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A Case Study on Reduction of Accident Rates through Geometric Road Design

Devid Kumar¹, Devendra Kumar Meena², Mahaveer meena³, Vishal Kumar Meena⁴,
Charat Lal Meena⁵, Javed Ul Islam⁶

UG Student, Department of Civil Engineering, Vivekananda Institute of Technology, Jaipur, Rajasthan, India¹⁻⁴.

Assistant Professor, Department of Civil Engineering, Vivekananda Institute of Technology, Jaipur, India⁵⁻⁶

ABSTRACT:-Road safety issue has become a major concern worldwide due to the serious consequences of road accidents on countries socio-economics and human lives. The main aim of this paper is to discuss and review the effects of geometric design elements on road accidents including statistical models used over the years and to compare the outcomes of the studies conducted in several countries. 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 evaluate and define the relationship between road geometric design elements and road accidents. Studies have tried to relate road geometric design elements such as lane number, sight distance, super-elevation, median width and type, lane and shoulder width, curve radius, gradient, and horizontal and vertical alignments to accident rates. Due to the interrelations between geometric design elements with each other and with other road accident factors, and also lack of reliable methodology of relationship estimation between road geometric design and safety. Ongoing enhancement of statistical methods has resulted in many road design-accidents analysis models which have been developed using a variety of statistical modelling approaches such as linear regression models, multiple linear regression models, Poisson regression models, Poisson-Gamma models, negative binomial models, bivariate and multivariate models, generalized estimation regression models, random parameters models, etc. However, some limitations have been encountered using the mentioned statistical models, thereby there are opportunities for road safety researchers to overcome the limitation challenges.

I INTRODUCTION

Road safety has become a major concern affecting countries' socio-economics. According to World Health Organization (WHO, 2013) statistics, there are approximately 1.25 million fatalities and 20-50 million who are seriously injured and living with long-term disability every year around the world due to road accidents. Road accidents are considered as the ninth prime leading cause of death among youth and expected to become the fifth by the year 2030. Majority of road accidents occur in developing countries costing USD \$ 518 billion worldwide per annum. There are three major factors that attribute to road accidents namely human-related factors, vehicle-related factors, and roadway-related factors (William Haddon, 1970). As stated in Highway Safety Manual published by American Association of State highway and Transportation (AASHTO) (2008), roadway factors contribute by 3% of road accidents, whereas 34% is attributed by a combination of roadway-related factors and other factors. The contribution percentage of each factor is shown in Figure 1. Since that the majority of road accidents factors are interrelated, it becomes complex to identify the certain cause of road accidents as the accidents occur due to a combination of several factors. Although human-related factors significantly contribute to road accidents, direct control and prediction of human factors are difficult.

THEREBY, THE HUMAN FACTORS CAN BE INDIRECTLY CONTROLLED AND PREDICTED THROUGH INVESTIGATION OF ROADWAY FACTORS PARTICULARLY ROADWAY GEOMETRIC DESIGN. SPEED IS A CRITICAL PARAMETER IN ROAD GEOMETRIC DESIGN AND RELATED TO ROAD SAFETY. ROADWAY GEOMETRIC DESIGN ELEMENTS WHICH HAVE BEEN INVESTIGATED TO INFLUENCE ROAD ACCIDENTS INCLUDE HORIZONTAL CURVATURE, VERTICAL CURVATURE, GRADE, NUMBER OF LANES, LANE WIDTH, SHOULDER WIDTH AND TYPE, MEDIAN WIDTH AND TYPE, NUMBER OF ACCESS POINTS, CURVE RADIUS, SUPER-ELEVATION, SIGHT DISTANCE, AND PAVEMENT CONDITIONS, HOWEVER SOME OF THESE ELEMENTS MAY NOT HAVE A SIGNIFICANT IMPACT ON ROAD ACCIDENT RATES.

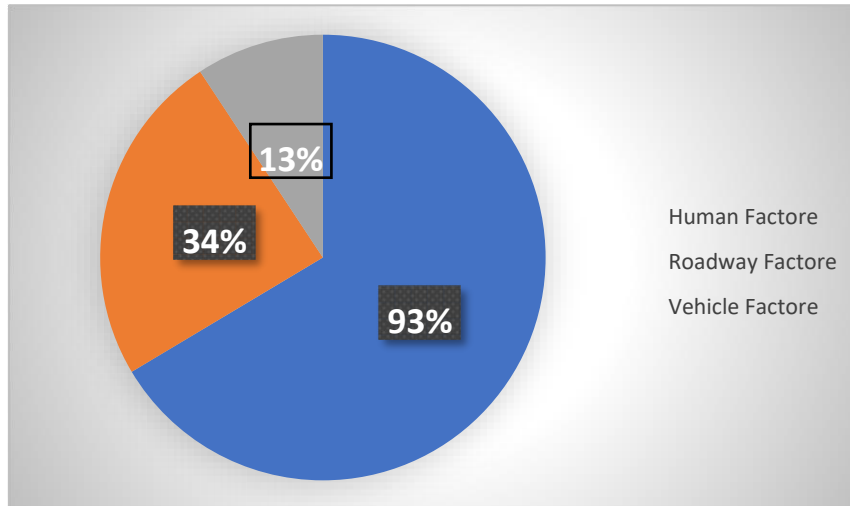


FIGURE 1. THE CONTRIBUTION OF ACCIDENTS FACTORS IN PERCENTAGE (SOURCE: AASHTO, 2008)

1.1 Review of Models Used to Quantify and Predict Accidents Rate Related to Road Geometry:-

Several Statistical models were developed to quantify the relationship between road geometric elements and road accidents, such as linear regression, Poisson models, Poisson-gamma models, negative binomial models, generalized estimating equation, random-parameters, and bivariate and multivariate models. Linear regression models were considered and developed in earlier studies to find the relationship between road accidents and road geometry elements, however it was reported that using conventional linear regression models showed unsatisfactory results as the properties of linear regression are normally distributed, which can generate negative or non-discrete values of accident rates (Jovanis and Chang, 1986; Saccomano and Buyco, 1988; Miaou et al., 1991). As a result, Poisson and negative binomial models were suggested to be used instead. Poisson models were suggested and used by Jovanis, P. and Chang, H. (1986), Joshua, H. and Garber, N. (1990), Jones, B. et. Al (1991), Miaou, S. and Lum, H. (1993), and Miaou (1994) for their consideration of random and sporadic data, in addition to easy estimation of variables relationships, however results can be overestimated or underestimated. When it comes to Poisson-gamma and negative binomial models, they have been adopted by Maycock, G., and Hall, R. (1984), Hauer, E., Ng, J.C., and Lovell, J. (1988), Br de, U., Larsson, J. (1993), Bonneson, J., McCoy, P. (1993), Miaou, S. (1994), Persaud, B. (1994), and Kumala, R. (1995) for their handy over-dispersed data estimation, but they lack this property when dealing with under-dispersed data. Generalized estimating regression can consider relationships changes over time only if data is collected accordingly without any data loss or limitations related, as stated in studies done in the early 2000s; such as Lord, D., and Persaud, B. (2000), and Lord, Mahlawat, (2009). Bivariate and multivariate models can handle non-linear correlations by complex matrix operations and are usually compared to generalized estimating processes in terms of functional forms. Some of the studies that investigated bivariate and multivariate models were conducted by Miaou, S. and Lord, D. (2003), and Ye, Pendyala, Washington, Konduri, and Oh (2009). Random-parameters models offer an accountancy for heterogeneity of unnoticed data, but they require a long estimation process and a lot more difficult of outcomes generalization, which was first adopted by Anastasopoulos, P., Mannering, F. (2009).

1.2 Geometric Design Elements Affecting Accidents Rates

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 evaluate and define the relationship between road geometric design elements and road accidents.

- A) **Road Curves Radii:-** Road curve radius is a primary element of roads geometric design that is associated with horizontal curve design and it is related to traffic accidents as the smaller the curve radius, the higher the possibility of accidents to occur on roads. Based on the theory of vehicle steering, vehicle transverse stability which includes the slippage and overturns determines the curve radius value to be selected when designing road horizontal curves (Zhang Yingxue, 2009). Zhang computed the radius mean and curvature degree for all categories

used in his research and then he regressed them against the mean of accident rates in every category, his findings supported some previous studies which found and stated that the curve sharpness has a significant impact on the accident rates. Brude et al. (1980) carried out a study on Swedish roads with a speed limit of 90 km/hr, the study aim was to develop accidents prediction model to compare accident rates which occur due to horizontal curves to base accident rate and it was concluded that the curve radius becomes significant factor when the curve radius is about 0 m. Similarly, a study which was conducted by Department of Transportation, UK (1984) pointed out that results showed a significant increase in accident rates when the curve radius reduces. Other studies showed that the increase in accident rates becomes significant with roads which have curve radius below 200 m. Simoson and Kerman (1982) noted that small radius curves can result in shorter overall curve lengths and the overall impact on accident rates is not as awful as it might be expected, however there is still an impact of curve radius on accident rates. Several previous studies performed by Glennon et al. (1985), Glennon (1987), and Zegeer et al. (1991) showed that sharper curves are associated with higher accident rates compared to milder curves which are associated with lower accident rates. It was also found that horizontal curves have more accidents such as roll-over crashes, opposite direction sideswipe crashes, etc. than other road sections (Ali Aram, 20). Different opinions were found in terms of determining at which radius curve value the impact on road accident can reduce. For instance, Oecd (1976) suggested that the critical curve radius to reduce the impact on accident rates is driving dynamic aspects. On the other hand, Glennon et al. (1985) pointed out that greater curve radii can increase the accident rates and costs and it was also concluded that road safety would decline when the road curve radius is above radius on road accident rates and concluded that small radius curves are more associated with higher accident rates and severity, however different views were encountered in determining the curve radius value that can reduce the accident rates.

- B) **Road Gradients:**-Road gradient is one of the geometrical design elements of roads to be considered in association with road accident rates as it has been agreed that it can have an impact on the accident rates on roadways. According to some studies conducted, roads with steep gradients found to be related to higher accident rates. Hedman (1990) quoted from a Swedish study done on road gradients and accident rates that the results showed that road with 2.5 % grade can increase road accidents by around % whereas roads with 4% grade can increase the accident rates by approximately 20 % compared to near-horizontal roads. Glennon et al. (1987) investigated the results obtained for several studies performed in US and concluded that roads which were designed with grade sections have a higher road accident rates compared to roads which were designed with level sections. They also observed that higher accident rates were found in steep gradient in comparison with mild gradient roads, it was also noted that down-grade roads have more potential accident rates compared to up-grade roads. In conclusion, the road gradient is significantly related to accident rates on roads as the increase in road gradients results in an increase of road accident rates
- C) **Lanes Number:**-A considerable number of investigations indicate that lanes number is associated with road accidents (Deo, Chimba, 2004). In a study of road geometrics, velocity and volume relationships with road accidents; lane volume was found to affect accidents occurrences positively (Garber, 2000). In a similar manner, a research finalized that urban highways lanes number increase raises accidents rates (Abdel-Aty et al., 2000). Noland, R., and Oh.L. (2004) concluded similar outputs of lane number positive influence on road accidents. Generally, various studies carried out suggest corresponding findings ranging from two to six-lane roadways.

As mentioned, widening carriageways does not necessarily provide safety improvement. To sum up, to a certain extent wider lanes are attributed by lower accident occurrence, however, while this proves true, safety is lower in wider cross sections (US Department of Transportation, 2007).

- D) **Crest Curves:**-The minimum number of crest curves to be provided on a road section rely on the stopping sight distances provision at all points. TRB (1987) in their report No. SR 214 developed an equation to estimate the accidents rate on a road section which has one crest curve and it is approaches of tangent. The report concluded that the geometrical design of vertical crest has not be proven to significantly affect the frequency and severity on roadways. On the other hand, a search conducted by Srinivasan (1982) showed that changes in vertical alignment can cause sight distances reduction at the vertical crest curves which is observed to influence the accidents occurrence frequency.
- E) **Median Barriers:**-Studies examining barriers had different views regarding the impact of barriers on accident rates (Nikiforos et al., 20). Hauer (2004) stated that the use of median may have a potential influence on road safety. Council and Steward (2000) have concluded that safety is increased in the existence of barriers. On the contrary, others suggested that barriers existence on the road is related to left shoulder width (Fitzpatrick et al., 2008). Another group of researchers indicated a general increase of accident rates with barriers presence, however a

decline of the severity was observed (Elvik, 1995). Moreover, the barriers present themselves as objects can potentially lead accidents on roads (Nikiforos et al., 20). Particularly, concrete barriers have a higher possibility of accidents involvement (Elvik and Vaa, 2004). Barriers can decrease accidents resulting from the errant manoeuvre, but also can increase the number of accidents which are involved with medians as medians can be used as stopping space (Nikiforos et al., 20). To conclude, barriers can decrease severe crossover accidents, thereby both type and severity of accidents should be taken into consideration with and without barriers.

II.DISCUSSION

One of the most widely adopted estimation methodologies is maximum likelihood estimation. Mainly, maximum likelihood estimation is useful for its form functions, however, likelihood function requires the definition of a more complex variable. The modelling of accidents rate has limitations; for instance, sampling errors, over-dispersion, under-dispersion, time changing parameters and omitted variables. In order to develop statistically accurate results, new methodologies have been embraced, such as random parameter models. Moreover, other common limitations of data availability and variations of traffic conditions are still affecting precision and generalization of findings. Therefore, accidents rate prediction simulators along with detailed data approaches have been introduced, which is an indication of the huge and promising possibilities. Past literature that investigated road geometric design elements and road accidents relationship have shown that some of these elements are more significant than others. For instance, lane width was found to be more crucial to crash rates than shoulder width, while this holds true, certain types of crashes decreased by the increase in both lanes and shoulders widths, particularly, opposite direction and run-off-road crashes, but to a certain width. Generally, accidents occurrence declines with more lanes provided, on another notice, road curves result in nearly four times more crash rates than road tangents. A shoulder width of up to 2.5 m have been found to maintain safety, but a wider shoulder may raise crash rates. For homogenous traffic conditions, the horizontal curvature is more effective on accidents rate than straight segments, specifically, at radii less than 200 m, which are associated with an average operating speed of 90 km/h. Especially, graded horizontal curves have a much higher impact on crash rates. In addition, studies have concluded that downgrades have a significantly more effect on accidents rate compared to upgrades. Since steep grades are often short than not, their influence on accidents occurrence is less effective than mild grades. On the other hand, mountainous terrains cause 30% more accidents than level terrains. Medians have been found to reduce head-on collisions, whereas, median barriers mitigate the severity of accidents. Studies interested in sight distance have reached a conclusion that sight distance lower than 0 m positively impact crash rates, however, barely affect safety.

III.CONCLUSION

There is a complexity encountered to understand the relationship between road geometric design elements and road accidents rate because of the interrelations among the geometric design elements themselves and also other accident-related factors, however it is obvious that some geometric design elements such as short sight distance and small curve radius can significantly increase the road accidents rate and severity. Moreover, a combination of certain geometric design elements can result in serious accidents occurrence. It is also found that the assessment of current studies reliability is a challenge because of variation in parameters definition and selection used in the studies, traffic volume and composition, and lack of control on statistical data and models. In addition, the studies outcomes that have been conducted in different countries may not necessarily be the same, applicable in other countries, and should not be generalized because of difference in traffic flow conditions, driver behaviour, environmental factors, actual road conditions, and road enforcement policies and practices. However, there is quite wide international agreement on the impact of road geometric design elements on road accidents. When it comes to statistical modelling of accident analysis and prediction, there is a potential opportunity for road safety researchers to develop more reliable models through more research work efforts and application of new statistical methodologies and approaches.

REFERENCES

- [1] Abdel-Aty, M.A., &Radwan, A.E. (2000). Modeling traffic accident occurrence and Involvement. Accident Analysis and Prevention 34, P.P 633-642
- [2] Ali Aram. (20). Effective safety factors on horizontal curves of two-lane highways. Journal of Applied Sciences (22), Malaysia, P.P 2814-2822.

- [3] American Association of State Highway and Transportation Officials (AASHTO). (2001). A policy on Geometric Design of highways and Streets. Academic Press, Washington, D.C.
- [4] Anastasopoulos, P., & Mannering, F. (2009). Anoteon modeling vehicle accident frequencies with random-parameters count models. *Accident Analysis and Prevention* 41(1),153–159. [5]
- Bonneson, J., & McCoy, P. (1993). Estimation of safety at two-way stop-controlled intersections on rural roads. *Transportation Research Record* 1401, 83–89.
- [6] Brüde, U., Larsson, J. (1993). Models for predicting accidents at junctions where pedestrians and cyclists are involved. How well do they fit?. *Accident Analysis and Prevention* 25(5),499–509.
- [7] Brude, U., J. Lassen, & H. Thulin. (1980).Influence of road alignment on traffic accidents. VTI Meddelande, PP: 235.
- [8] Council, F., & Steward, J.R. (2000). safety effects of the conversion of two-lane rural to four-lane rural roadways based on cross-sectional models. *Transportation Research Board Annual Meeting*.
- [9] Deo Chimba. (2004). Evaluation of geometric and traffic characteristics affecting the safety of six-lane divided roadways. M.Sc., The Florida State University College of Engineering.
- [10] Department of Transportation. (1984). Highway link design advice Note TA 43/84, London.
- [11] Department of Transportation. (2007). Safety Handbook for Secondary Roads. USA.
- [12] Douglas, W., Joseoh, E., &Kelth, K.(2000). Operational and safety effects of highway geometrics at the turn of the millennium and beyond .TRB, National Research Council, Washington, D.C.
- [13] Garber, N.J. (2000). The effect of speed, flow, and geometric characteristics on crash rates for different types of Virginia highways". Virginia Transportation Council.
- [14] Elvik, R. (1995). The safety value of guardrails and crash cushions. *Accident Analysis and Prevention*, 27(4), P.P 523-550.
- [15] Elvik, R., and Vaa,T.(2004), .The Handbook of Road Safety Measures . Amsterdam, Heidelberg (u.a.), Elsevier.
- [16] Fitzpatrick, K., Lord, D., & Park, B.(2008). Accident modification factors for medians on freeways and multilane highways in Texas. TRB Annual Meeting CD-Rom.
- [17] Glennon, J. (1985). Effect of alignment on highway safety, relationship between safety and key highway features. SAR6, TRB Ltd., Washington, D.C., P.P 48-63.
- [18] Gluck, J., Levinson H.S., & Stover, V.G. (1999). Impact of access management techniques.
- [19] Haddon, W. (1972). A logistic framework for categorizing highway safety phenomena and activity. *The Journal of Trauma*, Vol. 12.Lippinon Williams and Wilkins, Washington, DC, pp. 193207.
- [20] Hadi, M.A., Arulldhas, J., Chow, L.F., &Wattleworth, J.A.(1995). Estimating safety effects of cross-section design for various highway types using negative binomial regression.



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