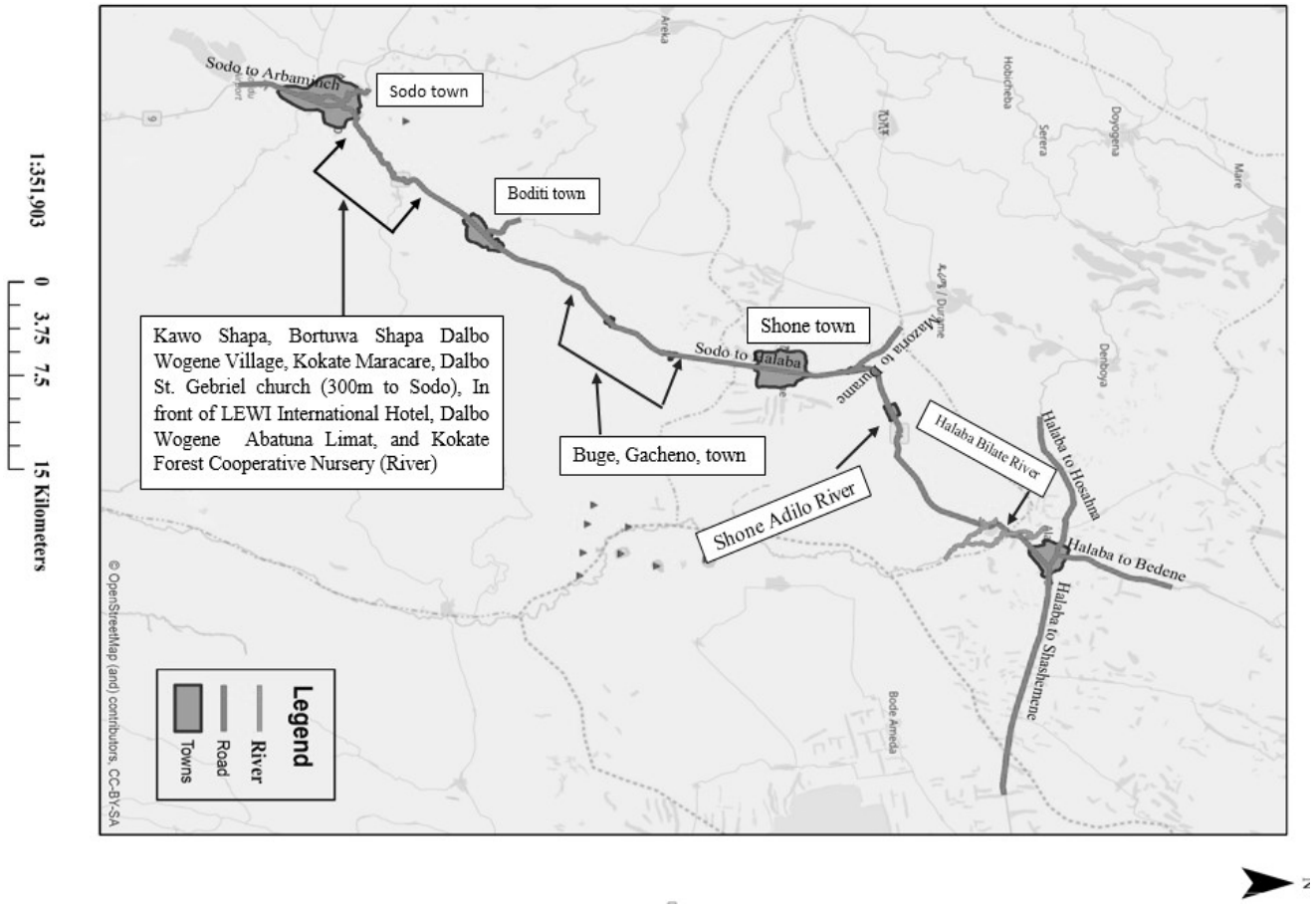


Figure 4.4 Black spots in study area

4.4 Determination of Major Contributing Factors of RTA

4.4.1 Questionnaire result of major causes and contributing factors to RTA

The average scores given by respondents for each and individual contributing factors to RTA is shown in Figure 4.5.

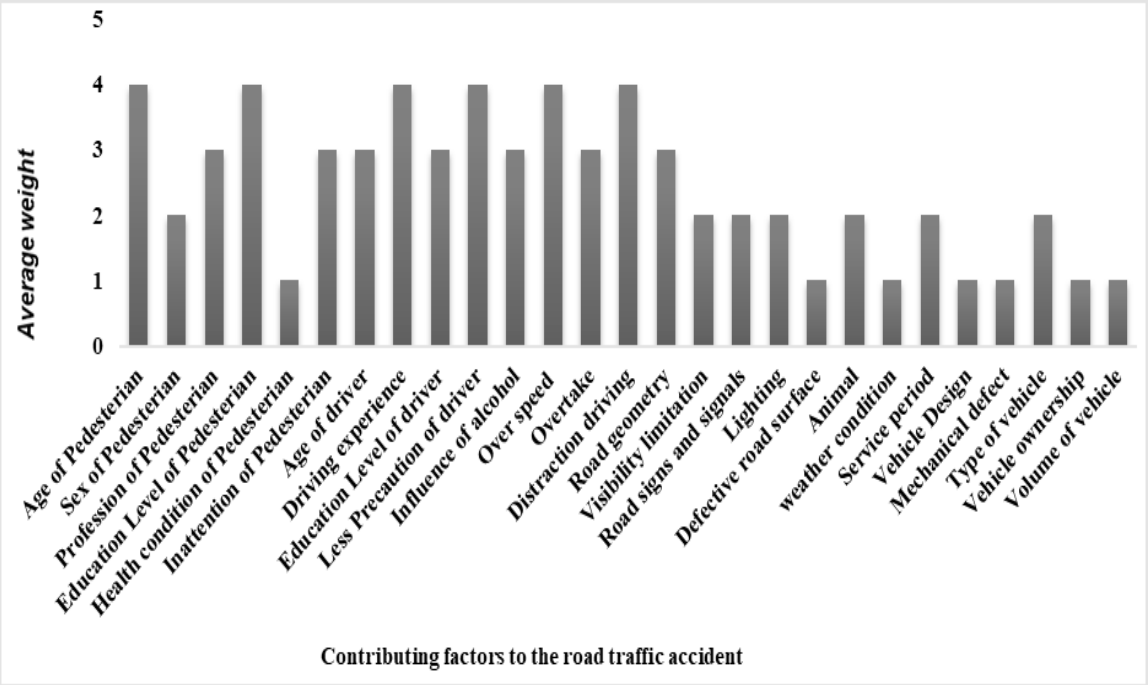


Figure 4.5 the average value for factors scored by traffic police and their officers

The factors with the highest score indicate that their contribution to RTA is very high compared to the other factors. The factors with the lowest average score of one out of four, indicates less effect in contrast to the above factors. In general, the traffic police officers response shows that nearly 79% of the road traffic accidents were caused by human factors, 15% was caused by road and its environment, and the remaining 6% was caused by vehicle-related factors.

4.4.2 Police reported accident records The contribution of human factors to the traffic accident shares more than two-third of other all factors. The contribution of vehicle related factors to road traffic accidents identified by the police is only 9 percent, which has a low contribution to a traffic accident when compared with human and road factors.

This section discusses the result of principal component analysis (PCA). The significant variables contributing to the road traffic accident was identified using the PCA based on the Eigen value, Eigen vector and factor loading values. The major variables selected are presented in Table 4.1. For the categorical variable (gender of driver and pedestrian) in the table below, it was Signified that 1 if gender is male, = 0 for female.

4.5 Trends of the Observed Variable

Table 4.1 Principal component descriptive analysis of human related factors

Variable	Observations	Min	Max	Mean	Std. deviation
Age of driver (yr.)	46	17	60	35.5	19.19
Education level	17	3	14	8.25	4.57
Driving experience (yr.)	38	0.5	8	3.12	3.35
Age of pedestrian (yr.)	46	4	64	34	21.67
Gender of driver	76	1	1	1	0
Gender of pedestrian	76	0	1	0.5	0.58
Health condition of pedestrian	76	0	0	0	0
Frequency of accident	46	71	132	102	26.22

Eigenvalue used to determine how many factors to retain. In this study, the first factor whose eigenvalues greater than one was retained. The eigenvectors are the weights that relate the scaled original variables. For the factor weighted average of the scaled variables, the weight of each variable given by the corresponding element of the eigenvector. The coefficients used to determine the relative importance of each variable in forming the factor. The Eigenvector is ordered from highest to lowest based on eigenvalues. The ordered eigenvector with a high eigenvalue gave the component in order of significance. Correspondingly; the education level of driver, driving experience, the age of pedestrian, and age of the driver with their corresponding eigenvectors 0.439, 0.432, 0.426, and 0.421 were selected among the other variables.

Table 4.2 Principal component analysis of road and its environment related factors

Variable	Observations	Min	Max	Mean	Std. deviation
Width of pavement (m)	10	7	9	7.76	0.77
Shoulder width Inner (m)	10	1.6	2	1.75	0.15
Shoulder width Outer (m)	10	1.5	2.2	1.76	0.23
Radius of curvature (m)	10	41	320	167.4	100.28
Length of curve (m)	10	45.6	339.8	159.16	100.68
Sight distance(m)	10	106	210	134.4	29.71
Super elevation (%)	10	2.5	7.5	3.92	1.88
Gradient of road (%)	10	3.8	6	5.04	0.63
Traffic control device	10	0	1	0.7	0.48
Traffic volume	10	1344	1611	1472.3	73.31
Frequency of Accident	10	4	13	7.1	2.8

The first, second, third, and fourth factors eigenvalues (4.75, 3.15, 1.56, and 1.42) whose magnitude greater than one selected among the nine factors. Based on the result of PCA, the width of pavement, shoulder width, the radius of curvature, the length of curve, sight distance, superelevation, and gradient of road retained as significant variable among others with their corresponding value.

Table 4.3 Principal component descriptive analysis of vehicle related factors

Variable	Observations	Min	Max	Mean	Std. deviation
Traffic volume	10	1434	1811	1616.8	149.04
Speed of Vehicle (Kph)	10	35	100	62	25.15
Service period of vehicle	10	0.35	18	6.36	7.14
Driver to Vehicle contact	10	0	1	0.8	0.45
Proprietorial of vehicle	10	0	1	0.8	0.45
Frequency of traffic accident	10	43	57	50.8	5.31

The first and second eigenvalues (5.16 and 1.16) whose magnitude greater than one were selected under four factors. These values represent 73.75% and 16.55% of the total variability in the vehicle related factors, respectively. Based on the result of PCA, the traffic volume, posted speed limit, and the service period of vehicles retained as significant variable among others with their corresponding values.

4.6 Analysis of accident caused by human factors

4.6.1 Drivers related factors

Among 532 number of accidents used in the analysis, 4% has occurred when they driving their own vehicle and other 96% occurred with employed drivers. From this one can simply understand that the driver who drives his/her own vehicle takes further care during traveling

time. Drivers within the age group (18 – 30) suffer the highest (53.4%) accident of the total accident. These age groups are economically active groups rather than drivers within other age groups. Most probably, this age group involved frequently in a traffic accident than other age groups. Drivers with secondary education level (within grade 9-10) share a large number of the accident (35%) within four categorized education level. It is not mean that the drivers within secondary education level always share a high number of the accident at all time in all area. This was due to the total number of the driver within the secondary level exceeds the drivers categorized in other education levels. The frequency of accident between driving experience (1 – 10) year is almost close to each other. Driving experience above 10 year shares less number of the traffic accident.

4.6.2 Pedestrian related factors

All persons involved in the accident are with normal body i.e. not disable. Pedestrians within age 7-13 are more victims of traffic accident than other age groups that might be lack of awareness about a traffic accident. The frequency of accident increases up to the age 50 and linearly decreases when the age of pedestrian greater than 50. It is likely that, on average, pedestrians within out of the workforce make fewer trips and activities per day. Amongst the total, male pedestrian share 62% of the total accident occurred. As stated in the traffic police records, the pedestrian failure to give a way for a vehicle, driver failure to give-way for pedestrians, vehicle following too closely, driving beyond the speed limit and overtaking are major causes of the accident under human factors.

4.7 Model Evaluation, Interpretation & Simulation Development

As stated in the methodology section, human factors model preceded employs partial least square regression technique and vehicular, road & its environment factors model analyzed with the multiple nonlinear regression method.

4.7.1 Evaluation of model and simulation result of human categorized accident

This section summarizes the partial least square regression model and the simulation result of dependent and independent (age of drivers, education level, driving experience, and age of pedestrian).
As expressed on the analysis section above, the frequency of accident in both age of pedestrian and driver increase up to age 50 especially between 18-50 and decrease when the age become above 50. Among age groups, driver's younger than 18 accounts for only 0.4% of total crash although they make up more than half the population, such that the 18-30 and 31-50 age groups account for more than three-fourths of total crashes.

The model parameters: The parameters (coefficients) of the model for the frequency of traffic accident projection are shown in the Table 4.4. The expected mean value of road traffic accident equal to 117.55 that indicates the number of traffic accident while all the variables are hold constant.

Table 4.4 *Model parameters*

Variable	Intercept	Age of driver	Education level	Driving experience	Age of pedestrian
Frequency of accident	117.554	2.04	-11.971	-9.719	1.167

Goodness of fit statistics for frequency of traffic accident: The goodness of fit of dependent variable for the performance of a model are presented in Table 4.5. The performance of the model is measured with the R-square (R^2) value and the root means square error (RMSE). RMSE is an indicator of the average error in the analysis expressed in the original measurement unit. The higher value of R2 and the lower RMSE value indicates higher precision and accuracy of the model to predict the frequency of traffic accident. The R^2 value of 0.987 shows that 98.7% of the variation of the dependent variable explained by the explained by the explanatory/independent/ variables. Similarly, the unexplained variation of the dependent variable is very low.

Table 4.5 Goodness of fit statistics (Variable frequency of traffic accident)

Observations	Sum of weights	DF	R^2	Std. deviation	MSE	RMSE
4	4	1	0.988	4.906	6.018	2.453

The analysis of the model shows that the model is well fitted with (R^2 = 0.988) and could be used

for prediction or simulation purposes. The relationship between observed and predicted values of frequency of road traffic accident is shown in Figure 4.6. Both the observed and predicted values of frequency of traffic accident are very closed in curve fitting.

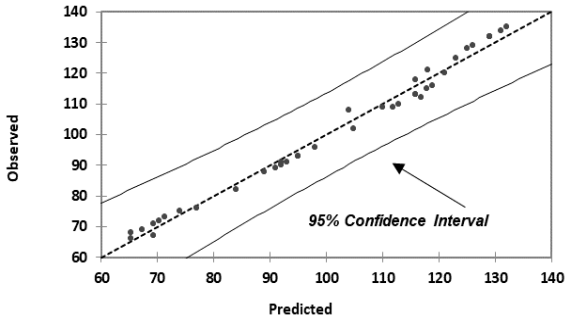


Figure 4.6 Comparison of predicted versus measured frequency of accident

Monte Carlo simulation result for human factors: The simulation was used to examine the interactive effect of individual components or variables in order to determine which ones are more correlated with the frequency of accidents. The Monte Carlo approach involves the repeated simulation of samples within the probability density functions of the input data. Sensitivity analysis is used to determine which parameters of the model are most critical (the "sensitive parameters") in determining the solution. Table 4.6 shows the sensitivity result of 10,000 times simulation and correlation with frequency of traffic accident. Education level and driving experience have a high contribution to traffic accident frequency with an absolute value of 55.47% and 18.01% respectively. While both education level and driving experiences are negatively correlated with the frequency of traffic accidents with correlation coefficients of -0.736 and -0.419 respectively. Whereas, the age of the driver and the age of the pedestrian positively

With a correlation coefficient of 0.359 and 13.19% contribution to accident frequency.

4.7.2 Evaluation of model and simulation result of road categorized accident

This section summarizes the multiple nonlinear regression model and simulation result of road factors.

The goodness of fit statistics for frequency of traffic accident: Table 4.7 show that the goodness of fit for road factors with the dependent variable (frequency of traffic accident).The performance of the model is correlated with the frequency of traffic accidents with a correlation coefficient of 0.361 and 0.359 respectively. A negative correlation coefficient indicates that the variables are negatively correlated with accident frequency. It is factual that awareness of a person increases as the level of education increases. The driving experience is also the next significant variable with a correlation coefficient of -0.419 and 18.01% of absolute contribution to an accident. Driver with many years of driving experience could take immediate action in any situation which leads to an accident. The age of the driver has also an important contribution to the frequency of traffic accidents with an absolute value of 13.33%. The magnitude of the correlation coefficient (0.361) is less because the relation between the age of the driver and the frequency of accidents was not linear. This was due to drivers especially under age 30 being involved in more accidents and above 50 slightly involved in fewer accidents. Therefore, accident frequency decreases as the education level, and awareness of a driver increases.

Table 4.6 Sensitivity (frequency of traffic accident)

Distributions	Correlation	Contribution	Contribution (Absolute)
Education level	-0.736	-55.47%	55.47%
Driving experience	-0.419	-18.01%	18.01%
Age of pedestrian	0.359	13.19%	13.19%
Age of driver	0.361	13.33%	13.33%

This result is similar to the findings of Zewude & Ashine, (2016) who found that young drivers are frequently involved in the highest proportion of risk behaviors and traffic accidents than all other age groups. That is why drivers at older ages are more responsible and careful about traffic safety than youth below 30 years old the time. The age of pedestrians has also the same influence on traffic accidents as driver age, with

measured by the coefficient of the model (R^2) square error (RMSE) of the average the analysis expressed in the original measurement unit. The higher the R^2 (closer to 1) and the lower the RMSE, the higher the precision and accuracy of the model to predict the frequency of traffic accident.

Table 4.7 Goodness of fit statistics

Observations	DF	R^2	SSE	MSE	RMSE	Iterations
10	2	0.987	0.836	0.418	0.646	64

The model parameters: Table 4.8 contains the parameters (coefficients) of the model for the frequency of traffic accident projection. This

table gives the value of each parameter after fitting it to the model.

Table 4.8 Model parameters

Parameter	pr1	pr2	pr3	pr4
Value	2.806	0.83	0.436	-0.062
Parameter	**pr5**	**pr6**	**pr7**	**pr8**
Value	-0.007	-0.002	-0.012	-0.032

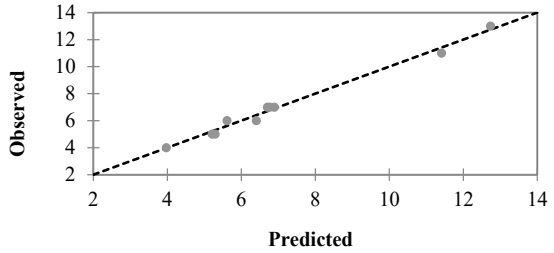


Figure 4.7 Predicted versus observed frequency of accident

The relationship between the observed and predicted values of frequency of RTA is presented in Figure 4.7. The observed and predicted values of frequency of traffic accidents are very close in curve fitting

Monte Carlo simulation result for road factors: The simulation was used to study the interactive effect of individual components or variables in order to determine which ones are more important. Except for the gradient of the road, all variables correlated negatively to a road traffic accident. A gradient of a road, sight distance, and radius of curvature has a high contribution to a traffic accident with an absolute value of 47.85%, 27.91%, and 18.09% respectively. The simulation result shows that the width of the shoulder and pavement have low effect on the frequency of traffic accidents with an absolute contribution of 0.44% and 0.14% respectively.

Table 4.9 Sensitivity (frequency of traffic accident)

Distributions	Correlation	Contribution	Contribution (Absolute)
Gradient	0.692	47.85%	47.85%
Sight distance	-0.529	-27.91%	27.91%
Radius of curvature	-0.426	-18.09%	18.09%
Super elevation	-0.236	-5.57%	5.57%
Shoulder	-0.066	-0.44%	0.44%
Width pavement	-0.037	-0.14%	0.14%

4.7.3 Evaluation of model and simulation result of vehicle categorized accident

This section also summarizes the result of multiple nonlinear regression and simulation results of the vehicle-related factors. The model result of dependent (frequency of traffic accident) and independent variables (Service Period of a vehicle, posted speed limit, and traffic volume) is presented below.

Goodness o fit statistics for frequency of traffic accident: The goodness of fit for vehicle-related factors with the dependent variable (frequency of traffic accident) is presented in Figure 4.6. Moreover, the traffic volume, posted speed limit and vehicle age have an adverse effect on the frequency RTAs.

Table 4.10 Goodness of fit statistics

Observations	R^2	SSE	MSE	RMSE	Iterations
10	0.96	4.989	0.007	0.001	54

The model parameters: Table 4.11 contains the parameters (coefficients) of the model for the frequency of traffic accident projection. The negative direction of the expected mean value shows the dependent variable is zero if all independent variables are zero. As indicated in the model equation above, the coefficients of traffic volume and posted speed limit have a

Positive magnitude of 0.001 and 0.004 respectively. This indicates that both factors directly influencs the road traffic accidents. While the service period of a vehicle has a negative coefficient

and shows a negative relationship with a traffic accident. From this result, it is possible to conclude

that as the service period of the vehicle increase, the operating speed of the vehicle decrease. It is obvious say that driving at a low speed always result in few traffic accident. The chart below allows visualizing the quality of the fit by comparing the predicted value to the observed variables of traffic accident frequency within a 95% confidence interval.

Table 4.11 Model parameters

Parameter	pr1	pr2	pr3	pr4	pr5
Value	–61.36	2.903	0.001	0.004	-0.013

Figure 4.8 presents the relationship between observed and predicted values of the frequency of road traffic accidents related to vehicular factors. A comparison of predicted and observed values is also used to evaluate the ability of the model prediction. As shown on the graph both observed and predicted values of frequency of traffic accidents are very close in curve fitting.

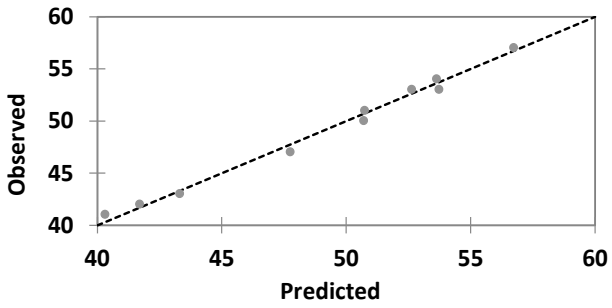


Figure 4.8 Predicted versus observed frequency of accident

Monte Carlo simulation result for vehicle related factors: The sensitivity result of the simulation is shown in Table 4.12. Traffic volume has a high contribution to a traffic accident with an absolute value of 69.11% and a positive correlation coefficient of 0.829. As the number of vehicles on a highway increases, the potential for conflicts within a traffic stream also increases. Whilst there is some argument between different scholars regarding the relationship between crash frequency and traffic volume. In this study, most of the accidents took place around offices, residential, schools, and commercial neighborhoods. It should be noted that these places are typically busy and have high traffic volume giving rise to an increase in the number of accidents.

Table 4.12 Sensitivity (Frequency of accident)

Distributions	Correlation	Contribution	Contribution
Traffic volume	0.829	69.11%	69.11%
Posted speed	0.448	20.21%	20.21%
Service period of vehicle	-0.326	-10.68%	10.68%

A study by Zewude & Ashine, (2016) reported the same result as this study. In contrast, some scholars conclude that the accident rate is very high in the lowest traffic volume (Segni, 2007). The reason behind this conclusion is that the road with a level of service A and B gives more freedom for drivers to choose the operating speed. Hence, drivers operate their vehicles above the speed limit. As traffic volume increase, traveling speed being decrease due to the driver cannot operate their vehicle freely in crowded traffic volume. However, this condition is significantly true for an urban area with highly congested traffic.

4.8 Comparison of the Observed Results and the Predicted Values for Selected Variables

The performance of the model is measured by the coefficient of the model (R2) and the root means square error (RMSE). For the above three categorized contributing factors to the road traffic accident, the R2 value is greater than 0.95. This shows that greater than 95% of the variation of the dependent variable is explained by the explanatory variables. In the same way, the unexplained variance is very low. The result of both predicted and observed frequency of accidents emanated within the assumed confidence interval. In addition, the goodness-of-fit statistics for the model show that the model fits reasonably well with the data. Similarly, p-value shows statistical significance with a value less than 0.01 (99% confidence interval)

5. Conclusion and Future Scope

5.1 Conclusion

The study investigated the main causes and contributing factors of a road traffic accident. According to police records and interview results, 70 and 79 percent of the total accidents in this particular road segment have been caused by human errors respectively.Under human-related factors, the education level of drivers and their driving experience make a high contribution to a traffic accident with an absolute value of 55.47% and 18.01% respectively. Both education level and driving experience

frequency of traffic accidents with correlation coefficients of -0.736 and -0.419 respectively. As the driving experience and education level increase the driver becomes more aware and the frequency of accidents occurring due to driver error decrease consistently. The age of driver and pedestrian correlated positively with the frequency of traffic accidents with a correlation coefficient of 0.361 and 0.359 respectively. The lesser magnitude of the correlation coefficient shows that the variables are not linearly correlated with accident frequency. This study also found the major road-related contributing factors along the most ranked black spot include horizontal curves, sight distance, steep gradient, super elevation, pavement, and shoulder width. Gradient, sight distance, and horizontal curve were highly correlated with accident frequency with a correlation coefficient of 0.692, -0.529, and -0.426 respectively among all other road geometric factors. The analysis of accidents by vehicle type indicates that highest number of the accidents was caused by medium trucks (11 - 40 quintals) with a 21.1% contribution. Finally, the influence of contributing factors has been expressed by both their direction and magnitude of the correlation coefficient.

5.2 Recommendation

Based on the results, most road traffic accidents are caused by human factors, especially by a driver. Therefore, the concerned body shall give priority to training time length and driving skills. In addition, the government should create awareness for drivers and pedestrians about traffic accidents and the rules and regulations. Expanding the road safety education for all stakeholders through mass medias including the private Media, informal organizations in schools and other governmental and non-governmental organizations, in religious institutions like churches, and mosques using religious leaders and using local respected figures in the community. As much as possible forming road safety in the school curricula could be a special method to create awareness for the students. For road geometry particularly on the black spots, the concerning body shall create awareness for drivers about the wait on the lane rule. Short-term maintenance like trimming trees from the inner side of a road which interrupts the visibility of objects to the driver, especially on the horizontal curve shall be taken once per year. The traffic accident occurred due to road environment factors like animal-drawn cart could be reduced by providing reflectors/painting bright colors on front and back.

5.3 Limitations and future proposed research areas

The study has limitations due to the fact that human factors especially; driver characteristics, driving behavior, mechanical defect of the vehicle, and the surface effect of pavement are not included in the development model by including these factors

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