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Study on Safety Performances of Two Lane Rural Highway under Mixed Traffic

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ABSTRACT:
On analyzing the influence of geometric design characteristics on traffic safety using bi-directional data on a divided roadway operated under heterogeneous traffic conditions in India. The study was carried out on a four lane divided inter-city highway in plain and rolling terrain. Statistical modelling approach by Poisson regression and Negative binomial regression were used to assess the safety performance as occurrence of crashes are random events and to identify the influence of the geometric design variables on the crash frequency. Negative binomial regression model was found to be more suitable to identify the variables contributing to road crashes. The study enabled better understanding of the factors related to road geometrics that influence road crash frequency. The study also established that operating speed has a significant contribution to the total number of crashes. Negative binomial models are found to be appropriate to predict road crashes on divided roadways under heterogeneous traffic conditions.

INTRODUCTION

Improving two-lane highway traffic safety conditions is of practical importance and has attracted significant research attention within the last decade. Many cost-effective and proactive solutions such as low-cost treatments and roadway safety monitoring programs have been developed to enhance traffic safety performance under prevailing conditions. A two-lane Highway Safety Enhancement Project (HSEP) was implemented on the major highway network in Beijing from 2004 to 2006 by the Ministry of Transport of the People's Republic of China. A series of engineering solutions was proposed and integrated to improve traffic safety performance network-wide. More than 170,000 hazardous sections of national or provincial highways were improved over 50,000 kilometers, which included improper curves, heavy gradients, insufficient sight distances, and vague clear zones. Cost- effective countermeasures against severe injuries and fatal crashes also included adding or replacing traffic signs, painting markings on pavement, installing different barriers on roadsides, and channelizing intersections.

Introduction of methods:

Substantial work has been conducted on engineering-based countermeasure development for improvement of safety performance. Bagdade et al. introduced specific traffic engineering improvements targeted at improving safety for seniors, which were developed to popularize the use of a number of engineering countermeasures throughout Michigan. Labi investigated the efficacy of roadway improvements in terms of crash reduction at various subclasses of rural two-lane highways using the empirical analysis method of the negative binomial modeling technique.

In this study, the HSEP research findings are presented to evaluate the engineering solutions and their effectiveness in reducing traffic crash severities on Highway G109 in Beijing, China. The potential causal factors were identified based on the proposed evaluation

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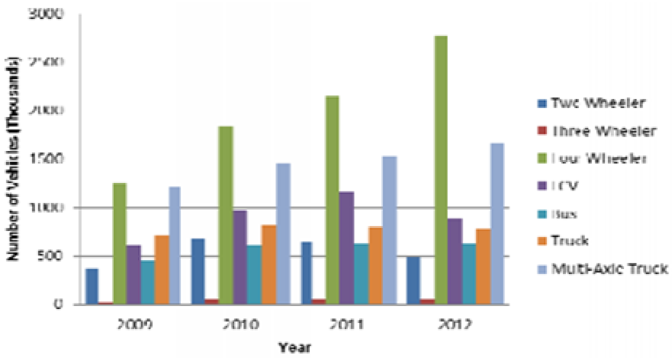
criteria, and primary countermeasures were developed against inferior driving conditions. Six cost-effective engineering solutions were specifically implemented to improve two-lane highway safety conditions:

1. Traffic sign replacement,
2. Repainting of pavement markings,
3. Installation of road side barriers,
4. Intersection channelization,
5. Drainage optimization, and
6. Sight distance improvement.

An Empirical Bayes (EB) model-based before-after study was conducted. The results indicate that the proposed engineering solutions effectively improved traffic safety performance by significantly reducing crash occurrence risks and crash severities. Fatality rate, which is defined as the number of persons killed per 100,000 in habitants per year, is 16.6 in 2014 in the country. Statistical data from India reveals that highways are facing a disparate rate of crashes, i.e., almost 53.7% of road crashes occurred on inter-city highways in the year 2014 when compared to urban roads (Transport Research Wing (TRW), Ministry of Road Transport & Highways, 2014). The heterogeneous traffic under high-volume conditions, share the available road space without sufficient safe lateral as well as longitudinal clearances. The lane-less movement further adds to the complexity of analyzing/modeling heterogeneous traffic. This motivates the need for a level of safety analysis under heterogeneous traffic conditions. Road crashes are complex events and are influenced by many factors such as road geometric design, traffic volume and composition, speed, weather, motivation for travelling, drivers' physical and mental conditions etc. Highway geometry should be designed for traffic safety and efficiency. Traffic-safety analysis was initially recognized in 1960's.Later several research works related to traffic safety analysis were performed by different research groups in different parts of the world by considering its seriousness to the public health, which resulted in different ways for evaluating safety performance. Safety Performance Function (SPF) is defined as the relationship between crash and the factors influencing crashes.

Heterogeneous Traffic Condition

The methodology for prioritization of accident black spots as well as for identification of accident causative parameters for rural highway based on computation of hazard ratings cores was developed (Robert2006).Accident prediction factors were developed by varying the roadway width and traffic volume. Models were also developed in the study for evaluating crash rate, casualties and injuries using Poisson, Negative Binomial and multiple regression models respectively. For evaluating the safety performance of two-lane undivided rural roads,Accident Prediction Models (APM's) were developed using Poisson model with random coefficients for predicting single vehicle and multi vehicle accident (Dinu2012). In the case of APM for single vehicle accident, parameters such as length of segment, average daily traffic, number of vertical curves have positive effect where as percentage of motorized two-wheelers and heavy goods vehicles have negative effect. But in the case of APM for multi-vehicle accidents model parameters such as length of segment, average daily traffic, number of vertical curves, percentage of motorized two-wheelers and heavy goods vehicles have positive effect. This indicates that accidents increase with exposure. Most of their search works found in literature considered homogeneous and lane disciplined traffic conditions and hence, the results of the above studies may not be directly applicable to heterogeneous traffic such as the one prevailing in developing countries like India. Hence the present study, a methodology for the evaluation of safety performance of multi-lane rural highways operating under heterogeneous traffic is presented.



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TRAFFIC FLOW IN HIGHWAY

Two-lane, two-way highways are a key element in the highway system of most countries, where they provide a variety of transportation related functions, are located in all geographic areas, and serve a wide range of vehicle traffic (TRB2000). Figure1 shows a typical view of a two-lane, two- way rural highway.

Fgure 1 Typical Two-Lane, Two-Way Highway (Picture Courtesy of FHWA)

Two-lane, two-way highways comprise the vast majority of highway facilities in areas where the bulk of vehicular travel takes place in rural settings. In the United States, two-lane, two-way highways constitute more than 82% of the National highway system as measured by length in miles. This corresponds to 64% in urban areas and 90% in rural areas excluding highways in Federal parks, forests, and reservations that are not part of the State and local highway systems (FHWA 2003). Traffic operations on two-lane, two-way highways differ from other facilities due to the unique relationship between traffic conditions in the two directions of travel. In particular, lane changing and passing maneuvers are restricted on two-lane, two-way highways and are typically performed using the opposing lane of travel when sight distance and more importantly gaps in the opposing traffic stream permit. For this reason, on two-lane, two-way highways, normal traffic flow in one direction influences flow in the other direction. Consequently, two-lane, two-way highways are known for their higher level of interaction between vehicles in the opposing directions of travel and therefore provide unique challenges to traffic analysts.

TWOPAS Computer Simulation

Evolution of TWOPAS As was mentioned in the opening; the TWOPAS simulation model is used to evaluate traffic performance on two-lane, two-way highways. TWOPAS is a microscopic computer simulation model for the analysis of traffic behavior on two-lane, two way highways. The predecessor of the TWOPAS model, known as TWOWAF (for TWO Way Flow), was originally developed in1978 by the Midwest Research Institute (MRI) and later improved by MRI in 1981. The development of the TWOWAF model is documented in the NCHRP Report 185 titled Grade Effects on Traffic Flow Stability and Capacity (Harwood et al,1999).

In 1983, the Texas Transportation Institute (TTI) and KLD and Associates made further updates to TWOWAF, which resulted in the version of the model that was used in the development of theHCM1985.ThisversionofTWOWAFhadthecapabilityt osimulatetrafficoperationsonnormal two-lane highways, including both passing and no-passing zones, as well as the effects of horizontal curves, grades, vertical curves and sight distance.

METHODOLOGY

The goal of transportation is generally stated as the safe and efficient movement of people and goods. To achieve this goal, designers use many tools and techniques. One technique used to improve safety on roadways is to examine the consistency of the design. Design consistency refers to highway geometry's conformance to driver expectancy. Generally, drivers make fewer errors in the vicinity of geometric features that conform to their expectations than at features that violate their expectations.

1. In the United States, design consistency on two-lane rural highways has been assumed to be provided through the selection and application of a uniform design speed among the individual alignment elements. The design speed is defined by the American Association of State Highway and Transportation Officials (AASHTO) as "the maximum safe speed that can be maintained over a

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specified section of highway when conditions are so favorable that the design features of the highway govern."

2. If a road is consistent in design, then the road should not violate the expectations of motorists or inhibit the ability of motorists to control their vehicle safely.

3. Consistent roadway design should ensure that "most drivers would be able to operate safely at their desired speed along the entire alignment."

4. One weakness of the design-speed concept is that it uses the design speed of the most restrictive geometric element within the section, which is usually a horizontal or vertical curve, as the design speed of the road. Consequently, the design-speed concept currently used in the United States does not explicitly consider the speeds that motorists travel on tangents. Other weaknesses in the design-speed concept have generated discussions and additional research into other methods for evaluating design consistency along two-lane rural highways. Both speed-based and non-speed-based highway geometric design consistency evaluation methods have been considered. These methods have taken several forms and can generally be placed in the following categories: vehicle operations-based consistency (including speed), roadway geometrics-based consistency, driver workload, and consistency checklists. Some of these methods may be incorporated into the Interactive Highway Safety Design Model (IHSDM). The IHSDM is being developed by the Federal Highway Administration (FHWA) as a frame work for "an integrated design process that systematically considers both the roadway and the road side in developing cost-effective highway design alternatives."

5. The focus of the IHSDM is on the safety effects of design alternatives. Design consistency is one of several modules built around a commercial computer-aided design package in the current vision of the IHSDM. The other modules include: crash analysis, driver/vehicle, intersection diagnostic review, policy review, and traffic analyses.

Route Planning

Planning with respect to road construction takes into account present and future uses of the transportation system to assure maximum service with a minimum of financial and environmental cost. The main objective of this initial phase of road development is to establish specific goals and prescriptions for road network development along with the more general location needs. These goals must result from a coordinated effort between the road engineer and the land manager, forester, geologist, soil scientist, hydrologist, biologist and others who would have knowledge or recommendations regarding alternatives or solutions to specific problems. The pattern of the road network will govern the total area disturbed by road construction.

The road pattern which will give the least density of roads per unit area while maintaining minimum hauling distance is the ideal to be sought. Keeping the density of roads to an economical minimum has initial cost advantages and future advantages in road maintenance costs and the acreage of land taken out of production.

DESIGNCRITERIA:

Design criteria consist of a detailed list of considerations to be used in negotiating a set of road standards. These include resource management objectives, environmental constraints, safety, physical environmental factors (such as topography, climate, and soils), traffic requirements, and traffic service levels. Objectives should be established for each road and may be expressed in terms of the area and resources to be served, environmental concerns to be addressed, amount and types of traffic to be expected, life of the facility and functional classification. Additional objectives may also be defined concerning specific needs or problems identified in the planning stage.

1. Resource management objectives: Why is the road being built; what is the purpose of the road (i.e., timber

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harvesting, access to grazing lands, access to communities,etc.)?

2. Physical and environmental factors: What are the topographic, climatic, soil and vegetation characteristics of the area?

3. Environmental constraints: Are there environmental constraints; are there social-political constraints? Examples of the former include erosiveness of soils, difficult geologic conditions, and high rainfall intensities. Examples of the latter include land ownership boundaries, state of the local economy, and public opinion about a given project.

4. Traffic requirements: Average daily traffic (ADT) should be estimated for different user groups. For example, a road can have mixed traffic--log or cattle trucks and community traffic. An estimate of traffic requirements in relation to use as well as changes over time should be evaluated.

5. Traffic service level: This defines the type of traffic that will make use of the road network and its characteristics. Table 3 lists descriptions of four different levels of traffic service for forest roads. Each level describes the traffic characteristics which are significant in the selection of design criteria and describe the operating conditions for the road. Each level also reflects a number of factors, such as speed, travel time, traffic interruptions, freedom to maneuver, safety, driver comfort, convenience, and operating cost. Traffic density is a factor only if heavy non-logging traffic is expected. These factors, in turn, affect: (1) number of lanes, (2) turnout spacing, (3) lane widths, (4) type of driving surface, (5) sight distances,(6) design speed, (7) clearance; (8) horizontal and vertical alignment, (9) curve widening, (10) turn-arounds.

6. Vehicle characteristics: The resource management objectives, together with traffic requirements and traffic service level criteria selected above will define the types of vehicles that are to use the proposed road. Specific vehicle characteristics need to be defined since they will determine the "design standards "to be adopted when proceeding to the road design phase. The land manager has to distinguish between the "design vehicle" and the "critical vehicle". The design vehicle is a vehicle which ordinarily uses the road, such as dual axle flatbed trucks in the case of ranching or farming operations, or dump trucks in the case of a mining operation. The critical vehicle represents a vehicle which is necessary for the contemplated operation (for instance, a livestock truck in the case of transporting range live stock) but uses the road in frequently. Here, the design should allow for the critical vehicle to pass the road with assist vehicles, if necessary, but without major delays or road reconstruction.

7. Safety: Traffic safety is an important requirement especially where multiple user types will beutilizingthesameroad.Safetyrequirementssuchasstoppingdistance,sightdistance,and allowable design speed can determine the selected road standards in combination with the other design criteria.

8. Road uses: The users of the contemplated road should be defined by categories. For example, timber harvest activities will include all users related to the planned timber harvest, such as silvi culturists, foresters, engineers, surveyors, blasting crews, and construction and maintenance crews, as well as the logging crews. Administrative users may include water shed management specialists, wildlife or fisheries biologists, or ecologists, as well as foresters. Agricultural users would include stock herders and rangeland management specialists and will have a different set of objectives than timber objectives. An estimate of road use for each category is then made (e.g., numbers of vehicles per day). For each category, the resource management objective over several planning horizons should be indicated. For instance, a road is to be built first for (1) the harvest of timber from a tract of land, then (2) access for the local population for firewood cutting or grazing, and finally (3) access foradministratio of watershed rehabilitation activities. The planner should determine if

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the road user characteristics will change over the life of the road.

9. Economics: The various road alternatives would undergo rigorous economic evaluations.

Type and Size of Vehicle	Design Speed (Km/Hr)		
	30	40	50
	Minimum Traveled Way Width (m)		
Recreational, administrative and service vehicle, 2.0 to 2.4 m wide	3.0	3.0	3.6
Commercial hauling and commercial passenger vehicles, including buses 2.4 m wide or greater			
1. Road with ditch, or without ditch where cross slope is 25% or less	3.6	3.6	4.2
2. Roads without ditch where ground cross slope is greater than 25%. The steepness of roadway backslope should be considered to provide adequate clearance.	3.6	3.6	4.2

Fig.3.2. Methods of vehicle detection and controlling with measurements.

ROADCONSTRUCTION

The most important pavement materials are soils, mineral aggregates, bituminous binders, and stabilizers like lime, cement, etc. Mineral aggregates constitute about 90 percent of total volume of road construction materials used. All roads have to be founded on soil and are required to make optimum use of the locally available materials, if it is to be constructed economically. Materials used in the structural layers of the pavement should be selected based on availability, economy and previous experience.
Soil as road construction material:

Sub grade soil is an integral part of the road pavement structure as it provides support to the pavement as its foundation. The main function of the sub grade is to give adequate support to the pavement and for this the sub grade should possess sufficient stability under adverse climatic and loading conditions. The formation of wave, corrugations, rutting and shoving in black top pavements are generally attributed to poor sub grade conditions. When soil is used in embankment construction, in addition to stability, incompressibility is also important as differential settlement may cause failure. Soil is used in its natural form (gravel and sand) or in a processed form (stabilized layer) for pavement construction. Soil is also used as a binder in water-bound macadam layers. Soil is therefore, considered as one of the principal highway materials. The foundation of other cross-drainage structures (culverts, bridges and retaining walls) rests on soils and their stability depends on the soil strength, knowledge of soil properties is necessary to select the embankment material, pavement structure, drainage system and foundation of structures. When a high embankment rests on soft ground, its stability can be predicted by studying the properties of soil. Frostaction, common in high altitudes, can be taken care of if the soil properties are well known. Soil consists mainly of minerals matter formed by the disintegration of rocks, by the action of water, frost, temperature, and pressure or by plant or animal life. Based on the individual grain size of the soil particles, soil have been classified as gravel, sand, silt, and clay.

The BIS gives the following limits of particle size.

Gravel	80-4.75 mm
Sand coarse	4.75- 2.00 mm
Medium	2.00-0.475 mm
Fine	0.475-0.075 mm
Silt	0.075- 0.002 mm
Clay	<0.002m

TWO LANE RURAL HIGHWAY CONSTRUCTIONS

Construction of new two-lane State highways, full reconstruction of long segments of existing two-laneStatehighways,ornewconstructionofruralmultilaneStatehighwayswithoutaccesscontrol are no longer common highway designs in Illinois. Instead, existing two-lane highways are more commonly improved using 3R guidelines or upgraded to a four-lane expressway design with partial access control.

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TWO-LANEHIGHWAYS

The minimum design for a State route is a two-lane, two-way highway. In some areas of the State,thetwo-lanehighwaysystemcarriesalargeportionoftheruraltraffic. Manyofthesehighways are located near major urbanized areas and are experiencing rapid growth in traffic. The following describes some of the more common situations where new construction or reconstruction projects might be proposed for a two-lane highwayimprovement:

- Realigning of an existing low-speed horizontalcurve;
- Raising the profile gradeline of a roadway to remedy floodingproblems;
- Providing a bypass around a smallcommunity;
- Modifying the vertical profile or improving an intersection to enhancesafety;
- upgrading a major route (i.e., arterial or collector) approaching an urbanized area where the current ADT is 5000 or greater, and where there is a small probability of traffic growth warranting four lanes in 20 years;and/or
- Increasing passing opportunities to break up platoons and to reduce delay. 47-2.02 Typical Sections Figure illustrates typical schematic cross sections for two-lane highways.

The tables in Section47-2.06 provide the minimum criteria for lane widths, shoulder widths, and other cross section elements that should be used on rural two-lane highways. 47-2.03 Passing Sight Distance 47-2.03(a) Design Derivation passing sight distance considerations are limited to two-lane, two-way highways. On these facilities, vehicles may over takes lower moving vehicles, and the passing maneuver must be accomplished on a lane used by opposing traffic. The minimum passing sight distance for two-lane highways is determined from the sum of four distances as illustrated in Figure and the following provides the basic assumptions used to develop passing sight distance values for design:

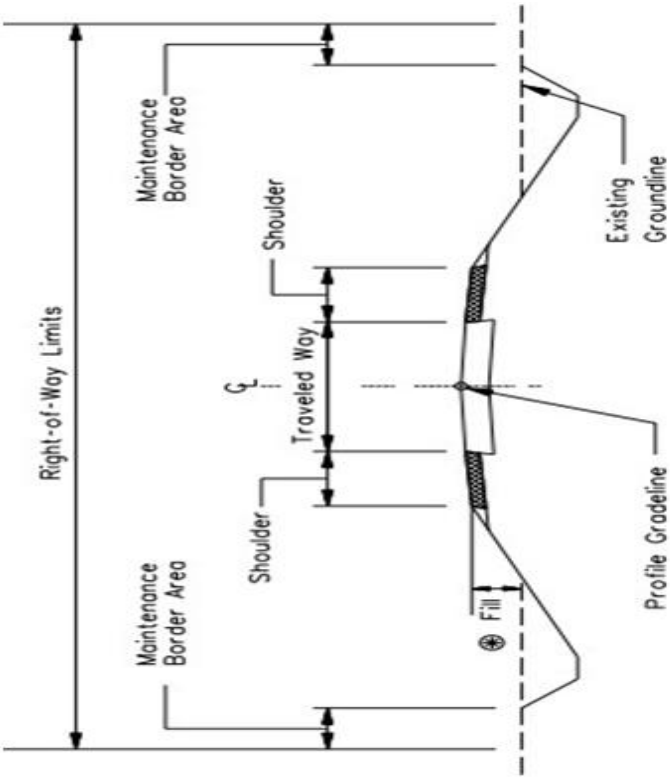

Fig.5.1. TYPICAL TANGENT SECTION FOR RURAL TWO-LANE HIGHWAYS.

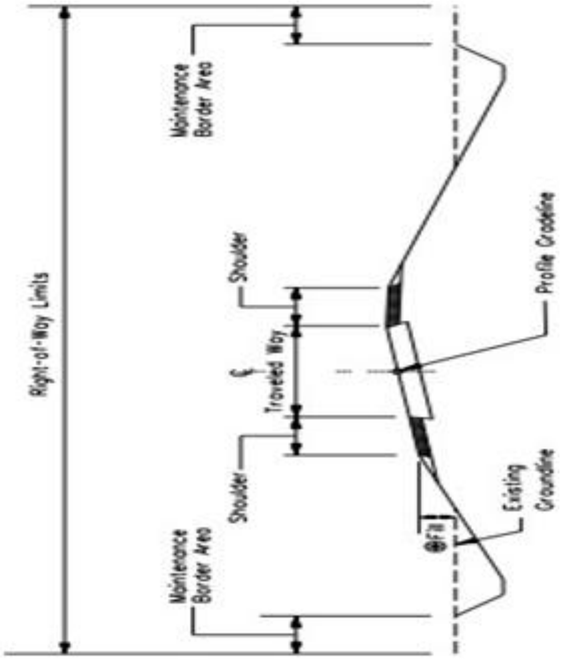

Fig.5.2. TYPICAL SECTION FOR SUPERELEVATED RURAL TWO-LANE HIGHWAYS

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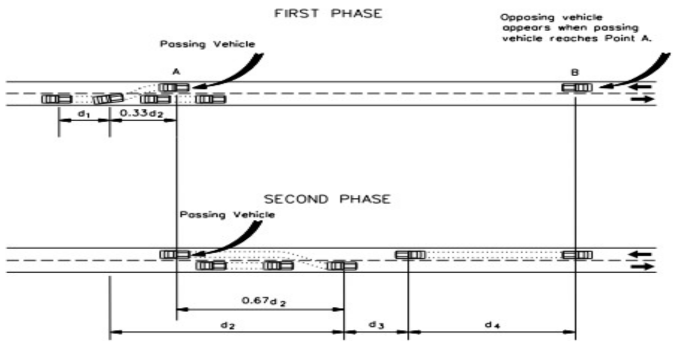

Fig.5.3. Twophase values.

DESIGN SECTION:

Capacity Analysis

Low Cost Methods for Improving Traffic Operations on Two-Lane Roads presents approximate adjustments that can be made to the capacity methodology in the Highway Capacity Manual. These adjustments can be used to estimate the level of-service benefits from adding passing lanes to two-lane facilities.

Spacing.When passing lanes are provided to improve the overall traffic operations over a length of roadway, they should be constructed systematically at regular intervals. Typical spacing for passing lanes may range from 3 miles to 10miles (5kmto15km). Actual spacing of passing lanes will depend on the traffic volumes, right-of-way availability, and existing passing opportunities.

Location: When determining where to locate passing lanes, the designer should consider the following factors.

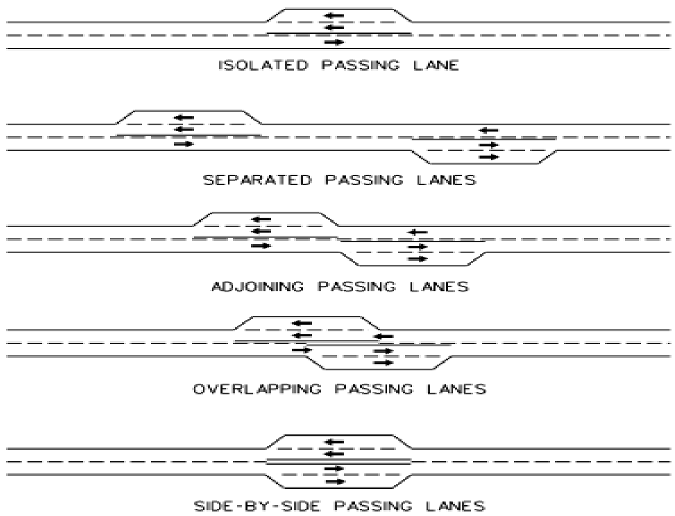

Fig.5.4. TYPICAL CONFIGURATIONS FOR PASSING LANES.

Vertical Alignment

Where practical, construct passing lanes on a sustained upgrade. The upgrade will generally cause a greater speed differential between slow moving vehicles and passing vehicles. However, passing lanes in level terrain still should be considered where the demand for passing opportunities exceeds supply.

Sight Distance

Locate the passing lane where there will be adequate sight distance to both the entrance and exit tapers of the additional lane. Because of sight distance concerns, do not locate exit tapers just beyond a crest vertical curve.

Intersections

Use special care when designing passing lanes through intersections and high-volume commercial entrances.

Structures

Avoid placing passing lanes where structures (e.g., large culverts, bridges) will restrict the overall width of the traveled way, passing lane, and shoulders.

Two-Way, Left-Turn Lanes (TWLTL)

TWLTL may be appropriate at isolated rural locations, where the highway is transitioning into a suburban or urban area having sizable left-turn volumes, or where there are several closely spaced driveways. Rural facilities will typically consist of a three-lane cross section illustrated inFigure. For posted speeds greater than 45 mph, exercise caution in designing the TWLTL. See Sections 48-4 and 34-3 for TWLTL designcriteria.

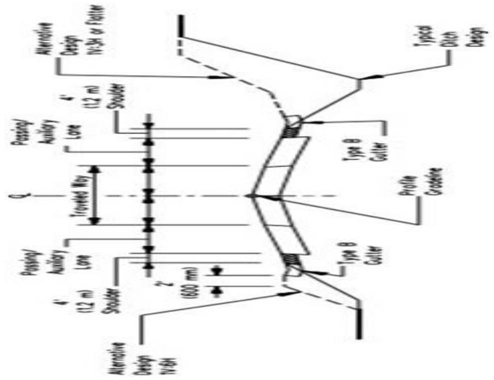

Fig.5.5. Left turn indication.

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CONCLUSION

The study was carried out to analyse safety performance of a four-lane divided highway in India, operated under heterogeneous traffic condition. The study was carried out in two sections, viz, development of safety performance functions and also operating speed models. Safety Performance functions (SPF's) were developed using GLM approach likes Poisson, Poisson-gamma regression, negative binomial and zero-inflated models where as operating speed models for the mid of curve as well as tangent were developed using multiple linear regression approach. As far as SPF's were considered, geometric design parameters such as gradient, cross slope, operating speed, median opening and annual average daily traffic have significant effect on crashes and this variation in turn affects the traffic characteristics thereby decreasing the level of safety, leading to more number of crashes. From the models developed based on the goodness of fit test, N B regression model was found to have lower value than that of Poisson regression and Poisson-gamma models, which shows the ability of NB model for predictingcrashes.

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