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EFFECT OF GEOMETRIC DESIGN PARAMETERS ON TRAFFIC ACCIDENT ALONG BLACK SPOT SECTION USING MULTIPLE REGRESSION METHODS A CASE STUDY SEKORU TOWN TO GIBE RIVER BRIDGE

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ABSTRACT

A traffic accident is one of the series problems frequently occur in developing countries, leads to loss of life and property. In Ethiopia, various road segments are facing the effect of geometric design elements on traffic accidents; one of the road sections is along with Sekoru town to Gibe River Bridge, which is located in the Jimma Zone of the Oromia Region. The main aim of this research study was to identify the main effects of road geometric design elements that cause road traffic accidents. Therefore, the mitigation of traffic accidents is one of the prime concerns. Henceforth, the scope of the study was limited to Sekoru town to the Gibe River Bridge road segment with a total length of 70 kilometers. This research was conducted using both descriptive and analytical methods; simple random sampling was used for interview, and questionnaires of drivers, the pedestrian's likewise purposive sampling was used for obtaining of recorded accident data from the traffic police officer, as a built drawing and annual average daily traffic data from Ethiopian Road Authority. These data were analyzed using prioritization value (P) for the last three years (three or more) road traffic accidents have occurred was first selected, then for value of P≥15 selected as black spot section. Generally, the segment has 15 black spot sections from which 10 black spot sections were found in Sekoru Woreda; QumbiMuzi tare has the highest 79 P-value and Doma have the smallest 15 p-values and the other 5 black spot section were founded in the Yem special woreda; Kosho has the highest 78 p-value and Saja town has the smallest 18 P-value. Also, analyzing the results based on multiple linear regressions for indicating variables using SPSS and excels tools; the value of R^2 is always between 0 and1 because r is between -1 and +1. Normally, when correlating geometric design elements; lane width, shoulder width, a radius of curves, vertical curve length, k-value, algebraic difference, stopping sight distance, passing sight distance with road traffic accident; they have R^2=0.999 which means strong positively correlate with TRTA and P= 0.035 which is significant because of $P<0.05$, as a shown in the summary of multiple regression output. Therefore, the countermeasures are needed because there are the effects of geometric design parameters bring road traffic accidents as investigated in the research.

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INTRODUCTION

Every year, more than 1.25 million people die and as many as 50 million people are injured or disabled on the world's road (WHO, 2015). Over 90% of death occurs in low and middle-income countries. The world report on road traffic injury prevention predicts a more than 80% increase in road crash deaths in sub-Saharan Africa in the period 2000-2020 (I. T. S. D. 2017).

Ethiopian currently loses almost 1700 lives each year; another 7500 are injured, and a further 7783 face property damage only due to road accidents (F. P. C. 2010). In most African countries, urbanization is growing and road infrastructure is expanding, safety considerations in the land – use planning and road design are not adequate to serve the mixed traffic that exists in the county (Bezabeh, 2013). Therefore, geometric design parameters have a direct relationship with a road traffic accident.

Key geometric design elements that influence traffic operations include the number and width of lanes, the presence, and widths of shoulders and highway medians, and the horizontal and vertical alignment of the highway (Iyinama). The major contributing factors to the occurrence of road traffic accidents (RTAs) are roadway geometry, driver error, vehicle factor, and environmental aspect (Kumaras, 1985). Of all the systems that people have to deal with daily, road transport is the most complex and the most dangerous (Margie Peden, 2004). Road infrastructure should be designed taking account of the same injury tolerance criteria as this development for vehicle occupant protection and pedestrian impacts so that roads and vehicles together provide an effective safety system (Zegeer, 1992).

The road condition is a primary reason for traffic accidents; the lack of coordination between drivers and the road can lead to an increase in driver's reaction time and miscarriage of justice and increases the risk of traffic accidents (Tao, 2014). The proper identification of the black spot is important in terms of efficient resource allocation. If the most hazardous site is identified and treated first, it becomes increasingly difficult to identify sites whose treatment will result in substantial social benefits (Evaluation of the Black Spot Program Report). The three broad approaches to identifying black spots are based on crash numbers, crash rates related to exposure to risk, and qualitative methods. Accident black spot on a national highway in Norway is defined as any place with a maximum length of 100 meters, where at least four injury accidents have been reported to the police for four years (Elvis, 2005). Although the main purpose of this study is to determine the effect of geometric parameters on driving behavior along with the black spot by using regression analysis. Geometric design consistency can be demarcated as how a driver's expectation and the road's performance match up (i.e., when a road with good consistency level matches a driver's expectations, the road user is not amazed while driving along with it) (Mulugeta Tola1, 2019). The values of geometric parameters were obtained from as-built road design outputs and a regression analysis was made between the variables (Yizengaw, 2017). Explanatory data analyses were conducted to investigate relationships underlying the use of correlations and regression analysis techniques. Correlations were established in the form of an equation of accident rate as a function of geometric parameters by considering the effect of individual elements on accident. Several countries have seen success in reducing road traffic deaths over the last few years, but progress varies significantly between the different regions and countries of the world. With an average rate of 27.5 deaths per 100,000 populations, the risk of a road traffic death is more than three times higher in low-income countries than in high-income countries where the average rate is 8.3 deaths per 100,000 populations (WHO). The severity of road collision in Ethiopia varies from region to region; more than one-third of the fatal injuries (36%) occurred in Oromia regional state. Oromia region has the largest number of road traffic collision fatalities as vehicles from every corner of the country to the capital city (Addis Ababa) passes through the region. Therefore, the Ethiopia traffic control system archives data on various aspects of the traffic system, such as traffic volume, concentration, and vehicle accidents (Negash, 2015).

Objective of the study: The objective of the study was to investigate the effect of geometric design parameters on Traffic accidents along the black spot section from Sekoru Town to the Gibe River Bridge road segment and to recommend countermeasures based on the result obtained from the regression analysis.

METHODOLOGY

This study was designed to be a descriptive research method and an analytical design approach was used in this study. The descriptive type of research would be considered to be an appropriate method to investigate the status; causes and countermeasures of road traffic were analyzed for different traffic accidents along with black spot locations along the study area.The population of the study was considered as road geometric features, pedestrians, drivers, traffic police, transport office, and woreda towns' administrative bodies between Sekoru towns to Gibe River Bridge. Both descriptive and analytical research methods were used for conducting this research; in a descriptive method describing the available (existing) data by graphical analysis forSekoru town to Gibe River Bridge road segment but in an analytical method in-depth study or evaluation were commenced using SPSS and Excel tools. The first step of the analysis was determining the most accident sites. Based on these data, the following criterion was used. For a site where in the last three years three or more accidents have occurred was selected. Then, a site was considered to be hazardous when its priority value (P), calculated using the following formula, equals 15 or more (Evaluation of the Black Spot Program Report, 1995).

$$P = X + 3*Y + 5*Z$$

Where X = total number of light injuries
Y = total number of serious injuries
Z = total number of deadly injuries

Primary data for the research was obtained through site observations of black spot sections, from questionnaires of drivers; town administrative body, traffic police, transport bureau, pedestrians, and direct measurements of geometric components at accident locations. While Secondary data was collected through reviewing the existing relevant documents such as built drawing from ERA, reports, literature, Sekoru woreda, and Yem special woreda traffic police commission office traffic accident data or any other relevant documents.

Multiple Linear Regression Model: The collected data were statistically analyzed to evaluate the effect of the selected parameters on accidents. The relationship between accidents and various factors was also obtained (Glennon). The statistical technique which will be most frequently encountered by a traffic engineer and traffic planner is the multiple linear regression analysis. The problem concerns the establishment of a relationship between a variable that is knownto respond to changes in two or more other variables. The variable which is known to respond, the Y variable, is commonly called the independent variable, and the other variable influencing it is called the independentvariablesi.e. X variable (Glennon).

$$Y=a0+a1x+a2x2+a3x3+\ldots +am\ xm$$

Where Y=true estimate of the dependent variable, x1, x2, x3……xm = independent variables, a0=regression constant a1, a2, a3….am=regression coefficients of the respective m independent variables (Glennon).

RESULTS AND DISCUSSION

The number of road traffic accidents in Yem Special Woreda had increased from 2016 to 2018, but a decrease in 2019 also had to increase in Sekoru Woreda from 2008 to 2019because of awareness was given to the drivers and the pedestrians. .However, the total property damage was 1,853,975.00Birr from Yem special woreda and 7,156,065.00 Birr from Sekoru Woreda. The total number of accidents and the property damage were very high; the figure below shows that in each year convince that the country had lost a huge amount of the economy every year along this road.

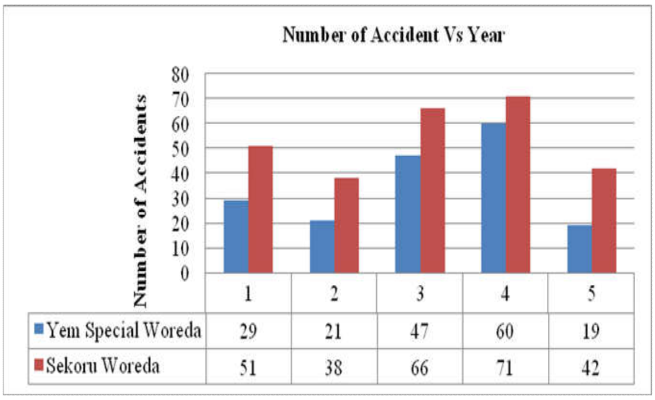

Figure 1: The Relationship between the Number of Accidents and Year

A total of 15 hazardous locations that fulfilled the first criteria which have 3 or more accidents within the last 3 years of blackspot location in Sekoru Woreda and the calculated values of priority value were based on fatalities and injuries for each black spot location. From fifteen black spot identified locations in figure 2below Qumbimuzterain Sekoru woreda has 79 p-values, the first ranking, and Domahave p-values of 15 which is the smallest eleventh ranking. Hence, the locations have 3 or more traffic accidents withinthe last 3 years of the study period, and the locations' priority value was more significant and equal to15.

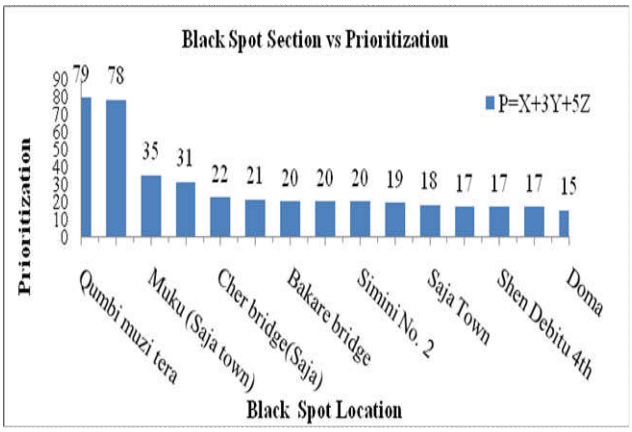

Figure 2. Prioritization of Black Spot Location for the Study Road section

Depending upon the data analysis the study area has Fatalities, Series injuries, slight injuries, and PDO along 15 black spot section among these sections; Qumbi muz tera has the highest degree of severity which is 39 total road traffic accidents due to the steepness grade of landscape and sharpness of curve, so the oppositely coming vehicles are suddenly crashing each other, but Doma from Sekoru woreda has the lowest Degree of Severity which is 9 total road traffic accidents.

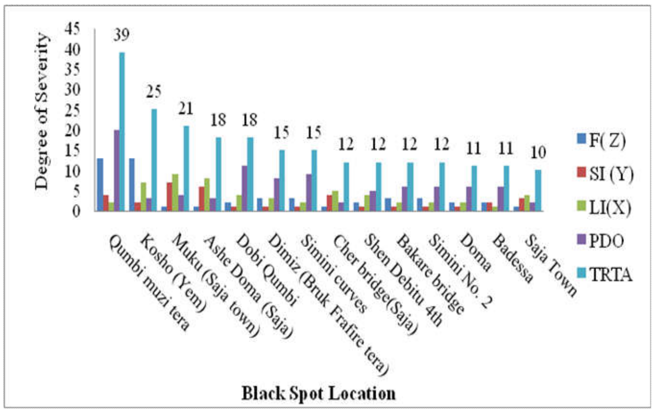

Figure 3. Degree of Severity along with Black Spot Section

The Correlation between GDP and RTA Using Regression Analysis: As black spot location identified the following geometric design elements were collected; curve radius, Algebraic difference, k-value, vertical curve length (checked and also calculated), shoulder width, lane width Passing Sight Distance were calculated from as a built drawing. The following table 1 shows, geometric parameters that cause traffic accidents and the relationship between them and with a total road traffic accident. The average elevation was measured on the field, minimum superelevation, maximum superelevation, minimum gradient, maximum gradient were taken from as a built drawing, Stopping Sight Distance and

The correlation between RTA and Geometric Parameters

The geometric design elements cause a traffic accident in the roadway. Therefore, the multiple linear regression analysis is very important in correlating road traffic accidents with geometric design elements like curve radius, Superelevation, lane width, shoulder width, Stopping sight distance, and passing sight distance. Consequently, as output obtained on the figure below the geometric elements has a very significant role in causing a road traffic accident in flat, rolling, mountainous& steep terrain highway; K-value is very significant in flat and rolling terrain highway and the vertical gradient is very significant in mountainous and steep terrain highway to cause an accident. Generally, all the above mentioned geometric parameters have a positive strong correlation with total road traffic accident because of the value of R^2=0.999 which means effect geometric parameters on traffic accidents and the value of P=0.35, it significant because of $P<0.05$. The Correlation between Geometric Parameters and TRTA.

The correlation between variables; geometric design parameters such as shoulder width, lane width, superelevation (e min, e max), gradient (G min, G max), average elevation, and road traffic accident (RTA). These variables are correlated under the bivariate correlation coefficient of Pearson test significant with two-tailed, Pearson correlation is a measure of linear association between two variables the value of the correlation coefficient range from -1 to 1 the sign of the coefficient indicate the direction of the relationship and absolute value indicate the strength, with larger absolute values indicating stronger relationship. The Sig. (2-tailed) is the probability of obtaining results as extreme as the one observed and in either direction when the null hypothesis is true. A two-tailed significant level tests a null hypothesisin which the direction of an effect is not specified in advance.

Table 1. The summary of Geometric Design Parameters and RTA

Black Spot Location	CR (m)	SW (m)	LW (m)	e min	e max	G min	G max	VCL	K	Ave. Elen.	A	SSD	PSD	TRTA
ShenDebitu 4th	33.00	0.70	2.75	2.50	7.00	2.80	5.77	50	16.83	1504.30	2.97	105.23	120.58	12
Doma	135.00	0.85	3.00	2.50	7.00	0.42	0.73	60	193.55	1682.00	0.31	356.87	408.93	11
Badessa	85.00	0.60	3.00	6.00	6.50	2.45	6.86	70	15.90	1837.06	4.40	102.28	117.20	11
Qumbimuzitera	52.50	1.20	2.75	2.50	6.50	2.21	3.97	60	34.09	1887.07	0.95	252.17	252.17	39
Dobi	160.00	0.30	3.00	2.50	2.50	4.09	6.32	80	35.84	1849.50	2.23	153.57	175.98	18
Muku (Saja town)	20.00	1.00	3.00	7.00	7.00	1.07	7.07	120	19.99	1859.59	5.49	119.95	485.67	21
Ashe Doma	19.50	0.40	2.75	2.50	6.50	2.17	5.66	120	34.47	1906.30	3.21	156.76	179.64	18
Cher bridge(Yem)	38.00	0.25	3.25	7.00	7.00	1.07	7.07	45	7.50	1859.86	6.00	45.85	45.85	12
Kosho (Yem)	22.00	0.00	2.96	2.50	7.00	1.11	1.56	20	7.49	1766.32	2.67	45.83	567.25	25
Dimiz (BrukFrafiretera)	57.50	0.80	2.95	2.50	6.50	5.26	7.21	80	40.96	1743.60	1.95	164.17	375.63	15
Bakare bridge	26.00	0.00	3.00	2.50	7.00	0.28	6.95	10	14.99	1772.71	6.67	31.41	35.99	12
Simini bridge	47.00	0.00	3.00	7.00	7.00	1.67	6.10	40	5.15	1750.16	7.77	35.44	35.44	9
Simini No. 2	13.75	0.30	3.00	5.50	7.00	5.44	5.83	50	127.23	1803.18	0.39	448.70	446.50	15
Simini curves	59.00	0.70	3.00	7.00	7.00	5.98	7.82	60	32.66	1825.23	1.84	141.93	140.93	12
Saja Town	167.0	1.00	3.00	2.50	7.00	5.17	5.66	60	124.74	1918.83	0.48	286.49	328.29	10

Table 2. The Correlation between Geometric Parameters and RTA

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	CR (m)	1													
2	SW (m)	0.295	1												
3	LW (m)	-0.297	-0.04	1											
4	e min	-0.31	-0.05	0.493	1										
5	e max	-0.485	0.192	0.288	0.295	1									
6	G min	0.244	0.226	-0.11	0.08	-0.21	1								
7	G max	-0.195	0.009	0.407	0.484	-0.07	0.439	1							
8	VCL	0.085	0.303	-0.09	0.077	-0.32	0.168	0.231	1						
9	K	0.507	0.247	-0.33	-0.23	0.121	0.144	-0.471	0.045	1					
10	AE	0.158	-0.16	0.025	0.2	-0.23	0.114	0.233	0.358	-0.034	1				
11	A	-0.449	-0.41	.603*	0.417	0.166	-0.5	0.383	-0.211	-.713**	-0.06	1			
12	SSD	0.102	0.118	-0.35	-0.04	-0.07	.628*	0.073	0.21	0.502	0.301	-.702**	1		
13	PSD	0.143	0.257	-0.28	-0.24	0.159	-0.09	-.686**	0.156	.643**	-0.08	-.592*	0.259	1	
14	TRTA	-0.228	0.053	-0.2	-0.29	-0.21	-0.15	-0.35	0.145	-0.198	0.295	-0.237	0.216	0.240	1

CR=Curve Radius SW=Shoulder Width LW = Lane Width VCL=Vertical Curve Length A= Algebraic difference k-value SSD= Stopping Sight Distance PSD= Passing Sight Distance AE= Average Elevation

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The algebraic difference is 0.603 significant at p>0.01 and 0.713 is significant at p>0.05

Stopping sight distance 0.628 significant at p>0.01 and 0.702 is significant at p>0.05

Passing sight distance 0.686 significant at p>0.01 and 0.643 is significant at p>0.05

Table 3.The summary output of correlation and SLR

TRTA	R^2	Sig. order based on R^2& P
-0.4679G+19.743	0.0726	>0.05
-1.0036emax+22.59	0.022	<0.05
-1.0525emin+20.35	0.0817	>0.05
-11.761LW+53.685	0.222	>0.05
-0.0341RC+18.124	0.0499	<0.05
8.23SW+12.253	0.1636	>0.05
-0.0277K+17.314	0.0393	<0.05
0.0219AE-23.303	0.0869	>0.05
0.0042AADT+36.301	0.0449	<0.05
0.0149SSD+13.846	0.0463	<0.05
-0.8536A+18.694	0.0698	>0.05
0.009PSD+13.603	0.0583	>0.05

Table 4. Summary Output of Multiple Regression Analysis

Regression Statistics								
Multiple R	0.9999							
R Square	0.9998							
Adjusted R Square	0.9978							
Standard Error	0.3634							
Observations	15							
ANOVA								
	Df	SS	MS	F	Sign. F			
Regression	13	843.868	64.913	491.503	0.035			
Residual	1	0.132	0.132					
Total	14	844						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	2.635	2.303	1.144	0.457	-26.623	31.893	-26.623	31.893
CR (m)	-0.166	0.007	-22.463	0.028	-0.259	-0.072	-0.259	-0.072
SW (m)	21.724	0.813	26.706	0.024	11.388	32.059	11.388	32.059
LW (m)	0.403	0.853	0.472	0.719	-10.434	11.239	-10.434	11.239
e min	-0.555	0.080	-6.918	0.091	-1.575	0.464	-1.575	0.464
e max	-6.027	0.249	-24.192	0.026	-9.192	-2.861	-9.192	-2.861
G min	1.496	0.243	6.168	0.102	-1.586	4.578	-1.586	4.578
G max	-3.752	0.173	-21.630	0.029	-5.957	-1.548	-5.957	-1.548
VCL	-0.121	0.008	-15.013	0.042	-0.224	-0.019	-0.224	-0.019
K	-0.018	0.008	-2.236	0.268	-0.122	0.085	-0.122	0.085
Ave. Eln.	0.040	0.002	20.350	0.031	0.015	0.065	0.015	0.065
A	1.820	0.231	7.882	0.080	-1.114	4.755	-1.114	4.755
SSD	0.004	0.003	1.278	0.423	-0.040	0.049	-0.040	0.049
PSD	-0.001	0.001	-0.880	0.541	-0.014	0.012	-0.014	0.012

The Sum of squares and cross – products is the cross – product deviation is equal to the sum of products of mean corrected variables. Covariance is also an unstandardized measure of association between two variables, equal to the cross product deviation divided by N-1. N is the number of cases or observations or records.

The result of multiple linear regression Analysis on table below, variance (ANOVA) shows that after correlating Total Traffic Accident with Geometric elements; Radius of curve, Shoulder width, Lane width, Super elevation, Gradient, Vertical curve length, K-value, Average elevation, Algebraic difference, Stopping sight distance and passing sight distance is expressed by the following multiple regression equation with its corresponding correlation coefficients, the correlation is strong correlation R^2=0.99 and significant (P=0.036) with all independent variables appear to contribute to predicting road traffic Accident because of P≤0.05. Therefore, the model developed is the best; that shows the relationship between variables as shown below.

Conclusion

From the identification of Blackspot locations that existed on the road from Sekoru to Gibe River Bridge, the following locations are found to be Black spots Locations.

A total of 15 black spot locations were identified.Based on the existing traffic and as a built data, priority value and accident frequency were used to rank the black spot locations.Based on correlation the effects of geometric design parameters such as shoulder width, lane width, superelevation, gradient, algebraic difference, k-value, stopping sight distance, passing sight distance, average elevation were correlated with total road traffic accident; have a strong positive correlation among variables R^2= 0.99 this show that; most of the locations have problems of inadequate shoulder width, lane width, curve radius, max superelevation, and min superelevation, improper gradient, and k-value, lack of traffic sign and spot speed installation, absence of roadside delineator, fading of pavement marking. Based on multiple regression analysis the model was developed with respect to both dependent and independent variables (TRTA =2.524 - 0.167CR+21.94SW+0.172LW-6.077 emax-0.543emin +1.558 Gmin-3.754 Gmax-0.124VCL 0.016K+0.04AE+1.874A + 0.003SSD-0.001PSD), the value of F= 0.035 (significant because F<0.05)

Recommendation

Based on the analysis of the black spot locations; the major countermeasures that should be applied to decrease the incidence of accidents along this road.

It is recommended that the shoulder width will be increased, the provision of lane width, the installation of traffic signals, spot speed and roadside delineator, the provision of roadside improvements, and painting of pavement markings. Finally, the Ethiopian Roads Authority should take the remedial measures as input and undertake Road Safety Audit regularly for all road sections under their responsibility area to mitigate the effects geometric parameters and also the traffic police officers should have to record, capture, store and manipulate accident data as a database by using a computer-based system or Geographical Information System.

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