International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue 10
September 2017

Geometric Features of Accident Rate in Highways

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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. The relationship between safety and road geometric design are examined through results of studies mad in different countries and it compares the results of studies in different countries and summarizes current international knowledge of relationship between safety and the principal non-intersection geometric design parameters. In general, there is broad international agreement on these relationships.*

INTRODUCTION:

Geometric design elements play an important role in defining the traffic operational efficiency of any roadway. Key geometric design elements that influence traffic operations include number and width of lanes, the presence and widths of shoulders and highway medians, and the horizontal and vertical alignment of the highway Generally speaking, any evaluation of road safety, such as in the driving.

Dynamicfield has been conducted more or less qualitatively. It is safe to say, from a traffic safety point view, that no one is able to say with great certainty, or prove by measure or number, where traffic accidents could occur or where accident black spots could develop however, everyone agrees that there exists a relationship between traffic safety and geometric design consistency. By all means, alignment consistency represents a key issue in modern highway geometric design. A consistency alignment would allow most drivers to operate safety at their desired speed along the entire alignment. However, existing design speed-based alignment policies permit the selection of a design speed that is less than the desired speeds of majority of drivers Much of the research in highway safety has focused on different factors which affect roadway safety. The factors are categorized as traffic characteristics, road geometrics, road surface condition, weather and human factors. Previous research has shown that geometric design inconsistencies, operations (traffic mix, volume, and speed), environment, and driver behavior are the common causes of accidents. Most of the studies have shown the influence of various geometric design variables on the occurrence of accidents and have concluded that not all variables have the same level of influence in all places From the relation of factor mentioned above, different researchers have developed the relationship of roadway safety in terms of crash frequency and crash rates, fatality and injury rates and the road elements, traffic characteristics, and pavement conditions. Many of these previous studies investigated the relationship of crash rates or frequency in terms number of lanes, lane width, presence of median, median width, type of median, shoulder width, access density, speed limit, vertical grade, horizontal curvature, weather condition. The relationship between safety on the highway and factors mentioned above is the primary focus in crash reduction and predictions

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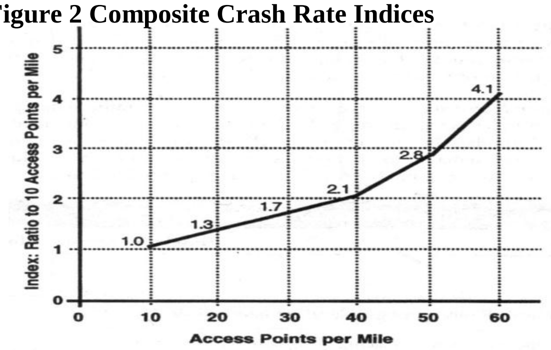
The vertical cross section of the roadway parameters include the width of the travel lane, width and type of the shoulder, and skid resistance of the surface of the travel way. The width of the travel lane does not only influence the comfort of driving and operational characteristics of a roadway, but is also an important parameter affecting the road crash frequency as well as crash severity. For any functional classification of roadway, whether it is an arterial road or a local road, and for any environment of the roadway, whether it is an urban road or a rural road, when the lane width reduces, the probability of crashes increases drastically. For example, a study which looked at safety risks on a two-lane undivided highway, found that when the lane width was increased from 2.75 meter to 3.65 meter, the probability for head-on or other related crashes was reduced by fifty percent (50%).[5]When the traffic volume is higher and the lane width is less, the probability for crashes, especially crashes like head -on or run-off the road, are greater. For example, in a multi-lane rural highway where the average annual daily traffic volume is greater than 2,000, the probability for a crash on a narrow lane i.e. 9 feet (2.75 meters) increases by more than thirty percent (30%).A shoulder is the portion of the roadway contiguous with the travel lane that accommodates stopped vehicles, emergency use etc. Generally, the shoulder width varies from 0.6 m to 3.6 m but there are places where no shoulder can be accommodated. While it is desirable that a shoulder be wide enough for a vehicle to be driven completely off the travelled way, narrow shoulders are better than no shoulder at all. One study found that the probability for a road with a 60 cm wide shoulder on each side, has thirty percent (30%) more crash risk than a road having a 1.8 metre wide shoulder on each side. Regardless of the width, a shoulder should be continuous and intermittent shoulders are better than no shoulders. The importance of wider shoulders is more acute in two-lane two way roads. For a two-lane two-way road, if the daily average traffic volume is greater than 2,000, the probability of crashes for a very narrow width or no shoulder increases drastically, and if no shoulder is present the chance of a crash increases by fifty percent (50%).The shoulder type also governs the crash frequency. The shoulder material and thus the surface condition have at least some impact on the recovery of an errant driver going out of the travel lane. A paved shoulder is the best type of shoulder in terms of road safety and better than gravel shoulders. A gravel shoulder is better than a composite shoulder (combination of different types). However, a turf shoulder is considered to be the worst in terms of road safety and can lead to ten percent (10%) more crashes. Literature shows that skidding crashes are a major concern in road safety. When the surface friction is not adequate to help stopping a vehicle, a vehicle goes out of control and crashes occur. Vertical and horizontal alignment, pavement types and texture affect a roadway's skid resistance. Different pavement distresses or faults like rutting, polishing, bleeding and also dirty**Roadside Condition** The safety of the road does not depend only on the characteristics of the roadway but also depends on the condition of the roadside. The term "clear zone" is used to designate the unobstructed, traversable area provided beyond the edge of the travel way for the recovery of the errant vehicle. The clear zone includes shoulders, bicycle lanes and any additional space, if available. The greater the width of the clear zone, the more room is available for an errant driver to recover before hitting an object; thus a greater clear zone means a safer road. In locations where right of way or the width available for providing clear areas is not sufficient, it is not practical or feasible to consider the concept of clear zones as expected in general. This type of environment is more common in densely populated urban areas. Considering safety aspects, a lateral offset to vertical obstructions (signs, utility poles etc.) is needed to avoid crashes. The presence of a median is another important factor governing crashes, especially head-on-collisions. Most two-lane highways do not have median barriers to avoid capacity reduction of the roadway. However, median barriers are highly desirable in multi-lane highways in terms of safety and operational efficiencies. Generally, the median width varies between 1.2 to 4 meters. The wider the median, the better the safety situation is: Harkey et al conducted a study that revealed that a multilane divided highway with a 3.0 meter wide median has a four percent (4%) greater probability of crashes than a highway with a 9.0 meter wide median.[7] Even for urban arterial roads, one study found that conversion from an undivided urban arterial to one with a raised-curb median could result, on average, in a ten percent (10%) reduction in road crashes.[8]

Sight Distance The alignment of the roadway has a great impact on road safety because a driver's ability to see ahead is necessary for the safe operation of the vehicle and thus for the overall safety of the system. A sight distance of sufficient length is necessary so that a driver can control the operation of their vehicles to avoid hitting an unexpected object on the road. This is known as "Stopping Sight Distance (SSD)". Another concept, of the sight distance is the "Passing Sight Distance (PSD)". For a two-lane road where the speed is 60 kmph the SSD and PSD are 85 meters and 180 meters respectively on level roadways. The passing sight distance is applicable to two-lane roads to enable drivers to use the opposing traffic lane for passing (overtaking) other vehicles without interfering with oncoming vehicles. While the concept of the SSD and the PSD are the prime importance in terms of road safety, the "Decision Sight Distance (DSD)" is another important topic to be addressed for the safety of the road users. SSDs are sufficient for reasonably competent and alert drivers to come to hurried stops under ordinary circumstances, but greater distances are needed for drivers to take complex decisions. The DSD is the distance needed for a driver to detect an unexpected or otherwise difficult to perceive information source or condition in a roadway environment; to recognize the conditions or its potential threat; to select an appropriate speed and path; and to initiate and complete complex maneuvers.[10] DSD provides drivers additional margins for errors whenever there is likelihood for errors in information reception, decision making or taking actions by the drivers. The DSD varies depending on the level of complexities and also on the road environment (e.g. urban, rural). To accommodate the variation in human capabilities in driving, a

Access Management: Access management is the concept that access-related vehicular maneuvers and volumes can have serious consequences on the performance of traffic operations and road safety. The benefits are significant, particularly in urban street environments where access points are numerous and traffic volumes are high. Access management complements geometric design by reducing the likelihood of access related vehicular conflicts or reducing the severity of the conflicts, by reducing the frequency of major conflicts of movements. Generally, it can be expected that a doubling of access point frequency from 10 to 20 per kilometer increases crash rates by roughly thirty percent (30%). Another doubling of access frequency from 20 to 40 driveways per kilometer is expected to increase crash rates by sixty percent (60%). Applications of access management principles alone to existing urban corridors generally results in reducing road crashes between 30 to 60 percent.[11] In Malaysia, poor access controlled or uncontrolled Federal Highways have much greater road crash rates than the well-controlled expressways.

Figure 2 Composite Crash Rate Indices



Analysis of national data: Figure 7 shows the official estimates for total number of RTI fatalities and fatalities per 100,000 persons in India from 1970 to 2013 (NCRB). The total number of deathsin 2014 was 12 times greater than in 1970 with an average annual compound growth rate (AACGR) of 6%, and the fatality rate in 2014 was 5.2 times greater than in 1970 with an AACGR of 3.9%. There have been a few periods when the growth in RTI fatalities has decreased briefly and for a small amount, but the causes for the same are not known. However, it is known that motor vehicle crash rates have a tendency of decreasing along with a downturn in the national economy for the following reasons (International Traffic Safety Data and Analysis Group, 2015): Economic downturns are associated with less growth in traffic or a decline in traffic volumes. Economic downturns are associated with a disproportionate reduction in the exposure of high-risk groups in traffic; in particular unemployment tends to be higher among young people than people in other age groups. Reductions in disposable income may be associated with more cautious road user behavior, such as less drinking and driving, lower speed to save fuel, fewer holiday trips. This may explain the reason why the rate of growth in fatalities slowed down in India in the late 1990s and in the period 2010-2014 as these were also periods of low economic growth. There is no indication of a long term trend indicating that the increase in fatalities is going to reduce significantly in the near future. Two modeling exercises have attempted to predict the time period over which we might expect fatality rates to decline in different countries (Koornstra, M., 2007, Kopits, E. and Cropper,M., 2005). Kopits and Cropper use the past experience of 88 countries to model the dependence of total number of fatalities on fatality rates per unit vehicle, vehicles per unit population and per capita income of the society. . Thus, based on projections of future income growth, they predict that fatalities in India will continue to rise until 2042 before reaching a total of about 198,000 deaths and then begin to decline. Koornstra uses a cyclically modulated risk decay function model, which in a way incorporates the cyclically varying nature of a society's concerns for safety, and predicts an earlier date of 2030 for the start of decline in RTI fatalities in India. If we assume the average growth rate of 6% per year declines to nil by 2030, then we can expect about 200,000 fatalities in 2030 before we see a reduction in fatalities.

STATE WISE ANALYSIS: Figure 9 shows the total number of fatalities by state and territory from 1971 to 2014. The states of Nagaland and Sikkim and Union Territories Lakshadweep, Daman & Diu, Andaman and NicobarIslands and Dadra and Nagar Haveli have not been included in the chart as they reported less than 100 fatalities in 2014. Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura are small hill states, and the union territories of Andaman and Nicobar Islands, Dadra and Nagar Haveli, Daman and Diu, Lakshadweep, Pondicherry, Chandigarh and Delhi union territories which are generally small and the lasttwo are cities. Therefore, these regions can have different traffic and fatality patterns. Andhra shows a decline in the number of fatalities between 2011 and 2014 because the state was divided in two states (Andhra and Telangana) in 2014. The total of fatalities in Andhra and Telangana in 2014 was 1,4814 as compared to 1,518 in undivided Andhra in 2011. In almost all the large states fatalities more than doubled between 1991 and 2014. In Maharashtra, Orissa, Rajasthan, Tripura fatalities increased by 4-6 times, and in Gujarat, Punjab, Haryana and Assam 8-10 times during the same period. Figure 10 shows the fatalities per 100,000 population for states and union territories in 1996 and 2014. Fatality rates per million population increased in most regions except in the north eastern hill states and the cities of Delhi and Chandigarh (union territories). The increase was 40%-50% in Madhya Pradesh, Manipur, Tamil Nadu, Meghalaya, Uttar Pradesh; 60%-100% in Himachal Pradesh, West Bengal, undivided Andhra Pradesh, Rajasthan, Karnataka and Orissa; and more than 100% in Haryana, Sikkim, Assam and Punjab. The reasons for these differences are not known. However, these data do indicate that there are states with high rates and those with low rates in all regions of the country. Figure 11 shows the association between fatalities per 100,000 persons (2014) and per capita income of states and union territories (2013-2014). These data show that many states with high per capita incomes have similar fatality rates as states with low incomes and that fatality rates do not seem to have a strong correlation with income. Since the above data show that RTI fatality rates in states and union territories do not seem to be influenced strongly by location in the country, state income or density, it suggests that state RTI fatality rates may be more influenced by infrastructure availability, vehicle modal shares, road design, and enforcement. It appears that if fatality rates have to be reduced in India, much more attention will have to be given to street and highway designs and enforcement issues that have influence on vulnerable road user safety than has been the practice up to now. This will probably require a great deal of research and innovation as designs and policies currently being promoted do not seem to be having the desired effect in improving road safety.

Transition Curve The curvature of transition curve will proportional charge with the curve length, this can make the drivers turning steering wheels equably in some speed. When vehicle enters into circle curve from straight route in some speed or from circle curve to straight route of from one curve to another, its track is consistent with mathematic convolution curve, so it takes convolution curve as transition one [44]. The minimum length of transition curve should meet the follow expression:

Where:

L= is the length of transition curve (m)

V= is design speed (km/hr)

t= is the shortest journey time on transition curve (sec) and is the adopted at least 3 seconds.

According to the characteristic of convolute curve, it can get the formula as follow:

C=rl=RLs

Where, C is the parameter of transition curve (m^2) which shows the change degree of transition curvature; r is the curvature radius of random point in the transition curve (m), l is the length from random point to the transition curve beginning point (m), Ls is the transition curve length (m), R is the circle curve radius of transition curve end (m). The transition curvature changes relatively slow when the parameter value C is large, this can make the drivers feel alignment is consistency and handle steering wheel easy. On the contrary, when the value C is small, the drivers handle steering wheel hard, this can cause accident easy. So it should adopt larger value of parameter C as possible [44]. Some studies have concluded that transition curves are dangerous because of driver underestimation of the severity of the horizontal curvature [58, 59]. Stewart [60] reports of a California Department of Transportation study involving a study of roads without transition curves which showed that roads with and without transition curves, which showed that roads with transition curves had, on average 73% more injury accidents (probability 1) than the others. Also the Department Report "Accidents on Spiral Transition Curves in California" recommends against any use of these curves. However, it is understood that recent studies in Germany and the UK have concluded that impact of transitions on safety in neutral [47].

Sight Distance: Sight distance is defined as the length of carriageway that driver can see in both the horizontal and vertical planes [61]. It is important for traffic accident. It will obviously bring high accident rate if the sight distance is not enough and this is visible on the places where have the bad visual distance of small horizontal curve radius,

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue 10
September 2017

small crest vertical curve radius, intersection, and lack of overtaking sight distance on some road section. In order to ensure traffic safety, the traveling sight distance should be design enough when design horizontal or vertical alignment Sight distances include stop vehicle sight distance and passing vehicle sight distance. Stopping sight distance is the distance required by the driver in order to be able to stop the vehicle before it hits an object on the highway This is the minimum sight distance provided and is one of the major factors controlling the cost and the environmental impact of road design since it is provision affects the size of many other design elements. Although minimum stopping sight distances are specified on safety grounds, little information is available on the relationship between stopping sight distance and safety. However, it is generally accepted that short

Design Speed (km/hr	120	100	80	60	40	30	20
Stopping Sight Distance (m)	210	160	110	75	40	30	20

Stopping Sight Distances For Different Design Speeds Are Listed As Above **Table (2)**.

Design Speed (km/hr)	100	80	60	40	30	20
Passing Sight Distance (m)	580	550	350	200	150	100

Table (3): Passing Sight Distance for Different Design Speeds [61]

CONCLUSION:

After reviewing on the many studies which are related the safety of cross-section and alignment elements can be concluded the following: Lane and shoulder conditions directly affect run-off road (ROR) and opposite direction (OD) accidents. Other accident types, such as rear-end and angle accidents, are not directly affected by these conditions. 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. Larger accident rates are exhibited on unsterilized shoulder, including loose gravel, crushed stone, raw earth or turf, than on stabilized (e.g. tar plus gravel) or paved (e.g. bituminous or concrete) shoulders. The probability of an accident two-lane rural roads is highest at intersections, horizontal curves and bridges. The average accident rate for highway curves is about three times the average accident rate for highway tangents. 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. the increase in crash rates becomes particularly significant at radii below 200 m. Small radius curves result in much shorter curve lengths and overall implications for crashes may not be as severe as would first appear. There is only a minor decrease in the speed adopted by drivers approaching curves of radii which are significantly less than the minimum radii specified for the design speed. However, curve radii below 200 m have been found to limit the mean speed to 90 km/hr. The average single vehicle accident rate for highway curves is about four times the average single vehicle accident rate for highway tangents. Regarding general terrain descriptions it was found that accident rates in mountainous terrain can be 30 percent higher than in flat terrain. Crashes increase with gradient and down-gradients have considerably higher crash rates than up-gradients. However, the overall crash implications a steep gradients may not be severe since steeper gradients are shorter. The geometry of vertical curves is not known to have a significant effect on crashes severity. There appears to be little erosion of safety resulting from the use of sight distances below the minimum values specified in geometric design standards, although there is a significant increase in the accident rate for sight distances below 100 m.The 2016 road fatalities per 100,000 population stood at 6.4 deaths compared to 6.34 deaths per 100,000 population in 2016.The road fatalities per 10,000 vehicles has been on decline for the last 5 years and stood at all time low of 12.34 deaths per 10,000 vehicles in 2016.Despite the fact that the absolute road fatalities in 2016 show a rise as compared to 2016,the fatality rates compensating for rising population, motorization and paved roads reveal a decrease in road fatalities.However these declining fatality rates as demonstrated above are unacceptably high and can be reduced further with appropriate interventions.

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