HIGHWAY ACCIDENT MODELING INFLUENCE OF GEOMETRICS

[1] **Surendra .Bajaru** [2] **Thejeshwar Nandimedala** [3]**Meher Manikanta Tripati Chunduri**
[1]B-Tech Civil Engineering, GITAM Institute of Technology, GITAM (Deemed to be University), Visakhapatnam
[2]B-Tech Civil Engineering, GITAM Institute of Technology, GITAM (Deemed to be University), Visakhapatnam
[3]B-Tech Civil Engineering, GITAM Institute of Technology, GITAM (Deemed to be University), Visakhapatnam

ABSTRACT: Road safety is an issue of prime importance in all motorized countries. The road accident results a serious social and economic problems. Studies focused on geometric design and safety aim to improve highway design and to eliminate hazardous locations. The effects of design elements such as horizontal and vertical curves, lane width, shoulder width, super elevation, median width, curve radius, sight distance, etc. on safety have been studied. The relationship between geometric design elements and accident rates is complex and not fully understood. Relatively little information is available on relationships between geometric design elements and accident rates. Although it has been clearly shown that very restrictive geometric elements such as very short sight distances or sharp horizontal curve result a considerably higher accident rates and that certain combinations of elements cause an unusually severe accident problem. In this paper, road geometric design elements and characteristics are taken into consideration, and explanations are given on how to which extent they affect highway safety.

I.INTRODUCTION

Motor vehicle accidents kill about 1.2 million people in a year world-wide and the number will grow to more than 2 million in 2020 unless steps are taken; a study released by the World Health Organization (WHO) and the World Bank. [Washington: Article-Traffic accidents becoming one of world's great killers, By Matthew Wald ,April 8, 2004]. Any design solution mitigating this kind of individual human behavior cannot be predicted, only some safety rules can be enforced. Also, vehicle factors ,related to mechanical behavior of vehicles are not the scope of civil engineering study. Hence, road factors are only considered as part of this study. It is very important for the highway to establish a harmony between all the three factors at the design stage of a highway. With a geometrically good design, it is possible to compensate for the other factors and thus decrease the number of traffic accidents.

Basic Parameters of Highway Geometric

1.3.1 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 as listed in Table 1.1

Table 1.1: Terrain Classifications

Terrain Classification	Cross slope of country (%)
Plain	Less than 10
Rolling	Greater than 10 up to 25
Mountainous	Greater than 25 up to 60
Steep	Greater than 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. The geometries of horizontal alignment are based on an appropriate relationship between design speed and curvature and on their joint relationship with super elevation and side friction. Typical horizontal curve furnished in figure 1.1as per Indian Road Congress (IRC) guidelines (IRC: 38-1988 & IRC: 73-1980)

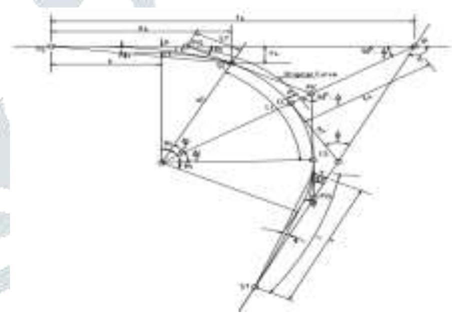

Figure 1.1: Typical Horizontal Curve

Where : Total deflection angle L : Total length of curve
IP : Intersection point of tangents ST : Short tangent
RC : Radius of circular curve LT : Long tangent
LS : Length of spiral curve Ts : Total tangent distance
LC : Length of circular curve Es : External distance

II. LITERATURE REVIEW

The study is an effective traffic accident modeling in minimizing the accident rates depending on road factors and finding the impact of highway geometric elements. Hence, a literature survey was carried out in the field of accident causative factors and accident prediction and optimization modeling and presented as below.

2.1 Accident Causative Factors Overview

Feng-Bor Lin (1990) studied on flattening of horizontal curve on rural two lane highways and found that horizontal curves on highways are on average more hazardous than tangent sections. As their curvatures increase, horizontal curves tend to have higher accident rates. He suggests that the differences between the 85th percentile speeds and the safe speeds have no statistically significant relationships with the accident rates. In contrast, the magnitudes of speed reduction, when vehicle moves from a tangent section to a curve, have a significant impact on traffic safety. Such speed reductions on horizontal curve with gentle grades are strongly correlated with the curvatures of the curves. Therefore, curvatures can be used as a safety indicator of the curves.

III. MATERIALS AND METHODOLOGY

Accident analysis has been carried out in order to determine the effects of different geometric elements of the highway with accident rate of the same highway. These geometric elements are horizontal radius, deflection angle, horizontal arc length, super elevation, rate of change of super elevation, vertical gradient, vertical curve length, K-value and visibility/sight distance. Finally, these geometric elements are statistically analyzed and considered for model development which are statistically significant.

4.2 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 kilometers of travels length during that same year. It is generally expressed in crashes per million vehicle-kilometers of travel

$$AR = \frac{C \times 100{,}000{,}000}{V \times 365 \times N \times L}$$

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

4.3 Analysis of Geometric Variables

The existing geometric elements of highway has been analyzed with accident rate of the same highway. Also, the variables are grouped with same manner as per highway terrain condition.

4.3.1 Analysis of Accident Rate versus Horizontal Radius

Total number of accidents has been counted within appropriate range of radius and then, the accident rate has been calculated as illustrated in Appendix-4.1and same has been plotted in Figure 4.1.

Variables	NH-22	NH-23	NH-87	NH-200
C	58	165	62	54
V	2108	5039	2300	2417
N	3	3	3	3
L	100	66.5	70	60
AR	**25.13**	**44.97**	**35.17**	**34.01**

RESULTS AND DISCUSSION

Cross Section Determination

The Flow Chart showed in Figure 4.1 details a procedure to help determine the most appropriate cross section to be used. References to other relevant sections of the Manual are given for assistance.

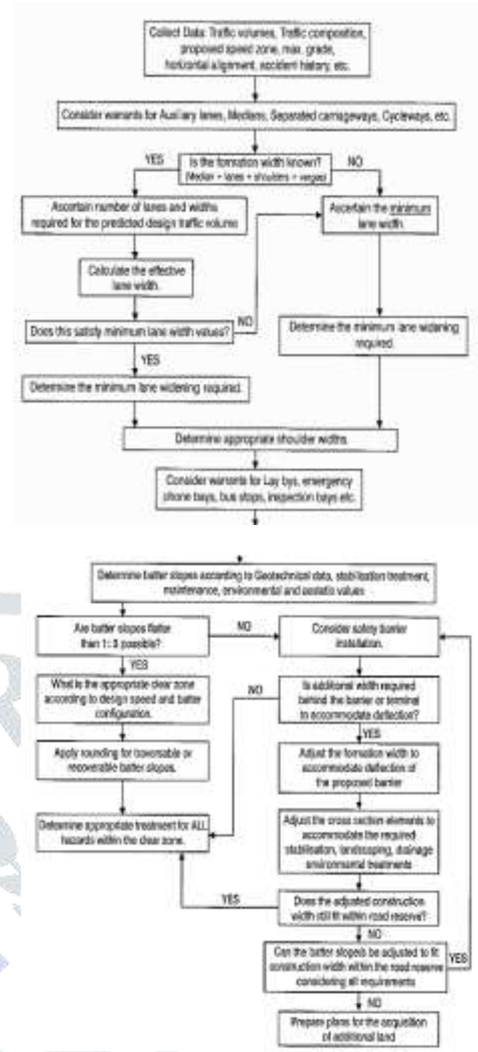

Figure 4.1: Cross Section Determination Flow Chart

Minimum Seal Widths for State Highways

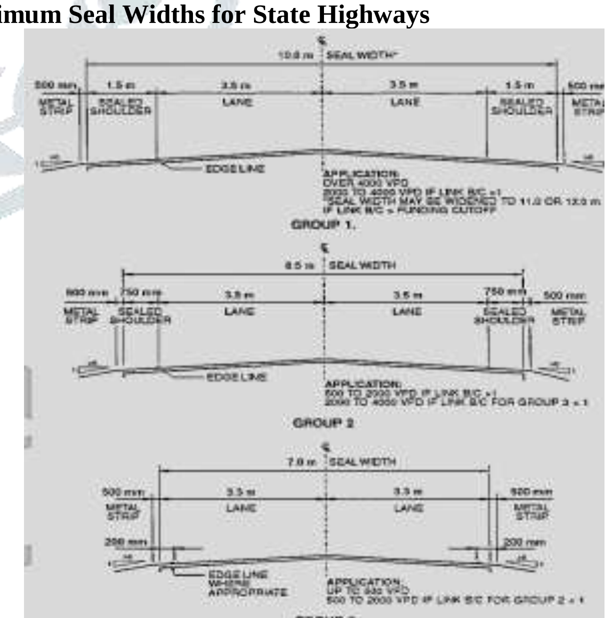

Figure 4.2: Minimum State Highway Sealed Widths

A traffic lane is that part of a roadway reserved for the norm alone way movement of a single stream of vehicles. Traffic lanes provide a variety of functions important to the overall efficient function of the road hierarchy, such as:

• through road,
• special - bus, transit, etc.,
• auxiliary (turning or overtaking),
• parking,
• cycling.

Traffic lane width is normally determined after consideration of the road's annual average daily traffic (AADT) and peak hour traffic volumes, where relevant. Vehicle dimensions and the combination of speed and traffic volume should also be taken into account.

Lane width and road surface condition have a substantial influence on the safety and comfort of road users. In rural areas the additional costs incurred in providing wider lanes can be partially offset by the reduction in long term pavement maintenance costs resulting from heavy vehicle wear in the vicinity of the pavement edge on narrow lane roads.

Narrow lanes also force vehicles to travel laterally closer tone another than their drivers are normally comfortable with, particularly at higher travel speeds.

Drivers also tend to reduce their travel speed, or shift closer to the centre of the lane/road, or both, when they perceive hazardous object is too close to either the nearside or offside of their vehicle. The most common driver reaction to this type of hazard is, however, a movement of their vehicle away from the hazard. The offset of a fixed hazard from the edge of the traffic lane beyond which this reaction is not observed is termed the 'Shy Line'. The shy line is normally taken as the distance from the edge of the traffic lane to the outer edge of shoulder, or the distance shown in Table 4.1, whichever is the greater.

Design or 85th Percentile Speed (km/h)	Shy Line Offset (m)	
	Nearside (Left)	Offside (Right)
≤ 70	1.5	1.0
80	2.0	1.0
90	2.5	1.5
≥ 100	3.0	2.0

Table 4.1: Shy Line Offsets

Reductions in lane width reduces the lateral clearance between vehicles and also to fixed obstacles. This leads to reduced travel speed and lane capacity and Tables 4.2 and 4.3 show the reduction in lane capacity caused by a fixed hazard close to the road.

Clearance to fixed obstacle close to the road	Lane Capacity (% of 3.5m lane capacity)			
	3.5 m lane	3.3 m lane	3.0 m lane	2.7 m lane
1.8	100	93	84	70
1.2	92	85	77	65
0.6	81	75	68	57
0.0	70	65	58	49

Table 4.2: Two-lane Two-way Road Lane Capacity

Clearance to fixed obstacle close to the road	Lane Capacity (% of 3.5m lane capacity)			
	3.5 m lane	3.3 m lane	3.0 m lane	2.7 m lane
1.8	100	95	89	77
1.2	98	94	88	76
0.6	95	92	86	75
0.0	88	85	80	70

Table 4.3: Four-lane Dual Carriageway Road Lane Capacity

Urban Roads

The desirable state highway traffic lane width in urban areas is 3.5 m. Where the road reserve width is restricted, lane width(s) may, with Standards and Strategy Manager approval, be reduced.

The differing functions and uses of each lane must be taken into account when 'squeezing' an extra lane from an existing or partially widened road formation, or fitting the required number of lanes into the space available, is necessary. Lane widths must be allocated on an equitable basis in these situations and the widths varied in 0.1 m increments from the desired 3.5 m to a minimum of 3.0 m, with the following provisions:

• On Straight Alignments: 3.1 m is the minimum width for a lane. All other lanes must be at least 3.0 m wide.
• On Curved Alignments: Widening in accordance with Table 4.5 must be applied.

Normal Lane Width (m)	Radius (m)	Widening (m per lane)
3.5	60 - 100	0.6
	100 - 150	0.3
3.0 to 3.4	60 - 100	0.9
	100 - 150	0.6
	150 - 300	0.4
	300 - 450	0.3

Table 4.5: Lane Widening on Curves in Urban Areas

It is desirable to locate a barrier kerb at least 0.5 m clear of the edge of the adjacent traffic lane, to compensate for a driver’s tendency to shy away from them. Usually, the width of the channel will provide an adequate clearance.

Where over-dimension vehicles use the road, e.g. heavy haulage by-passes, wharf access routes, etc, allowance must to be made for the size of these vehicles and their tracking characteristics. The local heavy vehicle operators must be consulted and a suitable design vehicle developed for these routes.

4.2.5 Bus Routes

The desirable lane width for a bus route on new construction projects is 3.5. The minimum width is 3.0 m. On existing roads the following conditions apply:

(a) Kerb side lanes used by buses should not be marked less than 3.0 m wide, as measured from the face of the kerb. Where a lane has to be 3.0 m or less in width the kerb side lane should be made wider than the adjacent lanes, to offset the effects of drivers shying

away from kerbs, channels, power poles and other roadside structures.
(b) Site specific measures to mitigate the effects of narrow lanes should be investigated. These include parking restrictions, median width variations, indented bus bays ,etc.
(c) The appropriate bus operator must be consulted during the planning stages to ensure that the road design proposed is acceptable to them.

4.2.6 Auxiliary Lanes

Auxiliary lanes, other than parking and turning lanes, should have the same width as the adjacent through traffic lanes

4.2.7 Parking Lanes

(a) Parking lanes are not normally provided on rural roads but provision for parking should be made at rest areas and lay by's.
(b) It is normal practice to provide parking lanes on urban roads and.

The provision of parking lanes on urban roads, where they often serve the function of a shoulder, is determined mainly by the operational requirements of the road. These are described briefly below:

• **Major Routes - Single Purpose**: Limited access urban routes and urban motorways which cater for moving traffic and only the occasional stop. Design parameters are similar to those of rural roads, shoulders are normally provided and the rural cross section forms are acceptable. Parking is not an issue other than providing for the occasional stopped vehicle, e.g. broken down, fatigue stop, etc.

• **Major Routes - Mixed Purpose**: These form the bulk of major urban routes. They normally have frontage development and have to cater for site access movements, parked vehicles, the parking and un-parking of these vehicles as well as moving traffic. Their design principles differ from those of rural roads and their cross sections usually include parking lanes, which often serve the function of shoulders, in addition to the traffic lanes.

• **Local Access Roads**: The main design controls for these types of road are property access, property drainage and the width between kerbs. Providing for parked vehicles is also an important factor.

• **Frontage / Service Roads**: These are not really a separate road class and they may be either local access or mixed purpose roads. The lowest class of service road provides only local access, e.g. residential access, industrial development, shopping centers, etc.
On urban corridors in large cities they can eventually carry significant proportions of through traffic. As the through traffic component of a service road increases there is tendency for fewer connections to the rest of the street system and in these cases service roads tend to provide a mixed function service with increasing importance given to other than local access traffic. They can eventually become arterial / collector roads in their own right.

(c) Lane Width

• An exclusive parallel parking lane should have a minimum width of 2.5 m. Where kerb and channel is used the width of the channel may be included in this width, although this is not a desirable practice. This minimum width should only be used in situations where there is no likelihood of the lane being required for traffic purposes in the future and the reduced capacity of the road produced by this arrangement is inadequate for the traffic volumes expected.
• A parallel parking lane which is used as a travel lane during peak times should have the same width as a normal traffic lane, i.e. desirably 3.5 m and 3.0 m minimum, as measured to the lip at the channel.
• Shared parallel parking and traffic lanes should be at least 5.5 m wide, i.e. 3.5 m traffic lane plus 2.0 m, as measured to the lip of the channel, parking lane. This is the borderline between acceptable and difficult traffic operations.
• In areas where frequent parking is combined with reasonable arterial traffic volumes all spare width should be put into the outer traffic lane/parking lane combination as this is where most of the 'side friction' occurs. This situation occurs mainly in suburban shopping/business areas on arterial roads. where speeds tend to be slower and there is merit in reducing the through traffic lane widths to obtain this additional space.

V.CONCLUSION

After reviewing on the many studies which are related the safety of cross-section and alignment elements can be concluded the following:
●The presence of a median has the effect of reducing specific types of accidents, such as head-on collisions. Medians, particularly with barriers, reduce the severity of accidents
●Rates of ROR and OD accidents decrease with increasing lane and shoulder width. However, the marginal effect of lane and shoulder width increments is diminished as either the base lane width or shoulder width increases.
●On multilane roads, the more lanes that are provided in the traveled way, the lower the accident rates.
●Shoulder wider than 2.5m give little additional safety. As the median shoulder width increase, accidents increase.
●From the limited information available, it appears that climbing lanes can significantly reduce accident rates.
●Lane width has a greater effect on accident rates than shoulder width.
●Horizontal curves are more dangerous when combined with gradients and surfaces with low coefficients of friction. Horizontal curves have higher crash rates than straight sections of similar length and traffic composition; this difference becomes apparent at radii less than 1000 m.

VI. REFERENCES

Highway accident modeling influence of Geometrics

Surendra .Bajaru

Thejeshwar Nandimedala

Meher Manikanta Tripati Chunduri

REFERENCES

1] Douglas, W., Joseoh, E., and Kelth, K., "Operational and Safety Effects of Highway Geometrics at the Turn of the Millennium and Beyond ", TRB, National Research Council, Washington, D.C, 2000.

[2] Lamm, R., Psarianos, B., Choueiri,E.M., and Soilemezoglou, G., "A Practical Safety Approach to Highway Geometric Design International Case Studies: Germany, Greece,Lebanan, and The United States ", Transportation Research Record, 1994.

[3] Deo, Chimba, "Evaluation of Geometric and Traffic Characteristics Affecting The Safety of Six-Lane Divided Roadways", M.Sc., The Florida State University College of Engineering,2004.

[4] Department of Transportation, "Safety Handbook for Secondary Roads", USA, 2007.

[5] O'Cinneide, D., "The Relationship between Geometric Design Standards and Safety", University of College-Cork, 1995.

[6] Finch, D.J. etal., "Speed, Speed Limits and Accidents", PR58, Transportation Research Laboratory, Growthorne, 1994.

[6] Fieldwick, P.T., and R.J., Brown, "The Effect of speed Limits on Road Casualties, Traffic Engineering and Control,1987.

[8] O'Cinneide, D., Mcauliffe, N., and O'Dwyer, D., "Comparison of Road Design Standards and Operational Regulations in EC and EFTA Countries, Deliverable 8, EU DRINE II Project2002, 1993.

[9] A.F. Lyinam, S. Lyinam, and M.Ergun, "Analysis of Relationship between Highway Safety and Road Geometric Design Elements: Turkish Case", Technical University of Istanbul, Faculty of Civil Engineering, Turkey.

[10] Jerry, Pigman, John, S., Wendel, R., and Dominique, L., "Impact of Shoulder Width and Median Width on Safety" , NCHRP Report 633, Transportation Research Board of The National Academies, Washington, D.C, 2009.

[11] Hearne, R., "Selected Geometric Elements and Accident Densities on the Network", Environmental Research Unit, Dublin, 1976.

[12] Hedman, K.o., "Road Design and Safety ", Proceedings of Strategic Highway Research Program and Traffic Safety on Two continents", Gothenburg, VTI Report 315 A, 1990.

[13] Zegeer, Deen, and Mayes, " Effect of lane and Shoulder Widths on Accident Reduction on Rural Two-lane Roads" , Transportation Research Board 806, P.P 33-34, Washington, D.C.,USA, 1981.

[14] Zegeer, and Council, "Highway Design, Highway Safety and Human Factors", Transportation Research Circular 414, P.P 20-34, Transportation Research Board. Washington, D.C., USA, 1993.

[15] Mclean, J.R., "Accident-Width Relationship for Single-Carriageway Rural Roads", Australian Road Research 15(4), P.P 271-275, Australia, 1985