Course Code: CE 455
Course Title: Traffic Engineering and Management

Lecture 4: Traffic accident studies

Course Teacher: Saurav Barua (SB)

Assistant Professor, Dept. Of Civil Engineering, DIU

Contact No: 01715334075

Email: saurav.ce@diu.edu.bd

Outline

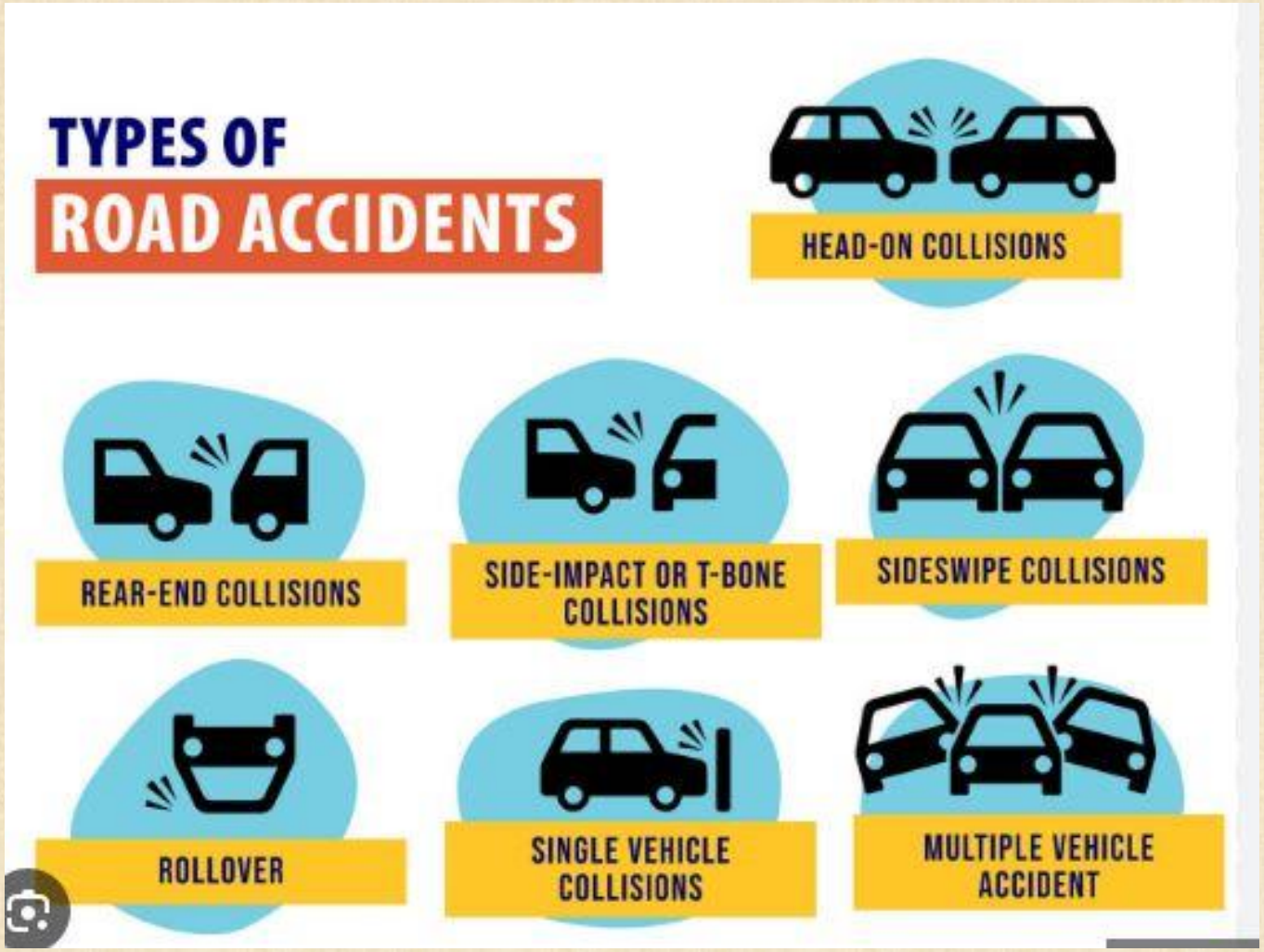
- Types of accidents,
- Causes of accidents,
- Collection of accident data,
- Investigation of accident cases
- Influence of road, the vehicle, the driver, the weather and other factors on road accident, preventive measures

Objectives of accident studies

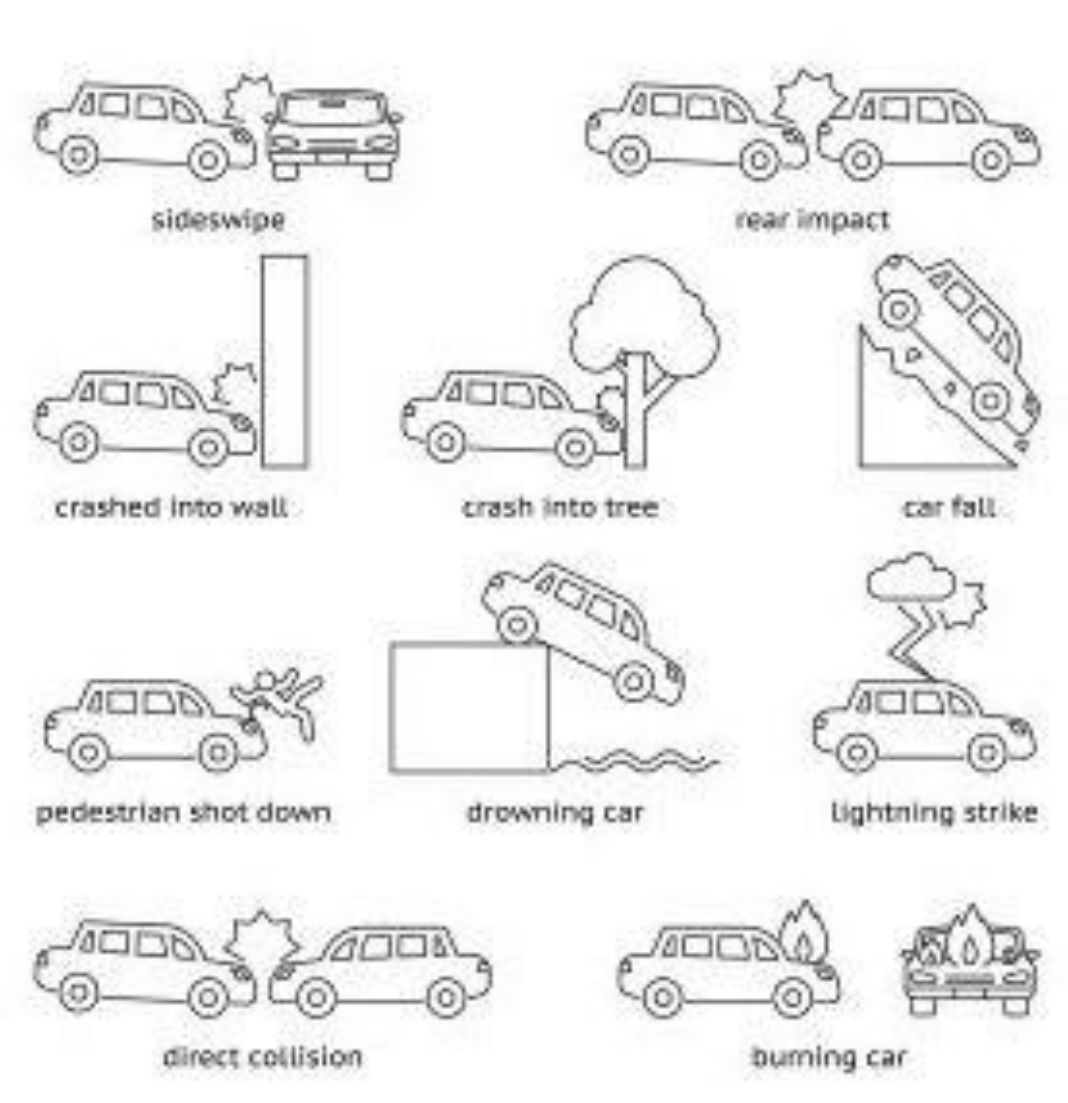
- To study the causes of accidents and suggest corrective measures at potential location
- To evaluate existing design
- To compute the financial losses incurred
- To support the proposed design and provide economic justification to the improvement suggested by the traffic engineer
- To carry out before and after studies and to demonstrate the improvement in the problem

Types of road accidents

1. Single car accident
2. Multiple vehicle collision
3. Vehicle rollover
4. Rear end collision
5. Side impact collision
6. Sideswipe collision
7. Head-on collision
8. Accident due to DUI
9. Distracted driving
10. Hit and Run
11. Chain Reaction Driving
12. Failure to yield
13. Accident at low speed



Types of road accidents



Direct Consequences of Accidents:

- Property damage only (PDO)
- Fatal
- Injury

Causes of road accidents

- 1.Over Speeding
- 2.Drunken Driving
- 3.Distractions to Driver
- 4.Red Light Jumping
- 5.Avoiding Safety Gears like Seat belts and Helmets
- 6.Non-adherence to lane driving and overtaking in a wrong manner

How different factors of Roads contribute in Accidents:

Drivers: Over-speeding, rash driving, violation of rules, failure to understand signs, fatigue, alcohol.

Pedestrian: Carelessness, illiteracy, crossing at wrong places moving on carriageway, Jaywalkers.

Passengers: Projecting their body outside vehicle, by talking to drivers, alighting and boarding vehicle from wrong side travelling on footboards, catching a running bus etc.

Vehicles: Failure of brakes or steering, tyre burst, insufficient headlights, overloading, projecting loads.

Road Conditions: Potholes, damaged road, eroded road merging of rural roads with highways, diversions, illegal speed breakers.

Weather conditions: Fog, snow, heavy rainfall, wind storms, hail storms.

Preventive measures for accidents:

1. Education and awareness about road safety
2. Strict Enforcement of Law
3. Engineering:
   (a) Vehicle design (b) Road infrastructure

- The accident data collection is the first step in the accident study.
- The data collection of the accidents is primarily done by the police.
- Motorist accident reports are secondary data which are filed by motorists themselves.
- The data to be collected should comprise all of these parameters:

1. **General** - Date, time, person involved in accident, classification of accident like fatal, serious, minor
2. **Location** - Description and detail of location of accident

3. **Details of vehicle involved** - Registration number, description of vehicle, loading detail, vehicular defects

4. **Nature of accident** - Details of collision, damages, injury and casualty

5. **Road and traffic condition** - Details of road geometry, surface characteristics, type of traffic, traffic density etc..

6. **Primary causes of accident** - Details of various possible cases (already mentioned) which are the main causes of accident.

7. **Accident cost** - Financial losses incurred due to property damage, personal injury and casualty

Used of accident data

- Identification of location of points at which unusually high number of accident occur.
- Detailed functional evaluation of critical accident location to identify the causes of accidents.
- Development of procedure that allows identification of hazards before large number of accidents occurs.
- Development of different statistical measures of various accident related factors to give insight into general trends, common casual factors, driver profiles, etc.

Accident investigation

The accident data collection involves extensive investigation which involves the following procedure:

1. **Reporting:** It involves basic data collection in form of two methods:

- Motorist accident report - It is filed by the involved motorist involved in all accidents fatal or injurious.
- Police accident report - It is filed by the attendant police officer for all accidents at which an officer is present.
- This generally includes fatal accidents or mostly accidents involving serious injury required emergency or hospital treatment or which have incurred heavy property damage.

2. **At Scene-Investigation:** It involves obtaining information at scene such as measurement of skid marks, examination of damage of vehicles, photograph of final position of vehicles, examination of condition and functioning of traffic control devices and other road equipments.

3. **Technical Preparation**: This data collection step is needed for organization and interpretation of the study made. In this step measurement of grades, sight distance, preparing drawing of after accident situation, determination of critical and design speed for curves is done.

4. **Professional Reconstruction**: In this step effort is made to determine from whatever data is available how the accident occurs from the available data. This involves accident reconstruction which has been discussed under Section No.7 in details. It is professionally referred as determining behavioral or mediate causes of accident.

5. **Cause Analysis**: It is the effort made to determine why the accident occurred from the data available and the analysis of accident reconstruction studies..

Accident data analysis

- The purpose is to find the possible causes of accident related to driver, vehicle, and roadway.

Accident analyses are made to develop information such as:

- **Driver and Pedestrian** - Accident occurrence by age groups and relationships of accidents to physical capacities and to psychological test results.
- **Vehicle** - Accident occurrence related to characteristic of vehicle, severity, location and extent of damage related to vehicles.
- **Roadway conditions** - Relationships of accident occurrence and severity to characteristics of the roadway and roadway condition and relative values of changes related to roadways.

It is important to compute accident rate which reflect accident involvement by type of highway. These rates provide a means of comparing the relative safety of different highway and street system and traffic controls. Another is accident involvement by the type of drivers and vehicles associated with accidents.

1. **Accident Rate per Kilometer :**

   On this basis the total accident hazard is expressed as the number of accidents of all types per km of each highway and street classification.

$$R = \frac{A}{L} \tag{1}$$

   where, R = total accident rate per km for one year, A = total number of accident occurring in one year, L = length of control section in kms

2. **Accident involvement Rate :**

   It is expressed as numbers of drivers of vehicles with certain characteristics who were involved in accidents per 100 million vehicle-kms of travel.

$$R = \frac{N \times 100000000}{V} \tag{2}$$

   where,R = accident involvement per 100 million vehicle-kms of travel, N = total number of drivers of vehicles involved in accidents during the period of investigation and V = vehicle-kms of travel on road section during the period of investigation

3. **Death rate based on population :**

The traffic hazard to life in a community is expressed as the number of traffic fatalities per 100,000 populations. This rate reflects the accident exposure for entire area.

$$R = \frac{B \times 100000}{P} \tag{3}$$

where, R = death rate per 100,000 population, B = total number of traffic death in one year and P = population of area

4. **Death rate based on registration :**

The traffic hazard to life in a community can also be expressed as the number of traffic fatalities per 10,000 vehicles registered. This rate reflects the accident exposure for entire area and is similar to death rate based on population.

$$R = \frac{B \times 10000}{M} \tag{4}$$

where, R = death rate per 10,000 vehicles registered, B = total number of traffic death in one year and M = number of motor vehicles registered in the area

5. **Accident Rate based on vehicle-kms of travel :**

The accident hazard is expressed as the number of accidents per 100 million vehicle km of travel. The true exposure to accident is nearly approximated by the miles of travel of the motor vehicle than the population or registration.

$$R = \frac{C \times 100000000}{V} \qquad (5)$$

where, R = accident rate per 100 million vehicle kms of travel, C = number of total accidents in one year and V = vehicle kms of travel in one year

3.3.1 Numerical Example

The Motor vehicle consumption in a city is 5.082 million liters, there were 3114 motor vehicle fatalities, 355,799 motor vehicle injuries, 6,721,049 motor vehicle registrations and an estimated population of 18,190,238. Kilometer of travel per liter of fuel is 12.42 km/liter. Calculate registration death rate, population death rate and accident rate per vehicle km.

Solution Approximate vehicle kms of travel = Total consumption o fuel × kilometer of travel per liter of fuel =$5.08 \times 10^9 \times 12.42 = 63.1 \times 10^9$ km.

1. Registration death rate can be obtained from the equation

$$R = \frac{B \times 10,000}{M}$$

Here, R is the death rate per 10,000 vehicles registered, *B* (Motor vehicle fatalities) is 3114, *M* (Motor vehicle registered) is 6.72×10^6. Hence,

$$R = \frac{3114 \times 10000}{6.72 \times 10^6} = 4.63$$

2. Population Death Rate can be obtained from the equation.

$$R = \frac{B \times 100,000}{P}$$

Here, R is the death rate per 100,000 population, *B* (Motor vehicle fatalities) is 3114, *P* (Estimated population) is= 18.2×10^6.

$$R = \frac{3114 \times 100000}{18.2 \times 10^6} = 17.1$$

3. Accident rate per vehicle kms of travel can be obtained from the equation below as:

$$R = \frac{C \times 100,000,000}{V}$$

Here, R is the accident rate per 100 million vehicle kms of travel, *C* (total accident same as vehicle fatalities) is 3114, *V* (vehicle kms of travel) is 63.1×10^9.

$$R = \frac{3114 \times 100 \times 10^6}{63.1 \times 10^9} = 4.93$$

Poisson impact theory

Restitution impulse e is given by:

$$e = \frac{u_2 - u_1}{v_1 - v_2} \tag{13}$$

The total impulse is $P = P_c + P_r$

$$P = (1 + e)\frac{m_1 m_2}{m_1 + m_2}\Delta v \tag{14}$$

The post impact velocities are given by:

$$u_1 = u - e\frac{m_2}{m_1+m_2}\Delta v = v_1 - \frac{(1+e)m_2}{m_1 + m_2}\Delta v \tag{15}$$

$$u_2 = u + e\frac{m_1}{m_1+m_2}\Delta v = v_2 + \frac{(1+e)m_1}{m_1 + m_2}\Delta v \tag{16}$$

Poisson impact theory

Two vehicles travelling in the same lane have masses 3000 kg and 2500 kg. The velocity of rear vehicles after striking the leader vehicle is 25 kmph and the velocity of leader vehicle is 56 kmph. The coefficient of restitution of the two vehicle system is assumed to be 0.6. Determine the pre-collision speed of the two vehicles.

Solution Given that the: mass of the first vehicle (m_1) = 3000 kg, mass of the second vehicle (m_2) = 2500 kg, final speed of the rear vehicle (u_1) = 25 kmph, and final speed of the leader vehicle (u_2) = 56 kmph. Let initial speed of the rear vehicle be v_1, and let initial speed of the leader vehicle be v_2.

Step 1: From equation. 15,

$$\begin{aligned} 25 &= v_1 - \frac{(1.6)2.5(v_1 - v_2)}{(3 + 2.5)} \\ 5.5v_1 - 4v_1 + 4v_2 &= 137.5 \\ 4v_2 - 1.5v_1 &= 137.5 \end{aligned} \tag{17}$$

Poisson impact theory

Step 2: From equation. 16,

$$56 = v_2 + \frac{(1.6)3(v_1 - v_2)}{(3 + 2.5)}$$

$$5.5\, v_2 + 4.8\, v_1 - 4.8 v_2 = 308$$

$$4.8\, v_1 - 0.7\, v_2 = 308 \qquad (18)$$

Step 3: Solving equations. 17 and 18, We get the pre collision speed of two vehicles as: v_1 = 73 kmph, and v_2 = 62 kmph.

Step 4: Initial speed of the rear vehicle, v_1 = 73 kmph, and the initial speed of leader vehicle, v_2 = 62 kmph. Thus from the result we can infer that the follower vehicle was travelling at quite high speed which may have resulted in the collision. The solution to the problem may be speed restriction in that particular stretch of road where accident occurred.

Energy theory

the skid resistance. So if the vehicle of weight W slow down from speed v_1 to v_2, then the loss in kinetic energy will be equal to the work done against skid resistance, where work done is weight of the vehicle multiplied by the skid distance and the skid resistance coefficient.

$$\frac{W(v_1^2 - v_2^2)}{2g} = W.f.S \tag{19}$$

where, f is the skid resistance coefficient and S is the skid distance. It also follows the law of conservation of momentum (m_1, v_1 are the mass and velocity of first vehicle colliding with another vehicle of mass and velocity m_2, v_2 respectively)

$$m_1 v_1 = m_2 v_2 \tag{20}$$

Energy theory

A vehicle of 2000 kg skids a distance of 36 m before colliding with a stationary vehicle of 1500 kg weight. After collision both vehicle skid a distance of 14 m. Assuming coefficient of friction 0.5, determine the initial speed of the vehicle.

Solution: Let the weight of the moving vehicle is W_A, let the weight of the stationary vehicle is W_B, skid distance before and after collision is s_1 and s_2 respectively, initial speed is v_1, speed after applying brakes before collision is v_2 and the speed of both the vehicles *A* and *B* after collision is v_3, and the final speed v_4 is 0. Then:

1. After collision: Loss in kinetic energy of both cars = Work done against skid resistance (can be obtained from equation mentioned below). Substituting the values we obtain v_3.

$$\frac{(W_A + W_B) \times (v_3^2 - v_4^2)}{2g} = (W_A + W_B).f.s_2$$

$$\frac{(v_3)^2}{2g} = 0.5 \times 14 = 7$$

$$v_3 = 11.71 m/s$$

Energy theory

2. At collision: Momentum before impact = momentum after impact (can be obtained from equation. 20)

$$\frac{W_A.v_2}{g} = \frac{(W_A + W_B)v_3}{g}$$

$$v_2 = \frac{(W_A + W_B)v_3}{W_A}$$

$$v_2 = 20.5m/s$$

3. Before collision (can be obtained from equation. 19): Loss in kinetic energy of moving vehicle = work done against braking force in reducing the speed

$$\frac{(W_A) \times (v_1^2 - v_2^2)}{2g} = W_A.f.s_1$$

$$\frac{(v_1^2 - v_2^2)}{2g} = 0.5 \times 36$$

$$v_1 = 27.8\ m/s = 100\ kmph$$

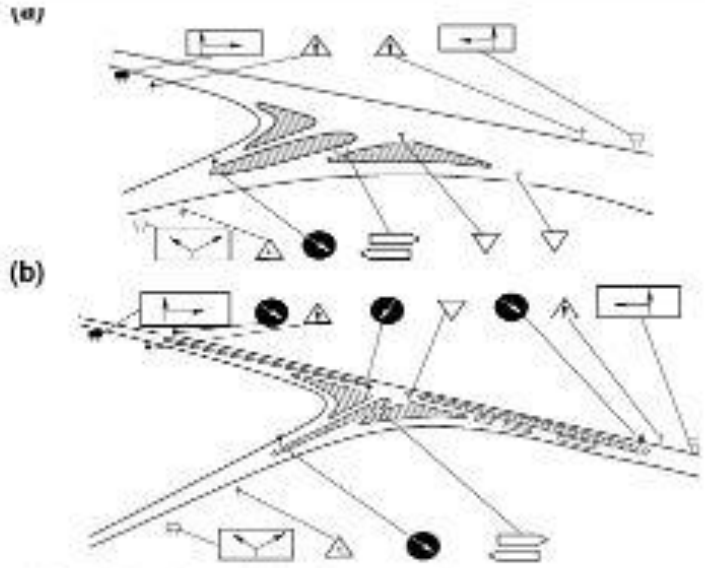
Ans: The pre-collision speed of the moving vehicle is 100 kmph.

5.1.3 Channelization

The Channelization of traffic at intersection separates the traffic stream travelling in different direction, providing them a separate lane that corresponds to their convenient path and spreading as far as possible the points of conflict between crossing traffic streams. The traffic lanes are separated by marking relevant lines or by constructing slightly elevated islands as shown in Figure 15. Proper Channelization reduces confusion. The number of decision required to be made by the driver at any time is reduced allowing the driver time to make next decision. The principles of proper channelized intersection are:-

1. The layout of intersection should be visibly clear, simple and understandable by driver.
2. Should ensure superiority to the vehicles using road of higher class.
3. Layout of intersection makes it necessary for a driver running through it to choose at each moment of time one of not more than two possible direction of travel. This is achieved by visual guidance, islands and markings.
4. The island provided should separate high speed, through and turning traffic flows.

5. The width of traffic lane should ensure unhampered turning to the big vehicles. Width of straight section without kerb should be 3.5 m and that of traffic lane near island is 4.5-5 m at entry and 6 m at exit.
6. Pedestrian crossing should be provided



a) Partially channelized intersection
b) Fully channelized intersection

Figure 15: Channelized Intersection ensuring safety

5.1.4 Road signs

Road signs are integral part of safety as they ensure safety of the driver himself (warning signs) and safety of the other vehicles and pedestrians on road (regulatory signs). Driver should be able to read the sign from a distance so that he has enough time to understand and respond. It is essential that they are installed and have correct shape, colour, size and location. It is required to maintain them as well, without maintenance in sound condition just their installment would not be beneficial.

Various other methods of traffic accident mitigation are described below:

1. **Street lighting**

   Street lightning of appropriate standard contributes to safety in urban area during night time due to poor visibility. Installation of good lighting results in 21% reduction in all accidents, 29% reduction in "all casualty" accidents, 21% reduction in "non pedestrian casualty" accidents, and 57% reduction in "pedestrian casualty" accidents.

2. **Improvement in skid resistance**

   If road is very smooth then skidding of the vehicles may occur or if the pavement is wet then wet weather crashes occur which account about 20-30%. Thus it is important to improve the skid resistance of the road. Various ways of increasing the skid resistance of road are by constructing high-friction overlay or cutting of grooves into the pavement.

3. **Road markings**

   Road markings ensure proper guidance and control to the traffic on a highway. They serve as supplementary function of road sign. They serve as psychological barrier and delineation of traffic path and its lateral clearance from traffic hazards for the safe movement of traffic. Thus their purpose is to provide smooth and safe traffic flow.

4. **Guide posts with or without reflector**

They are provided at the edge of the roadway to prevent the vehicles from being off tracked from the roadway. Their provision is very essential in hilly road to prevent the vehicle from sliding from top. Guide posts with reflector guide the movement of vehicle during night.

5. **Guard rail**

Guard rail have similar function as of guide post. On high embankments, hilly roads, road running parallel to the bank of river, shores of lake, near rock protrusion, trees, bridge, abutments a collision with which is a great hazard for a vehicle. It is required to retain the vehicle on the roadway which has accidentally left the road because of fault or improper operation on the part of the driver. Driver who has lost control create a major problem which can be curbed by this measure.

6. **Driver reviver stop**

Driver reviver stop are generally in use in countries like U.S.A where driver can stop and refresh himself with food, recreation and rest. They play a very important part in traffic safety as they relieve the driver from the mental tension of constant driving. These stops are required to be provided after every 2 hour travel time.

7. **Constructing flyovers and bypass**

   In areas where local traffic is high bypasses are required to separate through traffic from local traffic to decrease the accident rate. To minimize conflicts at major intersections flyovers are required for better safety and less accident rate

8. **Regular accident studies**

   Based on the previous records of accidents the preventive measures are taken and after that the data related to accidents are again collected to check the efficiency of the measures and for future implementation of further preventive measures.

5.2 Safety measures related to enforcement

The various measures of enforcement that may be useful to prevent accidents at spots prone to accidents are enumerated below. These rules are revised from time to time to make them more comprehensive.

5.2.1 Speed control

Checks on spot speed of all vehicles should be done at different locations and timings and legal actions on those who violate the speed limit should be taken

5.2.2 Training and supervision

The transport authorities should be strict while issuing licence to drivers of public service vehicles and taxis. Driving licence of the driver may be renewed after specified period, only after conducting some tests to check whether the driver is fit

5.2.3 Medical check

The drivers should be tested for vision and reaction time at prescribed intervals of time

5.3 Safety measures related to education

The various measures of education that may be useful to prevent accidents are enumerated below.

5.3.1 Education of road users

The passengers and pedestrians should be taught the rules of the road, correct manner of crossing etc. by introducing necessary instruction in the schools for the children and by the help of posters exhibiting the serious results due to carelessness of road users.

5.3.2 Safety drive

Imposing traffic safety week when the road users are properly directed by the help of traffic police as a means of training the public. Training courses and workshops should be organized for drivers in different parts of the country.

5.4 Safety audit

It is the procedure of assessment of the safety measures employed for the road. It has the advantages like proper planning and decision from beforehand ensures minimization of future accidents, the long term cost associated with planning is also reduced and enables all kinds of users to perceive clearly how to use it safely. Safety audit takes place in five stages as suggested by Wrisberg and Nilsson, 1996. Five Stages of Safety Audit are:

1. **Feasibility Stage** - The starting point for the design is determined such as number and type of intersection, relationship of the new scheme to the existing road, the relevant design standards.
2. **Draft Stage** - In this stage horizontal and vertical alignment, junction layout are determined. After the completion of this stage decision about land acquisition is taken.
3. **Detailed design stage** - Signing, marking, lighting, other roadside equipment and landscaping are determined.
4. **Pre-opening stage** - Before opening a new or modified road should be driven, walked or cycled. It should be done at different condition like bad weather, darkness.
5. **Monitoring of the road in use** - Assessment is done at the final stage after the road has been in operation for few months to determine whether the utilization is obtained as intended and whether any adjustment to the design are required in the light of the actual behavior of road users.

5.4.1 Road reconstruction safety audit

To estimate the effectiveness of improvement of dangerous section the number of accidents before and after is compared. To do this Chi Square test is used to check whether the experimental data meet the allowable deviation from the theoretical analysis. In the simplest case one group of data before and after road reconstruction is considered.

$$X^2 = \frac{(n_1 t_2 - n_2 t_1)^2}{t_1 t_2 (n_1 + n_2)} \geq X^2_{norm} \qquad (22)$$

where, t_1 and t_2 = period of time before and after reconstruction of a stretch of road for which statistical data of accident is available, n_1 and n_2 = corresponding numbers of accident, X_{norm}^2 = minimum values of Chi Square at which probability of deviation of laws of accident occurrence after reconstruction P from the laws existing before reconstruction does not exceed permissible values (usually 5%) The relationship between P and X_{norm}^2 is shown in Table. 2.

Table 2: Relationship between P and X_{norm}^2

P	10	8	5	3	2	1	0.1
X_{norm}^2	1.71	2	2.7	3.6	4.25	5.41	9.6

Before reconstruction of an at-grade intersection, there were 20 accidents during 5 years. After reconstruction there were 4 accidents during 2 years. Determine the effectiveness of the reconstruction.

Solution: Using Chi square test, we have (with P = 5 %)

$$X^2 = \frac{(20 \times 2 - 4 \times 5)^2}{5 \times 2(20 + 4)} = 1.67 < 2.7$$

Thus the statistical data available are not yet sufficient for considering with probability of 95 % that the relative reduction in number of accident is due to intersection reconstruction. Assuming one more accident occurs next year.

$$X^2 = \frac{(20 \times 3 - 5 \times 5)^2}{5 \times 3(20 + 5)} = 3.267 > 2.7$$

Therefore additional analysis confirms that the reduction in accident is due to road reconstruction.