STUDY ON THE EFFECT OF GEOMETRIC DESIGN CONSISTENCY ON LEVEL OF SAFETY OF INTERCITY ROADS.

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Abstract: Traffic comprises vehicles with diverse static and dynamic characteristics and all such vehicles use the same right-of-way without any physical segregation. Thus, the vehicles of the said heterogeneous traffic, under high volume conditions, move on Indian roads by sharing the available road space without sufficient lateral as well as longitudinal clearances. The lane-less movement further add to the complexity of analysing/modelling heterogeneous traffic. Under heterogeneous traffic, the effect of speed reduction on vehicles of the same class and vehicles of different classes and their speed differentials along curves on road safety needs an investigation focuses on analysing the influence of geometric design characteristics on traffic safety using bi-directional data on a divided roadway operated under heterogeneous traffic conditions in India. The study was carried out on a four lane divided inter-city highway in plain and rolling terrain. Statistical modelling approach by Poisson regression and Negative binomial regression were used to assess the safety performance as occurrence of crashes are random events and to identify the influence of the geometric design variables on the crash frequency. Negative binomial regression model was found to be more suitable to identify the variables contributing to road crashes. The study enabled better understanding of the factors related to road geometrics that influence road crash frequency. The study also established that operating speed has a significant contribution to the total number of crashes. Negative binomial models are found to be appropriate to predict road crashes on divided roadways under heterogeneous traffic conditions.

Keyword: **traffic, signal, cost optimization**

I. INTRODUCTION

The objectives of geometric design are:
(i) Planning a highway network for safe, efficient and fast movement of people and goods.
(ii) Keeping the overall cost of construction and maintenance of the roads in the network to a minimum.
(iii) Planning for future development and anticipated traffic needs for a specific design period.
(iv) Phasing road development programmers' from considerations of utility and importance as also of financial resources.
(v) Evolving a financing system compatible with the cost and benefits.

To fulfil these objectives, the following principles have to be borne in mind:
(i) The proposed road links should be a part of the planned road network for the state/nation.
(ii) The importance of the road shall be based on the traffic demand, and hence its type should fall under the standard classification.
(iii) The maintenance needs of the roads should receive prompt attention by setting aside funds for this purpose.
(iv) Statutory provisions for traffic regulation should be in place.

1.3 Classification of Roads:

The classification of roads depends on the criterion considered.
They may be all-weather roads if they can be used during all seasons of a year; fair-weather roads, if traffic is interrupted during monsoon at course ways where water overflows for a few hours. Based on the type of carriage-way or the road pavement, it may be a paved road with at least a water-bound macadam layer; or it may be an unpaved road. Earth roads and gravel roads fall in this category. Superior paved roads have bituminous surface or concrete surface for the carriage-way. A bituminous road is also known as a black-top road.
Traffic volume, load transported per day, and the location and function are important criteria for classification of roads. These criteria have been taken into account in the classification recommended by the Nagpur Plan—NH, SH, MDR, ODR and VR, as also in the one modified by the Lucknow Plan—with categories of Primary, Secondary and Tertiary roads.

Urban roads are classified based on their function and location:
(i) Expressways— for movement of heavy volume of traffic.
(ii) Arterial streets—for connecting the central area to expressways.
(iii) Sub-arterial streets—similar to arterial roads but with less spacing.
(iv) Collector streets—for collection and distribution of traffic through local streets in residential areas.
(v) Local streets—to access private property like residences, shops and industries. Traffic originates here or ends here.

a)

Geometric design of highway is the determination of layout and features visible on highway. The emphasis is more on satisfying the need of the driver as well as to ensure the safety of the vehicle, the comfort while driving and efficiency. Other related factors are also considered based on the project.

The main features considered for geometric design of highway are:

- Cross section elements
- The gradient
- The intersection
- The consideration of sight distance

The geometric design of highway is influenced by:

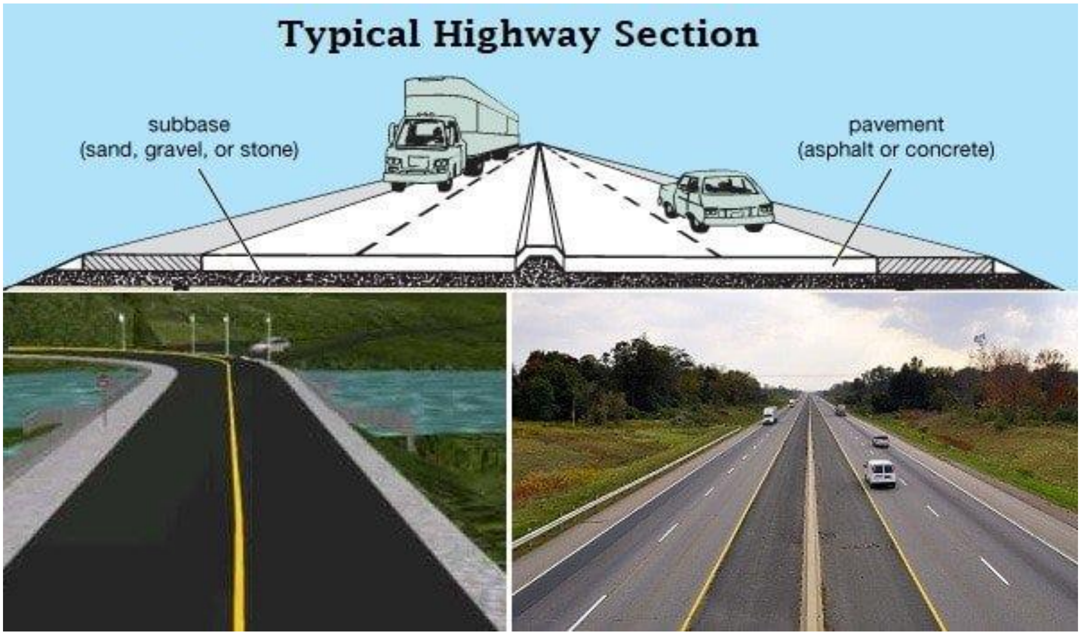
- The characteristics of the vehicle
- The behaviour of the driver

Traffic characteristics

- Traffic Volume
- Traffic Speed

Severity of movement and accidents can be reduced largely by implementing a proper design. The main objective of geometric design is to get optimum efficiency in the traffic operation period and maximum safety.

All these features must be attained with maximum economy in the cost and construction. Unlike the construction of pavement, the planning process is carried out in advance.



B. 1.2 Factors Affecting the Geometric Design of Highways

The various factors that govern the geometric design of highways are:

- The Design Speed
- The topography factors
- Other Factors

1)
2) 1.4.1 Design Speed of Highways

The most important factor affecting the geometric design of the highway is the design speed. The design speed parameter affects the:

- Length of the vertical curves
- The horizontal curves
- The sight distances

Speed is a parameter that has huge variation will the person driving, the vehicle type, the topography etc. This is the reason why the design speed is taken as a primary factor in the geometric design of highways.

The highest continuous speed, given that the weather conditions are conducive, to facilitate safety travelling of the vehicles is called as the design speed. Legal speed is different from the design speed. The legal speed is the speed at which the drivers tend to travel beyond a safe speed. Desired speed is the maximum speed at which the driver can travel when they are constrained by means of a local geometry or traffic.

As mentioned before, speed is a factor that brings variations of different types. This requires having different vehicle design speeds to satisfy the requirement of all vehicle drivers. So, by standard: 85^{th} percentile design speed is the normally adopted design speed.

85^{th} percentile design speed can be defined as the speed which is higher than speed taken by 85% of the drivers on that road. For some countries this value will be in the range of 95 to 98 percentile speed.

3) 1.4.2 Topography Factors

Second important factor that affects the geometric design is the topography. For a plain terrain, it is very easy to construct the highway as per the standards. As the terrain and the gradient increases the construction cost will increase for a specific design speed.

So, to keep the construction cost and time under control, the geometric standards vary with different terrain or topography. This is hence classified as steeper gradients and sharper curves.[1]

1.4.3 Other factors affecting geometric design :

In addition to design speed and topography, there are various other factors that affect the geometric design and they are briefly discussed below:

Vehicle:

The dimensions, weight of the axle and operating characteristics of a vehicle influence the design aspects such as width of the pavement, radii of the curve, clearances, parking geometrics etc. A design vehicle which has standard weight, dimensions and operating characteristics are used to establish highway design controls to accommodate vehicles of a designated type.

Human:

The important human factors that influence geometric design are the physical, mental and psychological characteristics of the driver and pedestrians like the reaction time.

Traffic:

It will be uneconomical to design the road for peak traffic flow. Therefore a reasonable value of traffic volume is selected as the design hourly volume which is determined from the various traffic data collected. The geometric design is thus based on this design volume, capacity etc.

Environmental:

Factors like air pollution, noise pollution etc. should be given due consideration in the geometric design of roads.

Economy: The design adopted should be economical as far as possible. It should match with the funds allotted for capital cost and maintenance cost.

Others: Geometric design should be such that the aesthetics of the region is not affected.[2] Large variety of vehicles is now made which range from tiny to massive units. The weight of the axle, the dimensions of the car and the characteristics of the vehicle influence greatly the design aspects. The design aspects involve the pavement width, the clearances, the radii of curve and the parking geometrics. To facilitate this requirement, a design vehicle is set which own a standard weight, operating characteristics, and dimension. This helps to establish a design controls so that vehicle of designated type is accommodated. The physical, mental and psychological characteristics of the human affect greatly the geometric design of the highway.

PROPOSED METHODOLOGY

STEP 1: Development of Safety Performance Functions To evaluate the relationship between roadway safety and the consistency of geometric elements, regression models were developed to test the significance between crash frequency and the geometric parameters provided in the dataset.

STEP 2: By forming roadway segments and utilizing multiple years of crash data, these relationships represent safety performance functions (SPFs) for the roadway classification(s) used in the study. The Highway Safety Manual (HSM) offers methods to calibrate generic SPFs to a particular location; however, given the extensive data set obtained, the development of jurisdiction-specific (Washington) safety performance functions may lead to a more effective method for modelling the subject at hand.

STEP 3: established the appropriateness of using count regression methods to model crash frequency; and hence, these methods have become a standard technique for the creation of most safety performance functions. Count regression was, therefore, investigated in this study. Given the typically over dispersed nature of crash data, negative binomial models may be the most appropriate distribution, as Poisson distributions constrain the mean and variance to be equal. Both count distributions are investigated; however, the over dispersion parameters in the preliminary models indicate that the crash frequency data are indeed over dispersed.

STEP 4: Since the crash data also contains observations from the same segments over multiple years, it is important to account for the heterogeneity of each individual segment. One method to account for this would be to develop cross-sectional time-series or longitudinal data (i.e., panel data). Panel data groups individual observations from the 35 same locations across time, which helps correct for the omitted time series variables that influence.

RESULT AND ANALYSIS

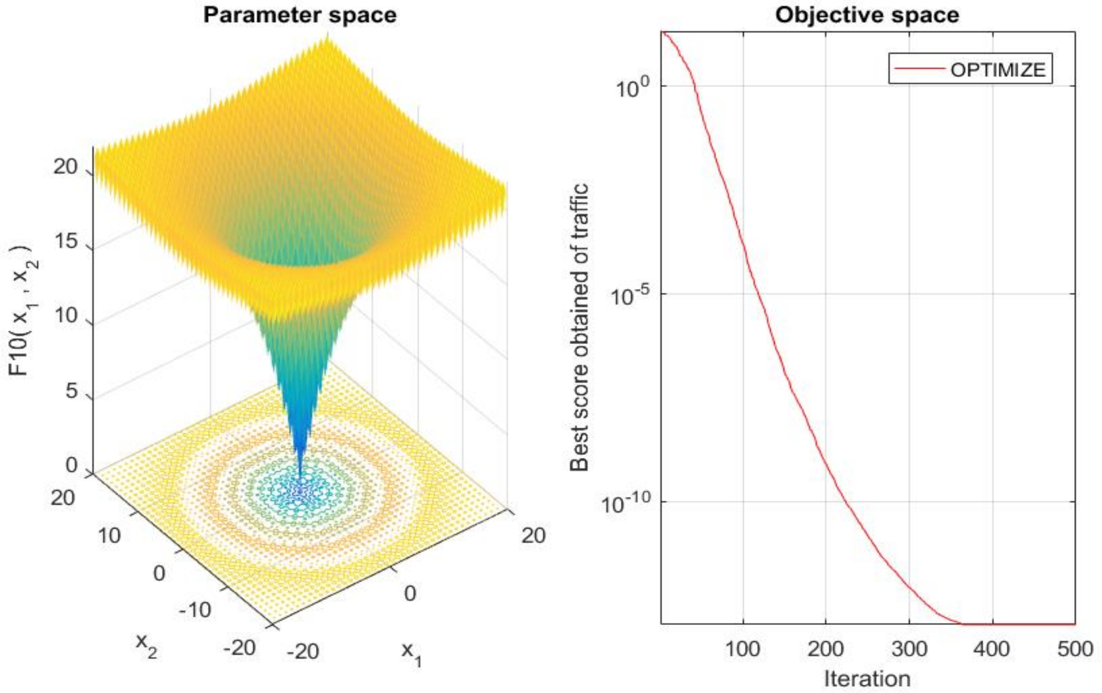


Fig 5.1 optimization process on traffic flow and geometry

In fig 5.1 to 5.4 show the different road network at simulate environment. These map analyses by proposed regression base optimization approach and existing prediction base approach. In fig 5.5 analysis of safety parameters converge by cost parameters. So reduce these parameters indicate reduce cost and high show improve

Traffic flow (numbers/hr.)	Safety cost (proposed)	Pavement cost(existing)
50	1.243333333	1.136666667
100	1.33	1.183333333
150	1.376666667	1.236666667
200	1.3	1.153333333
250	0.966666667	0.82
300	0.743333333	0.56
350	0.643333333	0.43
400	0.7	0.496666667
450	0.715	0.52
500	0.73	0.54

Table 5.1 optimization process on cost traffic flow and safety

Table 5.1 compares the existing and proposed cost parameters prediction. In prediction it does not improve in different iterations of different traffic flow but proposed approach improves in all iterations of different traffic types. In these results take average of all maps of different approaches but different flow indicates different tests of proposed approach which is shown in table 5.1 and fig 5.4.

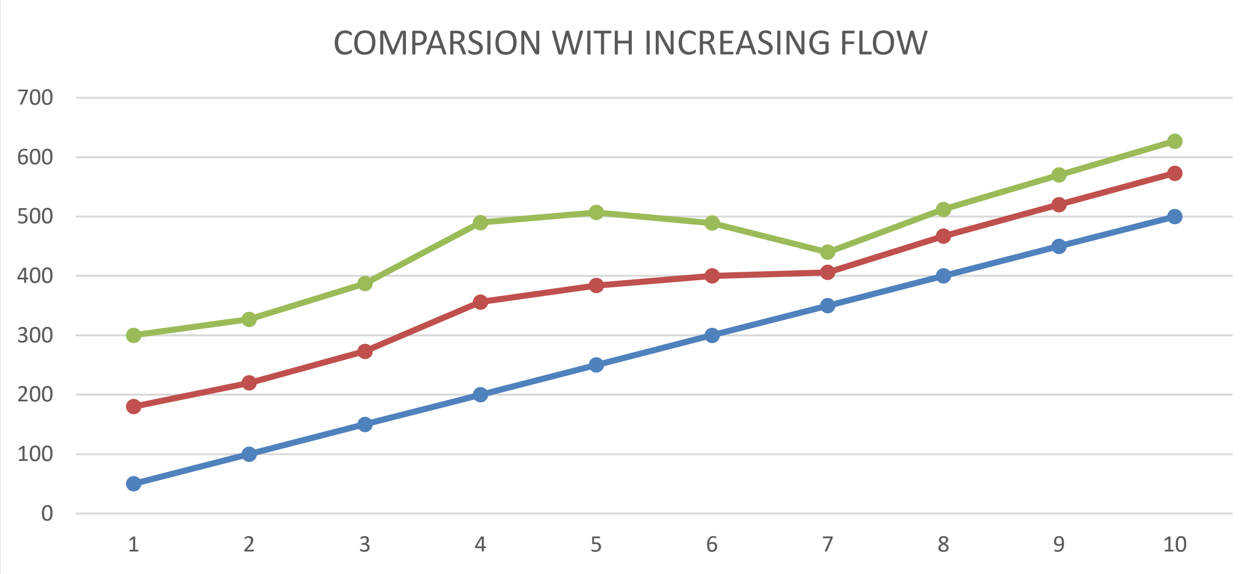


Fig 5.2 optimization process on cost traffic flow and safety

Table 5 compares the existing and proposed cost parameters prediction. In prediction it does not improve in different iterations of different traffic flow but proposed approach improves in all iterations of different traffic types. In these results take average of all maps of different approaches but different flow indicates different tests of proposed approach which is shown in table 5.2 and fig 5.6.

Traffic Iteration	Regression cost(a=0.4)	Regression cost(a=0.6)	Regression cost(a=0.8)	Regression cost(a=1)
50	125	125	113.5	121.166667
100	121.5	113.5	110.5	115.166667
150	139.5	118.5	124	127.333333
200	145	145	128.5	139.5
250	117	128.5	106	117.166667
300	78	94.5	61.5	78
350	61.5	45	39.5	48.6666667
400	68.5	56	47.5	57.3333333
450	71.5	60	52	61.1666667
500	73	63.5	54	63.5

Table 5.2 optimization process on regression cost traffic flow and pavement

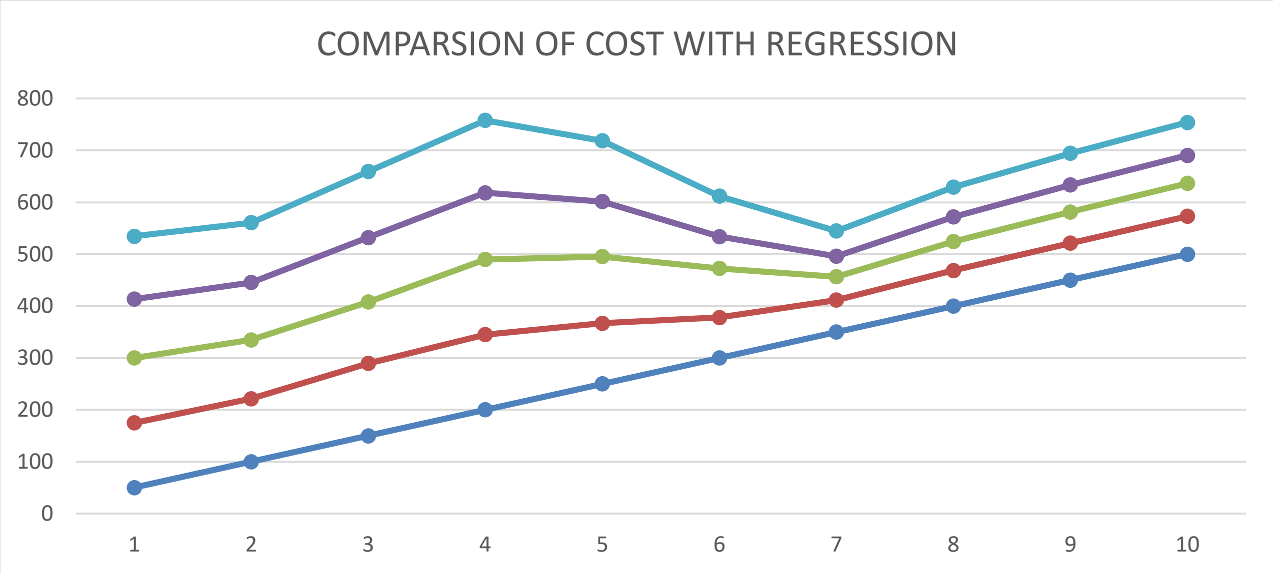


Fig 5.3 optimization process on regression cost traffic flow and safety

III. CONCLUSION

The influence of geometric design characteristics on the level of safety on a four-lane divided intercity roadway in India, operated under heterogeneous traffic condition was studied. Bi-directional data were used for developing models by statistical modelling approach. Poisson and NB regression models were developed for both year-wise and direction-wise. Based on the developed models, the following conclusions are drawn. Geometric characteristics were observed to vary for both directions of travel. These variations affect the traffic characteristics thereby decreasing the level of safety, resulting in more crashes.

Operating speed, access point, median opening and horizontal curvatures (inverse radius) are identified as the significant factors influencing road crashes in a divided highway under heterogeneous traffic using the same carriageway. It is found that a 10 km/h increase in operating speed increases the crash rate by 40% and a 0.1/km decrease in horizontal curvature reduces the crash rate by 1.40% only. The study resulted in a better understanding of the effect of geometric design characteristics on crash frequency and observed that operating speed contributes significantly to the number of crashes. The study recommends that the value of horizontal curvature, one of the main highway design characteristics, should be kept minimum as much as possible from the safety point of view. This will lead to maintaining safe operating speed along the highway. The developed negative binomial regression models may be suitable for analysing the level of safety on divided roadways operated under heterogeneous traffic.

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