

The Correlation of Road Geometry and Environmental Features with Road Accidents in Bungoma and Uasin Gishu Counties

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Abstract

Road accidents in the Transport Industry are a threat to public health and national development in many developing countries. They contribute to poverty by causing deaths, injuries, disabilities, grief, loss of productivity and material damages. The study was undertaken in Uasin Gishu and Bungoma counties, with specific focus on road network. The major objective was to determine the effects of Geometry and environmental features on road accidents. The methodology and procedure for data collection was based on both qualitative and quantitative approach. Interviews, focus group discussions, observations and review of secondary data, were used in data collection. Statistical analyses of data were done by simple regression, descriptive statistics employing the measures of central tendencies. The results show that the road accident rate per kilometer per annum is significantly related to the vehicle flow whereas the rate per hundredth vehicle kilometers was found to be significantly related to the following physical characteristics of the road geometry; junctions per kilometer, surface irregularity and road width. The road accident rates in Uasin Gishu and Bungoma Counties were found to be consistently greater for similar values of vehicle flow and geometric design.

Key Words: Road Accidents, Highway Geometric Factors, Alignment, Environment Factors, Circular Curve Radius, Junctions, Surface Irregularity and Road Width

INTRODUCTION

Road accidents in transport industry are one of the leading causes of death and disability worldwide. They account for more than 1.2 million deaths—3.6% percent of the global mortality burden (WHO, 2009). It is also estimated that in 2004, Road accidents in transport industry injuries contributed to 2.7% percent of the total disability-adjusted life years lost globally, a proportion that is expected to rise to 4.9 percent by the year 2030 and position as the third leading contributor to the global burden of disease (WHO, 2008).

Risk is the probability of harmful consequences or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions. Communities need information both on hazards and their vulnerabilities to determine

priorities for reducing their risk (Peden *et al.*, 2004). According to the World Report on accidents in the Transport Industry Prevention, accidents in the Transport Industry account for about 3000 daily fatalities worldwide (Peden *et al.*, 2004).

Injury as a public health problem has not been well addressed in many developing countries (Morrisey *et al.*, 2006)). In developing countries the trend of accidents in transport industry has reached an alarming state, but very little attention is paid to the problem (Odero *et al.*, 2003).

In developing countries, including Kenya, accidents in the Transport Industry are increasing with time (Anh *et al.*, 2008). Taking the population figures into account, developing countries in Sub-Saharan Africa have the highest frequency of various accidents worldwide (Peden *et al.*, 2004). Road transport is the basic mode of transportation for goods and passengers in Kenya; taking care of 90% of National freight tonnage and 95% of the transport volume. Despite the fact that the development of road systems and transport is an important factor in socioeconomic development, accidents in Transport industry account for high death rates in the country and pose a threat to public health and developmental progress (Down, 1997). Therefore there is need to identify the risk factors that enhance accidents in Uasin Gishu and Bungoma Counties. Kenya has high population density and relatively difficult terrain. As a result, large Loading expenditure has been limited and the country continues to rely largely on two-lane roads of varying standard to link the major urban areas.

In a study conducted by Kononov (2002) it was observed that increasing the number of lanes causes an increase in number of vehicles changing lane as traffic jam (number of vehicles per kilometer) increases, which results in increased road accidents. Mergia *et al.* (2013) study showed that increased number of lanes on freeway mainlines and ramps increase the chance of severe injuries at freeways' merging locations. However, a study by Liu and Subramanian (2009) held that roadways with fewer lanes (one or two lanes) tend to have a relatively higher likelihood of being locations of run-off-road accidents when compared with roadways with more than two lanes. This study was set to determine the relationship of geometry of roads on road accidents in Uasin Gishu and Bungoma counties, Kenya

Highway curves have been identified as one of the most significant geometric factors that cause fatal and injurious accidents on highways (Eustace *et al.*, 2011). For example, a study by Eustace *et al.* (2011) found that a significant majority (more than 70%) of road accidents that occurred on curved sections of roads were either fatal or caused injuries. In addition, they noted that for accidents that occurred on curved sections, approximately half of them were associated with ice or wet road surfaces. This is despite the fact that far fewer vehicle miles were logged in such conditions (Dissanayake *et al.*, 2011).

Many of these roads in Kenya especially in Uasin Gishu and Bungoma counties, have —evolved from the original muram roads, rather than being properly designed for modern motor vehicles. They often contain many sub-standard curves out of character with the surrounding environment. Therefore there was need to find out the impact of road geometry on road accidents in Bungoma and Uasin Gishu counties, and the findings can be projected to the whole country at large.

The literature review has addressed the major factors that enhance road accidents. The issues of road geometry and environmental features in Bungoma and Uasin Gishu counties had not been adequately addressed as reasons for perpetual road accidents. Hence, this study was set to identify the impact of geometry and environmental features on road accidents. The study sought to answer the question if geometry and environmental features of the road, were adequate reasons for perpetual road accidents in Kenya especially in Uasin Gishu and Bungoma counties. The study focused on finding out the relationship between road geometry, environmental features and road accident rates on roads in Uasin Gishu and Bungoma counties.

MATERIALS AND METHODS

The study was conducted in Uasin Gishu County and Bungoma Counties. It focused on roads in Uasin Gishu county, urban roads based in Eldoret Town. It further focused on roads in Bungoma County and the urban roads in Bungoma Town.

Uasin Gishu County is a county in the former Rift Valley Province of Kenya. It has a population of 894,179 as per 2010 household demographic data and covers an area of 33452 km². 50% of the population lives below the poverty line (Sindani, 2011). These highlands rise sharply from the western edge of the Rift Valley, the highest points being the Cherangany hills (3450m) and Mau summit (3090m). Between these highland masses, the level of the western highlands drops at an average of 2200m. Eldoret lies at an altitude of 2084 meters above the sea level (Cheserek *et al.*, 2012).

Bungoma County is a county in the former Western Province of Kenya. It has a total population of 1,375,063 and covers an area of 3,032.2 km². The Population density is 453.5 people per km² and 53% of the population lives below the poverty line (Statoids, 2005).

The targeted population for the study comprised, four wheeled vehicles drivers (PSV), two/ three wheeled vehicles (PSV) drivers, pedestrians in Uasin Gishu and Bungoma counties, victims of accidents in hospitals facilities in Uasin Gishu and Bungoma counties and road network in Uasin Gishu and Bungoma counties.

The study employed survey, correlation and summative evaluation research designs. This enabled the researcher to collect both qualitative and quantitative data. The objective was; determine the effects of geometry and environmental features on road accidents. Measureable indicators; curved roads, straight roads, road widths, junctions safety signs and vegetations.

The data was generated from both primary and secondary sources. For primary data, questionnaires, interview schedules and focus group discussion were used. The researcher used Convenience/Chunk sampling procedures to describe the nature and composition of motor vehicle related injuries causality in a period of 2008 - 2013. In this case, the sample is obtained by target population units. A chunk refers to that fraction of the target population being investigated which was selected neither by probability nor by judgment. The sample was obtained from readily available lists/ records from Hospitals in Uasin Gishu, Eldoret Police stations and Bungoma Police stations.

Data collection was conducted using questionnaires, interview, focus group discussions and observations. The validity of the questionnaires was ascertained using a pilot study while the reliability was ascertained using test-retest method. The questionnaires were taken personally to the selected respondents where the purpose of the study and its potential benefits to them were explained. Finally they assured that the information provided were to be used only for the purpose of the study and would be maintained in strict confidence. After familiarization, data was then collected from the respondents. The completed instruments were verified and were collected from the respondents within a period of ten days from the day of distribution.

In order to correlate road accidents rates with road design it was necessary to have, for each section of road, the precise location of each personal injury accident taking place over a given period of time, an accurate measurement of traffic flow throughout the year, basing on secondary data from traffic police and measurement of factors such as road width, horizontal and vertical curvature, surface irregularity (in those areas in Bungoma and Uasin Gishu counties).

The data collected included: Personal injuries road accidents occurring in 2008-2013, the length of road sections, the average annual daily traffic flow, the average road width (meters), the number of junctions (per kilometer), the average horizontal curvature (degrees per km), the average vertical curvature (meters per km) and Surface irregularity (millimeters per km).

From the above data, personal injuries accidents per kilometer per annum and road accidents per hundredth vehicle-kilometers were obtained.

Geometric Design Parameters

The road width was the surfaced section of the road excluding the gravel shoulders. The vertical curvature of a road can be described most easily by its 'average gradient' or their total verticals 'rise and fall'. The development of this technique allowed a high degree of accuracy to be obtained even on roads with irregular surfaces. Horizontal curvature is simply the 'bendiness' of a road. A particular bend can be defined either by the radius of curvature measured in meters or by the degree of curvature, defined as the angle in degrees between the straight sections of road which are joined by the curve. Surface irregularity is sometimes called the riding quality of the road. A method of measuring surface irregularity was developed from the principles of the 'bump integrator' in which the vertical movements of the axle of a single-wheel trailer are summed over a test section by an integrating clutch. The system that was developed provided an index of the irregularity which was useful for comparing the surface renditions of the test sections. The parameters obtained for the sections of road were used in the data analysis. An investigation was carried out on the deficiencies of the road network in Uasin Gishu with detailed inventories being made of the existing road system (secondary data). For each section of 'A' road the following parameters were obtained: Average width (meters), Gradients (per cent), Average vertical curvature (m/km), Average horizontal curvature (degrees/km), Average surface irregularity, Average sight distance (meters) and the number of junctions (per km).

Average road width was obtained by taking five measurements at equal intervals every Kilometer. The vertical curvature was obtained by measuring the elevation at every crest and hollow and accurately measuring the distances in between. Thus, as in Uasin Gishu and Bungoma Counties, the 'rise and fall' per unit length of road was obtained. The gradient was obtained using an Abney level mounted in a survey car and modified to read grade directly. In Uasin-Gishu and Bungoma Counties, the horizontal curvature was measured in terms of degree of curvature or 'bendiness' per unit length of road, but in this case, it was obtained by taking measurements from 1 : 12,500 scale land valuation maps. The average surface irregularity for each section of road was obtained by using a towed bump integrator where, as described above, the vertical movement of a wheel relative to its mounting was measured, thus providing a measure of the unevenness of the road surface. The average sight distance of each section was obtained by measuring how far ahead a driver could see an obstruction on the road. Measurements were made by putting down markers at 100 m intervals along the road and, at each marker, counting how many markers could be seen on the road ahead. Twelve-centimeter high rubber cones were used as markers. This method has the advantage of simplicity and speed. The average sight distance was calculated from the total of the numbers of cones counted in the section and the number of observations made within the section.

Data Analysis Procedure

Regression analysis was used to establish and quantify relationships between one dependent variable and one or more independent variables. In this study, four dependent variables were studied separately:

1. Personal injury in road accident per kilometer per annum Bungoma County
2. Personal injury in road accidents per kilometer per annum Uasin Gishu County
3. Personal injury in road accident per hundredth vehicle-kilometers Bungoma County
4. Personal injury in road accident per hundredth vehicle-kilometers Uasin Gishu County

The choice of independent variables implied that they were 'sensibly' related to the dependent variable.

The equations derived were of the form:

$$y = a + b_1x_1 + b_2x_2 + \dots + b_nx_n$$

Where

y = dependent variable

a = regression constant

b₁ = regression coefficient

But because most of the road design features are inter-related, simple regression analysis may give a misleading impression of the relationships that they have with road accidents rate. The multiple regressions, where the road accidents rate is expressed as a function of

several ‘independent’ variables simultaneously was a better guide; Hence, the equation derived was in the form:

$$y = a + b_1x_1 + b_2x_2 + b_3x_3 + \dots + b_nx_n$$

Where:

y = independent variable

a = regression constant

b_i = regression coefficient

x_i = dependent variable as desired number

b_n = regression coefficient as per desired number

Statistical analysis of data were done by simple regression, descriptive statistics employing the measures of central tendencies, frequency distributions, difference between a set of observed frequencies and a corresponding expected frequency.

Data for Sections on Roads in Bungoma County

Nairobi-Malaba, Bungoma-Chwele-Kitale, Bungoma-Bokoli, Kimilili-Kitale, Bungoma-Mumias, Bungoma Town Road Networks.

Data in table 1 and table 2 were collected for a period of FIVE years (secondary data), in relation to injuries at particular sections of the roads, basing on road geometry factors such as, Average road width (m), Vertical curvature m/km, Horizontal curvature deg/km, Surface Irregularity Mm/km and Junctions in Km.

Table 1. Person injury road crashes

Section No	Person injury road crashes/hundredths per- kilometers/annun	Average road width(m)	Vertical curvature m/km	Horizontal curvature deg/km	Surface Irregularity Mm/km	Junctions in Km
1	2.90	6.10	10.00	19.42	2200	0.66
2	2.14	6.10	1.34	4.59	2200	0.39
3	2.30	6.10	0	0.73	29030	1.43
4	2.79	6.10	5.2	12.54	3164	0.63
5	3.51	6.10	14.4	35.53	29086	0.43
6	1.64	6.10	14.4	40.74	2986	0.56
7	2.79	6.10	14.4	16.98	3208	0.32
8	2.64	6.10	15.0	2.08	3208	0.35
9	1.06	6.10	15.0	31.5	3203	0.12
10	2.8	6.10	14.1	1.19	3208	0.43
11	2.39	6.10	2.60	50.7	3208	0.32
12	1.85	7.10	5.55	53.79	1533	0.17
13	4.57	7.00	8.84	12.73	1533	1.94
14	1.92	7.00	5.57	4.78	1533	0.12
15	1.30	7.00	4.43	7.22	1533	0.26
16	1.51	7.00	5.03	38.90	1533	0.21
17	1.88	7.00	13.00	38.90	1533	0.31
18	1.64	7.00	1.89	10.42	1533	0.56
19	2.26	7.00	11.10	30.44	1388	0.56

Data Variation in Parameter Values

Table 2. Variations in parameter values for Bungoma County

Parameter	Maximum	Minimum	Mean	Standard Deviation
Average width(m)	7.50	6.90	6.50	0.500
Vertical curvature(m/km)	15.01	0	7.91	5.41
Horizontal curvature(deg/km)	53.80	0.72	20.0	17.33
Surface irregularity(mm/km)	3307	1487	2625	770.5
Junctions/ Km	1.94	0.11	0.49	0.460

Data for Sections of Roads in Uasin- Gishu

Nairobi-Malaba, Eldoret-Kapsabet road, Eldoret-Iten, Eldoret-Nziwa road, Eldoret-Kitale road

Data in table 3 and table 4 were collected for a period of FIVE years (secondary data), in relation to injuries at particular sections of the roads, basing on road geometry factors such as, Average road width (m), Vertical curvature m/km, Horizontal curvature deg/km, Surface Irregularity Mm/km, Junctions in Km, and Sight distance (meters)

Table 3. Person injury road crashes

Section No	Person injury road crashes/hundredth per-kilometers/ annum	Average road width(m)	Vertical curvature m/km	Horizontal curvature deg/km	Surface Irregularity Mm/km	Sight distance (meters)	Junctions in Km
1	2.10	7.30	2.43	25.40	2824.8	237.22	4.80
2a	3.00	6.90	3.27	47.70	3883.4	209.50	6.63
2b	1.90	6.10	12.41	134.41	4900.9	126.54	6.81
3a	3.70	6.10	9.29	102.86	4800.9	146.36	7.71
3b	3.70	5.80	35.93	274.16	5106.5	96.34	8.31
4a	2.50	6.20	51.36	322.42	4555.5	106.71	4.83
4b	1.30	6.70	19.10	130.62	4364.3	139.65	5.87
5a	1.00	6.30	8.93	111.12	3118.5	168.64	2.50
5b	3.00	5.60	7.56	124.66	4600.8	133.25	3.17
6	6.10	5.50	8.09	184.66	4963.6	127.760	8.18
8	2.80	6.20	11.23	19963	4253.9	122.00	5.39
9	1.60	6.40	1.77	97.95	3800.6	163.75	3.74
10y	1.90	6.50	14.73	148.32	4868.9	134.78	3.11
10z	2.20	6.60	6.08	106.71	3307.7	169.54	4.60
11y	1.80	5.90	11.31	133.04	4679.7	131.74	4.48
11z	3.40	5.20	20.94	249.63	4965.6	110.38	7.16
12	1.50	5.10	12.79	273.04	6100.0	1101.38	3.26
13y	1.90	5.40	11.50	243.48	5810.7	105.82	6.49
13z	4.00	5.10	15.68	339.57	6035.9	95.43	4.52
14y	3.00	4.10	18.89	250.75	4727.0	92.08	5.74
14z	3.20	4.10	18.89	250.75	4727.0	92.08	5.74
15	5.00	5.40	15.58	138.32	5454.4	135.69	4.41
16	2.20	5.60	29.79	368.32	4934.0	80.48	8.00
17x	1.10	6.70	8.87	161.18	4317.0	117.69	2.82
17y	0.90	7.60	22.31	38.32	2188.0	149.44	4.34
17w	1.20	6.00	39.56	423.60	6085.2	68.59	1.16
17z	3.40	5.50	29.62	346.34	6984.1	71.94	3.87
18	2.60	5.40	40.87	232.42	5942.3	96.95	2.61

Data Variation in Parameter Values Uasin-Gishu County

Table 1. Variations in parameter values for Uasin-Gishu County

Parameter	Maximum	Minimum	Mean	Standard Deviation
Average width(m)	7.5	4.96	6.0	0.68
Vertical curvature(m/km)	51.35	1.76	17.26	12.33
Horizontal curvature(deg/km)	423.6	25.3	193.4	102.86
Surface irregularity(mm/km)	6991.2	2193.0	193.4	102.86
Junctions/ Km	8.32	1.16	5.01	1.86
Average sight distance (m)	237.3	68.5	126.9	37.60

Simple Regression Analysis Results

Table 2. Simple regression analysis results Bungoma County

Independent variable	Regression Constant a'	Regression Coefficient b'	Correlation Coefficient r'	t' value	Level of Statistical significance
Average width (m)	3.9162	-0.2480	0.1502	-0.6282	Not sig at 10%
Vertical curvature (m/km)	2.2840	0.0020	0.0140	0.0600	Not sig at 10%
Horizontal Curvature (deg/Km)	1.7668	0.0266	0.5640	2.8200	Sig at 5%
Surface irregularity(mm/km)	1.1831	0.0002	0.3979	1.7903	Sig at 10%
Junctions per Kilometer	1.6849	1.2474	0.6961	4.0060	Sig at 5%

RESULTS AND DISCUSSIONS

From the analysis, equations which related road accidents per kilometer per annum to vehicle flow and road accidents per hundredth vehicle-kilometers to the geometric parameters were derived. Table 3 and 4 give the maximum, minimum and means of the parameters obtained on the roads studied in Uasin Gishu and Bungoma Counties. The standard deviation, which measures the variance about the mean, is also given.

Correlation between Number of Junctions and Number of Road Accidents

In both counties, the most significant parameter of those considered in this study was found to be the number of junctions per kilometer. The correlation between the junctions and the road accident rate was greater on the Nairobi-Malaba road and other roads in Bungoma County, than in Uasin Gishu County but as can be seen from (Table 1) the ranges were quite different in the two counties. In Bungoma where there were initially no more than two junctions per kilometer an addition of one junction per kilometer was associated with an increase in the road accidents rate of over one road accident per hundredth vehicle-kilometers.

Correlation between Road Width and Number of Road Accidents

In Uasin Gishu County 'A' roads, road width was a significant factor, the wider the road the lower the road accident rate (table 4). On the Nairobi-Malaba road, there was very little variation in the road width and the small amount of variation (table 3) did not provide a significant relationship with road accident rate.

Multiple Regression Analysis

The results obtained in the previous section show how various features of the road considered separately were related to the road accident rate. In order to determine how the combined factors are associated with the road accident rate, multiple regression analysis was carried out.

The parameters were given the following notation:

y = road accident rate per hundredth vehicle-kilometers
 x_1 = road width
 x_2 = horizontal curvature (degree)
 x_3 = surface irregularity (mm/m)
 x_4 = junction per kilometer
 x_5 = sight distance (meters)

The regression equation of factors related to the road accident rate (significant at the 5% level) in Bungoma County were as follows: $y = 1.45 + 1.02 x_5 + 0.017x_3$ (Take note that the independent variables in this equation and those below were listed in order of significance; Hence, in Bungoma county, junctions per kilometer was found to be the variable which had the greatest 'impact' on the road accident rate). Whereas other parameters were not significant at the 5% level, they were significant at the 10% level. But 5% is the level normally accepted in statistical analysis, in this study, taking into account the limitations of the data, the 10% level was considered as acceptable. The equation for Bungoma County then becomes; $y = 1.09 + 0.031x_3 + 0.62x_5 + 0.0003x_4 + 0.062x_2$

The impacts of surface irregularity and vertical curvature were less than those of junctions per kilometer and horizontal curvature. But they were important to be included; especially surface irregularity where, the improvement under consideration was the upgrading of a 'muram' road to a bituminous-surfaced road and the change in riding quality was considerable.

The multiple regression equation for Uasin Gishu County (basing on parameters significant at the 5% level) was as follows: $y = 5.77 - 0.755 x_1 + 0.275x_5$. In the equation above, road width was the variable most closely associated with the road accident rate.

It was also observed that, in Uasin Gishu County, the road accident rate was related separately to road width, junctions per kilometer and surface irregularity (based at the 5% level). But in the multiple regression analysis it was found that surface irregularity was

not significant. The reason given was that surface irregularity and road width were themselves related, the correlation between the two variables being significant at the 5% level. The most significant factor was road width; it entered the equation first and since this was closely related to surface irregularity, it also explained most of the variation associated with surface irregularity, which was found not to be significant.

Simple Regression Analysis Results for Bungoma County

In table 6, t' value is the ratio of the regression coefficient to the standard error and was used to test whether the relationship was statistically significant. That is; were unlikely to have occurred by chance. The tables indicate the relationships which were found to be significant at the 5% or 10% levels (That is to say that there is only a 5% probability that the relationship could have occurred by chance). Considering many factors affecting road accidents rates, a relationship found significant at the 10% level in this study could be considered satisfactory. The correlation coefficient r' is also given. The value r^2 provides a measure of the proportion of variability in y that is accounted for by variability in the appropriate x value. For instance in Bungoma County, junctions per kilometer was found to be the most significant independent variable. The r^2 value of 0.49 indicates that 49% of the variation in road accidents rate is explained by variation in the number of junctions per kilometer alone.

Table 6. Simple regression analysis results for Bungoma County

Independent variable	Regression Constant a'	Regression Coefficient b'	Correlation Coefficient r'	t' value	Level of Statistical significance
Average width (m)	3.9162	-0.2480	0.1502	-0.6282	Not sig at 10%
Vertical curvature(m/km)	2.2840	0.0020	0.0140	0.0600	Not sig at 10%
Horizontal Curvature (deg/Km)	1.7668	0.0266	0.5640	2.8200	Sig at 5%
Surface irregularity(mm/km)	1.1831	0.0002	0.3979	1.7903	Sig at 10%
Junctions per Kilometer	1.6849	1.2474	0.6961	4.0060	Sig at 5%

Simple Regression Analysis Results for Uasin Gishu County

In Uasin Gishu County, where there were often as many as 8 junctions per kilometer, an increase of three junctions per kilometer would increase the road accident rate by one road accident per hundredth vehicle-kilometers (table 7). On the Uasin Gishu County A' roads, road width was a significant factor, the wider the road the lower the road accident rate. On the Nairobi-Malaba road, there was very little variation in the road width and the small amount of variation.

Table 7. Simple regression analysis results for Uasin Gishu County

Independent variable	Regression Constant <u>a'</u>	Regression Coefficient <u>b'</u>	Correlation Coefficient <u>r'</u>	<u>t'</u> value	Level of Statistical significance
Av width (m)	7.6655	-0.8414	0.4802	2.8441	Sig at 5%
Vertical curvature (m/km)	2.6963	-.0030	0.0346	0.1794	Not sig at 10%
Horizontal Curvature (deg/Km)	2.3648	0.0010	0.1224	0.6403	Not sig at 10%
Surface irregularity(mm/km)	0.7745	0.00035	0.3643	2.10	Sig at 5%
Ave. sight distance (m)	3.1755	-0.0040	0.1324	0.6940	Not sig at 10%
Junctions per Kilometer	1.1080	0.3050	0.4847	2.8795	Sig at 5%

The Surface Irregularity

In both counties, the surface irregularity was related to the road accident rate; the rougher the road the higher the number of road accidents per hundredth vehicle-kilometers. In Uasin Gishu County, the relationship was statistically significant at the 5% level whereas in Bungoma County, it was significant at the 10% level. Again, in Uasin Gishu County, the range was greater than in Bungoma County. The effect of surface irregularity was very similar in both counties; an improvement in roughness of 2000 millimeters per kilometer was associated with a reduction in the road accident rate of 0.8 road accident per hundredth vehicle-kilometers per annum.

Horizontal Curvature

In Bungoma County, the horizontal curvature was found to be significantly related to the road accident rate, a decrease of 35⁰ per kilometer reducing the road accident rate by one road accident per hundredth vehicle kilometers. In Uasin Gishu County, neither horizontal curvature nor sight distance was found to be a significant factor. This is a somewhat unusual result since the range of horizontal curvature is much greater in Uasin Gishu County than it is in Bungoma County.

The Vehicle Flow and the Road Geometry Characteristics

The road accident rate per kilometer per annum was found to be significantly related to the vehicle flow whereas the rate per hundredth vehicle kilometers was found to be significantly related to the following physical characteristics of the road geometry:

- i. Junctions per kilometer
- ii. Surface irregularity
- iii. Road width.

The road accident rates in Uasin Gishu and Bungoma Counties were found to be consistently greater for similar values of vehicle flow and geometric design. The Junctions per kilometer, Surface irregularity and Road width are the major factors of the road geometry design that contribute to road accidents in Bungoma County and Uasin Gishu County.

Environment Road Net Work

The factors that facilitated the occurrence of road Accidents in Uasin Gishu / Bungoma counties according to the respondent attitudes were; wet slippery roads, fog/ mist road, muddy roads and gravel roads. The respondents had different attitudes as what indeed caused accidents. The responses were recorded as shown in the graph (figure 1).

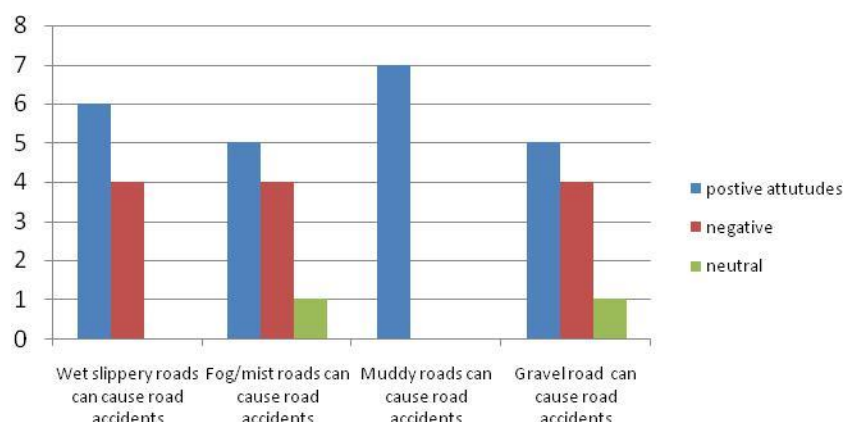


Figure 1. Environmental risk factors for road accidents

Road Geometry

The factors that facilitate the occurrence of road Accidents in Uasin Gishu / Bungoma counties according to the respondent attitudes were; straight grade road curved level roads and curved grade roads. The respondents had different attitudes as what indeed caused accidents (Where _na' represents negative attitudes and _pa' represents positive attitudes. The responses were recorded as shown in the graph (figure 2).

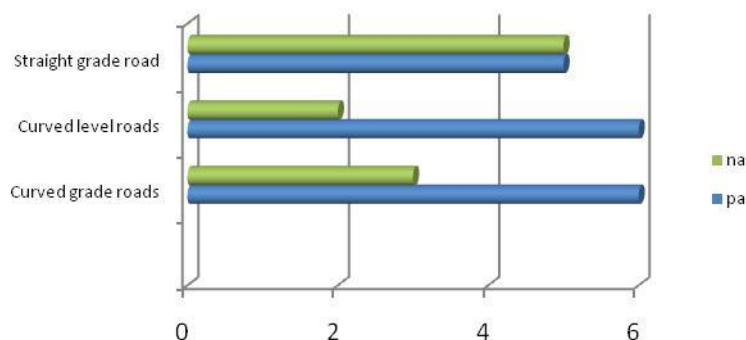


Figure 2. Environmental risk factors for road accident

DISCUSSIONS

The road accident rates in Uasin Gishu and Bungoma Counties were found to be consistently greater for similar values of vehicle flow and geometric design. From data obtained from various sources in Bungoma and Uasin Gishu Counties, it has been shown that, using multiple regression analysis to relate the Road accident rates on roads in these counties is important to certain geometrical design and characteristics of the road. In Bungoma, the road accident rate per hundredth vehicle-kilometers was significantly related to the number of junctions per kilometer, the horizontal curvature, the vertical curvature and the surface irregularity.

It was found that in Uasin Gishu County, road width and junctions per kilometers were related. The road Engineers and physical planners may wish to use these regression equations in other counties to obtain estimates of changes in road accident rate following given road improvements where traffic and road conditions are similar to those described here. Where conditions were similar to those on the Nairobi- Malaba road, the equation derived from the Bungoma county data would appear the most appropriate since same road pass through the two counties. Similarly, where there were extremes of horizontal and vertical curvature and surface irregularity the equation derived for Uasin Gishu County may be most appropriate. But there was little variation in road width on the Nairobi-Malaba road and this did not appear to be a significant parameter, whereas in Uasin Gishu County it was the most important parameter. Hence, where a road was being widened as the construction was going on; it might be difficult to decide which equation was the most appropriate equation to use particularly if conditions were similar to those on the Nairobi-Malaba road. The other factors which were involved were road users' behavior and vehicle condition and maintenance.

CONCLUSIONS

The road accident rate per kilometer per annum was found to be significantly related to the vehicle flow whereas the rate per hundredth vehicle kilometers was found to be significantly related to the following physical characteristics of the road geometry, junctions per kilometer, surface irregularity and road width. The road accident rates in Uasin Gishu and Bungoma Counties were found to be consistently greater for similar values of vehicle flow and geometric design. The Junctions per kilometer, Surface irregularity and Road width are the major factors of the road geometry design that contribute to road accidents in Bungoma and Uasin Gishu Counties.

RECOMMENDATIONS

The recommendations seek to address the Relationship between Road Geometry, Environmental Features on Road Accidents in Bungoma and Uasin Gishu Counties

- i. The junctions should have adequate safety information such as pumps, rambles, clear sign posts that warns drivers and road users that they are entering main roads.
- ii. The road designers should design roads that are wide as possible.
- iii. The surface irregularity should be removed by regular road maintenance.
- iv. The horizontal curvature should have wall protection.

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BIO-DATA

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