IMPACTS OF ROADWAY CONDITION, TRAFFIC AND MANMADE FEATURES ON ROAD SAFETY

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In

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(With Specialization in Transportation Engineering)

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MAY 2013

DEDICATED

TO

THE BEST TEACHERS OF THE WORLD

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CERTIFICATE

This is to certify that the work contained in the thesis entitled **"*Impacts of Roadway condition,Traffic and Manmade Features on Road Safety*"** submitted by ***Mr.AchutaNanda Dehuri (Roll No:211CE3242)*** in partial fulfillment of the requirements for the award of the degree of Master of Technology in Transportation engineering during the session 2011-2013 in the department of Civil engineering, National Institute of Technology Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree.

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ABSTRACT

India is a developing country and safety of road is still in a premature stage. Accident severity is increasing in increasing order due to increasing in vehicle population. Accident leads to disablement, death, damage to health and property, social suffering and general degradation of environment. The road accident situation in India is alarming. Records show that there is one death at every 2.75 minutes because of road accidents. The high accident rate is largely attributed to the inadequacy of the highways and other main roads to meet the traffic demands, road user behavior, vehicle defects, poor road geometrics and visibility. Road accidents inflict heavy economic loss to the country. Road Safety is necessary to reduce accident involving both human and vehicles there by making the road more safe and user friendly to traffic.

NH-55 is one of the major connectivity from Cuttack to Sambalpur which caters to the need of transportation of light goods to heavy goods and passengers. Study area was undertaken on road NH-55 from Angul to Bhushan steel plant with stretch Km 159/0 toKm157/0 in Odisha state. The coal based power plants and steel industries have been set up since 2006. The study Stretch is a major connectivity to no of heavy industries like Nalco, Bhushan steel, Jindal steel, Gmr, Essar steel, Adani power, Monnet and many more small scale industries based on Talcher coal mines. The no of accidents is rising up every year due to increasing vehicles population. The location in a roadway where the traffic accident often occurs is called a black spot. The accident data is analyzed using accident frequency and severity index method. The safety deficiencies were detected to minimize accidents and save the road users. The deficiencies along with the measures for further improvement have been presented in this thesis.

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ABBREVIATIONS

MORTH	Minstry of Road Transport and Highways
CAGR	Compound Annual Growth Rate
ADT	Average Daily Traffic
AADT	Annual Average Daily Traffic
BAC	Blood Alcohol Concentration
THC	Tetra Hydro cannabinol
ANOVA	Analysis of Variance
NH	National Highway
ITS	Intelligent Traffic System
LOS	Level of Service
FIR	First Information Report
IPC	Indian Penal code
MVKY	Million Vehicle-Kilometer-Years
Q_{MAX}	Capacity
PCU	Passenger Car Unit
IRC	Indian Road congress
X	Cross Junction
O	Off Set Junction
T	Tee Junction
VOL	Traffic Volume
R^2	Co efficient of Determination
SSE	Sum of Squares Eroor
SSR	A Variance
χ^2	Chi-Square
Cal	Calculated
Crit	Critical

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Chapter-1

INTRODUCTION

1.1General

Road crashes take away the right to life of 3,000 people every day. This is a global humanitarian disaster, and it is man-made. (Global Road Safety Partnership Annual Report 2011)

Road safety is one of the most important problems in our society. Every year 1.2 million of people are killed and between 20 and 50 million people are injured in road accidents. If current trends continue road traffic accidents are predicted to be third leading contributor to the global burden of Disease and injury by 2020(Torregrosa et al.,2012)

India had earned the dubious distinction of having more number of fatalities due to road accidents in the world. Road safety is emerging as a major social concern around the world especially in India (Shivkumar and Krishnaraj,2012).

Accidents are a drain on the national economy and may lead to disablement, death, damage to health and property, social suffering and general degradation of environment.

To minimize the no of crashes by any kind and severity expected to occur on the entity during a specific period is known as road safety. Accidents and the fatalities on road are the result of inter-play of a number of factors. Road users in India are heterogeneous in nature, ranging from pedestrians, animal- driven carts, bi-cycles, rickshaws, hand carts and tractor trolleys, to various categories of two/three wheelers, motor cars, buses, trucks, and multi-axle commercial vehicles etc., The vehicle population has been steadily increasing because of change in the style of living of people. Increase in vehicle population with limited road space used by a large variety of vehicles has heightened the need and urgency for a well thought-out policy on the issue of road safety. In India the rate of accident is directly proportional to growth of vehicle population.

Road accidents are a human tragedy, which involve high human suffering. They impose a huge socio-economic cost in terms of untimely deaths, injuries and loss of potential income. The ramifications of road accidents can be colossal and its negative impact is felt not only on individuals, their health and welfare, but also on the economy. Consequently, road safety has become an issue of national concern. Road Safety is a multi-sectoral and multi-dimensional

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. Road accident in India is shown in Table 1.1

Table 1.1 Road accident in India (2002-2011)

Number of Road Accidents and Number of Persons Involved: 2002 to 2011					
Year	No of Accidents		Number of Persons		Accident Severity
	Total	Fatal	Killed	Injured	
2002	4,07,497	73,650	84,674	408,711	20.8
2003	4,06,726	73,589	85,998	435,122	21.1
2004	4,29,910	79,357	92,618	464,521	21.5
2005	4,39,255	83,491	94,968	465,282	21.6
2006	4,60,920	93,917	105,749	496,481	22.9
2007	4,79,216	1,01,161	114,444	513,340	23.9
2008	4,84,704	1,06,591	119,860	523,193	24.7
2009	4,86,384	1,10,993	125,660	515,458	25.8
2010	4,99,628	1,19,558	134,513	527,512	26.9
2011	4,97,686	1,21,618	1,42,485	5,11,394	28.6

Source: Road statistics of India (2011)

Causes of accidents and their contribution are as follows by statistics of Road accidents in India(2011)

Drivers fault- 77.5%

Defects in road condition- 1.5%

Defects in motor vehicle- 1.6%

Fault of bicyclist- 1.3%

Fault of pedestrian- 2.4%

Weather condition- 1%

All other causes- 14.8%

Road safety in India is the poorest in the world. According to MORTH 2013 India has the highest no of accidents in the world. Awareness among road users and safe design of road components is necessary to reduce accident involving both human and vehicles.

1.11 Road Safety & Various Causes of Accident

Road traffic safety refers to methods and measures for reducing the risk of a person using the road network being killed or seriously injured. The users of a road include pedestrians, cyclists, motorists, their passengers, and passengers of on-road public transport, mainly buses and trams. Best practice road safety strategies focus upon the prevention of serious injury and death crashes in spite of human fallibility. Safe road design is now about providing a road environment which ensures vehicle speeds will be within the human tolerances for serious injury and death wherever conflict points exist.

The various causes of accidents may be due to three factors shown in fig 1.1

(i) Driver

(ii)Vehicle

(iii) Environment

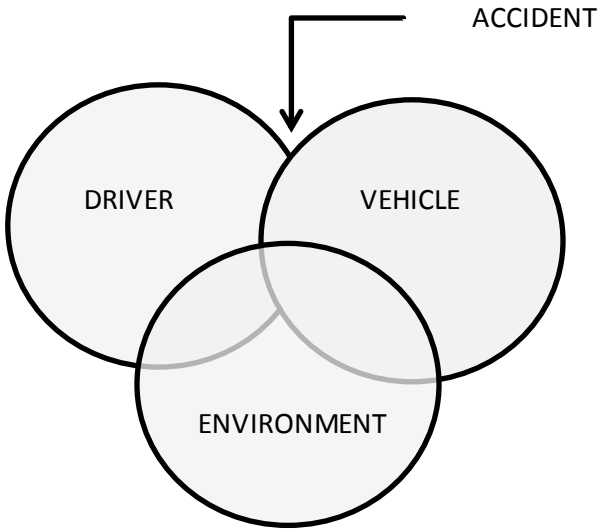


Fig1.1 Causes of Accident

The details of these factors are shown in Table 1.2 below

Table 1.2 Various Factors Related to Accident

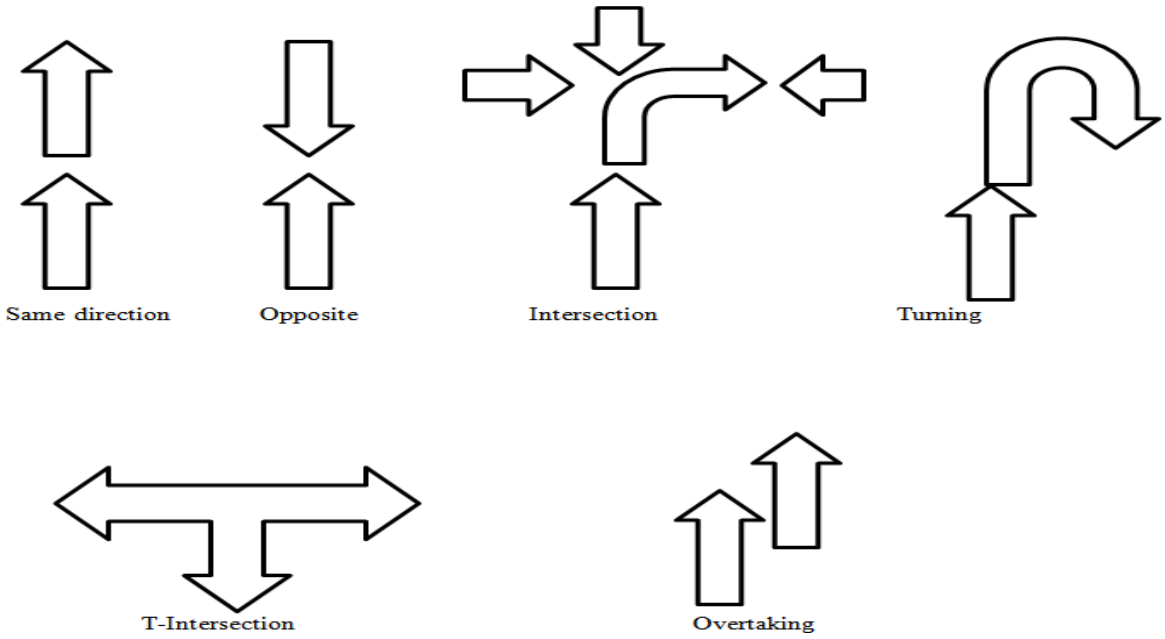
Driver-Related	
Alcohol and drugs	Sickness
Unsafe speed	Cell Phone Use
Drowsing or Fatigue	Distraction
Fatigue	Improper Passing or Turning
Disregard traffic controls	Non Use of Restraint
Vehicle-Related	
Over Loading	Steering defect
Brake defect	Tire failure
Light defect	Improper wheel alignment
Environmental- Related	
Road side hazard	Vision obstruction
Ruts	Improper traffic control
Debris or Garbage on the road	Road Side Hazard
smoke or fog	Fixed Objects
Glare	Water ponding
Improper/nonworking traffic controls	Shoulders defective

1.12 Types of Accident,Position of Vehicles and Consequences

Accident imposes both tangible and intangible cost.The details are shown in Table 1.3 and Fig 1.2

Table 1.3 Types of Accident,Position of Vehicles and Consequences

Type of Accident	Position of Vehicles
Head on	Vehicle from opposite direction
Rear end	Vehicle in same direction
Angle and turning	Vehicle from adjacent direction(Intersection)
Parking or Backing	Overtaking
Roll over	On path
Run-off-road	Off path
Moped bike	On curve turning
Fixed Objects(Trees and Poles)	Off path curve
Pedestrian	
Animal	
Consequences	
Property Loss	Contusion (Head injury without skin unbroken)
Spot Death	Fracture
Loss of consciousness	Freezing
Amputation (Loss of one or more limb)	Trauma
Head/Neck injury	Laceration (Injury involving cut)
Abrasion	Vision/Speech/Hearing Impairment
Sprain (Ankle/Joint twist)	Chest pain/Respiratory impairment



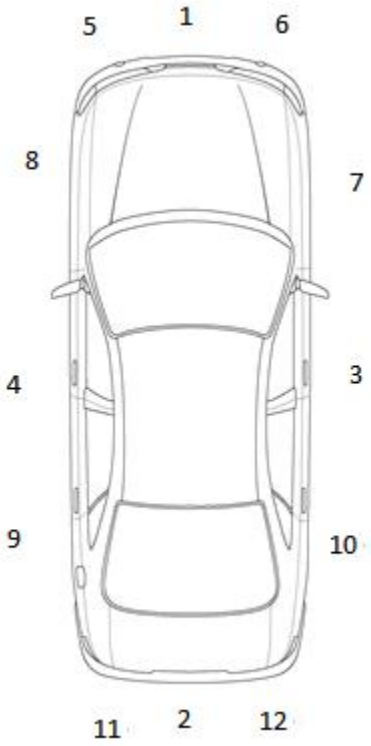


Fig1.2 Position of vehicle and points on vehicle where object collides.

1.13 Accident Theory

Collision may be two types (i) Collinear Impact

(ii) Angular collision

Further collision is divided into two types (i) Rear end collision

(ii)Head on collision

Two theory – (i) Poisson Impact theory

(ii)Energy theory

Poisson impact theory-It is based on compression and restitution

Suppose two vehicles travelling at initial speed v_1 and v_2 collide and obtain a uniform speed say u at compression. After compression is over the final speed is u_1 and u_2

Then according to newton's law

Reaction force $-F = m_1\frac{dv_1}{dt}$ and action force $F = m_2\frac{dv_2}{dt}$

$m_1(u-v_1) = -p_c \quad m_2(u-v_2) = p_c$

Where $p_c=\int_0^{Tc} F.dt$ is compresson impulse and T_C is compression time

Velocity after collision $u = \frac{m_1v_1+m_2v_2}{m1+m2}$

Compression impulse $p_c = \frac{m_1m_2}{m1+m2}(v_1-v_2)$

In the restitution phase the elastic part of internal energy is released

$m_1(u_1-u) = -p_r$

$m_2(u_2-u) = p_r$

where $p_r = \int_0^{\tau_r} F\ dt$ is restitution impulse

τ_r = Restitution time

According to poisson hypothesis restitution impulse is proportional to compression impulse

Restitution impulse $e = (u_2 - u_1)/(v_1 - v_2)$

P = Pc+Pr

Total impulse $p = (1+e)\frac{m_1 m_2}{m_1 + m_2}\Delta v$

Post impact velocity $u_1 = u - e\frac{m_2}{m_1 + m_2}\Delta v = v_1 - \frac{(1+e)m_2}{m_1 + m_2}\Delta v$

$$u_2 = u + e\frac{m_1}{m_1 + m_2}\Delta v = v_2 + \frac{(1+e)m_1}{m_1 + m_2}\Delta v$$

where $\Delta v = v_1 - v_2$

v_1 and v_2 are calculated from u_1 and u_2

Energy theory

Principle of conservation of energy

$\frac{w(v_1^2 - v_2^2)}{2g}$ = wfs

f = co efficient of friction

s = Skid resistance

m_1, v_1 are mass and velocity of first vehicle colliding with another vehicle of mass and velocity m_2, v_2 respectively.

$m_1 v_1 = m_2 v_2$

1.14 Haddon's matrix

Developed by William Haddon in 1970, the matrix looks at factors related to personal attributes, vector or agent attributes, and environmental attributes before, during and after an injury or death. By utilizing this framework, one can then think about evaluating the relative importance of different factors and design interventions. A typical haddon matrix is shown in Table 1.3

Table 1.3 A typical Haddon Matrix

Phase	Human Factors	Vehicles and Equipment Factors	Environmental Factors
Pre-crash	Information Attitudes Impairment Police Enforcement	Roadworthiness Lighting Breaking Speed Management	Road design and road layout Speed limits Pedestrian facilities
Crash	Use of restraints Impairments	Occupant restraints Other safety devices Crash-protective design	Crash-protective roadside objects
Post-Crash	First-aid skills Access to medics	Ease of access Fire risk	Rescue facilities Congestion

1.2 Need and Objectives of Study

Expansion in the road network, surge in motorization and a rising population of a country contribute towards increasing numbers of road accidents, road numbers of registered motor vehicles in the country and the country's population have increased at a compound annual growth rate (CAGR) of 3.4 per cent, 9.9 per cent and 1.6 per cent, respectively, during the decade 2001 to 2011. During the same period, the number of road accidents in the country increased at a CAGR of 2.1 per cent. Similarly, the number of road accident fatalities and the number of persons injured in road accidents in the country between 2001 and 2011 increased by 5.8 per cent and 2.4 per cent, respectively.

Very little work has been done in India to analyze accidents on two-lane roads.

The major objectives of the present work are listed below

(i)To study the annual, monthly, daily and hourly variation in accident rate on selected Stretch of urban two-lane road.

(ii)To study the effect of traffic volume, density and capacity on accident rate on urban Two-lane road.

(iii) To study the maintenance of road surface and shoulder on rate of accident.

(iv) To develop an accident prediction model based on AADT, road condition, road side Features.

1.3 Outline of the Report

The work has been documented in the following manner. The first chapter gives overall understanding about the present accident scenario at national level. It also includes the importance of the two-lane roads, factors affecting accident and their contribution, and defines objectives of the study. Chapter two is comprised of review of literature. Site selection for data collection, methodology adopted for data collection are discussed in third chapter. Chapter four depicts traffic and surface properties data of Study stretch. Chapter five is comprised of accident investigation and Black Spot analysis. Significant conclusion drawn from study and further work are given in chapter six.

Chapter-2

REVIEW OF LITERATURE

Many factors may exhibit a measurable influence on driving behavior and traffic safety on two-lane highways (Bhuyan, 2003). These include, but are not limited to,

(i)Human factors such as improper judgment of road ahead and traffic, driving under the influence of alcohol or drugs, driver education and experience, young driver, age and sex.

(ii)Traffic factors like speed, volume, density, capacity, traffic mix and variation.

(iii)Vehicle deficiencies, such as defective brake, headlight, tyres, steering and vehicle condition

(iv) Road condition like slippery or skidding road surface, ravels, pot hole, ruts etc.

(v)Road design such as inadequate sight distances, shoulder width, no of lanes ,improper curve design, improper lighting and traffic control devices.

(vi) Weather condition like fog, heavy rainfall, dust, snow etc.

(vii)Other causes such as enforcement, incorrect sign and signals, service station, badly located advertisement, stray animals etc.

2.1 Driver characteristics

2.1.1 Age, Gender and Personality

Hassan and Aty (2012) studied 680 young driver behavior involvement in traffic crash in Florida. The result revealed that aggressive violation, in-vehicle distraction and demographic characteristics were the significant factors affecting young drivers involvement in crashes at the age of 16-17.Invehicle distraction, attitude towards speeding and demographics characteristics were the significant factors effect young drivers crash risk at the age of 18-24.

Constantinou et al.,(2011) found that young novice driver(<25 yrs.) are in high risk related to traffic offence. The study was based on gender, sex, age and personality.

Chandraratna et al.,(2006) studied licensed driver involvement in a crash. Using logistic regression it was found very young and old male drivers are responsible due to both speeding and non-speeding

2.1.2 Perception

Sagberg and Bjornskau (2006) conducted a video-based hazard perception test and concluded that male novice driver had relatively longer reaction time and initial risk involved.

Deery (1999) studied about hazard and risk perception among young novice driver and concluded that hazard and risk perception are fundamental skill that young drivers need to develop.

2.1.3Alcohol and Drugs

The leading cause of traumatic death is motor vehicle accidents, falling accidents and blunt trauma. The use of drugs such as alcohol or illicit such as opium, cocaine increases the risk of trauma by traffic collision. Other drugs such as benzodiazepines increase the risk of trauma in elderly people.

Alcohol causes deterioration of driving skills even at low levels and the probability of accidents increases with rising blood alcohol levels. Alcohol needs no digestion and is absorbed rapidly into the blood stream; about 10% to 15% of alcohol users develop alcohol dependence and become alcoholics. After drinking, the judgment power of the driver gets impaired which is a threat to road safety. Due to its effects, driver tends to take more risks, becomes more aggressive and takes a longer reaction time. The relative probability of causing accidents increases with the rising blood alcohol levels keeping road safety at stake. (shivkumar and krishnaraj, 2012)

Another study funded by the Swedish National Road Administration reveals that impaired driving is an important road safety problem, and the characteristics of drivers impaired by alcohol or drugs are relevant to targeted interventions. The study considers young driver's socio demographic attributes: age, sex, class of origin and educational attainment, based on national young Swedish drivers (1988–2000) followed up in police registers for their first motor vehicle crash. Driving under the influence of alcohol or any other sub- stance is forbidden in Sweden. The legal limit for drunken driving is 0.2% concentration in blood, or 0.10 mg per litre in breath. For aggravated drunken driving, the corresponding limits are 1.0% concentration and 0.50 mg/l, respectively. The limit for any substance classified as a narcotic is zero. (Vaez and Laflame, 2005)

Anne et al.,(2010) summarized that fatalities during a crash rises when drinking age is lowered and fatalities during a crash rises when drinking age is lowered and fatalities decreases when drinking age is raised. He showed a relationship between minimum legal drink age and highway crash relationship. He concluded that lowering drinking age to eighteen will increase fatalities rate among young people.

Peter and Robert(1995) conducted a roadside survey using alcohol breath analyzer and found that drivers with BAC < 0.04 were responsible for night traffic injury crashes which was low level drinking(one or two drink) using regression analysis.

Campos et al.,(2011) analyzed breath test of 4234 drivers during 2007-2009 in brazil after a new traffic law imposed since 1989 i.e. BAC limit 0.08g/using logistic regression he found that there was a 45% decrease in driver behavior and traffic death decreased by 63% downtown and 14% on road.

Longo et al.,(1999) analyzed blood sample for alcohol, cannabinoids(THC),benzodiazepines from 2500 injured Australian drivers. He found drivers tested positive for alcohol only, benzodiazepine only. The combination of alcohol and cannabinoids and Combination of alcohol and benzodiazepines were more culpable for the crash than drug-free group. Analysis of Results for crashes are shown in Table 2.1

Table 2.1 Alcohol and Drugs

Drug Combination	Single Vehicle(% culpable)	Multiple Vehicle(% culpable)
Alcohol only	95.7	79.7
Cannabinoids only	90.9	42.9
Alcohol + Cannabinoids	100	83.3
Benzodiazepine only	80	65.6
Stimulants	100	66.7
Alcohol + Benzodizpine	100	85.7
Stimulants + Cannabinoids	-	100
Other combination	100	100

Brazil had world's highest accident rates 77 deaths/100,000 vehicles in 2007.Boni et al.,(2010) investigated of 609 patients (victims of traffic crashes) who were treated in a trauma center. He conducted experiment like- breath analyzer and saliva testing with the victims. He concluded that most of them were using alcohols, marijuana and cocaine. Mostly injured victims consuming alcohol made a crash between 6 PM to 6 AM and they were coming from bars or pubs or parties.

Fatally injured in traffic accident is a function of alcohol, pharmaceuticals and illict drugs(Holmgren et al.,2000)

Labat et al.,(2003) conducted a new study during 2003-2004.They found urine ethanol as positive in 50 cases, cannabinoids in 85 cases, opiates in 41 cases, amphetamines in 3 cases,

cocaine in 1 case, buprenorphine in18 cases, methadone in 5 cases and benzodiazepines in 4 cases. Drugs in particular ethanol and cannabinoids are responsible for fatally injured drivers.

Labat et al.,(2008) studied post-mortem blood and urine sample of 1047 victims of traffic fatalities between 2000-2006 in UK. Out of these 54% of total victim were found to be positive for drugs and/or alcohol.63% male pedestrian between the ages of 17-24 were involved in road traffic accident. Alcohol and cannabinoids were common substances among victim group. The presence of drugs and/or alcohol was of similar frequency in those victims in control (55% of driver, 48% motorcyclist , 33% cyclist) and not in control of a vehicle(52% of car passenger,63% of pedestrians).He found some other drug like anti-psychotics, diabetic drug, heart drug and anti-inflammatory in the victim group.

Rio et al.,(2001) studied the blood samples reports of 5745 Spanish drivers killed in road accident during 1991-2000.He found psychoactive drugs among 50.1% of those driver killed in road accidents. Mainly alcohol(43.8%), illicit drugs(8.81%) and medicinal drug(4.7%).For one every three cases(32%) a BAC over 0.8g/l was recorded, cocaine(5.2%),opiates(3.2%) and cannabis(2.2%) were three illicit drugs most frequently detected. Among medicinal drugs were benzodiazepines (3.4%), antidepressant drugs (0.6%) and analgesics (0.4%)

Keall et al.,(2002) investigated the effect of alcohol, driver age and influence of passengers of driver fatal injury in New Zealand. They calculated risk factor as follows

Relative risk = (Risk associated with BAC) x (Risk associated with age) x (Risk associated with passenger)

A logistic model data was fitted for drivers under 200mg/dl(2%) which showed that risk at all BAC levels were statistically significant higher for drivers aged under 20 and for drivers aged 20-29(three times) than for driver aged 30 and over.

2.1.4 Speed

Driving speed is an important factor in road safety. Aarts and Schagen (2006) studied relationship between speed and risk of a crash. The conclusion was when speed increases crash increases.

Lee at al.,(2006) developed a real- time crash prediction model by taking total travel time and Crash potential reduction. The study result indicated the variable speed limit could reduce crash potential by 5-17%.

Prabhakharn et al.,(2011) analyzed that imparting training among drivers reduces speeding behavior. They used speed as dependent variable and distance as function in ANOVA.

Golob and Recker (2003) analyzed accident in southern California and found accident characteristics as a function of traffic flow characteristics, controlling for lighting and weather condition. Result indicated that type of collision is strongly related to median traffic speed and temporal variation in speed in the left and interior lanes. Hit-object collision involving multiple vehicle that are associated with lane-change maneuvers are more likely to occur on wet road while rear end collisions are more likely to occur on dry roads during day light controlling weather and light condition.

2.1.5 Fatigue

Houquani et al.,(2012) investigated hospitalized drivers who were involved in road traffic collision between April 2006 to October 2007 in UAE.A logistic model was fitted using the variables like drivers demographic data, time, date, location, mechanism of collision, speed at collision and sleepiness. The conclusion was sleep is an important factor to road traffic collision. Further they advised to discontinue driving on highways feeling sleepy especially during lunar month of Ramdan.

Driver fatigue is a main problem in long journey due to restlessness. Blower et al.,(1998) observed that 20% of all fatal crash and 10% of all injuries involving truck occurred between 12AM to 6AM,the peak period for driver fatigue.

2.1.6 Cell phones

Tornros and Boiling (2005) conducted an experiment with 48 drivers by covering a distance of 15 Km on a rural two-lane road. They concluded that driving performance reduced by dialing hand held phone and speed decreased with hands free phone. Reaction time to warning sign at road side decreased for hand held phone user.

2.1.7 Restraints

Bendak (2005) studied the relationship between seatbelt use and road accident fatalities and injuries. Result shows that there was a significant drop in certain types of injuries due to traffic accident after the enactment of seat belt law since 5 December 2000.He found that seat belt use rate in Riyadh were 87% for drivers and 41% for front seat passengers.

Seatbelt use reduces injury severity during accident and saves life. In Malaysia 350 death occurs related to unbelted condition Jamalludin (2012).

A helmet reduces the severity of head injuries. Nonstandard helmets appear to offer little head protection during a crash (Asa et al.,1999)

Gabela et al., (1990) conducted a case study in Elpaso Colorado to estimate differences in risk of head injury among riders in motorcycle crashes. They found those riders not wearing helmets were 2.4 times as likely to sustain head injuries.

Joseph(1979) made a relationship between determinants of motor cycle. He observed that motorcycle helmet use laws have saved lives.

Sreedharan et al.,(2010) explored the determinants use of crash helmets among motorcyclist in India. A cross sectional study conducted in Kerala .The study found only 73.1% of motorcyclist were not using helmet which results more head injuries during crash in that region.

2.2 VEHICULAR CHARACTERSTICS

Vehicle plays an important role in a crash. This may be due to defective wheel alignment, tyre bursting, brake failure, overloading, one or two head light defect, back light defect, indicator defect, steering defect.

2.2.1Tyre Defect

Tyre defect may be due to under or over inflation, overloading, ageing behavior, external impact due to pothole, debris, nail etc. Tires up to six years from the date of manufacturer should be changed including spare tires (Osueke and Okorie,2012)

2.2.2 Brake Failure

Accident imposes high intangible cost (pain, grief and suffering).Vehicle accident can be fatal and constitute a high economic burden. Oduro (2012) surveyed a no of accident and found that 83% break failure result in accident. Brake ineffectiveness is due to vehicle overloading, uneven tyre pressure, incorrect brake adjustment, air in breaking system, automatic brake adjuster not working, brake fluid on lining .Brake failure is due to broken pipe, low brake fluid level, cracked brake drum, brakes overheating.

2.2.3 Overloading

One overloaded axle causes damage equivalent to 22 legally loaded axles. Overloaded vehicle increases maintenance cost and hazard (Osama et al., 2012)

Overloading truck reduces braking ability of truck, stability of truck, unexpected defect of road and damage of vehicle. Fatal crashes involving overloaded large truck increases by 52% (Chan, 2008)

2.3 ENVIRONMENT CHARACTERISTICS

2.3.1 Road Elements

Roadway design is one of the most significant factors that affect driving behavior and perceived safety. Bassat and Shinar (2011) studied combined effect of roadway design element such as shoulder width, guardrail and roadway geometry (curvature) by taking objective driving measures (speed and lane position) and subjective measure(perceived safe driving speed and estimated road safety) into account. They found the shoulder width had a significant effect on actual speed and lane position but when a guard rail had a significant effect on perceived safe driving.

Zegeer et al.,(1991) studied the relationship between lane or shoulder widening and accident reduction rate. He concluded that 21% reduction in accident can be achieved by widening the lane 4 feet per side. The result obtained from different studies are shown in Table 2.2

Table 2.2 Lane width and percent accident reduction

Total amount of lane or shoulder widening(ft.)		Percent accident reduction		
Total	Per Side	Lane Widening	Paved Shoulder Widening	Unpaved Shoulder Widening
2	1	5	4	3
4	2	12	8	7
6	3	17	12	10
8	4	21	15	13
10	5	-	19	16
12	6	-	21	18
14	7	-	25	21
16	8	-	28	24
18	9	-	31	26
20	10	-	33	29

Bamzai et al.,(2012)investigated into safety impacts of highway shoulder attributes in Illinois. Data were analyzed to establish correlation between shoulder related crashes by type and severity category. Widening of pavement and accident relationship is shown in Table 2.3

Table 2.3 Pavement widening and accident

Shoulder Paving		**Fatal**	**Injury**	**PDO**
Rural Interstate	Paving for all	3-6%	2-6%	20-36%
	Widening from 4, 6ft, to 8ft	-6 to -3%	2-8%	19-33%
Rural multilane	Paving for all	19-22%	0-3%	18-20%
	Adding 4ft or 6ft	2-5%	2-5%	21-23%
Rural two-lane	Paving for all	-10-1%	4-8%	7-30%
	Widening from 4,	-7 to -4%	3-7%	18-41%
	Adding 6ft or 8ft	-11 to -8%	5-8%	25-43%
Urban Interstate	Paving for all	1-2%	2-5%	16-28%
	Widening from	1%	4%	2%
Urban multilane	Paving for all	7-15%	1-5%	5-10%
	Adding 4ft or 6ft	7-17%	0-2%	0-3%
Urban two-lane	Paving for all	1-3%	4-28%	6-11%
	Widening from 4,	-4 to -2%	31-35%	3-13%
	Adding 6ft or 8ft	-11 to -9%	7-37%	20-23%

2.3.2 Surface Discontinuity

Forest et al.,(2009) established a relationship between accident data and surface discontinuities(pavement edge drops, pavement ruts, potholes etc.).No of accidents from discontinuity are shown in Table 2.4

Table 2.4 Surface discontinuity and accidents

Disturbance	Frequency	Disturbance	Frequency
Water	143	Patch	11
Dropped	173	Bump	9
Soft	71	Dip	9
Curb	62	Rocks	4
Edge	59	Ruts	4
Hole	34	Track	3
Rail	24	Manhole	2
Rock	19	Bump	2

2.3.3 Road Side Features

Somchainuek et al., (2013) investigated road side safety on Thai NH. The result showed that speeding vehicles were involved in roadside crashes accounted for about 70% of the total crashes and 30% of road side crashes were due to road side trees.

Jinsun and Doohee (2003) established a relationship between accident severity and roadside features. The result shows that run-off-roadway accident can be reduced by avoiding cut side slopes, decreasing the distance from outside shoulder edge to guard rail, decreasing the no of isolated tree along road way section and increasing the distance from outside shoulder edge to luminaire poles. Run-off road way accident is a complex interaction of road side factors such as presence of guardrails, miscellaneous fixed object, sign supports, tree groups and utility poles along the road way.

In a further study by Zeeger (1991) found that by increasing clear roadside recovery distance on a horizontal curve reduces accidents. Roadside improvement include removing trees, relocating utility poles or other obstacle from road way. Road side recovery distance and percent reduction accident is shown in fig. 2.5

Table 2.5 Road side recovery and percent reduction in accidents

Road Side Recovery Distance(ft.)	Percent Reduction in Total Curve Accidents
5	9
8	14
10	17
12	19
15	23
20	29

2.3.4 Signs and Signals

Chen et al., (2011) developed traffic safety model using regression in New York city. The result shows that signal related countermeasure that are designed to reduce conflict are split phase, timing, signal installation, all pedestrian phase and increasing pedestrian crossing reduces crashes. Traffic calming measures including road diets are also found to be significant in safety benefits. Countermeasures that are designed to alert driver cognitive attention such as high visibility crosswalks and posted speed limit reduction signs appear to have lesser effect.

2.3.5 Fog and Smoke

Mohmed et al., (2011) studied on crash related to visibility obstruction due to fog and smoke in Florida. It was found that fog smoke related crashes are more likely to occur at night without street lighting leading to more severe injuries. Head-on and Rear-end are common crashes in terms of crash risk and severity. These crashes are more prevalent on high speed road, undivided roads, roads with no sidewalks and two lane rural roads.

2.3.6 Volume

Hiselius(2004) studied the accident frequency and homogeneous flow of vehicle. It was found that the accident rate decreases when the traffic flow is homogenous in nature. For Lorries there was an decrease in no of accident and for car the accident rate was constant.

Golob et al.,(2004) made a relation between traffic flow and traffic accident. It was from the study that means volume and median speed affect safety. Lane- change crashes tend to occur when there is the highest variability in speed. While rear end crashes tend to cluster where there is a lower variation in speed. There suggestion was to improve traffic engineering and implementation of ITS (Intelligent Transportation System) and enhance driver education.

Kurlaftis and Golias (2002) studied between road geometric characteristics and accident rate. They found AADT, lane width, Serviceability index, friction, pavement type, access control are the main factor contributing to accidents. Relative importance was 100% for AADT, 72% for lane width, 59% for serviceability, 32% for friction, 30% for pavement type and 14% for rural two-lane road.

Good LOS tends to occur at night when volumes are low. Single vehicle crash rate is higher because more drivers are drowsy or less alert. When traffic volume is heaviest multi-vehicle crashes are likely to occur (Ivan et al., 2004).

Caliendo et al.,(2006) fitted a Poisson and negative binomial model using accident as dependent variable and length, curvature, sight distance, side friction coefficient, longitudinal slope, presence of junction as independent variable.

Zhuanglin(2009) fitted a multiple logistic relationship between accident severity and a series of potential factors like- Cross section, pavement type, accident location, traffic environment, traffic environment, lighting. He found that major accident was on expressway as compared to arterial street.

DATA COLLECTION

The only information available for accident studies is the FIR (First Information Report) lodged in the police stations. The data from these records of last ten years (2002-2011) were extracted from the FIR record filed under IPCno.279/337/338/304(A).Vehicles those involved in accidents and reported in the F.I.R. The categories of vehicles include tempo, auto, mini-truck, minibus, Tata indica,Tata-407,trecker,motor cycle, tanker, tailor(articulated vehicle),truck and bus.

3.1 Road selected for study

Two-lane roads from Angul to Bhushan steel on NH-55 was chosen

For this study. The following stretches were selected for data collection. The study area is shown in fig.3.1

(i)Angul to Turanga , Km159/ 0-Km164/0

(ii)Turang to captive power plant (CPP) Nalco, Km164/0-Km 169/0

(iii)CPP to Banarpal Km169/0-Km174/0

(iv)Banarpal to Bhushan steel, Km 174/0-Km 179/0

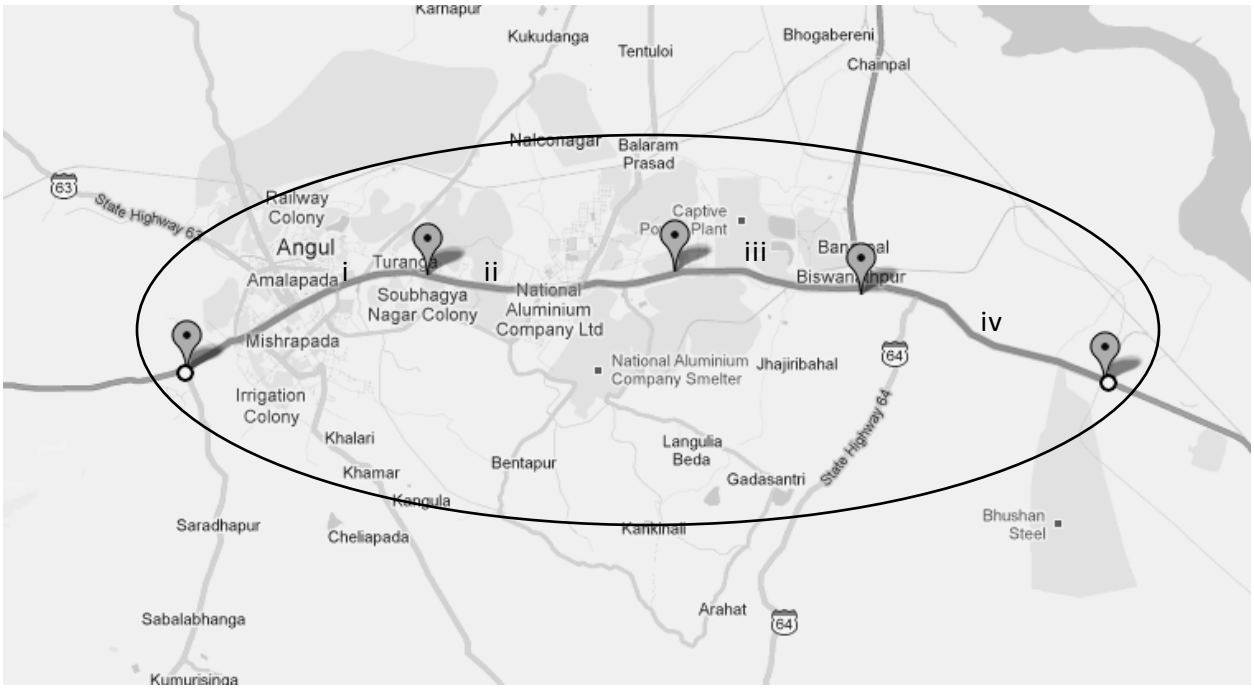


Fig 3.1 Study area Source: Google Map

3.2Data collected from Police Records

With the prior permission of the concerned S.P, the accident data were collected on two-lane highways from three police stations as shown in Table 3.1.

TABLE 3.1 Police stations and road sections covered

Police Station	Road section covered under the police station
Angul	Km159/0 to km164/0 on NH-55
Nalco	Km164/0 to Km 174/0 on NH-55
Banarpal	Km174/0 to Km 179/0 on NH-55

The police stations have their own FIR records of several years. The data from these records of last ten years were extracted from the FIRs filled under IPC NO.279/337/338/304 (A).A sample copy of the proforma is shown in the Table 3.2

Table 3.2 Proforma for accident data from FIR records

Date/Day/Time	Location of Accident	Details of Accident	Vehicle(s) Involved	Possible Reasons

Accident details during 2002-2011 on this road section are shown in Table 3.3. Accident data were collected year wise from each police station records then sorted out month wise. Average yearly variation of accidents stretch wise during 2002-2011 are shown in Table 3.4.

Table 3.3 Details of accidents

Year	Fatal	Major injury	Minor injury
2002	15	16	37
2003	11	35	50
2004	16	25	45
2005	20	32	39
2006	21	34	40
2007	18	41	84
2008	4	24	61
2009	13	32	81
2010	18	34	84
2011	11	30	58
Total	147	303	579

Table 3.4 Details of accident stretch wise

	Fatal					Major					Minor				
year	S1	S2	S3	S4	Total	S1	S2	S3	S4	total	S1	S2	S3	S4	total
2002	9	3	0	6	15	4	5	1	6	16	15	8	2	12	37
2003	6	3	0	2	11	10	18	1	6	35	10	26	2	12	50
2004	3	1	1	11	16	5	13	0	7	25	11	24	0	10	45
2005	9	4	1	6	20	7	17	2	6	32	10	20	2	7	39
2006	10	3	1	7	21	11	11	2	10	34	14	12	1	13	40
2007	6	4	1	7	18	23	3	2	13	41	33	15	7	29	84
2008	1	2	0	1	4	9	10	1	4	24	14	23	2	22	61
2009	6	2	3	2	13	18	7	3	4	32	22	18	5	36	81
2010	8	3	0	7	18	25		9	0	34	36	18	2	28	84
2011	2	3	1	5	11	10	6	1	13	30	16	16	3	23	58
Total	60	28	8	54	147	122	90	22	69	303	181	180	26	192	579

S1- Stretch 1 S2-Stretch 2 S3-Stretch 3 S4-Stretch4

3.3 Data collected from P.W.D Records

P.W.D (Public Works Department) records are the main source of details of road. The proforma used to record these details is shown in Table 3.5

Table 3.5 Proforma for details of road section

Width of Carriage way in Mt	7	7	
Width of Formation in Mt	12	12	
Width of Land in Mt	45	45	

In addition to the above, traffic volume data were also obtained from PWD records. These are shown in Table 3.6

Table 3.6 Traffic volume data

YEAR	ADT	AV PCU PER DAY	PCU/HR
2002	14533	24656.11	1027.338075
2003	12584	21501.46	895.8942667
2004	12679	21655.23	902.301225
2005	10484	18102.4	754.2667667
2006	12700	21689.22	903.7175

ANALYSIS OF DATA AND DISCUSSION

4.1 Accident Rate and Frequency

Accident Rate = $\frac{M}{L}$

Where M = Total no of Accidents of a stretch

L = Length of Road

Table 4.1 Accident Rate

Name of stretch	Length	No of accidents in a year	
		Sum of 10 year	Accident rate
Angul to Turanga(I)	5km	228	45.6
Turanga to CPP (II)	5km	208	41.6
CPP to Banarpal (III)	5km	26	5.2
Banarpal to Bhushan Steel(IV)	5km	239	47.8

Table 4.2 Frequency Of Accident

Distance of origin	No of accidents (2002-2011)	Frequency	Total frequency
0-5	228	32.5	32.5
6-10	208	29.6	62.1
11-15	26	3.7	65.8
16-20	239	34.1	100
Total	701	100	

From the Table 4.1 and 4.2 it is observed that frequency and rate of accident is more for stretch-4 followed by stretch-1,2,3 respectively

4.2Annual Variation in Accidents

Fig. 4.5 shows the annual variation in accidents of total stretches during year 2002-2011.It is observed that percentage accidents are increasing relatively in most of the year. In the year 2007 accident rate was high and low in the year 2002.It may be due to increase in no of vehicles, bad traffic environment, and increase in population.

Fig. 4.6-4.10 shows annual variation in accidents of the four stretches. It is observed that no of accidents are more for stretch-1 and 4 are more higher than stretch -2 and 3.This is because of high traffic volume on stretch 4.Traffic volume decreases on stretch-3 as stretch -4 is connected to NH-23 which goes towards coal mines.Stretch-1has high population density as this is the main town of the Angul district. Accident rate is more due to more no of commercial and noncommercial vehicles on the road, bad traffic environment.

4.3 Monthly Variation in Accidents

Fig 4.3 shows the monthly variation in accidents.peak accident occurs in summer season i.e in the month of march,april and may.This is due to distraction related to environment.Problem in these months are glare,fatigue, inconvienient heat.

4.4 Hourly Variation in Accidents

Fig 4.17shows hourly variation in accidents.One can observe more accidents occurs in between 8PM to 9PM.In this hour line truck(Truck Series) start their long journey.Most of the driver do not use speedometer as they drive by approximation.Speed crosses limiting speed as a result accident occur.Also they drink and drive in the evening hour.In the late night they use marijjuana as a result reaction time increases and loss of contro occurs.Some drivers make the vehicle over load.In india load

capacity is 10 ton or 16.2 ton for goods carriage but they carry more than that results uncontrol and leads to accidents.

4.5 Vehicles Involved in Fatalities

Vehicle users related to fatalities during 2002-2011 are shown in pie chart in percent. The results indicate that 59 percent of fatalities are due to truck drivers followed by 26 percent by unknown driver,7 percent by motor cycles,5 percent by car and jeep,3percent by bus respectively as shown in fig.4.18.They consume alcohol and drugs in long driving. As a result reaction time increases and loss of control occurs during speed driving leads to fatalities.

4.6Accidents Related to Traffic Volume

In order to find the relationship between accident rate and traffic volume, accident rate was presented in two forms. In one case it is the number of accident that occurred in a road section per kilometer per year and presented as accident per km-year. And in other case, it was the number of accidents that occur in a road section per million vehicles (MV) taken in terms of passenger car unit(PCU) per Kilometer(K) per year(Y),represented as Accident per MVKY.

The rate of accidents in terms of accidents per km-year is shown in Fig 4.12.The curve indicate that accident rate per Km-year increases with AADT

Fig.4.13 shows the plot between accidents per MVKY and AADT on the road. It was found that accident per MVKY increases with increase in AADT. It may due to faulty design and operational features of highway and influence of other parameters like roadside features, shoulder condition and operational environment.

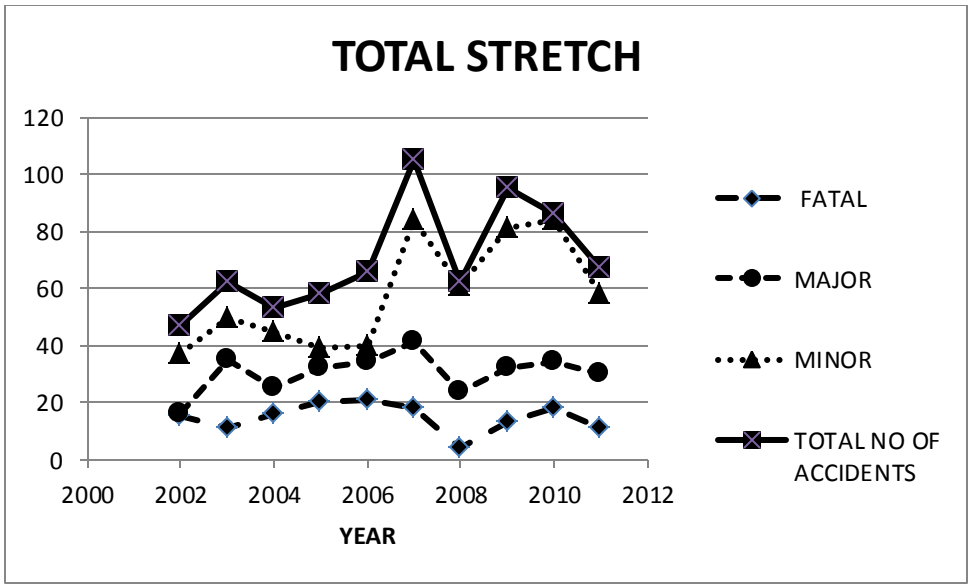


Fig.4.5 Annual variation in accidents of total stretch

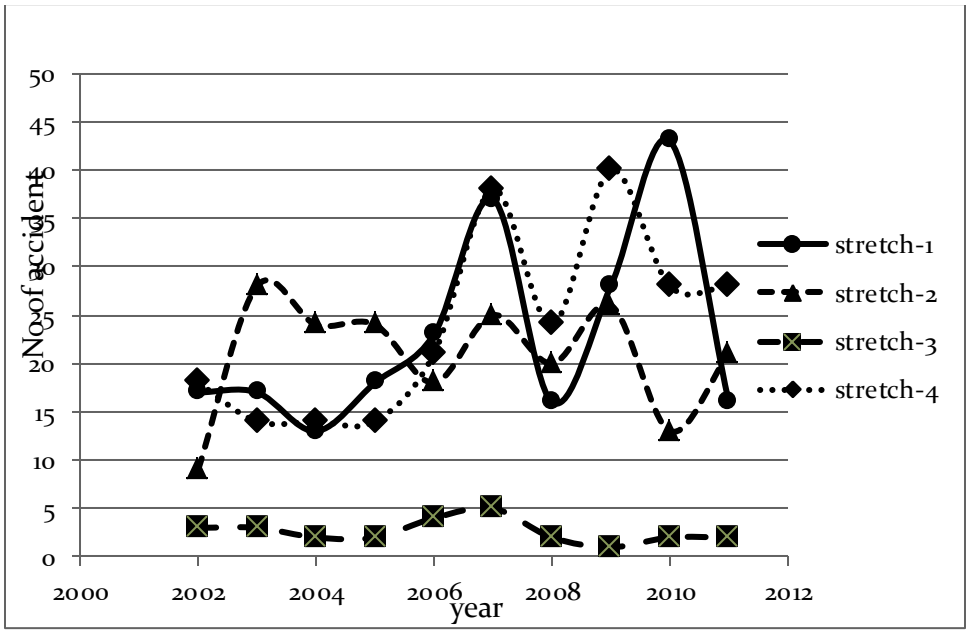


Fig.4.6 Annual variation in accidents of four stretches

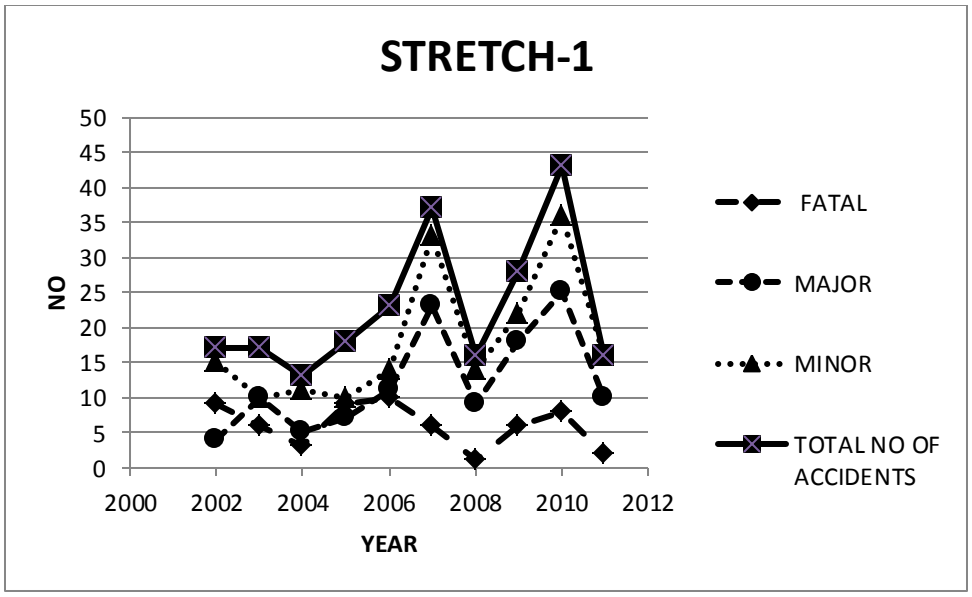


Fig.4.7Annual variation in accidents of stretch 1

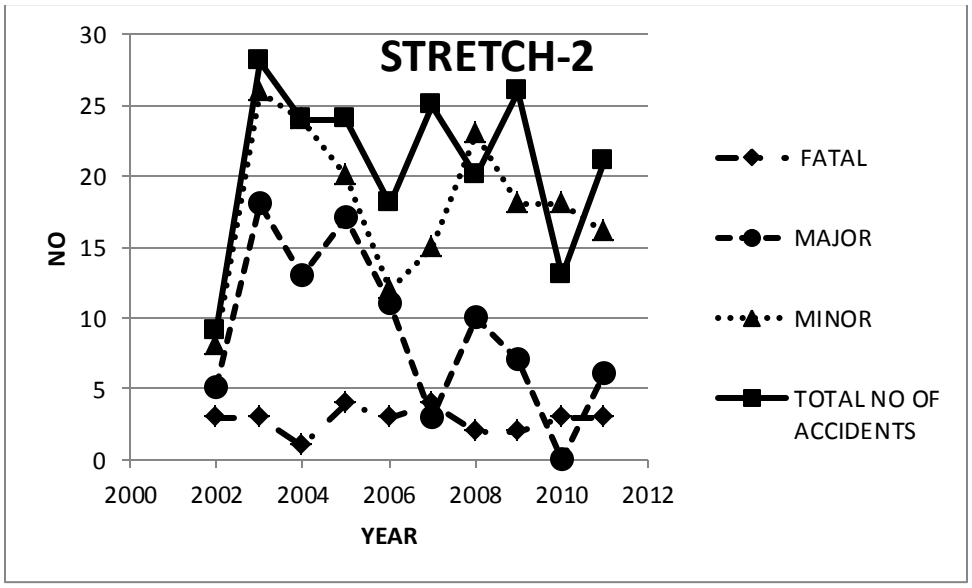


Fig.4.8 Annual variation in accidents of stretch 2

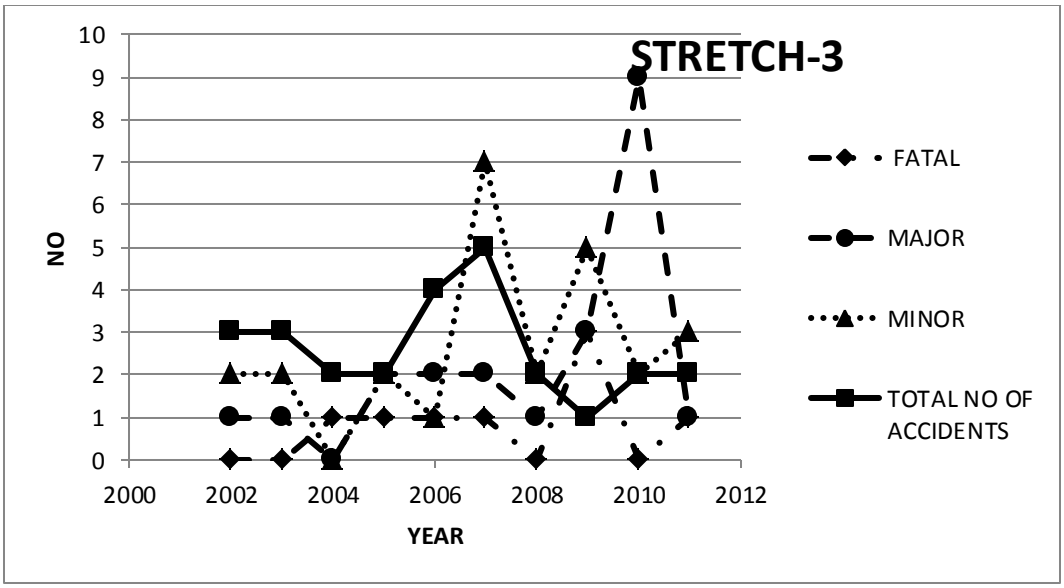


Fig.4.9 Annual variation in accidents of stretch 3

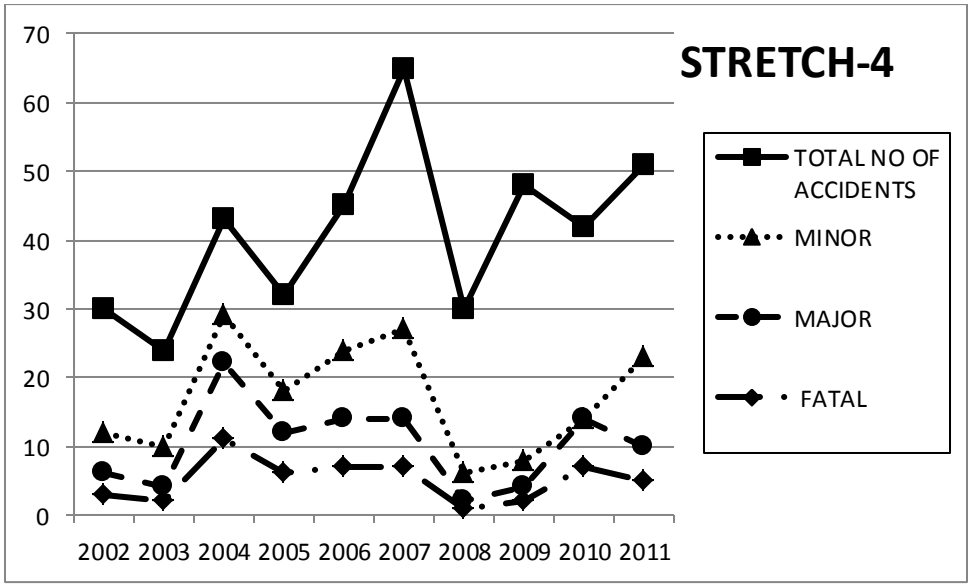


Fig.4.10 Annual variation in accidents of stretch 4

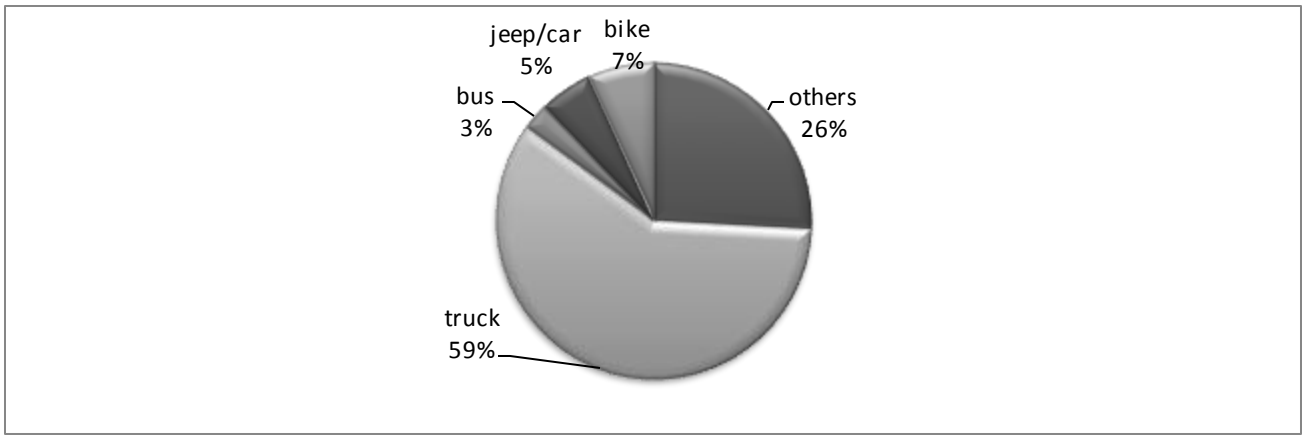


Fig.4.11Vehicle involved in fatalities during(2002-2011)

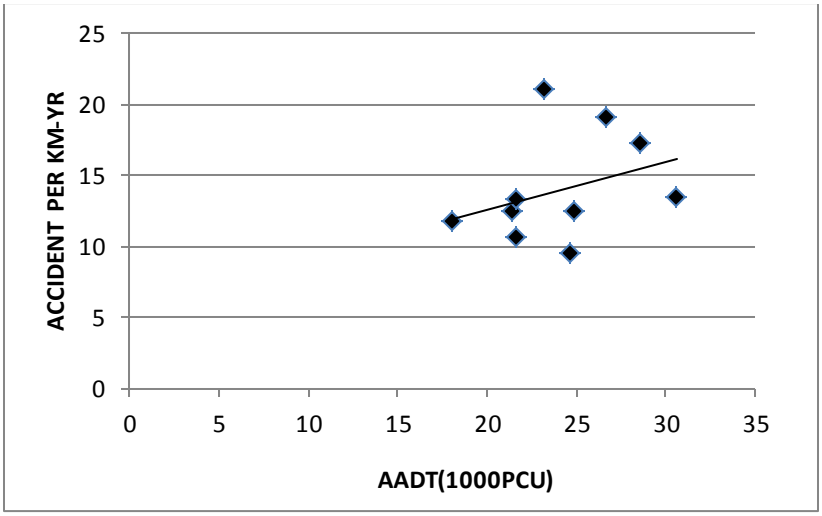


Fig.4.12 Accidents per km-year as related to traffic volume

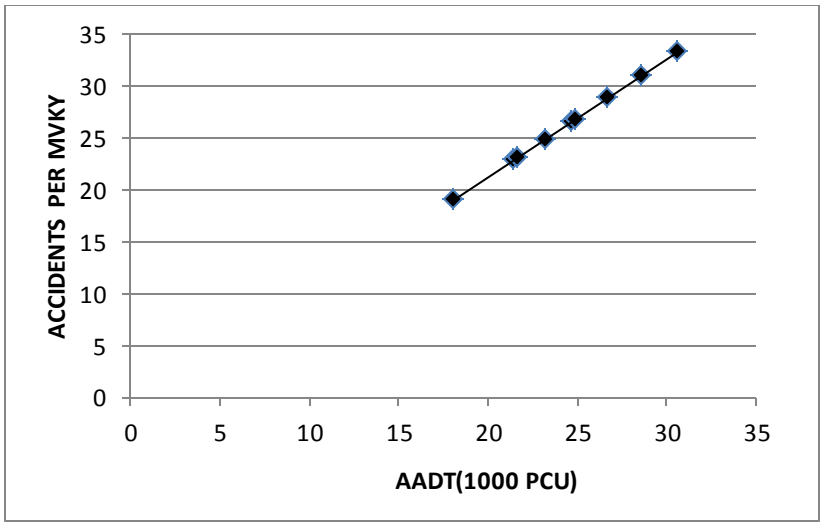


Fig.4.13 Accidents per MVKY as related to traffic volume

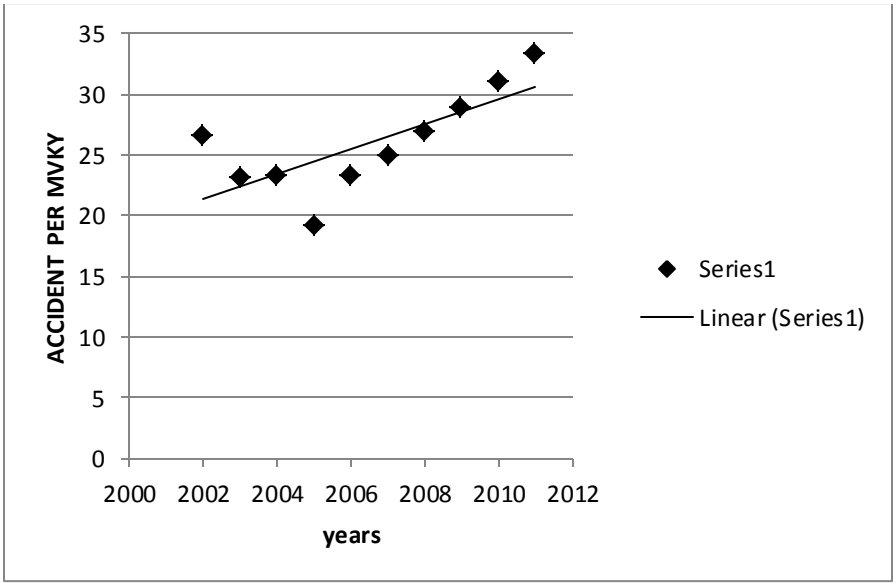


Fig 4.14 Trend of Accidents (2002-2011)

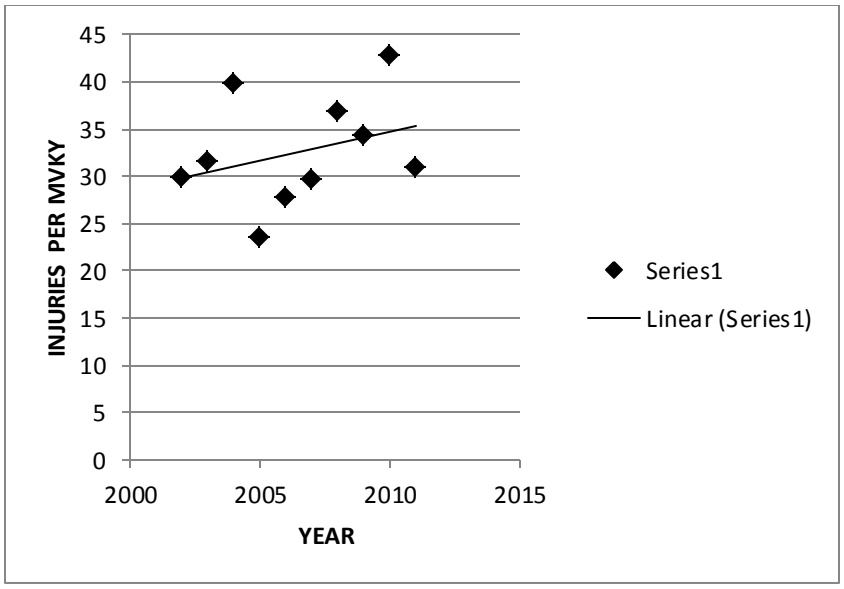


Fig. 4.15 Trend of injuries

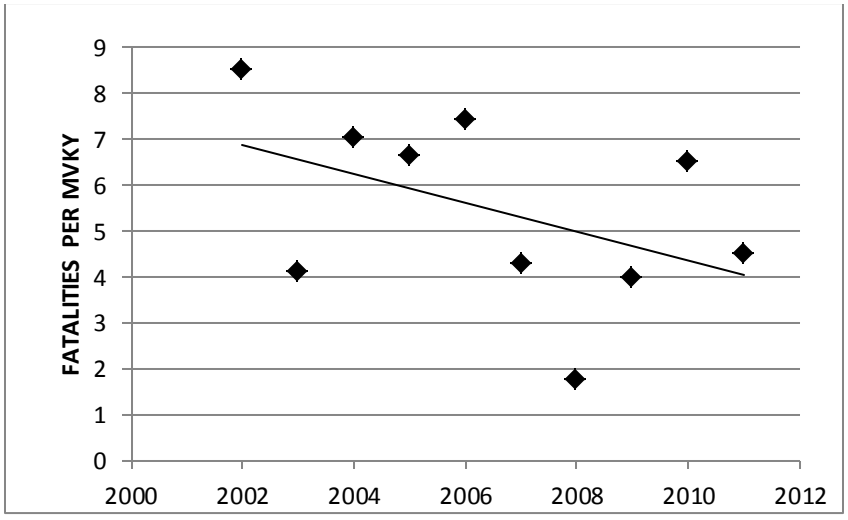


Fig.4.16 Trend of Fatalities (2002-2011)

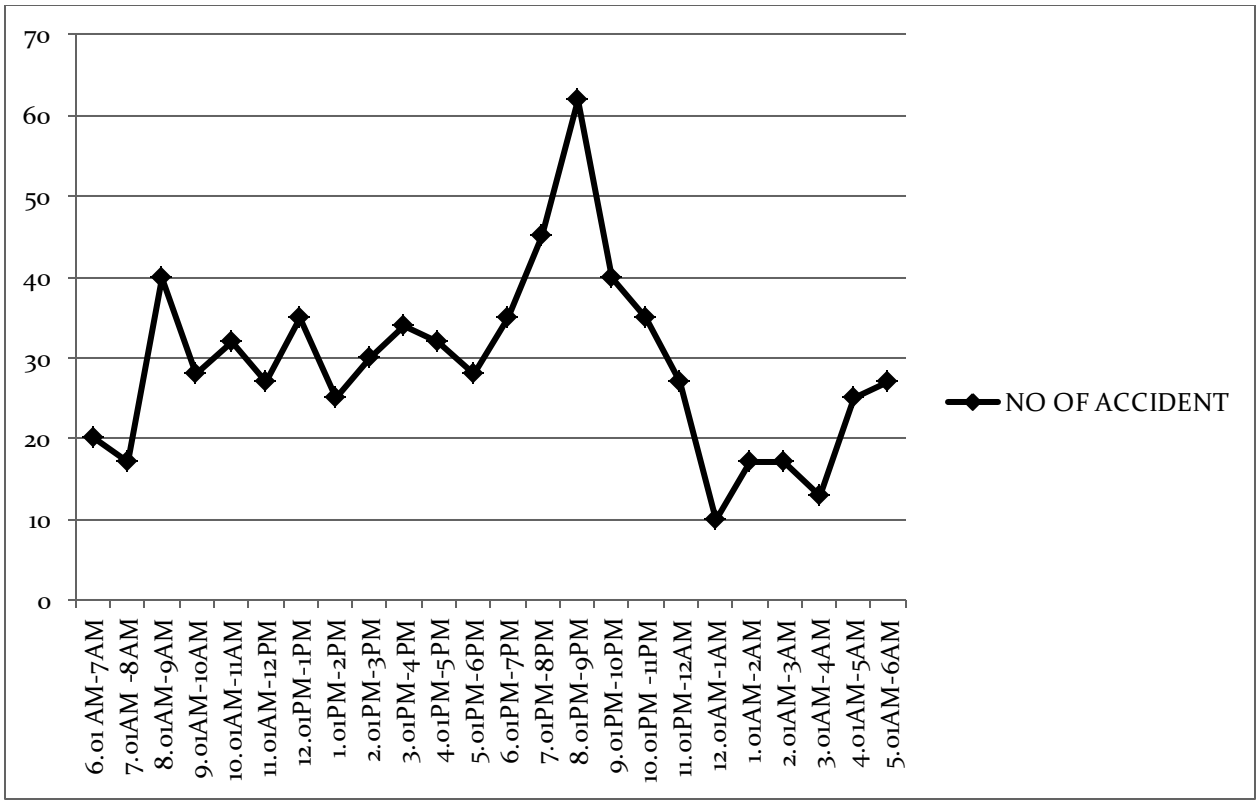


Fig.4.17 Accident time wise (2002-2011)

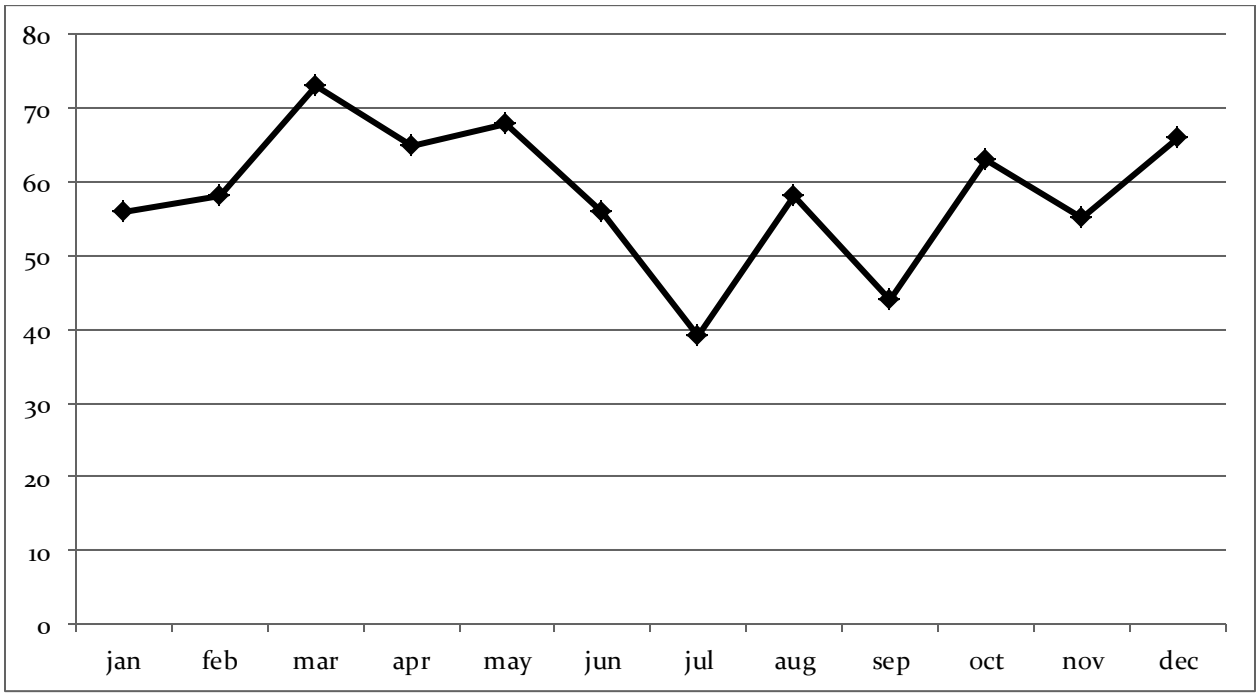


Fig.4.18 Accident month wise (2002-2011)

4.7Trend of Accidents, Injuries and Fatalities during 2002-2011

The yearly trend of accident per million vehicle-kilometer-years (MVKY) on the road is shown in Fig 4.14.From the figure it is found that accident rate per MVKY increases in each subsequent Year. The increasing trend in accident rate may be due to increase in population due to town growth, industry growth, poor maintenance of shoulder, electric poles on the road, transformer station on the shoulder, old girth trees on the shoulder, sight distance obstruction due to trees, unsignalized intersection, on street parking of vehicles and lack of general awareness of road safety among road users.

The yearly trend of injuries is shown in Fig.4.15.Injuries per MVKY is increased in subsequent years as accident rate is increasing.

The yearly trend of fatalities is shown in Fig 4.16.The fatalities rate per MVKY has decreased. This trend may also be attributed to the cautious driving or regular road users.

4.8Traffic and Road side feature Data

The Traffic data were collected from different stretches. Volume, density, speed were calculated from these data which is shown in Table 4.3

Table 4.3Traffic and Roadside features data of four stretches(2013)

Stretch No	ADT	Q_{max} (pcu/s)	Access Road	Trees on Shoulder	Poles	Curves	Shoulder condition	Lighting condition
1	63600	0.82	35	23	53	6	Good	Good
2	32160	0.74	21	25	21	5	Average	Average
3	32160	0.74	6	0	0	3	Poor	Poor
4	48960	0.92	4	1	1	6	Poor	Poor

From the table it is observed that flow for traffic condition exceeds the limit for a two way traffic flow of two lane system as per IRC. Hence wider of lane is necessary.

4.9 Surface Property

Skid Number

$$SN = \sqrt{\frac{v^2}{2gl}} \text{ x100}$$

Where

SN=Skid Number

v =Velocity of the Vehicle

g = acceleration due to gravity

l = skid length

The value of skid number for different stretches were calculated by using a Tata Indica V2 car with kerb weight 1050 kg with Two Person are shown in Table 4.4 .Normally for a Asphaltic surface skid no varies between 70 to 100. From the below observation it is found that surface friction lies in normal limit.

Table 4.4 Skid Number values of four stretches

STRETCH	SKID LENGTH(mt)	SPEED KMPH	BRAKING	SKID NO
1	8	40	N	77
2	11	50	N	87
3	13	60	N	106
4	12	50	N	80

Average Surface Texture Depth

Average surface depth was determined by modified sand patch method (Pestle method).Sand passing through 300 micron and retaining on 150 micron was collected as sample.50 ml (85gm) sample was spread evenly on road surface such that it will fill the depression completely in the shape of a circle. The dia of circle was measured.

$$\text{Average Surface Texture Depth} = \frac{35416.66}{0.785\ X\ d^2}$$

The average surface texture depth along the stretch are shown in the Table 4.5

Table 4.5Average Surface Texture values of Road Surface

Sample	Vol(ml)	Dia(cm)	Avg Depth(mm)	Remark
1	50	32.5	0.43	Normal
2	50	30	0.5	Normal
3	50	30	0.5	Normal
4	50	30	0.5	Normal
5	50	38.5	0.3	Sllipery Surface

ACCIDENT INVESTIGATION AND BLACK SPOT ANALYSIS

5.1 Accident Investigation

Accident no-1

Accident type: Head-on collision

Location: Captive power plant gate, Nalco Angul

Date and Time: MAR 30, 2013; 4.30PM

Vehicle 1: Tata Truck no OR-06/ B-6545

Vehicle 2: Bajaj CT- 100 motor cycle no OR-05/U-3323

Fatalities/Injuries: One person dead and one person severe Injured.

Description: On 30th march 2013 one Bajaj motor cycle with two person collided with a aluminium loaded truck in front of captive power plant Nalco gate around 4.30PM.The motor cycle was coming from captive power plant and truck was moving on highway. The motor cycle rushed to the right side of truck front. The truck applied brake and turned towards left side. The bike fell down under the rear right wheels. The victims were severely injured. The rider lost his right leg completely and left leg scratched while other was under truck with severe knee and head injuries. The rider had used helmet and saved from head injury. The ambulance came after 30 minutes and took victims to the hospital. The victims were two brothers from Jajpur town and rider lost his life after two hour of incident. Cause of accident was due to presence of old banyan tree on the corner of T-junction and ditches of shoulder was filled with water. The motor cycle could not notice the truck due to that big tree and collided with truck on the highway. The tyre skid mark length was 11mt. The accident diagram is shown in fig 5.1

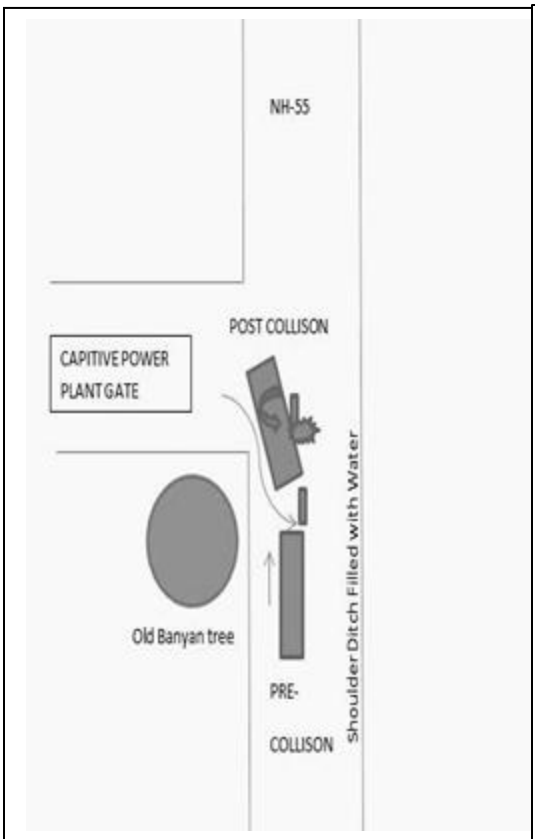


Fig5.1 Accident diagram and photos of stretch II

Accident no: 2

Accident type: collision with tree

Location: In front of police station Angul

Date and Time: JUN 13, 2012; 12.30PM

Vehicle 1: Asok Leyland trailor

Vehicle 2: Bajaj Auto

Fatalities/Injuries: Two person minor Injured

Description: The trailer was on the highway with normal speed. At a T-junction one auto with nine passenger was changing direction (left turn) from bus stop road to highway .Both vehicles became front to front. The trailer driver applied sudden brake and struke the vehicle with a old tree present at corner of junction. The auto was escaped from collision. Driver and helper became injured. The accident diagram is shown in fig5.2

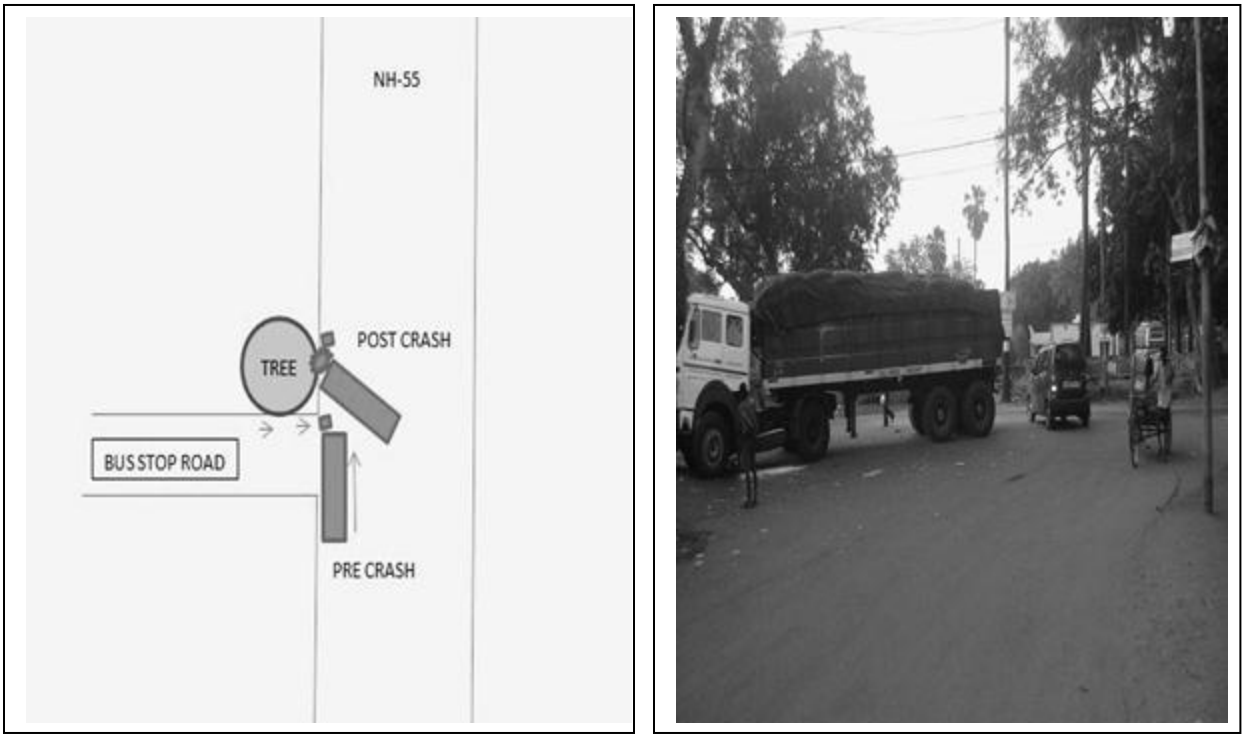


Fig5.2 Accident diagram and photos of stretch I

Accident no: 3

Accident type: collision with tree and compound wall

Location: Smelter traffic post Angul

Date and Time: JUN 12, 2012; 6.10AM

Vehicle 1: Tata truck

Fatalities/Injuries: One person severe Injured and one minor injured

Description: The truck was moving on NH-55.Near traffic post the truck driver could not notice traffic median due to absence of sign post and signal. The truck ran over median and hit with a tree and finally struck with compound wall. The driver became severe injured and helper became minor injured. The vehicle, tree and the compound wall were completely smashed. The accident diagram is shown in fig5.3

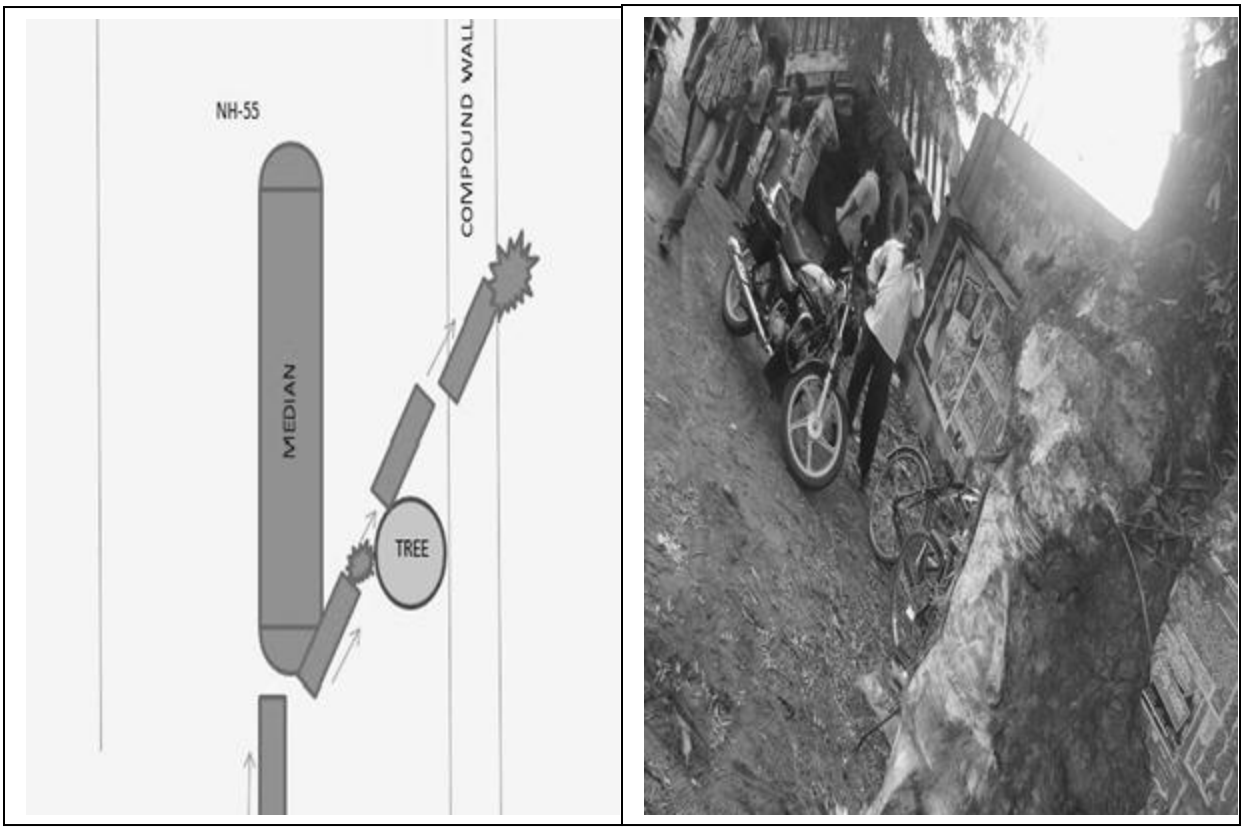


Fig5.3 Accident diagram and photos of stretch II

5.2 Black Spot Analysis

The point where accident occurs frequently is known as black spot or accident point. Analysis is required for improving traffic environment. The detail analysis of four stretches are shown in Fig5.4-5.7 and Table 5.1-5.4

Fig 5.4 Black Spot Points Stretch-1

Table 5.1Black Spot Analysis Stretch-1

Accident Point	Nos	Problems	Safety Enhancement
Divyajyoti Takies	13	X-Unsignalised,10w Garages, Sight distance obstruction by Shops	Junction Improvement, Sight distance visibility
Bazar Chowk	6	O-Unsignalised,Transformer,2w Show Rooms	Junction improvement, Clearance Of obstruction on the Shoulder,
Budhi Thakurani	8	O-Unsignalised, Taxi stand, Stalls on the Shoulder	Clearance of obstruction on Shoulder, Sight distance visibility
SBI Angul	6	T ,Taxi stand, Vegetable Market	Clearance of obstruction on Shoulder, Sight distance visibility
Traffic Chowk	15	X-Signalized, Cinema Hall,2w garages, Trees and Poles on Shoulder	Clearance of obstruction on Shoulder, Sight distance visibility
Kanchan Talkies	10	T, Cinema Hall, Trees on Blind Corner, Trees and Poles on Shoulder, Main Bus Stop	Clearance of obstruction on Shoulder, Sight Distance Visibility
Raz Hotel	16	X-Signalized, Paved Shoulder with no Marking, Transformer on blind corner, On Street Parking of Vehicles	Clearance of obstruction on Shoulder, Sight Distance visibility
Police Training Center	20	Paved Shoulder with no Marking, On Street Parking	Installation of Speed Breakers, Marking
Caltex	11	T, Petrol Pump, Transformer on blind corner, Sight Distance obstruction	Junction Improvement, Clearance of Obstruction on Shoulder
Fci	7	On Street Parking, Motor garages	Clearance of obstruction on Shoulder
Durga Hotel	7	On Street Parking, Hotel Verandah Shoulder	Clearance of obstruction on Shoulder
Turanga	21	On Street Parking, Village Area on Both Side, Bad Shoulder, Trees and Poles on Shoulder	Installation of Speed Breakers, Clearance of obstruction on Shoulder
Kandsor	43	T, Village Area on Both Side, School, Shrubs on Shoulders, Trees And Poles on Shoulder, Steep Gradient	Installation of Speed Breakers, Clearance of obstruction on Shoulder
Kargil Sahid Petrol Pump	15	Bad Shoulder, Front area of Petrol Pump damaged	Shoulder maintenances, Petrol Pump Front should be repaired
Sbi Kandsor	20	Petrol Pump, Taxi Stand. Trees and Poles on The Shoulder	Clearance of obstruction on Shoulder

Fig 5.5 Black Spot Points Stretch-2

Table 5.2Black Spot Analysis Stretch-2

Accident Point	Nos	Problems	Safety Enhancement
Nalco Gate	10	Vegetable and Betel shop on Shoulder, Bus Stop	Clearance of Road Side, Speed Restriction
Nalco Market	14	Vehicle Parking on Shoulder, Trees and Poles on Shoulder	Clearance of Road Side
Tulsi Dhaba	8	Meat and Fish Shop on The Shoulder, Old Trees on The Shoulder	Discouragement of Fish and Meat Shop on The Shoulder, Trees on Shoulder should be removed
Smelter Gate	15	Median without Sign on the Road, Temple on the Shoulder, Trees on the Shoulder	Medians to be Painted, obstacle on The Road Should Be Removed
FCI Chhak	10	T, Wine Outlet, Unpainted Median, Trees on Shoulder	Median to be Painted, Junction Improvement
Kulad Chhak	6	T, Unpainted Median,	Junction Improvement,
Kulad	14	Village Area on Both Side, Godown, Plants on Shoulder	Speed Restriction, Shoulder Improvement

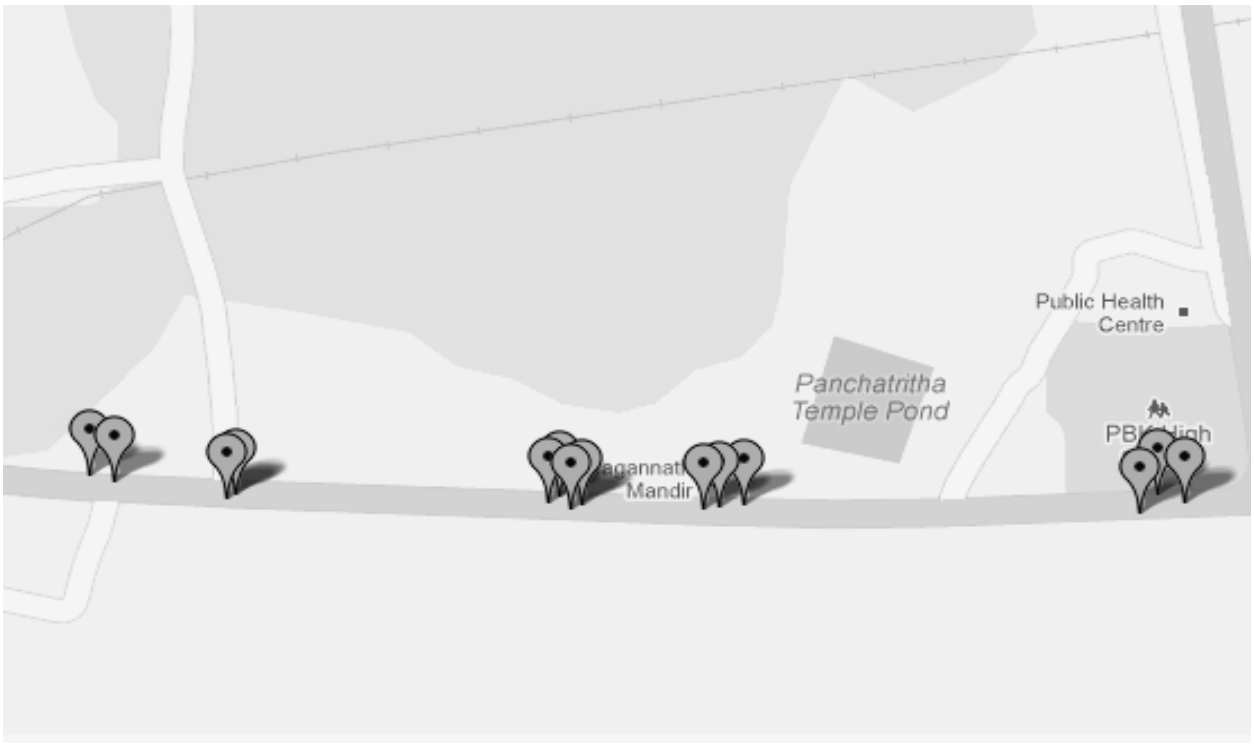


Fig 5.6 Black Spot Points Stretch-3

Table 5.3 Black Spot Analysis Stretch-3

Accident Point	No	Problems	Safety Enhancement
Bonda	10	Steep Gradient	Speed restriction, Junction Improvement
Banarpal Hata	15	Trees on Shoulder, Edge drop	Road maintenance, Shoulder maintenances
Jaganath Temple	6	Bad Shoulder	Shoulder maintenance

Fig 5.7 Black Spot Points Stretch-4

Table 5.4 Black Spot Analysis Stretch-4

Accident Point	Nos	Problems	Safety Enhancement
Banarpal Chowk	24	T, On Road Bus Stop, Auto and Taxi Stand, Trees on Edge, Shop Verandah on Shoulder, Shoulder Ponding	Separate Bus Stop, Shoulder obstruction Clearance and Maintenance, Junction Improvement
Ganesh Bazar	11	Petrol Pump, Betel and Tea shop on shoulder, Shoulder Ponding by Drain Water, Heavy Machinery Garages	Road Side Clearance, maintenance of Shoulder
Asha Talkies	5	Cinema Hall, Shoulder Drop Off, Old Girth Tree Branches	Visibility by Cutting old Tree Branches, Shoulder Maintenance
Santri Chhak	21	Motor Show Room, Dhabas, Shoulder Ponding By Drain	Off Street Parking Facility, Shoulder maintenance
Nuahata	44	Dhaba, Village Area both Side, Chicken Center, Meat and Teashop on Shoulder, Curve Sight Distance obstructed by old and dead Trees	Curve Sight Distance Visibility. Shoulder maintenance, Speed Restriction, Off Street Parking Facility
Jorgadia	32	Ditches on Shoulder, Curves Sight Distance obstructed by Trees, Shoulder covered by Grass and Shrubs, Motor Garages, Vertical Curve	Shoulder maintenance, Sight Distance Visibility Near Curves, Off Street parking facility

5.3 Accident Prediction Model

CALIBERATION OF MODEL

The accident per year was regressed with ADT and Road side features. The general form of equation with zero intercept is represented as

No of accident = 0.504 x Vol+ 1.825 x No of Trees and Poles on Shoulder + 19.87 x No of curves -59.49 x shoulder condition.

The above equation shows that accidents increases with increasing in ADT, No of Trees and Poles on shoulder and no of Curves. The accident decreases with increase in shoulder condition. Hence regular maintenance of road should be done. Old girth trees should be removed.

VALIDATION OF MODEL

Table 5.5 and Fig 5.8 shows the statistical validation of the fitted model.

Table 5.5 Statistical Validation of Model

Name of Stretch	Actual Value(Yi)	Value from Model(Y)	Error (e)	e^2
1	16	15.28	-0.72	0.5184
2	21	20.6	-0.4	0.16
3	2	1.83	-0.17	0.0289
4	28	27.76	-0.24	0.0576

Co efficient of determination $R^2 = SS_R/SS_Y$

$S_{YY}=\sum Y_i^2 - (\sum Y_i)^2/n$

$SS_E=\sum e^2$

$SS_R=S_{YY}-SS_E$

$R^2= SS_R/S_{YY}$

For the above data R^2=0.99.Model holds a good fit.

Chi-Square Test

H_0=No significant difference between expected and observed data

$\chi^2_{cal} = 0.059561$

χ^2_{crit} (At 5% level of significance with df 3) =2.366

$\chi^2_{cal} < \chi^2_{crit}$ Hence accept Null Hypothesis

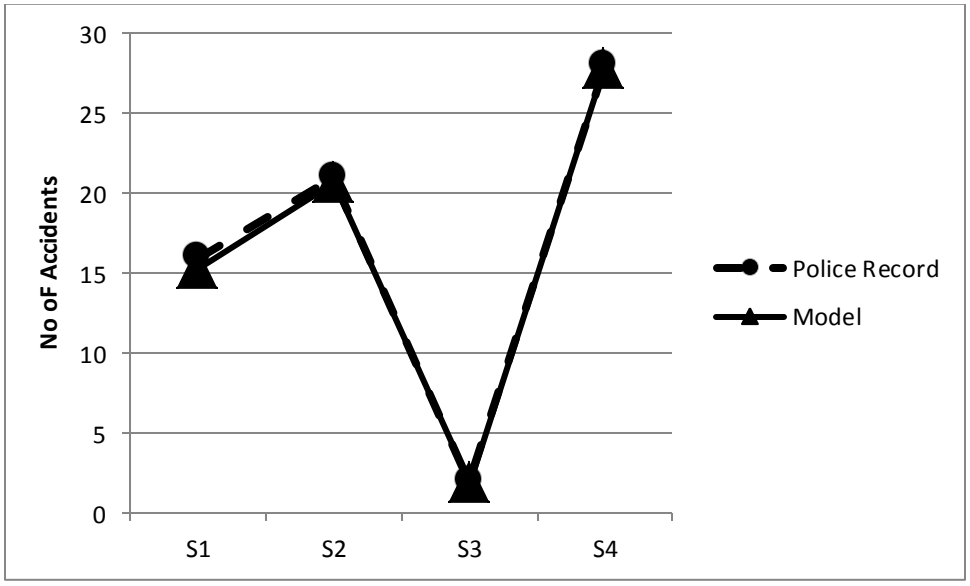


Fig 5.8 Comparison of observation and model data

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

(1)The available literatures on accident analysis indicate that 77.5 percent of road accidents in India are caused due to driver's error.

(2)Heavy vehicles like truck are involved in maximum no of accident on two-lane roads. It is estimated that fatalities caused by truck is 59 % followed by other (26%) and bike (7%) and jeep (5%) and bus (3%).Road safety awareness should be raised among road user.

(3)Stretch IV has the highest no of accidents which accounts for 34.1% of total accidents .The accident rate can be decreased by road side clearance, proper maintenance of shoulders, lighting, and junction improvement. Speed limit should be brought down by providing humps near accident spots. Sight distance near curves should be obstruction free.

(4)Stretch I have the second highest no of accidents accounts for 32.5% of total accident. The Accident rate can be reduced by providing signalized junction, junction improvement, and shoulder Clearance, installation of humps, shifting of poles, removal of trees near the edge of pavement etc.

(5)No of accidents in stretch II accounts for 29.6% of total accidents. The accident rate can be Minimized by clearing-off shoulders, reducing speed limit, junction improvement, providing Signals on the median, shifting structures on the shoulder.

(6)Stretch III has minimum no of accidents accounts for 3.7% of total accidents. Speed limit reduction near junction should be reduced to prevent accidents.

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