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Influence of Geometrical Design Elements on Traffic Safety

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ABSTRACT: Road safety has become a major concern. There are five lakh road accidents every year in India. The tremendous traffic growth generally observed in road transportation has led to a lot of negative consequences in the form of road accidents both in developed and developing countries. It is important to find the cause for the road accidents to avoid them. To reduce the road accident, abiding the road safety rules is very much essential. This observation calls for considerable attention towards development a system for the road safety mechanism of rural highway. Road accident prediction plays an important role in accessing and improving the road safety. In this study literatures were identified and thoroughly studied. Based on the previous research done by the authors of the paper, I got better understanding on the topic. From the literatures identified, the significant relationships were also identified between the geometric elements and accident rate. Some of the geometric elements were found as critical factors affecting the highway traffic safety.

KEYWORDS: Road Safety; Geometrical elements; safety audit;

I. INTRODUCTION

Road Safety is a multi-sectoral and multidimensional issue. It incorporates the development and management of road infrastructure, provision of safer vehicles, legislation and law enforcement, mobility planning, provision of health and hospital services, child safety, urban land use planning etc. In other words, its ambit spans engineering aspects of both, roads and vehicles on one hand and the provision of health and hospital services for trauma cases (in post-crash scenario) on the other. Road safety is a shared, multi-sectoral, responsibility of the government and a range of civil society stakeholders. The success of road safety strategies in all countries depends upon a broad base of support and common action from all stakeholders.

Road accidents are an outcome of the interplay of various factors, some of which are the length of road network, vehicle population, human population and adherence/enforcement of road safety regulations etc. Road accident causes injuries, fatalities, disabilities and hospitalization with severe socio economic costs across the country. Consequently, road safety has become an issue of concern both at national and international level. The United Nations has rightly proclaimed 2011-20 as the Decade of Action on Road Safety. India is also signatory to Brasilia Declaration and is committed to reduce the number of road accidents and fatalities by 50 per cent by 2020.

Table 1 Accidents Statistics in India and TamilNadu

YEAR	INDIA		TAMILNADU	
	Accidents	Killed	Accidents	Killed
2003	4,06,726	85,998	51,025	9,275
2004	4,29,910	92,618	52,508	9,507
2005	4,39,255	94,968	53,866	9,758

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2006	4,60,920	1,05,749	55,145	11,009
2007	4,79,216	1,14,444	59,140	12,036
2008	4,84,704	1,19,860	60,409	12,784
2009	4,86,384	1,25,660	60,794	13,746
2010	4,99,628	1,34,513	64,996	15,409
2011	4,97,686	1,42,485	65,873	15,422
2012	4,90,383	1,38,258	67,673	16,175
2013	4,86,476	1,37,572	66,161	15,563
2014	4,89,400	1,39,671	67,250	15,190
2015	5,01,423	1,46,133	69,059	15,642
2016	4,80,652	1,50,785	71,431	17,218

The high socio-economic cost of the injuries and fatalities, occurring due to road accidents and the need for effective policies for curbing road accidents make it imperative to study the causes of road accidents. The present study aims to detect and identify the role of alignment geometric elements on accident. Objectives of the study is to identify the geometrical elements that affects the traffic safety and to study the IRC codal provisions of the geometrical elements

II. LITERATURE REVIEW

Prof.VeeraragavanAmirthalingam and Mr.PraveenVayalamkuzhi (2016) This paper 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. They carry out their study on a four lane divided intercity highway of 100km aligned in plain and rolling terrain which connecting Krishnagiri and Thoppur. Crash history of past four years 2009 to 2012 was collected for the study stretch. The data includes the type and cause of the crashes, time of day, details of the vehicles and victims, weather, roadway geometrics etc. From the field observation and preliminary analysis such as scatter plot and correlation matrix, the variables influencing crashes are identified and are used for the model development to analyse safety performance. HameedAswad Mohammed (2013) This paper discusses the importance of road safety issue in all motorized countries. They identify some of the primary geometric design elements that can affect on highway safety are carriageway, grade, horizontal curvature, shoulder, median, vertical curve. The result of the study showed the drivers were poor at evaluating the actual road conditions. Less than 30 percent evaluations are coincided with the actual condition. 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. On multilane roads, increase in number of lanes reduces the accident rates. Shoulder wider than 2.5m gives a little additional safety.

Salvatore Cafiso&BhagwantPersaud et.al., (2009) This paper envisages in describing a novel and extensive idea on unique combination of exposure, geometry, consistency and context variables directly related to the safety performance of the roadway. The data were collected on a 168.2 km two lane local rural roads located in Italy. Five year was taken as investigation period to compensate for the low traffic flow and accident frequencies. They modeled in Generalized linear modeling approach which has the advantages of overcoming the limitations of conventional linear regression in accident frequency modeling. They mentioned that curvature change rate and average paved width are the main factors to describe the road geometry and the annual average daily traffic is the key factor to divide the sample into homogeneous sections. NikiforosStamatiadis and Dominique Lord et.al., (2009) This paper emphasis in developing a set of recommendations to be used in evaluating safety implications from design element trade-offs. An understanding of the impacts of such alternative designs on both the safety and the operational character of the roadway is essential to making an informed design choice. Negative binomial models are typically used in developing Accident Modification

Factors (AMF). AMF is a constant that represents the safety change due to a change in a value of the segment. These factors are typically the ratio of the expected values of crashes with and without the change. Their model typically identifies the available variables contributing factors that could influence safety and then use them to estimate the change in crashes due to a change in one unit of the variable of concern.

Dominique Lord and Kay Fitzpatrick et.al., (2009) This paper aims to investigate the safety effects of geometric features especially ramp density and horizontal curves in the freeway. Increased emphasis has been placed on improving the explicit role of highway safety in making decisions on highway planning, design, and operations. They had identified number of lanes, degree of curvature, outside shoulder width, inside shoulder width, median type, median width, presence of barrier and distance between edge of travel lane to barrier as the segment characteristics of the horizontal curve. They had collected the crash data from texas crash electronic database for the years 1997 to 2001. They created the negative binomial regression models for cross sectional data to estimate the safety of freeways. Comparison of result reveals that urban freeways have more crashes than the rural freeways. Six-lane urban freeways have fewer crashes than four-lane urban freeways. Matthew G Karlaftis and IoannisGolias (2001) This paper revisits the question of the relationship between rural road geometric characteristics, accident rates and their prediction. It develops a methodology that quantitatively assesses the effects of various highway geometric characteristics on accident rates and provides a straightforward, yet fundamentally and mathematically sound way of predicting accident rates on rural roads. They had collected the data from road inventory database and Indiana department of transportation. Their methodology for study is using hierarchical tree based regression because negative binomial regression does not treat satisfactorily discrete variables with more than two levels. Hierarchical tree based regression is a tree-structured non-parametric data analysis methodology.

Venkataraman Shankar, Fred Mannering and Woodrow Barfield (1995) This paper explores the frequency of occurrence of highway accidents on the basis of a multivariate analysis of roadway geometries, weather, and other seasonal effects. Background for the study is the implementation of intelligent transport system on interstate of Washington to reduce the likelihood of vehicular accidents. The study area consists of 61 km portion of I-90 and having three-lanes of 3.66m wide in cross-section in each direction, with 3.05m shoulders and a 104.6 kph speed limit. They mentioned that grade appears to have a strong positive effect on accident frequency, although in a stepwise, as opposed to a continuous, manner. In comparison to those sections with grades less than 2%, those with maximum grades exceeding 2% will experience a significant increase in accident frequency. Maximum rainfall played a significant, positive role in accident occurrences. Andrew J. Butsick, Jonathan S. Wood and Paul P. Jovanis (2017) This paper establishes a method for identifying sites with promise for safety improvement with specific issues. The primary purpose of their research was to develop a method for identifying sites with promise for safety improvement that are problematic due to a specific characteristic. Roadway and crash data were acquired from the highway safety information system which is maintained by the University of North Carolina highway safety research centre. Likelihood-ratio tests were used to compare the use of mixed effects negative binomial regression over standard negative binomial regression. It was found that the mixed effects negative binomial regression fit the data better than the standard negative binomial.

PengpengXu ,Helai Huang and Ni Dong (2015) This .paper addresses the modifiable areal unit problem which was generally ignored by safety analysis. Trip distribution and generation, land use pattern and various demographic characteristics were the factors affecting crashes. They suggest that there is a need for transportation agencies to regularly monitor region level safety and provide incentives to reduce the number of traffic casualties in a region's safety program. In this study, several commonly used area-wide factors were considered, including road network characteristics such as intersection density and percent of road segment length with various speed limits, as well as socioeconomic factors such as population density and median household incomes. Automated zoning procedure is a heuristic-based optimization approach which starts with an initial zonal system and iteratively refines the solution by reassigning objects to neighbouring regions. Roger Johansson (2009) The scope of this paper is to outline, in a general way, the safety philosophy inherent in present road- and street design, trace the origin of this philosophy, and to present the principles for a new design of streets and roads. Vision Zero means that eventually no one will be killed or seriously injured within the road transport system." Vision Zero does not presume that all accidents that result in personal property damage or in less serious injuries must be eliminated. Seat-belt wearing and alcohol consumption were the biggest problem for traffic safety in concern with driver characteristics. Vision Zero is said to be a long-term goal for the design

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and functioning of the road transport system. They mentioned the road designers that the designers of the system are always ultimately responsible for the design, operations and use of the road transport system and are thereby responsible for the level of safety within the entire system. If road users fail to obey these rules due to a lack of knowledge, acceptance or ability, or if injuries do occur, the system designers are required to take the necessary further steps to counteract people being killed and seriously injured.

Robert B Noland and Lyoong Oh (2004) This paper focuses whether various changes in road network infrastructure and geometric design can be associated with changes in road fatalities and reported accidents. Reductions in traffic casualties, especially fatalities, have traditionally been linked to three general areas of transport policy. These include efforts to change risk-taking behaviour, such as drunk driving, regulations to improve the safety of vehicles, and efforts to build and design safer road infrastructure. Most estimates tend to combine fatal and injury accident data, a logical step when data is sparse, but potentially mis-leading as the infrastructure factors associated with fatalities could be quite different than those associated with injuries. Shaw-Pin Miaou (1994) This paper evaluates the performance of Poisson and negative binomial regression models in establishing the relationship between truck accidents and geometric design of road sections. Three types of models are considered: Poisson regression, zero-inflated Poisson regression, and negative binomial regression. Maximum likelihood method is used to estimate the unknown parameters of these models. The performance of the Poisson and NB regression models in establishing the relationship between truck accidents and geometric design of road sections is evaluated. The Poisson and zero inflated Poisson regression models are estimated using the maximum likelihood method, while the negative binomial regression model are estimated using the maximum likelihood, moment, and regression based estimators. The negative binomial model based on the moment method is quite sensitive to the inclusion of short road sections. While the negative binomial model using the regression estimator tends to understate the dispersion of the data. Both estimators should be used with caution. Under the maximum likelihood method, the estimated regression parameters from al1 three models are quite consistent and no particular model outperforms the other two models in terms of the estimated relative frequencies of truck accident involvements across road sections. The negative binomial model performs the best in estimating the frequency of road sections with zero truck accident involvement. The zero inflated poisson model, on the other hand, performs the best in estimating the frequencies of road sections with one, two, and three truck accident involvements.

Zhongren Wang (2013) This paper mainly focuses on the sight distance issue in the horizontal curve. It is well-known that obstruction inside a highway horizontal curve will lead to impaired sight distance. A HOV lane moves more people with fewer vehicles by requiring the minimum passenger occupancy level. Installation of a HOV lane can be accomplished through ‘take-a-lane’ or ‘add-a-lane’ strategies. ‘Take-a-lane’ means to designate one of the existing mixed-flow lanes for HOV purpose only; while ‘add-a-lane’ means to widen the existing facility and increase one additional lane for high occupancy vehicles. Perception reaction time, driver eye height, object height, vehicle operating speed, pavement co-efficient of friction, deceleration rates and roadway design are identified as the essential design variables in determining the stopping sight distance. They suggest that geometric improvement would be the most desirable. Increasing horizontal curve radius, increasing left and right shoulder width for the single-lane facility would help. A.M.Boroujerdian and E. Seyadabrishami et.al., (2016) In this paper, the vehicle operating speed has been influenced by geometric design characteristics. Speed is one of the important parameter for evaluating the facility quality of service in view of road users. Operating speed is the most common index for design consistency evaluation. Slope, lane width, shoulder type, tangent length and road side type are the geometric characteristics were studied. They studied about the impact of geometric design elements on vehicles speed on downgrade and upgrade tangents in north of Iron. They found that vehicle speed along tangents followed the normal distribution.

Francisco J Camacho et al., (2013) The objective of this paper is to develop a new design consistency model that may be used as a surrogate measure for road safety evaluation for two-lane rural roads. Several measures will be obtained based on operating speed profiles, with the aim of obtaining a single consistency value for the whole road segment instead of focusing only on individual or consecutive road geometric elements. Road fatalities are one of the most important problems in our society, causing thousands of victims every year. To contribute with the improvement of the road safety, this paper presents a new design consistency model that may be used as a surrogate measure for road safety evaluation of two-lane rural roads. Taha Saleem and Bhagwant Persaud (2017) The design element of interest for this paper is horizontal curvature on rural 2-lane highways. Crash Modification Factors are used to represent the effects on crashes of changes to highway design elements and are

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usually obtained from observational studies based on reported crashes. The data for this study came from the Washington State database in the Highway Safety Information System. Roadway type should be rural 2-lane highways, minimum curve radius should be 30.5 m, maximum curve radius should be 3493 m, posted speed on the curve section should be between 80 – 100 kmph were used as guidelines for the study.

Shewkar E. Ibrahim, Tarek Sayed and Karim Ismail (2012) This paper envisages in optimizing the safety of highway in horizontal curves with restricted sight distance. The simplest measure of safety is the central factor of safety which is the ratio of the average supply to the average demand. A more common measure of safety is the conventional factor of safety where the average demand is increased by some multiple of the standard deviation for demand whereas the average supply is decreased by some multiple of the standard deviation for supply. The term optimization is used in the context that an optimal solution is achieved based on the inclusion of the variables outlined in the objective function. highway safety can be maximized by applying the most conservative geometric design standards. Ali Aram (2010) This paper aims to detect and identify factors in vehicle accidents on horizontal curves in rural roads. These factors include traffic volume and mix, geometric features of the curves, cross section, road side hazards, stopping sight distance, vertical alignment, distance between curves and also between curves and nearest intersection or bridges, pavement friction and traffic control devices. The design of the horizontal alignment which consists of level tangents connected by circular curves is influenced by design speed and super elevation of the curve itself. Average crash rates are higher on horizontal curves than on tangent sections of rural two-lane highways. Radius or degree of curvature consistently tops the list of geometric variables that significantly affect operating speed and crash experience on horizontal curves.

Kay Fitzpatrick, Dominique Lord, M.ASCE and Byung-Jung Park (2010) The objectives of this study were to develop a horizontal curve accident modification factor for rural four-lane divided and undivided highways and to determine if the effect of driveway density is different for horizontal curves as compared to tangent sections. The authors were identified lane width, outside shoulder width, inside shoulder width, median type and median width as segment characteristics for the horizontal curve. Degree of curvature being significant when considering segment crashes i.e., both driveway and non-intersection crashes is logical since runoff-road crashes would be a notable portion of non-intersection crashes. Said M. Easa and AtifMehmood (2008) This paper presents an idea about optimization of design of design of highway horizontal alignments. The dimensions of highway geometric design elements affect road collisions. The optimization model determines the values of these decision variables based on explicit consideration of safety. The optimization model determines the values of decision variables based on explicit consideration of safety. Safety is measured in terms of the expected collisions at the successive geometric elements of the highway alignment.

IV. THE ROAD SAFETY AUDIT

A Road Safety Audit (RSA) is a formal procedure for assessing safety performance examination of an existing or future road or intersection by an independent audit team. Road Safety Audit (RSA) is a review of a project to assess and identify the safety concerns of road users. In this RSA process emphasis is laid on improving safety for vulnerable road users such as pedestrians and cyclists. The purpose of a road safety audit is to manage safety by identifying and addressing risks associated with road safety deficiencies. Auditing at different stages of a project, starting from the planning stage can lead to the timely elimination of problems and minimize time and costs of retrofitting roads/ transport infrastructure to improve safety at a later stage. The objectives of the Road Safety Audit is to assess projects for potential accident elimination / reduction on the basis of road user knowledge, attributes and skills, day/night, wet/dry road conditions.

Road Safety Audit is based on the principle of an independent review. The process reveals the involvement of Client, Designer, Auditor and the Road User. The client normally appoints the designer and the auditor who are two separate consultants. In India, where proper connectivity in the rural area has recently been taken up, the road user also should be made a part of the team to make the audit and counter measures effective. Safety Audit can be applied to New Roads, Existing Roads. On new roads or roads to be improved or built, the audit will lead to identification of accident-prone situations and on existing or already constructed roads, the

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audit will suggest appropriate mitigation measures to reduce the possibility of accidents. Road Safety Audit (RSA) basically comprises of three (3) Stages:
Stage 1 - Audit during design and planning
Stage 2 - Audit during Construction
Stage 3 - Audit after the completion of the project
The corridor should be divided into sections based on the following guidelines:

a. The sections can be divided from intersection to intersection and should preferably be less than 500m with more or less uniform cross section throughout the section.

b.When significant variation in a cross section is found (like lane reduction, footpath width reduced by more than 1m, etc.) then sections of roadway prior to the transition point and after the transition point should be audited as different sections.

c. The breakup of roadway into sections should be clearly indicated on the checklist with sufficient landmarks demarcating beginning and end points of a section.

d. When standard checklists/ design checklists/ construction checklists are filled out for a roadway at different stages of a project, demarcation of the sections need to be the same for easy comparison.

e. Audits at all stages should be done separately by direction of travel on two- way roads, i.e. separate checklist should be filled for each side of the road section.

f. For a one- way road, audit for pedestrian, bicycle and parking facilities should be done separately on both sides. Carriageway and public transport facilities could be part of any one checklist.

g. If a particular facility is not allowed on the road section under audit, the corresponding section of the checklist need not be filled and evaluated.

Stages of road safety audit in New Construction

- During Feasibility Study (Stage 1 Audit)
- During Preliminary Design (Stage 2 Audit)
- Completion of Detailed Design (Stage 3 Audit)
- During Construction Stage (Stage 4 Audit)
- Completion of Construction (Pre-opening) (Stage 5 Audit)

Stages of road safety audit in Existing Roads

- On Existing Roads (Monitoring)

Stage 1 is recommended for major schemes, including in urban areas, in order to influence route choice, alignment selection, standards, impact on and continuity with the existing network, junction provision, possible hazards from roadside development etc. Reviews of initial project/planning study. Stage 2 is recommended on completion of preliminary design, to assess horizontal and vertical alignments, sight lines and layout of junctions including slip roads and lay-byes. After this stage, land acquisition may be taken up. Examination when preliminary design is completed i.e., where the alignment has largely been decided, but can still be modified before approval

Stage 3 is recommended on completion of detailed design and before preparation of contract documents, to assess detailed junction layout, markings, signs, signals, lighting details, etc. Examination when detailed design is completed and the limits of expropriation have been set, but before the tender documents are prepared and tenders are invited. Stage 4 audit is done during construction stage. Construction zone is that area of the road which is affected by the works and which affects traffic flow and safety of workers and road users. In this context it can also be called Traffic Control Zone'. In rural areas, problem at these zones is accentuated by the reduced availability of carriageway, acquisition of land for diversions, etc. In urban areas, the problems are even more acute as diversions may have to be over adjacent road street of the road network as well as the sharing of road space by different categories of road users.

Stage 5 is recommended immediately prior to opening of scheme, involving the site staff and local traffic police in car and truck. This should take the form of driving and when appropriate, walking and/or cycling the new route. This is checked during night time also to ensure that required night time safety standards have been achieved. Safety Audit methodology is also successful on existing roads which includes both Operation and Maintenance (O&M) of existing roads. The existing roads represent the present condition of the road after completion of construction as well as any hazardous conditions that may have been created during its lifetime such as encroachments, ribbon development or deterioration of road conditions as well as traffic

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conditions, etc. An analysis of any accident data and inspection of the scheme every year, with a view to determine whether or not road users use the scheme appropriately.

V. RESULTS AND DISCUSSION

The problems are identified based on the standards and literature mentioned above. The reasons of traffic accidents were mostly known and uncontrollable. Speeding, Taking on phone, Drunk Driving, Riding without a helmet or not wearing seat belt, Breaking the traffic rules, Poor road infrastructure, Driving in fog are the problems identified from the literatures. Poor road infrastructure is a very common cause of accidents in India. Unlike other factors, the driver here has to suffer without a fault of his own. A bad road is distinguished by signs such as piles of debris, spilled oil, pits and defective highway lamps. Annual average daily traffic, Curve features, Lane width, Friction, Operating speed, Sight distances, Traffic volume & mix, Distance to adjacent curves, nearest intersection, Median width and Median opening were identified as important factors through literature study and IRC recommendations.

Some mitigation strategies to avoid traffic accidents are listed below:

1. Road safety has been made an integral part of road design at the planning stage
2. Road safety audit for problematic stretches has been taken up.
3. High priority has been accorded to identification and rectification of black spots on national highways
4. Publicity campaign on road safety through the electronic and print media
5. Implementing a new National Road Safety policy which outlines safety measures such as promoting awareness, encouraging safer road infrastructure, enforcement of safety laws etc.
6. Tightening of safety standards for vehicles like seat belts, power-steering, anti-lock braking system etc.

VI. CONCLUSION

The goal of the study is to identify the geometric elements that influences the safety of the highway road network. In order to identify the elements, the literatures of previous research were studied and to find the values of such element which were recommended in the Indian roads congress codes were studied. The study assessed the traffic safety performance of roads and geometric elements that contributed to the traffic accidents. Generally an accident not take place is caused by one factor but several reasons in any specific location. As the highway alignment concern, horizontal & vertical curve design is one of the important aspects involving highway safety. The design value of each curve factor and it's range need to be decided with design consistency. Analysis indicated that, the variables such as horizontal radius, super elevation, K-value, vertical gradient and visibility indicate very strong correlation with the frequency of accidents. The combined effects of sharp horizontal radius, higher super elevation and poor visibility tends to increase the accident frequency and provide very high accident rate on the model. On the other hand, the combination effect of flatter horizontal radius, lesser super elevation and more visibility tends to decrease the accident frequency and provide very less accident rate. Many developed nations started a campaign with the motto of "vision zero" that was predicted zero deaths on roads. It is suggested that more importance should be given to the Road Safety issue considering all accident causing factors and a highway safety system should be developed.

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