The Influence Of Traffic Control Devices And Road Geometric Characteristics On Traffic Crushes Of Rural Two Lane Road

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ABSTRACT
Traffic accidents worldwide are among the most alarming phenomena because they cost billions of dollars due to death rates and property damage. In Ethiopia, the accident fatality rate is becoming one of the most serious problems. Specifically, in rural highways where there are problems with traffic control device enforcement and geometric deficiencies. Gedeo zone faces a similar problem that is considered a hot issue on-road crash. This study focused on the influence of traffic control devices and geometric characteristic related to road crashes. The data collection method was a purposive sampling technique considering both primary and secondary data collection system. Direct field observations were conducted, such as field survey and recording of the existing road geometric elements to figure out which geometric element contributory to traffic crashes. The data collected from the police traffic was categorized by clustering the road into different road segments composed of the same geometric characteristics. The severity of the accident analyzed and identified the hazardous road sections (black spot area). The relationships of accident crash established between the influence of traffic control access devices and geometric elements on the crash reduction at the identified accident-prone areas. Further, the study used ANN modeling through engineering software MATLAB to analyze the weight age of crashes on specified road segments concerning geometric road characteristics. Hence, the gradient carriageway width, super-elevation, cross slope, gradient, sight distance number of the horizontal curve, number of vertical curves, and AADT are the major factors for the occurrence of both fatal and injury at the blackspot segment along the rural highway.

Keywords: Black spot, Road geometry, Traffic accident, Traffic control devices, ANN.

1. INTRODUCTION
1.1 Background
Road safety is one of the extreme problems within the universe. In keeping with the [1] file, an approximated 1.25 million human beings are killed and as much as 50 million injured international each year; on common, three,287 fatalities an afternoon in road crashes. Moreover, road traffic crashes are the leading motive of death for teenagers elderly 15 to 29, cost governments approximately three to 5% of GDP, and nearly ninety% of the sector’s fatalities at the roads occurs in low and center-earnings international locations, that have most effective 54% of the world's registered cars. The major intention of transportation is stated as safe and effective movement of human beings and commodities from one function to some other. Right road design is a prerequisite for safe movement of roadtraffic. Normally, drivers make fewer mistakes at geometric features that conform to their expectations. Deficiency in design may be described as a geometric function, or aggregate of features that has any such high motive force workload requirement and those drivers might also power in an unsafe way.

This example could cause inappropriate using maneuvers and/or an unwanted degree of crashes. In line with the roadway geometry, traffic conditions and roadside environment are the number one inputs to the riding venture that determine the workload requirement of the driver. How fast and how nicely those inputs are dealt with depends on driver expectancy and other human factors. As soon as these inputs are processed, they may be translated into automobile operations. The road traffic coincidence is becoming international and countrywide trouble and developing social and monetary burden for countries. In line with the sector health corporation file, the financial costs of avenue crashes and injuries are estimated to be 1% of Gross home Product (GDP) in low-earnings nations. Ethiopia is one of the growing international locations with high road traffic injuries costing the country round zero.8% - 0.Nine% of the GDP for the beyond consecutive years (Ethiopian Federal Police commission, 2008). Like several developing economies, Ethiopia has been experiencing a large quantity of traffic accidents annually. To curb the problem, strong interventions and techniques are anticipated to deal with the demanding situations a good way to lessen its effect by means of 50% at the stop of 2020.
1.2 Statement of the problem
Maximum massive cities within the world are nonetheless struggling crashes, despite extraordinary solutions are cautioned to reduce it. For example, an intoxicated man or woman driving a defective vehicle at excessive pace on a geometrically deficient avenue is far more likely to enjoy a crash than a sober and alert driver of a roadworthy automobile travelling at a reasonable pace on a geometrically good enough avenue [2]. Research into road safety in growing countries is scarce, mainly in Africa. That is inconsistent with the dimensions of the problem: it’s been expected that by means of 2020, road traffic accidents will rank as excessive as third among causes of incapacity adjusted existence years lost. In Africa, it has been estimated that 59,000 people lost their lives in road traffic crashes in 1990 and that this figure will be 144,000 people by 2020, a 144% increase [3]. In Ethiopia also, road traffic accident is a perennial problem, specifically in Gedeo zone Road Section. This incidence has long been adversely affecting the surrounding people through fatalities, injuries and property damages costing the area and the nation’s significant resources. Further, the trend of crashes is increasing on the road section from time to time.

1.3 General Objective
The general objective of the study is to investigate the influence of traffic control device and geometric elements on the occurrence of road accidents within the study area.

1.4 Specific Objectives
- To identify black spots along the road segment
- To develop a model that depicts the relation between the geometrical elements and traffic crashes; and
- To identify the geometric character in the reduction of traffic accidents

2. REVIEW OF RELATED LITERATURE

2.1 Road Traffic Accident Trend
Road accident is one of the causes for the death of people and has been ranked as one of the top leading causes of death in the world. Over millions of people are killed each year. Every day, thousands of people are killed and injured in road by traffic accident. It is the leading cause of death, disabilities and hospitalization, sever socioeconomic costs, across the world. According to [1], it has been estimated that RTA takes the life of nearly 1.3 million each year, as a result, nearly 3500 people die each day. In addition, the people who suffer serious injuries, including disability are about 20 to 50 million worldwide. RTAs injuries are becoming public health issues, disproportionately affecting the vulnerable group of the road users, including the poor. More than half the people who die in traffic crashes are young adults whose age are between 15 to 44[4]. Ethiopia is one of developing countries. Road traffic accident in Ethiopia is a serious problem. The death rate presently stands near 70 per 10,000 vehicles. To curb the problem, strong interventions and strategies are expected to deal with the challenges so as to reduce its impact by fifty percent (50%) at the end of 2020. Despite all these efforts, the challenges of road traffic accidents are still increasing from time to time.

2.2 Black spot Definition and identification method
One of the definitions for highway accident Black spots is they are highway or road locations where the potential for accidents is unacceptably high. According to this definition repetition of accidents on a road section result the section of the road with the accident black spot location[5]. Others define traffic accident black spot in terms of accident rate (accident per vehicle-kilometers or per entering vehicles), some use accident frequency (accident per kilometer-year) and some use the combination of the two[6]. In addition to the above definitions hazardous locations are sites where crash frequencies, calculated on the bases of the same exposure data are higher than the expected value for other similar locations or conditions. In this explanation hazardous locations are located based on comparison of different sites [7]. Different researchers use different types of methods for the identification of road traffic accident blackspots. The application of the methods depends on the availability of recorded accident data and on the standards designed by the countries as it is explained earlier. As it is known most of the developing countries record crash data’s by using manual methods. Thus, the opportunity of using modern applicable database system for the analysis will be limited. In Belgium, each site where in the last three years, three or more accident shave occurred, is selected. Then, as it is considered to be dangerous when its priority value (P), calculated using the following formula, equals 15 or more. This could be the simplest and clear method to rank a given location and can be used if the three parameters are available [8].

\[ P = X + 3Y + 5Z \]

Where, \( P \) = priority value; \( X \) = total number of light injuries; \( Y \) = total number of serious injuries; \( Z \) = total number of deaths.
2.3 Factor Contributing for Traffic Crashes

**Driver Characteristics**- The causes of this include; the driver's behavior, distractions, the influence of alcohol, drugs (or medication), drowsiness, fatigue, illness, or black out, speeding, and failure to obey signs, signals or traffic police, which could be due to confusion or unfamiliarity with the roadway [9].

**Vehicle Characteristics**- Faulty brakes, worn tires, and other vehicle defects, affect the controlling of a vehicle, especially at high speeds[9].

**Road Geometric Characteristics**- The number of horizontal curves, number of lanes, number of vertical curves, and number of accesses and gradients per kilometer were found to be the main influencing road geometric related variables that significantly affect traffic safety[10]. As per the studies Road Alignments, Cross-sectional Elements, Traffic Control Device, Traffic signs are taken as factors affecting road traffic accident,

### 3. MATERIALS AND METHODS

#### 3.1 Sampling Techniques and Sample Size

The sample was taken out from the Gedeo zone. The method of sampling used is purposive sampling technique. The areas to be sampled in this research are districts located on the major Federal Road networks, which are vulnerable to a traffic accident in the area, characterized by high traffic accident and improper road geometric features and traffic control access devices.

#### 3.2 Data Collection Method

The study conducted on both primary and secondary data with quantitative and qualitative data type. This paved the way to go through objective in the identification of blackspot area and identifying weighted accident-causing geometric element.

#### 3.3 Primary and Secondary Data Collection Methods

The primary data were identified through direct field surveying measurement by using measuring tape, leveling instrument and GPS to know the road geometry condition and picturing road segment for identifying traffic control device traffic accident does exist. The secondary data road traffic accident was obtained from the zone police office as well traffic volume data from ERA.

#### 3.4 Road Traffic Accident Data

Road traffic accident data was collected from Zone traffic police station. The method used for the collection was review of historical road accident data organized at zone level and discussion with traffic officials during the site survey on the causes of road crashes and how road accidents are happening in the locations based on the documented data. The collected data from traffic police office was organized according to their severity. The collected road accident data ranges from September 2016 - June 2019 (2008-20011E.C) in both zone and woredas of the Gedeo. Thus, for analysis purpose and prioritization a four-year data was used, i.e. 2016-2019G. c.

**Road Geometry**

Road geometric characteristics such as road segment length, number of horizontal and vertical curve, lane width, curve length, median type (raised or painted), shoulder width, cross slope, gradient, number of lanes were conducted directly through actual measurement from the selected road segment in the Gedeo zone.

**Traffic Control Device**

Traffic control device such as warning sign, informative sign, regulatory sign pavement and curb side marking were collected directly by camera.

#### 3.5 Study variable

Dependent variable; -road traffic accident is the dependent variable and Independent variable; - the road geometric variable which are radius, sight distance carriage way width, shoulder width, crosss lope, curve length, supper elevation, grade, NHC,NVC and AADT.

#### 3.6 Candidate Variables Identification

The main target of getting effective parameter was to select influencing variable to develop a more realistic model. The effective explanatory and exposure variable that influences the road traffic crashes were evaluated through statistical analysis. The table below shows the independent candidate variable suggested in the crash prediction model.
Table 1: Candidate Variable Description

| No. | Variable | Description |
|-----|----------|-------------|
| 1.  | R        | Radius of the curve |
| 2.  | SD       | Sight distance on horizontal curve |
| 3.  | NHC      | Number of horizontal curves per road section |
| 4.  | NVC      | Number of vertical curves per road section |
| 5.  | G        | Gradient of the road segment |
| 6.  | CS       | Camber slope % |
| 7.  | CW       | Carriage Width of the road surface in meter (m) |
| 8.  | SHW      | Shoulder width in meter (m) |
| 9.  | CL       | Curve length of road segment in meter |
| 10. | AADT     | Average Annual daily Traffic on road section |
| 11. | SUP      | Supper elevation of each segment |

4. DATA ANALYSIS

4.1 Black Spot Identification Method

The accident rate method used to analyze the black spot segment and ranking by identifying black spot location by prioritizing the spot.

**Accident Rate Method (Ra):** Location with higher than pre-determined rate is classified as high accident locations.

\[ Ra_i = \frac{U_i \times 10^6}{365.25 \times AADT_i \times n \times L_i} \] 

Where,
- \( Ra_i \) = accident rate in the time period of \( n \) years at site \( i \)
- \( U_i \) = number of reported accidents during the period \( n \) at site \( i \)
- \( n \) = period length (years)
- \( L_i \) = section length (Km) of site \( i \)

**For Road section**

\[ Ra_i = \frac{U_i \times 10^6}{(365.25 \times AADT_i \times n \times L_i)} \times Injury \ per \ MK \] 

Where,
- \( Ra_i \) = Accident rate in the time period of \( n \) year at segment \( i \)
- \( U_i \) = number of reported accidents during the period \( n \) at segment \( i \)
- \( n \) = period length (years)
- \( L_i \) = section length (Km) of segment \( i \)

**Average accident Rate**

The rate of average accident was conducted based on

\[ Ra_{ave} = \frac{\sum(U \times 10^6)}{365.25 \times AADT_{ave} \times n \times \sum L_i} \] 

Where:
- \( \sum(U \times 10^6) \) = total number of reported accidents during the period \( n \) at segment \( i \)
- \( AADT_{ave} \) = Weighted Annual Average Daily Traffic (AADT)
- \( n \) = period length (years)
- \( \sum L_i \) = Total Road length (Km)

\[ AADT_{ave} = \frac{AADT \times L_i}{\sum L_i} \] 

4.2 Critical accident rate method (Rc);

Which used to compare the accident rate at a site with average accident rate calculated a group of site having similar characteristics.

\[ Rc = Ra_{ave} + \text{confidence level} \times \sqrt{\frac{1}{MEV} \times 2MEV} \] 

Where:
- \( Rc \) = Critical Accident Rate (accidents per million vehicles or accidents per million vehicle-km)
- \( Ra \) = average crash rate
- \( MEV \) = Million’s vehicle-km of vehicles traversing road segment during the analysis period

\[ MEV = \frac{AADT \times 365.25 \times n \times L}{1,000,000} \]
$R_c = R_{av_r} + k \sqrt{\frac{R_{av_r} + 10^{6}}{365.25 \times n \times L \times AADT_i}} \times 10^6$ \hspace{1cm} \text{eqn .7}

Where, AADT = Average annual daily traffic for the spot $(i)$.

$R_{av_r}$ = Average Crash Rate

$n$ = Number of years being analyzed

$L$ = Length of the segment in kilometer

$k$ = Confidence level (95% confidence level, $k=1.645$)

Compare the location crash rate to the critical crash rate. If the location crash rate exceeds the crash rate, classify the location as an accident black spot.

4.3 Prioritization of Black spot for analysis of geometric characteristics

After identifying the blackspot road segment, prioritizing of the black spot segment is undertaken. For prioritizing those black spots, the ratios of accident costs by degree of severity were established by TRL the weight given for fatal accident is 5, for serious injury is 3, for light injury and property damage are 2 and 1 respectively.

$$p = \frac{1+W+2X+3Y+4Z}{D} \hspace{1cm} \text{eqn .8}$$

Where $W$ = Property Damage; $X$ = total number of light injuries; $Y$ = total number of serious injuries, $Z$ = total number of deadly injuries and $D$ = total Number of distances of black spot section in Km.

4.4 Designing Process of Artificial Neural Network in accident prediction

The ANN designing process involves five steps. This is (1) data gathering, (2) preprocessing data, (3) building the network, (4) training, and (5) test performance of the model. In the training, nine input variables have been used. These are gradient, carriage width, shoulder width, supper elevation, cross slope, curve length, NHC, NVC and AADT.

4.5 Programming the neural network model

MATLAB is a numerical computing environment and also a programming language. It contains the Neural Network Toolbox for designing, implementing, visualizing and simulating neural networks. Here MATLAB (R2010a) is used to write script files for developing MLP models and performance functions for calculating the model performance error statistics such as $R^2$ and RMSE.

5. RESULTS AND DISCUSSIONS

5.1 Ranking of Black Spot Road Segments

Ranking of accident spots allows to assess which place is to take delivery of on-the-spot attention. Exceptional control is the approach used for identity of black spot segments and roads so that the twist of fate frequencies of all of the spots 4-years duration is calculated.

| Table 2 Ranking Black Spot Of The Gedeo Zone Of Dilla District |
|-----------------|----------------|---|---|---|---|---|---|
| From            | To             | W  | X  | Y  | Z  | D(km) | P-value | RANK |
| Abenezer Hotel  | Mola Golja     | 11 | 4  | 5  | 9  | 0.82  | 81.41   | 1    |
| Michot Hotel    | Delight Hotel  | 7  | 0  | 3  | 3  | 0.41  | 41.07   | 5    |
| Mazoriya        | Netsanet Hotel | 7  | 1  | 3  | 5  | 0.675 | 46.37   | 4    |
| Netsanet Hotel  | Menahariya     | 8  | 1  | 2  | 4  | 0.41  | 47.51   | 3    |
| Michile         | Hassedela      | 12 | 6  | 4  | 6  | 0.79  | 69.19   | 2    |

| Table 3 Ranking Black Spot Of The Gedeo Zone Of Yirgacheffe District |
|-----------------|----------------|---|---|---|---|---|---|
| From            | TO             | W  | X  | Y  | Z  | D   | P-value | Rank  |
| Chitu           | Dumerso        | 8  | 1  | 0  | 1  | 1.04 | 14.69    | Not Black spot |
| Dumerso         | Adamea         | 4  | 0  | 1  | 1  | 1.5  | 10.67    | Not Black spot |
| Adamea          | Konga          | 9  | 2  | 1  | 0  | 1.2  | 14.5     | Not Black spot |
| Konga           | Wetea          | 16 | 5  | 2  | 4  | 0.9  | 53.78    | 1      |
Table 4 Ranking Black Spot Of The Gedeo Zone Of Gedeb District

| GEDEB | W | X | Y | Z | D  | P-value | Rank       |
|-------|---|---|---|---|----|---------|------------|
| Geshe |    |   |   |   |    |         |            |
| Dibanidle | 4 | 2 | 0 | 1 | 1.2| 12.33   | Not Black spot |
| Dibadindle | 6 | 0 | 1 | 1 | 1.5| 12      | Not Black spot |
| Harmufo |    |   |   |   |    |         |            |
| Gubita   | 6 | 0 | 1 | 1 | 1 | 14      | Not Black spot |
| Gubita   | 9 | 3 | 1 | 2 | 1.5| 25      | 1          |

5.2 Model Developed based on Geometric Elements and Traffic Crash Data

Modeled Relationship of Traffic Fatal Accident against Road Geometry

In the ANN, in order to avoid the over fitting of the model there is a training and testing phase. It consists of 80% in the training and testing data and 20% validation test data. In this study, a three-phase neural network has been used consisting of an input layer with 11 explanatory variables, hidden layer with 20 neurons, and the output layer that represent traffic crash. It went through different iterations and yields this result.

The ANN analysis result between traffic fatal accident and road geometry had been done as follows.

\[
Y_{\text{fatal}} = 19.5144 - 0.0548R - 0.2081SD + 0.6991NHC + 1.2688CS + 1.3120AADT - 1.4075CW + 2.2693\text{Sup} + 3.4687\text{NVC}
\]

As it was seen in the above equation from the eleven independent variable radius of the curve, sight distance, carriage width, supper elevation, cross slope, NHC and NVC are significant variable for fatal accident. From this radius, sight distance, carriage width had a negative relationship with fatality as this variable increases the rate of fatality decreases else cross slope, NHC and NVC are positively related with fatality which means as cross slope, NHC and NVC increases the fatality rate also increases. Number of observation is 57 with 49 degree of freedom. It had a strong coefficient of determination between the number of fatality versus road geometry is \( R^2 = 0.94 \) and adjusted \( R^2 = 0.96 \), RMSE = 4.8, \( F = 124.64 \) and \( P = 3.85315 \times 10^{-9} \). RMSE-provides information on short term performance, which is measured data. The lower RMSE, the more accurate is the estimation. \( F \)-Ratio indicates the level of significance of all the parameters and higher value is preferred. The \( P \) value indicates the degree of significance level and the obtained \( P \) values are less than 0.05.

Model validation test is the method of verifying the observed values which are collected in the field and predicted values that are obtained from the model as an output. A plot is drawn between the observed number of fatal accidents and the predicted number of fatal accidents. The graph clearly indicates the closeness between the observed and predicted values. Hence the developed model is said to be validated and appropriate to use appropriate to use for the analysis.
The same parameter was done for traffic injury accident as the traffic death injury. It had 57 observations for 11 explanatory variables (input). 80% data used for training.

Number of observations: 57, Error degrees of freedom: 48
Root Mean Squared Error: 2.08
R-squared: 0.866, Adjusted R-Squared: 0.844
F-statistic vs. constant model: 38.8, p-value = 2.16e-18

The ANN analysis result between traffic injury accident and road geometry has been done as follows.

\[
Y_{\text{injury}} = -1.36 - 0.016R + 0.022\text{AADT} + 0.178G + 1.034\text{SUP} - 1.195\text{CW} + 2.315\text{NVC} + 2.206\text{CS} + 4.266\text{NHC}
\]

Here in the injury accident, R, G, CW, SUP, CS, NHC, NVC and AADT are significant variables which have weightage on injury accident. And also they have a relationship which is both positively and negatively. Radius, gradient, Carriage width had negatively related to the injury accident and super elevation, CS, NHC, NVC and AADT had positive relationships with the injury accident which means as it increases the injury accident also increased. It had a coefficient of determination between number of injuries versus road geometry is \( R^2 = 0.866, \) RMSE = 2.08, F = 38.7 and \( P = 2.1607e-18. \) RMSE provides information on the standard deviation of the residuals (prediction errors). The lower RMSE, the more accurate the estimation. F-Ratio indicates the level of significance of all the parameters and higher value is preferred. The P value indicates the degree of significance level and the obtained P values are less than 0.05.

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CONCLUSION

The research has advanced a crash weight age version on the effect of road geometric characteristics on avenue crash the usage of field surveyed accrued statistics of the street section and on 4 years crash coincidence report from 2016-2019. A total of 539 accidents were suggested out of this 111 were fatal, 161 have been essential injuries, 25 moderate accidents and 242 belongings damage have been passed off on this four year. From the district Dilla, Y/cheffe and Gedeb possed the highest number accident frequency 28.77%, 20.4% and 18. Fifty-five% respectively. Also from the recorded 12 months 2017/18 is the year with maximum accident frequency which is ninety-one. Moreover, descriptive widespread evaluation of crush fashion in the Gedeo region rural trunk road section is included within the take a look at.

The examiner become conducted on 20 street sections based totally at the accumulated accident statistics and avenue with high accident frequency is taken for road geometry evaluation modeling. The chosen avenue geometric characters are in the modeling had been; radius, sight distance, gradient, carriage manner width, shoulder width, supper elevation, cross slope, curve length, number of horizontal curve and vertical curves, median kind and annual average daily Traffic (AADT). Further to road traffic get admission to manage devices are protected in the study.

The version shows that the road fatal accident within the decided-on avenue segment inside the study avenue phase is influenced with the aid of radius, sight distance, carriage width, supper elevation, pass lope, variety of horizontal curve, quantity of vertical curve and AADT. But, gradient, shoulder width and curve period have been discovered as insignificant. A swell, for damage accident the weighted variables had been radius, gradient, carriage width, go slope, range of horizontal curve and variety of vertical curves and AADT are the huge variable the opposite ultimate insignificant. Beside this traffic get entry to manage device additionally have major involvement within the occurrences of road crashes. But, shoulder width, pass slope and median kind had been observed statistically insignificant into the output of the version. Further, gradient, splendid elevation, variety of vertical curves and AADT had high-quality relation to the traffic coincidence. In addition, the end result means that as the range of these explanatory variable increases in the road segments the corresponding overwhelm occurrences additionally increases in the road segments. Then again, carriage width, curve duration and number of horizontal curves had poor coefficient. This suggests that when this explanatory variable increases the ability traffic overwhelm reduced.
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