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EFFECT OF HIGHWAY GEOMETRIC ELEMENTS ON ACCIDENT RATE AT TWO-LANE STATE HIGHWAYS OF GUJARAT

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Abstract - *A way to improve road safety is improving road geometric design to mitigate accidents occurrence and severity on roadways. In order to improve the road design, it is crucial to establishing relationship between road geometric design elements and road accidents rate. The main aim of this study is to discuss and review the effects of geometric design elements on road accidents including statistical models and to compare the outcomes of the studies conducted. Study has tried to relate road geometric design elements such as horizontal radius, horizontal arc length, deflection angle, algebraic difference of vertical gradients and vertical curve length to accident rates. The study is conducted on three road segments from plain & rolling terrain state highways within the Gujarat state (India) territory. Multiple linear regression analysis is performed for development of the model to establish relationship between accident rates and road geometric elements.*

Key Words: *Highway Geometric Elements, Accident Rate, Horizontal Radius, Deflection Angle, Horizontal Arc Length, Vertical Curve Length, Algebraic Difference of Vertical Gradients*

1.INTRODUCTION

Road transport plays key role in economic development, trade and social integration, which depend on the movement of both people and goods. With the growing economy, the vehicular traffic transporting goods and people has increased, resulting in an increase of traffic accidents. World Health Organization (WHO) has revealed in its Global Status Report on Road Safety-2018 that the number of road traffic deaths continues to rise steadily, reaching 1.35 million in upcoming years. Hence, currently, more emphasis is given on Road Safety Audit (RSA) and its training for professional engineers. The major factors governing road accidents are, *viz.*, human, roads and vehicles. It is very important for the highway to set up a concord between the all the three parts at the design stage of a highway. With a geometrically good design, it is possible to reduce traffic accidents. Relationship between accident rates and highway geometric elements plays an important role in accessing and improving the road safety. The study is conducted on three road segments of plain and rolling terrain on two-lane highways within the area of the Gujarat state (India) territory. Geometric elements like horizontal radius, horizontal arc length, deflection angle, algebraic difference of vertical gradients and vertical curve length are analysed with accident rate.

1.1 Basic Parameters of Highway Geometry

Terrain/Topography: The classification of the terrain is done by means of cross slope of the country, i.e. slope approximately perpendicular to the center line of the highway location. To characterize variations in topography, engineers separate it into four classifications according to terrain, namely, plain terrain (with country slope less than 10%), rolling terrain (with country slope of 10-25%), mountainous terrain (with country slope of 25-60%) and steep terrain (with country slope more 60%).

Horizontal Alignment: The horizontal alignment is the route of the highway, defined as a series of horizontal tangents and curves. Horizontal curve is the curve in plan to change the direction of the center line of the highway.

Vertical Alignment: Vertical alignment is the longitudinal section of a roadway to provide easy and safe change of gradient. It is defined as a series of gradients and vertical curves. Gradient is the rate of rise or fall with respect to the horizontal along the length of a road expressed as a percentage or as a ratio or in degrees.

1.2 Accident Statistics

Profile of Road Accident: The total numbers of accidents reported by all the States/ Union Territories (UTs) in the year 2019 were 4.49 lakhs, of which 1.51 lakh people were killed and more than 4.5 lakh persons injured, many of whom are disabled for rest of their lives (Source: Ministry of Road Transport & Highways). These numbers translate into one road accident every minute and one road accident death in less than four minutes. Occurrence of accidents is observed due to type of road users, colliding vehicles, environmental/road related factors (road geometry, design, visibility etc.), vehicle related, nature of traffic management, composition and adherence/enforcement of road safety regulations. The main thrust of accident prevention and control across the world has been on Education, Enforcement, Engineering and Environment & Emergency care of accident victims.

Accident Rate: The accident rate is defined as the ratio between the number of accidents which happened in a given

year and the number of vehicles with kilometres of travels length during that same year. It is generally expressed in crashes per million vehicle-kilometres of travel.

AR=(C×10,00,00,000)/(V×365×N×L)

The variables in this equation are:

AR = Accident Rate expressed as crashes per 100 million vehicle-kms of travel (100mvkm)

C = Total number of crashes in the study period

V = Traffic volumes using Annual Average Daily Traffic (AADT)

N = Number of years of data

L = Length of the roadway in km

1.3 Objective of Study

The following are the objectives of the study:

1) To identify the accident black spots on the selected state highways.
2) To extract existing geometric elements of identified black spots.
3) To identify major attributes affecting significantly to the accidents on the identified black spots locations.
4) To develop the model for establishing relationship between accident rates and road geometric elements.
5) To validate the model using statistical techniques.

2. REVIEW OF LITERATURE

The accident rates are significantly affected by the road geometric design elements, such as design speed, horizontal and vertical curve lengths, radius, superelevation, sight distances, vertical gradients, etc., their combinations with each other and their combinations with other factors such as seasonal, land-use (rural or urban), etc. Vertical alignment's geometry elements like as algebraic different of vertical gradients, vertical curve length did not consider while study in majority of research work.

The accident rates are mainly affected by the design speed and the visibility at the blackspot location. The terrain and the geographical constraints affect the horizontal and vertical alignment of the road; thus the geometric elements cannot be provided up to the standards. This might lead to the increase in number of accidents. The cross – sectional elements also affects accident rates as the accident rates are significantly affected by number of lanes, width of lanes, width of shoulder and width of median. With the increase in the number of access points to the roadway, the possibility of occurrence of accident is more.

3. METHODOLOGY

The following is the methodology used for the research study:

1) Phase 1 (Formulation of Objectives and Literature review): In the first phase, objectives and goals are selected followed by the literature review on road geometry design elements' effect on accident rate.
2) Phase 2 (Study area selection & Data collection): This phase consists of selection of the study area and collection of required data for research work of concern study corridors.
3) Phase 3 (Data extraction and analysis): This phase includes extraction of data and analyzing the data with statistical programs.
4) Phase 4 (Model development and validation): This phase is include the development of mathematical model and its statistical validation.
5) Phase 5 (Results and Conclusions): This phase includes results analysis, conclusions and recommendations for minimizing accident rate observed in the study area.

4. DATA COLLECTION

4.1 Study Area

The following are the stretches used for the research study:

1) State Highway 55 (SH-55) – It provides the connectivity between Two National Highways in east west direction and North Gujarat to Kutch.
2) State Highway 39 (SH-39) – It provides the connectivity between Central Gujarat and Saurashtra.
3) State Highway 31 (SH-31) – It provides the connectivity between Central Gujarat and Saurashtra.

4.2 Topographic Survey

The topographic survey has been carried out with Total Station survey equipment at accident locations. Total Station is a high precision surveying equipment to carry out 3-dimensional feature of the existing road. The captured digital data has been downloaded into a CAD programme (AutoCAD) to visualize the surveying data as vector entities. This data has been analyzed later with the design execution software (MX Road) which is extensively used for highway design.

4.3 Traffic Volume

The primary objectives of traffic surveys are to determine the characteristics of traffic movement in the study corridor. To find out the annual average daily traffic (AADT), seven days traffic survey has been carried out at the respective location of the road.

4.4 Accident Data Collection and Blackspot Identification

As per Ministry of Road Transport and Highways' Circular (RW/NH/15017/109/2015/P&M-RSCE_28/10/2015), 'Road Accident Black spot is a stretch of National Highway of about 500m in which either 5 road accidents in all three years put together involving fatalities/grievous injuries took place during the last 3 calendar years or 10 fatalities took place during the last 3 calendar years.' Here, in this research

work above same definition applied for State Highways for blackspot identification.

The Accident records have been collected for 6 years (2014 to 2019) from concerned police station from their accident record books and based on them accident black spots locations identified and have been furnished in Table-1.

Table -1: Identified Blackspot Locations

Sr. No.	SH No.	Black Spots code	Existing Chainages	Accident Rate (100mvkm)
1	SH-55	SH-55-1	8/000 km	1.818
2	SH-55	SH-55-2	15/000 km	1.901
3	SH-55	SH-55-3	18/350 km	1.736
4	SH-55	SH-55-4	33/950 km	1.074
5	SH-55	SH-55-5	38/550 km	1.984
6	SH-55	SH-55-6	44/450 km	1.240
7	SH-55	SH-55-7	56/065 km	2.149
8	SH-39	SH-39-8	3/900 km	2.805
9	SH-39	SH-39-9	7/250 km	2.404
10	SH-39	SH-39-10	15/000 km	2.805
11	SH-39	SH-39-11	22/400 km	3.205
12	SH-31	SH-31-12	2/610 km	4.029
13	SH-31	SH-31-13	5/330 km	3.741
14	SH-31	SH-31-14	15/560 km	2.590
15	SH-31	SH-31-15	24/550 km	2.878

Table-2 shows the geometry of existing road at blackspot locations as mentioned in Table-1.

Table-2: Existing Road Geometry at Identified Blackspot Locations

Sr. No.	Black spot Code	R (m)	Δ (degree)	L_C (m)	VCL (m)	Δg (%)
1	SH-55-1	2000	1.25	43.6	170	0.63%
2	SH-55-2	1800	2.66	53.6	155	0.67%
3	SH-55-3	2500	0.92	40	180	0.63%
4	SH-55-4	1500	3.23	49.6	150	0.76%
5	SH-55-5	1200	4.32	50.4	140	0.70%
6	SH-55-6	900	6.19	42.3	125	0.73%
7	SH-55-7	700	8.28	31.2	110	0.83%
8	SH-39-8	1000	6.83	89.2	135	0.67%
9	SH-39-9	800	7.88	80	120	0.80%
10	SH-39-10	600	9.88	23.5	95	0.88%
11	SH-39-11	500	10.47	66.4	90	0.91%
12	SH-31-12	300	18.46	81.6	60	1.23%
13	SH-31-13	350	16.72	67.2	70	1.11%
14	SH-31-14	400	12.63	68.1	80	0.94%
15	SH-31-15	360	14.09	68.5	75	1.00%

5. ANALYSIS OF DATA AND RESULT

The extracted existing geometric elements of all identified black spots locations have been analysed with their accident rate. MX Road software used for extraction of existing geometric elements of all identified black spots locations. The relation of accident rate versus horizontal radius, deflection angle, horizontal arc length, vertical curve length and algebraic difference of vertical gradient is represented in Chart-1, Chart-2, Chart -3, Chart-4 and Chart-5, respectively.

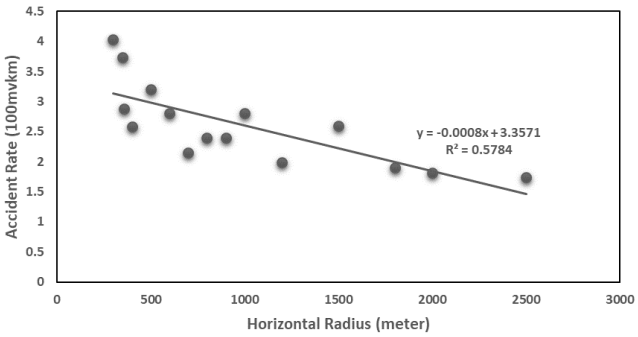

Chart-1: Accident Rate versus Horizontal Radius

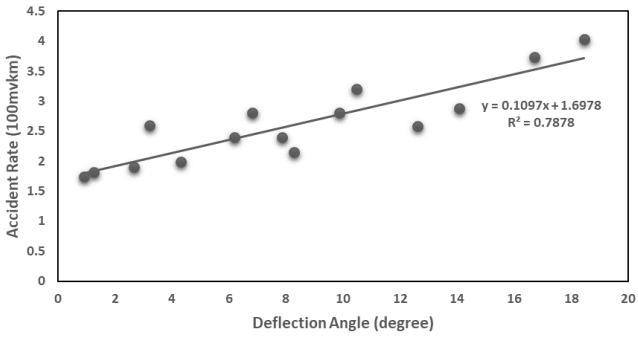

Chart-2: Accident Rate versus Deflection Angle

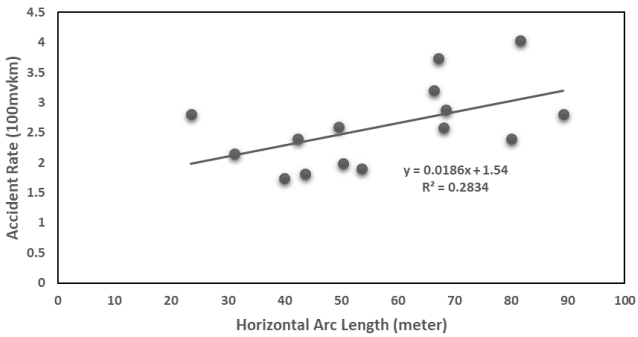

Chart-3: Accident Rate versus Horizontal Arc Length

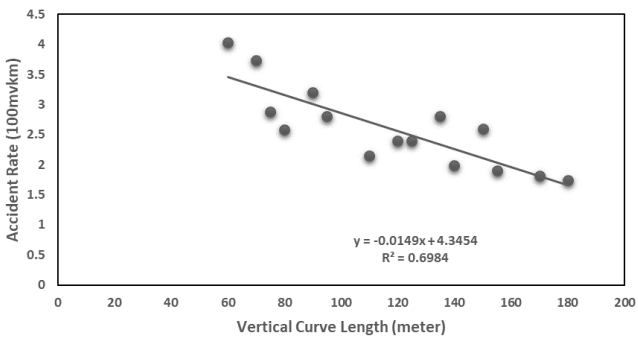

Chart-4: Accident Rate versus Vertical Curve Length

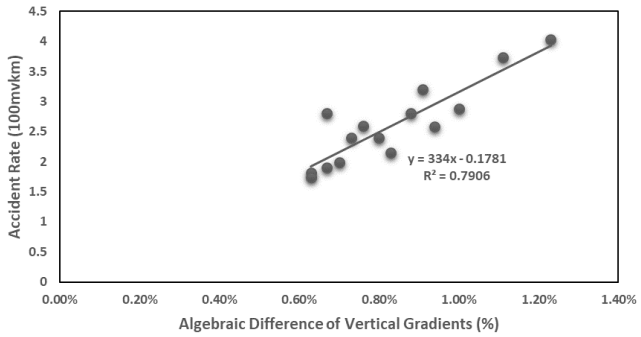

Chart-5: Accident Rate versus Algebraic Difference of Vertical Gradients

Development of Model:

The group effect of highway geometric element on accident rate has been calculated through regression model as below.

Y = 0.606(X1) – 0.667 (X2) + 0.124(X3) + 1.342(X4) + 0.971(X5)

The variables in this equation are:
Y = Accident Rate in 100mvkm
X1 = Deflection Angle in Degree
X2 = Horizontal Radius in meter
X3 = Horizontal Arc Length in meter
X4 = Vertical Curve Length in meter
X5 = Algebraic Difference of Vertical Gradients in percentage

Table -3: Summary of Regression Model

R	R^2	Adjusted R^2	Standard Error
0.923	0.852	0.769	0.3242

Validation of Model:

The model is validated using ANOVA and F-Test by using SPSS software.

Table -4: Summary of Validation of Model

Model	degree of freedom	F(observed)	F (critical)
Regression	5	10.325	3.482

The observed F value is more than F critical value at 95% significant level. Hence, it is concluded that developed model is validated and useful for finding effect of various geometric parameters on accident rate.

6. CONCLUSIONS

The main aim of the present study is to identify major attributes affecting significantly to the accidents on the plain & rolling terrain two-lane highways and to develop model to show the relationship between accident rates and highway geometric elements. In this study, a model is developed for establishing the relationship of traffic accident rate with highway geometric elements i.e., horizontal radius, deflection angle, horizontal arc length, vertical curve length, algebraic difference of vertical gradients. The present study shows that the higher accident rate occurs with decreasing horizontal radius, decreasing vertical curve length, higher deviation angle and higher algebraic difference of vertical gradients of highway alignment.

The following are the major observation of study.

1) Study shows that when the horizontal radius increases, the accident rate comparatively decreases
2) It has been observed that when the deflection angle increases, the accident rate increases.
3) It has been observed that the relationship between horizontal arc length and accident rate is quite complex.
4) Study shows that when the vertical curve length is increasing, the accident rate comparatively decreases.
5) It has been observed that when the algebraic difference of vertical gradients is increasing, the accident rate also increases.

7. RECOMMENDATION

- The identification of relation of geometric elements with accident rate might help the engineers to design new roads or redesign existing roads in a way that it leads to safety of passengers and goods.
- For the improvement of blackspot locations, bigger horizontal radius with larger deflection angle shall be provided than that of existing curves.
- Moreover, the vertical profile can be improved by providing vertical curves with longer curve length and lower algebraic difference of vertical gradients. These improvements in horizontal alignment and vertical profile would result in reduced accident rate.
- Further studies are needed to find the effects of geometrics parameter using long-term data and larger sample size on the accident analysis.
- The parameter like traffic speed, traffic volume, road surface conditions and environment aspect shall be considered with traffic accidents.
- Many developed nations started a campaign with the motto of "vision zero" that was predicted zero deaths on roads. Thus, there is so much research made on traffic accidents in developed countries. Developing countries like India need to give emphasis to research on traffic accidents. It is suggested that more importance should be given to the Road Safety issue considering all accident causing factors.

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