Course Code	Course Title			Core / Elective
OE801CE	**Road Safety Engineering**			Elective
	Contact Hours per Week	CIE	SEE	Credits
	6	30	70	3

UNIT-1

- **Introduction:** Road Safety scenario in India and World, Road Accident Characteristics.
- **Traffic Safety Analysis:** Fundamentals of Traffic Engineering **-** Basic Characteristics of Motor-Vehicle Traffic, Highway Capacity, Applications of Traffic Control Devices, Design of Parking Facilities, Traffic Engineering Studies; Statistical Methods in Traffic Safety Analysis – Regression Methods, Poisson Distribution, Chi- Squared Distribution, Statistical Comparisons.

Need of the Course

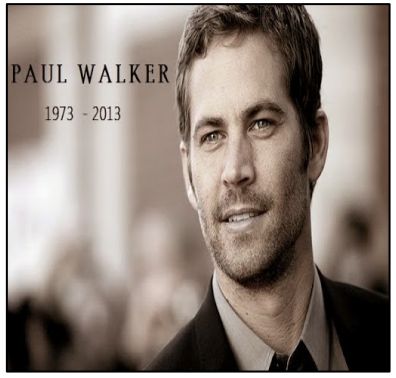
Princess Diana

Kota Anjaneya Prasad

Rama Krishna Nandamuri

Bharath

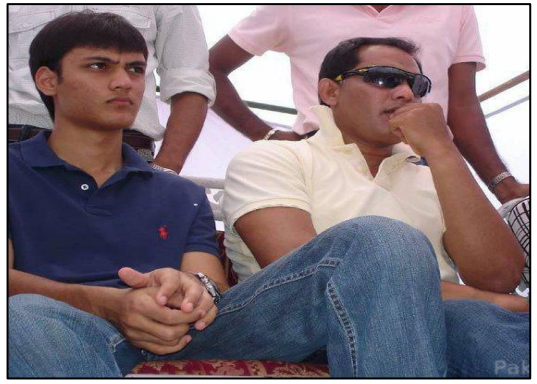
Nishith Narayana



Paul Walker

Yerram Naidu

Janaki Ram & Hari Krishna



Muhammad Ayazuddin

Shobha Nagi Reddy

Need of the Course

Road injury is one of those man-made problems that we have the ability to solve

Driving on Indian roads is much more different than driving else at some other place,

Safe road transport must be a key foundation stone of modern society,

More than 100 governments committed at the UN to support the goal of the Decade of Action

According to the WHO, in the years 2008-2011 thirty-five Countries, with a total population of 680 million, introduced new road safety laws.

Need of the Course

The rapid development and expansion of the road network, along with an increase in the number of registered motor vehicles, led to a substantial rise in levels of both passenger and freight movement.

The improvement in Transportation system has also lead to an increase in the number of crashes leading to an increased focus on road safety.

Constantly, the number of road crashes and fatalities have increased at an alarming rate

The fatalities in road crashes was documented as the 8th leading cause of deaths, worldwide, in 2018.

Over 1.35 million people were killed, worldwide, in road crashes during 2016.

Need of the Course

The economic losses associated with road crashes exceed $250 billion, annually, just in developed countries such as the United States

Road traffic crashes in most countries cost 3% of their GDP. They have emerged as an important public health issue that kills approximately 1.50 lakh people every year especially the young one. This needs to be tackled by a multi-disciplinary approach.

Road traffic crashes can be prevented by suitable engineering and management techniques.

Road safety engineering has become an important aspect and relevant to all engineering disciplines in the present scenario.

Thus study of Road Safety Engineering plays an important role to prevent or reduce .

Suggested Readings

- ***Principles and Practice of Highway Engineering*** by L.R. Kadiyali and N. B. Lal
- ***Traffic Engineering,*** Roger P. Roess, Elena S. Prassas, William R. Mcshane
- ***Guidelines on Design and Installation of Road Traffic Signals***,IRC:93.
- ***Road Delineators***, IRC:79
- ***Road Signs***, IRC:67
- ***Specification for Road Traffic Signals***, IS: 7537-1974.

Road Safety Engineering (RSE)

- The road safety engineering (RSE) function has the overarching aim of reducing the risk of collisions on the road network.
- **Road traffic safety** refers to the methods and measures used to prevent road users from being killed or seriously injured. Typical road users include: pedestrians, cyclists, motorists, vehicle passengers, horse-riders and passengers of on-road public transport (mainly buses and trams)

Road Accident Characteristics

- Road traffic accident occurs when a vehicle that is moving along a roadway collides with another vehicle or object.
- A road accident refers to any accident involving at least one road vehicle, occurring on a road open to public circulation, and in which at least one person is injured or killed.

Factors Involved in Transportation Crashes

- Driver or Operator Action:
  - Major contributing cause of many crash situations is the performance of the driver of one or both
- Vehicle Condition:
  - Mechanical condition of a vehicle can be the cause of transportation crashes
- Roadway Condition:
  - The condition and quality of the roadway, which includes the pavement, shoulders, intersections, and the traffic control system, can be a factor in a crash
- Environment:
  - The physical and climatic environment surrounding a transportation vehicle can also be a factor in the occurrence of transportation crashes

ROAD ACCIDENTS
Terminology

1. ***Fatal traffic accident*** *is one which involves a person who dies as a result* of an injury sustained in the accident (usually within 30 days); it excludes confirmed suicides
2. ***Serious accident*** *involves a person who is* detained in hospital as an in-patient, or who suffers any of the following injuries: fractures, concussion, internal injuries, crushings, severe cuts and lacerations, or severe general shock, that require medical treatment
3. ***Slight accident*** *is one involving a person* who is only slightly injured, e.g. a person who sustains a sprain, bruise or cut, which is not judged (by the police) to be severe, or slight shock requiring only roadside attention
4. ***Damage-only accident*** *does not involve people who sustain personal injuries*

Road Safety Scenario in India and World

- 70% of the fatal road accidents in India occurred in the eight States only
- UP 12%; TN 11%; AP+TS 10%; MH10%; KA 8%; RJ & MP 7% each state and GJ 5%
- 1/3rd of road accidents occurs on NHs only whereas the percentage share of NHs in the total road network in India is merely 2% (1.7%)
- 45% of the road accidents LMVs involved and 55% of road accidents attributed to HMVs

ROAD ACCIDENTS
Facts

Over 80% vulnerable road users (pedestrians, bicyclists, users of two wheeler/auto) are killed in road accidents in India

Nearly 90% of the road accidents are attributed to the drivers (human) fault leaving only 10% due to other factors like poor road geometry, lack of safety elements, poor conditions of the vehicles and bad weather etc.

about 50% road accident victims age group of less than 40years

As per the consortium of Delhi IIT & DMITS, commissioned by MORTH to estimate the socio-economic costs of road accidents, the total estimated socio economic cost of road accidents reported by India in 2018 was Rs 1,47,114 crores which was equivalent to 0.77% of the nation's GDP

Table 1: Number of road accidents and number of persons Involved: 2002 to 2011

Year	Number of accidents		Number of persons		Accident severity*
	Total	Fatal	Killed	Injured	
2002	40,7497	73,650 (18.1)	84,674	4.08,711	20.8
2003	406726	73,589 (18.1)	85,998	4,35,122	21.1
2004	429910	79,357 (18.5)	92,618	4,64,521	21.5
2005	439255	83,491 (19.0)	94,968	4,65,282	21.6
2006	460920	93,917 (20.4)	1,05,749	4,96,481	22.9
2007	479216	1,01,161 (21.1)	1,14,444	5,13,340	23.9
2008	484704	1,06,591 (22.0)	1,19,860	5,23,193	24.7
2009	486384	1,10,993 (22.8)	1,25,660	5,15,458	25.8
2010	499628	1,19,558 (23.9)	1,34,513	5,27,512	26.9
2011(P)	497686	1,21,618 (24.4)	1,42,485	5,11,394	28.6

P: Provisional, Source: Information supplied by States/UTs (Police Departments), Figures within parentheses indicate share of fatal accidents to total accidents *Accident Severity: No. of Persons killed per 100 accidents

Road accidents, Number of persons killed and injured in the last five years 2015-2019 in India

Year	Total Number of Road Accidents (in numbers)	% change	Total Number of Persons Killed (in numbers)	% change	Total Number of Persons Injured (in numbers)	% change
2015	5,01,423		1,46,133		5,00,279	
2016	4,80,652	-4.14	1,50,785	3.18	4,94,624	-1.13
2017	4,64,910	-3.28	1,47,913	-1.90	4,70,975	-4.78
2018	4,67,044	0.46	1,51,417	2.37	4,69,418	-0.33
2019	4,49,002	-3.86	1,51,113	-0.20	4,51,361	-3.85

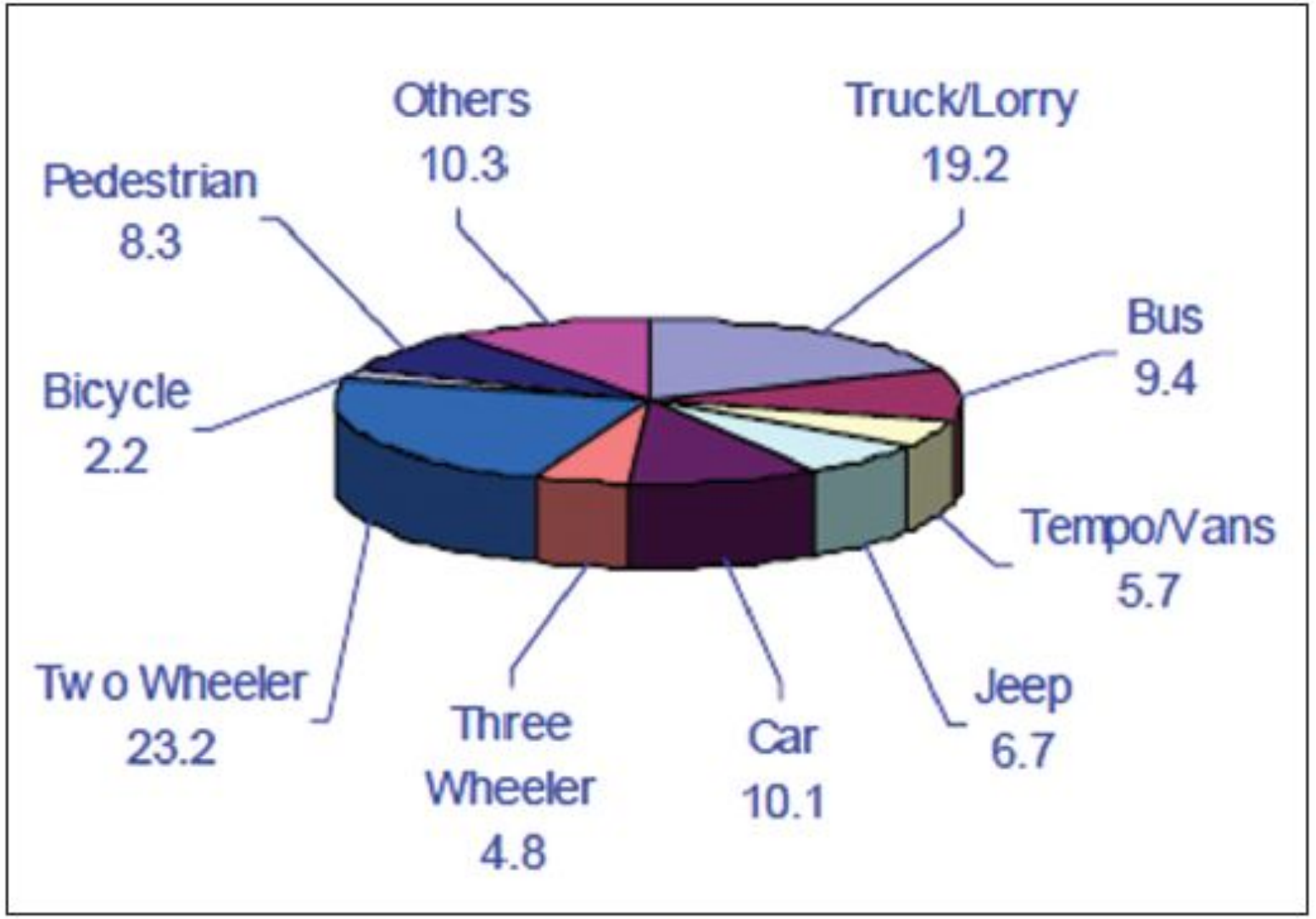


Figure 3: Road accident deaths by various modes of transport during 2012

Road Safety scenario in India and World

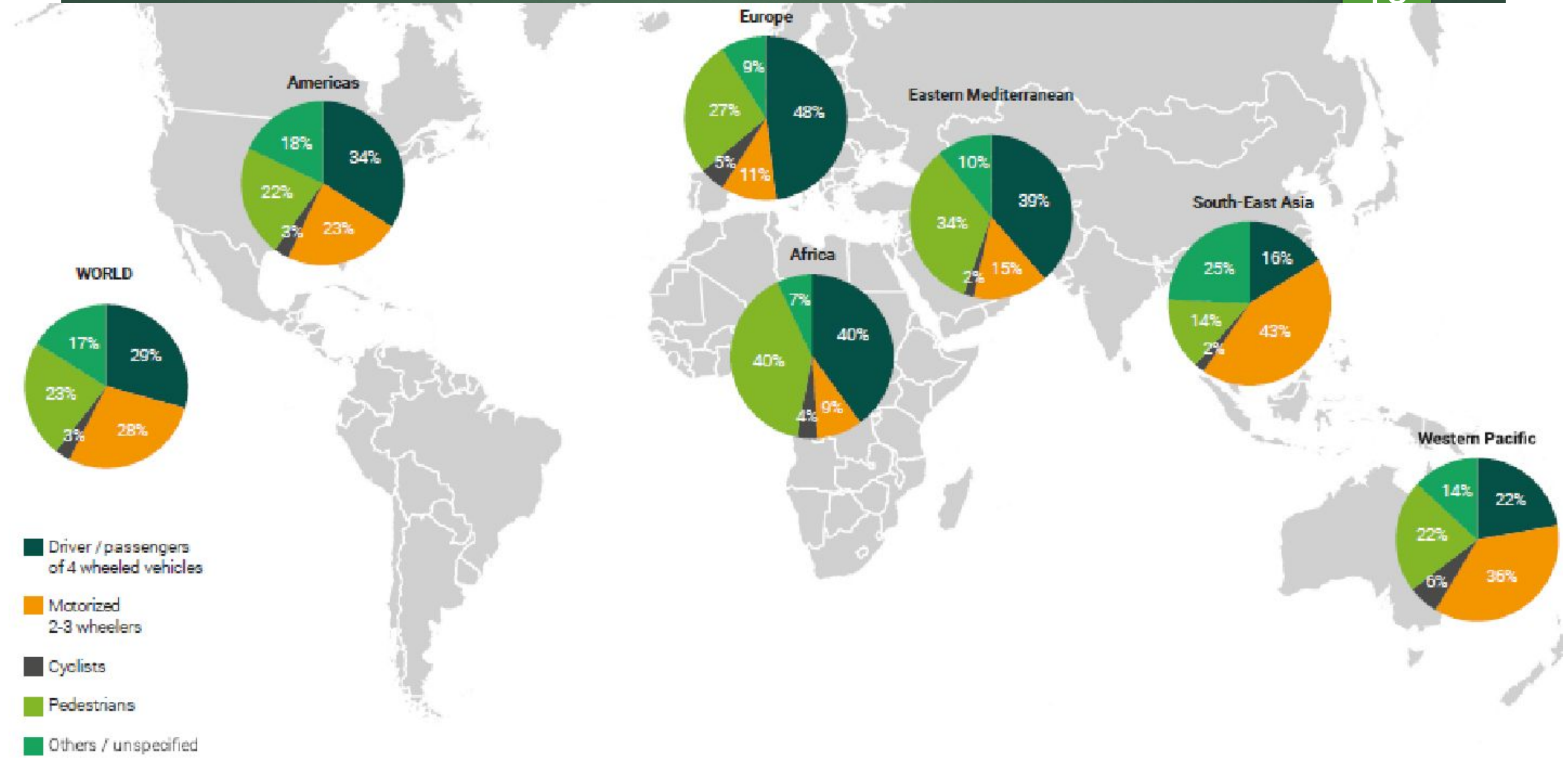
- **Key facts**
- **Approximately 1.3 million people die each year as a result of road traffic crashes.**
- **The United Nations General Assembly has set an ambitious target of halving the global number of deaths and injuries from road traffic crashes by 2030 (A/RES/74/299)**
- **Road traffic crashes cost most countries 3% of their gross domestic product.**
- **More than half of all road traffic deaths are among vulnerable road users: pedestrians, cyclists, and motorcyclists.**
- **93% of the world's fatalities on the roads occur in low- and middle-income countries, even though these countries have approximately 60% of the world's vehicles.**
- **Road traffic injuries are the leading cause of death for children and young adults aged 5-29 years.**

https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries

Road Safety scenario in India and World

- The *Global status report on road safety 2018*, launched by WHO in December 2018, highlights that the number of annual road traffic deaths has reached 1.35 million.
- Road traffic injuries are now the leading killer of people aged 5-29 years.
- The burden is disproportionately borne by pedestrians, cyclists and motorcyclists, in particular those living in developing countries.
- The report suggests that the price paid for mobility is too high, especially because proven measures exist.
- Drastic action is needed to put these measures in place to meet any future global target that might be set and save lives.

Distribution of deaths by road user type by WHO Region



Definition and goal of Traffic Engineering

- Definition:
  - It is the phase of transportation engineering that deals with the planning, geometric design and traffic operations of streets and highways, their networks, terminals, abutting lands for the safe, convenient and economic transportation of persons and goods.
- Goal: Explore how to provide for the safe, rapid, comfortable, convenient, economical, and environmentally compatible movement of people and goods.
  - Safe --- public safety
  - Rapid --- time value and customer service
  - Comfortable/convenient --- level of service
  - Economical --- social cost
  - Environmental --- clean air and sustainability

Traffic characteristics-Road user characteristics

1. Road user characteristics
   a. **Physical characteristics:**
      a. **Vision:**

         very distinct vision:- zone of acute 3 degree angle cone about retina center

         Satisfactory vision:- 10 to 12 degree cone about retina center (sign board location)

         Peripheral vision: deals with total visual field of two eyes, 160^0 horizontal, 115^0 vertical, varies with speed, the angle of cone falls from 110^0 at 30kmph to 40^0 at 100kmph

         Glare recovery time:- 3 to 6 seconds

      b. **Hearing:** an aid to vehicle driver and pedestrian

      c. Temporary physical characteristics are **fatigue, alcohol /drugs & illness**.

   b. **Mental characteristics:**
      a. Knowledge: Specific information about traffic

      b. Skill: ability acquired by training

      c. Intelligence: The capacity to acquire and apply knowledge

      d. Experience: The accumulation of knowledge or skill that results from direct participation in events or activities related to traffic

Traffic characteristics-Road user characteristics

1. Road user characteristics

   c. **Psychological factors:**

   Perception, Intellection, Emotion and Volition (PIEV) theory

   Perception is the process of perceiving the sensations received through eyes, ears, nervous system and the brain. the exact time required for this is dependent upon the individual's psychological and physiological build-up

   Intellection is the identification of the stimuli by the development of new thoughts and ideas. It is slightly different from simple recognition by past experiences, which is part of normal perception process.

   Emotion is the personal trait of the individual that governs his decision making process, after the perception and intellection of the stimuli

   Volition is the will to react to a situation

   Break reaction time is the time lag between the perception of danger and the effective application of the breaks

   IRC/AASHTO suggests Perception and Break reaction time as 2.5seconds

   d. **Environmental factors:** traffic stream characteristics, facilities to the traffic, atmospheric conditions and the locality

Traffic characteristics- Vehicular characteristics

2. Vehicular characteristics

1. Static characteristics

1. Maximum dimensions of road vehicles

   Width= 2.5m, Height=3.8-4.2m for single decked, 4.75m for double decked

   Length =11m for single unit with 2axles, 12m for single unit with more than 2axles, 16m for tractor semi trailer combination

   18m for tractor and trailer combination

2. Weight of loaded vehicle :Single axle 10.2 tonnes, Tandem axle 18 tonnes
3. Axle configuration: no.of std. axles count used in pavement structure design
4. Power to weight ratio of vehicle: it characterizes the ease with which a vehicle can move (human powered vs motorized vehicles, heavy vs light vehicle)
5. Turning Radius and Turning Path: radius of circle traced out by vehicle when its steering turned to the max. extent possible. Effective width of vehicle increases near turns

Traffic characteristics- Vehicular characteristics

2. **Dynamic characteristics**
    1. **Speed and acceleration**: depends on engine power. Useful for geometric design of roadway
    2. **Stability of vehicle**: it depends on vehicle dimensions and Center of Gravity.
    3. **Breaking distance**: depends on the speed and friction between tyre surface and pavement surface

    $$d=V^2/254(f+/-G) \text{ in meters}$$

    where v=speed in KMPH, f=coefficient of friction, G=gradient

Fundamental parameters of traffic flow
Traffic stream parameters

Speed

- Speed is considered as a quality measurement of travel
- It is defined as the rate of motion in distance per unit of time

Spot Speed

- Spot speed is the instantaneous speed of a vehicle at a specified location
- Spot speed can be used to design the geometry of road like horizontal and vertical curves, super elevation etc. Location and size of signs, design of signals, safe speed, and speed zone determination, require the spot speed data.
- Accident analysis, road maintenance, and congestion are the modern fields of traffic engineer, which uses spot speed data as the basic input.
- Spot speed can be measured using an **Enoscope, pressure contact tubes or direct timing procedure or radar speedometer or by time-lapse photographic methods**. It can be determined by speeds extracted from video images by recording the distance travelling by all vehicles between a particular pair of frames

Fundamental parameters of traffic flow
Traffic stream parameters

Running speed

- Running speed is the average speed maintained over a particular course while the vehicle is moving and is found by dividing the length of the course by the time duration the vehicle was in motion. i.e. this speed doesn't consider the time during which the vehicle is brought to a stop, or has to wait till it has a clear road ahead
- The running speed will always be more than or equal to the journey speed, as delays are not considered in calculating the running speed

Journey speed

- Journey speed is the distance between the two points divided by the total time taken for the vehicle to complete the journey including any stopped time.
- If the journey speed is less than running speed, it indicates that the journey follows a stop-go condition with enforced acceleration and deceleration. The spot speed here may vary from zero to some maximum in excess of the running speed
- A uniformity between journey and running speeds denotes comfortable travel conditions.

Fundamental parameters of Traffic flow

Flow or Volume

- **Flow or volume** is defined as the number of vehicles that pass a point on a highway or a given lane or direction of a highway during a specific time interval
- Generally, the period of time is taken as one hour and the unit of volume is stated as **vehicles per hour**
- The measurement is carried out by counting the number of vehicles, n_t, passing a particular point in one lane in a defined period t. Then the flow q expressed in vehicles/hour is given by

$$q = n_t/t$$

- The reciprocal of flow (across a point) gives the **average time headway** between vehicles at that point
- Flow is expressed in planning and design field taking a day as the measurement of time.

Highway Capacity

- Capacity of a facility is defined as the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane or road way during a given time period under prevailing roadway, traffic and control conditions. Expressed in **no.of vehicles (PCU) per hour**
- Capacity is a probabilistic measure and it varies with respect to time and position. Hence it is not always possible to completely derive analytically the capacity. In most cases it is obtained, through field observations
- Capacity is the maximum flow rate that a facility can afford. This maximum flow rate is taken for the worst 15 minutes of the peak hours while finding out the capacity.
- Capacity is measured as a reasonably expected value and not the maximum flow rate ever observed in the facility
- Capacity is independent of the demand. It speaks about the physical amount of vehicles and passengers a road can afford
- C=1000V/S veh/hour/lane where v=speed in kmph s=spacing b/w vehicles

Highway Capacity

- The highway capacity depends on below listed conditions;
  - Traffic conditions: It refers to the traffic composition in the road such as the mix of cars, trucks, buses etc in the stream. It also include peaking characteristics, proportions of turning movements at intersections and the like.
  - Road way characteristics: This points out to the geometric characteristics of the road. These include lane width, shoulder width, lane configuration, horizontal alignment and vertical alignment.
  - Control conditions: This primarily applies to surface facilities and often refer to the signals at intersections etc.
  - Technology:

    Intelligent Transportation Systems (ITS) includes any technology that allows drivers and control system operators to gather and use real time information to improve vehicle navigation, road way system control or both

Applications of Traffic Control Devices

Various devices used to control, regulate and guide traffic

- SPEED BUMPS AND RUMBLE STRIPS
- ROAD MARKING (PAVEMENT, OBJECT, KERB, REFLECTORS)
- ROAD SIGNING (REGULATORY, WARNING, INFORMATORY)
- SIGNALIZATION (TRAFFIC CONTROL, PEDESTRIAN)
- RLY-CROSSINGS
- ISLANDS (DIVISIONAL, ROTARY, CHANNELIZING, PEDESTRIAN LOADING)

Traffic Engineering Studies

Traffic studies can be broadly classified into two categories

- Concerned with the characteristics of traffic in transit
  - Volume studies and characteristics
  - Speed and delay studies
  - Origin and Destination (O&D) studies
  - Road life studies
  - Motor vehicle use studies
- Studies related to land use movements
  - Parking studies
  - Accident studies

Objectives of traffic studies

- A detailed knowledge of the operating characteristics of the traffic is essential to form a basis for the establishment of **traffic control** or for **design of streets and highways**.
- The results of data collected during traffic studies are used in
  - **Traffic planning**
  - **Traffic management**
  - **Economic studies**
  - **Traffic and environmental control and**
  - **Monitoring trends , both for establishment and updating of design standards**

Design of Parking Facilities

ILL effects of On-road parking

1. Congestion:
   - Parking takes considerable street space leading to the lowering of the road capacity. Hence, speed will be reduced, journey time and delay will also subsequently increase. The operational cost of the vehicle increases leading to great economical loss to the community.
2. Accidents:
   - Careless maneuvering of parking and unparking leads to accidents which are referred to as parking accidents. Common type of parking accidents occur while driving out a car from the parking area, careless opening of the doors of parked cars, and while bringing in the vehicle to the parking lot for parking.
3. Environmental pollution:
   - They also cause pollution to the environment because stopping and starting of vehicles while parking and unparking results in noise and fumes. They also affect the aesthetic beauty of the buildings because cars parked at every available space creates a feeling that building rises from a plinth of cars.
4. Obstruction to fire fighting operations:
   - Parked vehicles may obstruct the movement of fire fighting vehicles. Sometimes they block access to hydrants and access to buildings

Vehicle Parking

- Terminal facilities form an integral part of any transportation system
- Failure to provide suitable parking facility can result in congestion and frustration
- As a general rule increase in vehicle ownership results in increased parking demand
- The availability of less space in urban areas has increased the demand for parking space especially in areas like Central business district (CBD). This affects the mode choice also. This has a great economical impact
- Purpose of parking studies
  - To determine the congestion in the city/town areas
  - To assess the suppressed parking demand
  - To evaluate capacity of the existing parking facilities
  - To estimate the desires and demands of the public for parking facility
  - To decide the capacity, location and type of future parking facilities

Minimum parking space for different types of buildings

- Residential plot area less than 300 sq.m: only community parking space.

  from 300 to 500 sq.m, 1/3rd of the open area

  from 500 to 1000 sq.m, 1/4th of the open area

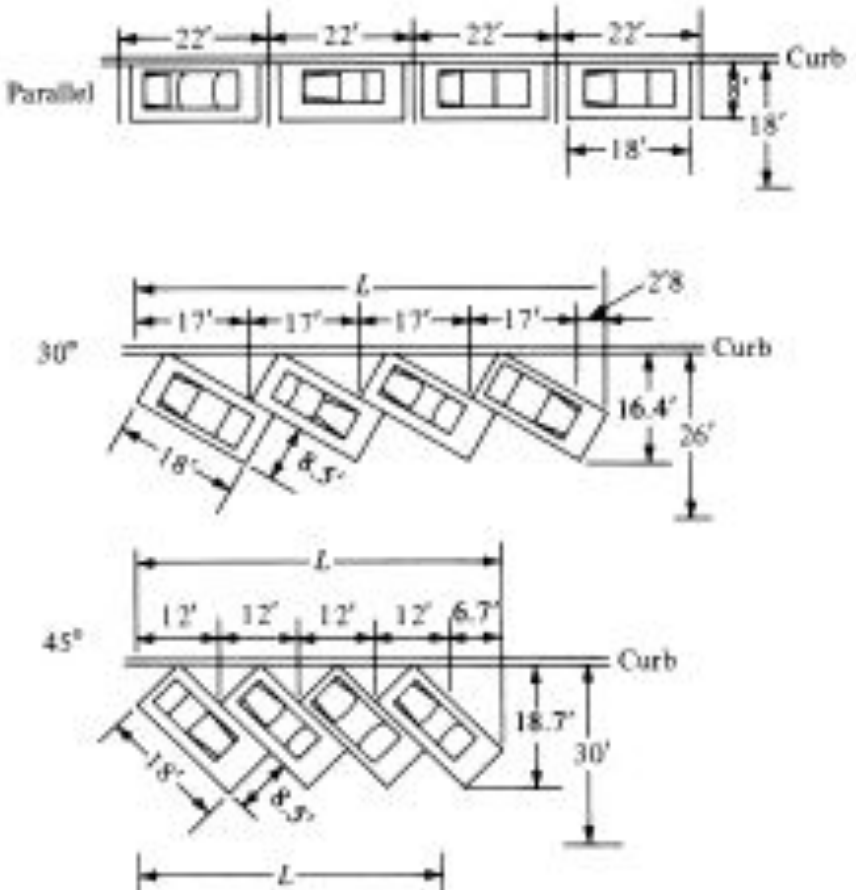
  above 1000 sq.m, 1/6th of the open area

- Flats (apartments): 1space for every 2dwellings (50-100sq.m)
- Multistoried group housing:1space for every 4dwellings
- Offices: 1 parking space for every 70 sq.m.
- Shops & markets: 1 parking space for every 80 sq.m.
- Restaurants: 1 parking space for every 10 seats
- Hotels and motels
  - Five/Four star hotels: 1parking space for every 4 guest rooms
  - Three star hotels: 1parking space for every 8 guest rooms
  - Two star hotels: 1parking space for every 10guest rooms
  - Motels: : 1parking space for each guest rooms
- **Theatres** need to keep only 1 parking space for 20 seats. : **Hospitals**: 1parking space for every 10beds

Parking types

Parking facilities may be broadly divided into two types

- On street/Kerb parking
  - On street parking means the vehicles are parked on the sides of the street itself. This will be usually controlled by government agencies. Common types of on-street parking are as listed below. This classification is based on the angle in which the vehicles are parked with respect to the road alignment. As per IRC the standard dimensions of a **car is taken as 5.0X2.5** metres and that for a **truck is 3.75X7.5 metres**
  - Parallel parking: The vehicles are parked along the length of the road. Here there is no backward movement involved while parking or unparking the vehicle. Hence, it is the most safest parking from the accident perspective. However, it consumes the maximum curb length and therefore only a minimum number of vehicles can be parked for a given kerb length. This method of parking produces least obstruction to the on-going traffic on the road since least road width is used.
  - 30, 45, 60, 90 deg. parking
- Off-street parking



$$N = \frac{L}{22}$$

$$N = \frac{L - 2.8}{17}$$

$$N = \frac{L - 6.7}{12}$$

$$N = \frac{L - 6.6}{9.8}$$

$$N = \frac{L}{8.5}$$

N = number of spaces
L = curb length

Figure 15.33 Street Space Used for Various Parking Configurations

Off-street parking

- These facilities may be **privately** or **publicly** owned; they include
  - Surface lots and
  - Garages.
- **Self-parking garages** require that drivers park their own automobiles;
- **Attendant-parking garages** maintain personnel to park the automobiles.

Off-street parking

Surface lots

Elevated Parking

Mechanized
Elevated Parking

Statistical methods of analysis of accident data

- Accident statistics are measures (or estimates) of the number and severity of accidents. They should be presented in a way that is intended to provide insight into the general state of highway safety and into systematic contributing causes of accidents. These insights can help develop policies, programs, and specific site improvements intended to reduce the number and severity of accidents
- Accident statistics generally address and describe one of three principal informational elements:
  - Accident occurrence
  - Accident involvements
  - Accident severity

Accident statistics

- *Accident occurrence* relates to the numbers and types of accidents that occur, which are often described in terms of rates based on population or vehicle-miles travelled.
- *Accident involvement* concerns the numbers and types of vehicles and drivers involved in accidents, with population-based rates a very popular method of expression.
- *Accident severity* is generally dealt with by proxy: the numbers of fatalities and fatality rates are often used as a measure of the seriousness of accidents

Accident Analysis

common types of analyses include:

- Trends over time
- Stratification by highway type or geometric element
- Stratification by driver characteristics (gender, age)
- Stratification by contributing cause
- Stratification by accident type
- Stratification by environmental conditions

Accident Analysis

- Accident analyses allow the correlation of accident types with highway types and specific geometric elements, the identification of high-risk driver populations, quantifying the extent of DUI/DWI influence on accidents and fatalities, and other important determinations.
- Many of these factors can be addressed through policy or programmatic approaches
- Changes in the design of guardrails have resulted from the correlation of accident and fatality rates with specific types of installations

Accident Analysis

- Changes in the legal drinking age and in the legal definition of DUI/DWI have resulted partially from statistics showing the very high rate of involvement of this factor in fatal accidents.
- Improved federal requirements on vehicle safety features (air bags, seat belts and harnesses, energy-absorbing steering columns, padded dashboards) have occurred partially as a result of statistics linking these features to accident severity

Accident data Analysis- statistics

- Accident Rate/km (R): Accident hazard is expressed as a number of accidents of all types per Km of each highway and street classification.

$$R=A/L.$$

Where, A= Total no.of accidents in one year.

L= Length of control section in kms.

Contd….

- Accident involvement rate: It is expressed as number of drivers of vehicles with certain characteristics who are involved in accident per 100million vehicle kilometers of travel.

$$R = (N/V) \times 100000000$$

Where N= Total no.of drivers of vehicles involved in accidents during the period of investigation.

V= Vehicle-kms of travel on road section during the period of investigation.

- **Death rate based on population:** Traffic hazard to life in a community is expressed as the no. of traffic fatalities for 100000 population. This reflects the accident exposure for entire area.

$$R = (B/P) \times 100000.$$

Where, B= Total no.of accident deaths in one year.
P= Population of the area.

- **Death rate based on registration:** Traffic hazard to life in a community can also be expressed as the no. 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.

$$R = (B/M) \times 10{,}000$$

Where, B= Total no.of traffic death in one year.
M= no.of motor vehicles registered in the area.

- Accident rate based on vehicle-Kms of travel: The accident hazard is expressed as the no.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.

$$R=(C/V) \text{ X } 100000000.$$

where, C= No.of total accidents in one year.

V= Vehicle-kms of travel in one year.

Prob1:

The mortar vehicle consumption in a city is 5.082millions litres there were 3114 mortar vehicle fatalities 355799 mortar vehicle injuries 6,721,049 mortar vehicle registrations and an estimated population of 18,190,238 km of travels per litre of fuel is 12.42 km/lit. calculate registration death rate, population death rate and accident rate per vehicle km.

Sol:

appox vehicle km of travel =total consumption of fuel*Km of travel per litre of fuel

$= 5.08 \times 10^9 \times 12.42$

$= 63.01 \times 10^9$ Km.

1.Registration death rate

$R = (B/M) \times 1000 = (3114 / 6721049) \times 10000 = 4.63$

2. Population death rate $R = (B / P) \times 100000$

$= (3114 / 18190238) \times 10000$

$= 17.1$

3. Accident rate per vehicle Kms of travel $R = (C/V) \times 100000000.$

$R = (3114 / 63.1 \times 10^{9)}) \times 10^8$

$R = 4.93$

Statistical methods for Analysis of Accident data

- Qualitative methods of analysis of accidents can provide a deep view in to the causes that contribute to the accident and
- can often help to identity the blackspots on this Highway/street system.
- In recent times the application of statistical techniques in planning and analyzing experiment resulted in producing more effectiveness in accidental preventive measures.

Contd…

The no.of statistical methods are currently being applied in accident research include:

- Regression methods
- Poisson distribution
- Use of chi-squared test for comparing accident data

Regression Analysis

Simple linear regression :

Find the relation between the two through regression analysis.
Number of accidents happening in months is as follows.

Number of two-wheeler registrations	Number of two wheelers involved
1	1
2	1
3	2
4	4
5	3

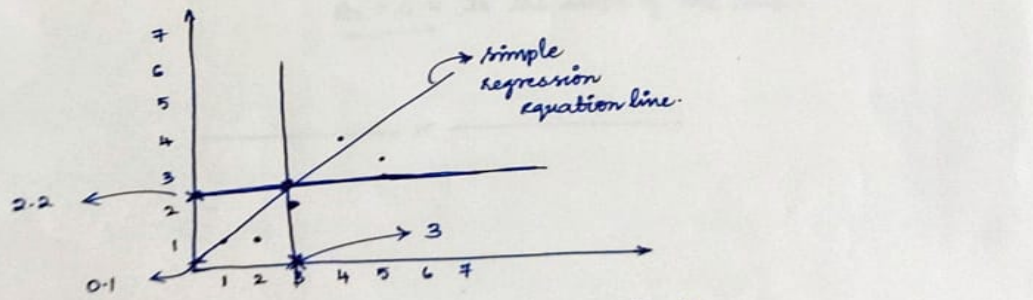
Step 1 : Identify the dependent variable & independent variables

→ Here no of accidents is independent variable & is denoted as x.

→ no. of two wheelers involved is dependent variable & is denoted by Y.

Getting (x, y) components. (1,1) (2,1) (3,2) (4,4) (5,3).

Step 2 : Draw a scatter plot with the given points.



Step 3 : Solving through least square method.

∴ simple regression equation is given by $\boxed{y = \beta_0 + \beta_1 x + \epsilon}$

x	y	$x-\bar{x}$	$y-\bar{y}$	$(x-\bar{x})^2$	$(x-\bar{x})(y-\bar{y})$
1	1	−2	−1.2	4	2.4
2	1	−1	−1.2	1	1.2
3	2	0	−0.2	0	0
4	4	1	1.8	1	1.8
5	3	2	0.8	4	1.6
				7	

mean of $x \rightarrow \bar{x} = \frac{1+2+3+4+5}{5} = 3$

Similarly $\bar{y} = \frac{1+1+2+4+3}{5} = 2.2.$

Now $\beta_1 = \frac{\sum[(x-\bar{x})(y-\bar{y})]}{\sum[x-\bar{x}]^2} = \frac{7}{10} = 0.7.$

$\therefore \quad \hat{y} = \beta_0 + \beta_1 x$

$2.2 = \beta_0 + 0.7(3)$

$2.2 = \beta_0 + 2.1$

$\beta_0 = 0.1$ → is the intercept.

$\beta_1 = 0.7$ is the slope of the line.

———— × ————

Poisson's Distribution

The Mathematical formula for poisson's distribution is given by

$$P(r) = \frac{e^{-m} \cdot m^r}{r!}$$

where $P(r)$ is the probability of Occurance of 'r' events.
m is mean of the events.
e is napeian algorithm.

→ The probability of a diver causing an accident is given by

$$m = P \cdot M$$

where m is mean of incidents occuring in the length of M kms
M is kms. driven by each diver.
P is probability of having an accident per km travelled.

∴ Probability of diver having 'r' accidents is given by

$$P(r) = \left(\frac{e^{-m} \cdot m^r}{r!}\right) N.$$ where N is no. of divers.

Eg 1: It has been found that on an average, one in 100 divers in a bus company are involved in an accident every year. If there are 500 divers in the company, what is the probability that there are exactly 4 divers who are involved in an accident during a year?

Sol: Given probability of having an accident $= \frac{1}{100} = 0.01$

$N = 500.$

$m = N \cdot P$
$= 500 \times 0.01 = 5.$

$\therefore m = 5.$

$$P(r) = \frac{e^{-m} \cdot m^r}{r!}$$

$$P(4) = \frac{e^{-5} \cdot 5^4}{4!} = 0.175.$$ is the probability where exactly 4 divers involve in a accident every year.

Eg. 2: The no. of accidents of autorikshaws in a year with mean of 3 follows poisson's distribution. If there are 500 divers in total. find the divers who commits no accidents & also no. of divers who commits more than 5 accidents?

Sol: (i) No. of divers who commits no accidents.

mean $m = 3$

no. of divers in the city $N = 500.$

$= N.P$
$= N \times P(\text{no. accidents})$
$= 500 \times P(0)$
$= 500 \times 0.0498$
$= 24.9 \simeq 25.$

$$P(0) = \frac{e^{-3} \cdot 3^0}{0!}$$

$P(0) = 0.0498.$

(ii). No of divers who commits more than 5 accidents $= N \times P(r > 5)$

$\Rightarrow N \times P(r \geq 6) \Rightarrow N \times P[1 - P(r \leq 5)]$

$\Rightarrow N \times [1 - \{P(0) + P(1) + P(2) + P(3) + P(4) + P(5)\}]$

$\Rightarrow N \times \left[1 - \left\{\frac{e^{-3} \cdot 3^0}{0!} + \frac{e^{-3} \cdot 3^1}{1!} + \frac{e^{-3} \cdot 3^2}{2!} + \frac{e^{-3} \cdot 3^3}{3!} + \frac{e^{-3} \cdot 3^4}{4!} + \frac{e^{-3} \cdot 3^5}{5!}\right\}\right]$

$\Rightarrow N \times \left[1 - e^{-3}\left\{\frac{3^0}{0!} + \frac{3^1}{1!} + \frac{3^2}{2!} + \frac{3^3}{3!} + \frac{3^4}{4!} + \frac{3^5}{5!}\right\}\right].$

$\Rightarrow N \times [1 - e^{-3}\{1 + 3 + 4.5 + 4.5 + 3.375 + 2.025\}] = 500 \times 0.08368 = 41.84$
$\simeq 42$ divers.

Poisson distribution in accident analysis

- Poisson distribution is appropriate for accident study because accidents are prone by the loss if chance and the occurrence of accidents.
- It is a rare event in time or in distance or amongst drivers.
- The mathematical formula for Poisson distribution is:

$$P(r) = (e^{-m} m^{r})/r! \quad \text{——Equation-1}$$

Where, P(r)= probability of occurrence of r events.

m= Average rate of occurrence of events.

e= Base of Napierian logarithms.

Applying the above formula to determine the probability of a driver causing an accident.

$$m = PM$$

Where,

M= kilometers driven by each driver.

P= probability of having of an accident per kilometer travelled.

m= Average rate of occurrence of accidents in a travel of M kilometers length.

The probability of a driver having r accidents ,

$$P(r) = (e^{-m} m^{r}) / r! \qquad \text{Equation-2}$$

Contd…

Also the no.of drivers having "r" accidents

$$P(r)=N\left(\left(e^{-m}\, m^{r}\right)/r!\right) \quad \ldots\ldots \text{Equation-3}$$

Where N= no.of accidents

In the above formula value of P is very small and the value of N is very large.

equation-2 can be used to determine the probability of accidents occurring in a given time span.

Let m be the average no.of accidents occurring in a year at a given location.

Then, $P(r)= \left(e^{-m}\, m^{r}\right) / r!$.

Prob:2

- It is observed that on an average a vehicle driver drives 5000km driving the course of a year. The probability of having an accident is 100 per 200 million vehicles kms . What is probability of driver having at least 2 accidents during his driving carrier extending to 25 years.

Sol: no.of accidents = 100 per 200 million vehicle Kms

$$P = 100/\ 200000000 = 0.0000005$$

Probability of having an accident per km travelled P= 0.0000005.

Kms driven by each driver M = 5000X25 = 1,25,000 km

$$m = PM = 0.0000005 \times 125000 = 0.0625$$

$$P(r) = \{e^{-m}.\ m^r / r!\} = e^{-0.0625} (0.0625)^r / r!$$

contd

P(r= at least 2 accidents) $P_{(r>2)} = 1-p_{(r<2)} = 1 -(p_{(r=0)}+p_{(r=1)}$

$= 1-p_{(r=0)}-p_{(r=1)}$

$= 1-p_{(r=0)}-p_{(r=1)}$

$= 1- \{ (e^{-0.0625} x\ 0.0625^{o} / 0!)-(e^{-0.0625}(0.0625)^{1}) / 1!) \}$

$=1- e^{-0.0625} – e^{-0.0625} x\ 0.0625$

$= 1-e^{-0.0625}(1-0.0625)$

$= 1- e^{-0.0625} x\ 0.9375$

$= 0.119301.$

Prob:3

The accident records of three consecutive years at an uncontrolled junction indicate the following no.of accidents.

year	no.of accidents
1972	3
1973	6
1974	9

Calculate the probability of 4 accidents occurring per year at the site

:r=4 accidents m= Average rate of occurrence of accidents

$m = 3+6+9 / 3 = 6$

$p(r) = \{e^{-m} m^{r} / r! \}$

$p(4) = e^{-6} * 6^{4} / 4!$

$= 0.133$

Chi-Squared distribution for Comparing Accident frequencies.

Extensively used to compare data before and after accidents and predict the pattern for particular road in particular time.

Generalised formula for Chi Square is $\chi^2 = \frac{(a-bc)^2}{(a+b)c}$ * In this particular case.

where a – no. of accidents after improvement of a section.
b – no. of accidents before improvement of a section.
c – no. of expected accidents if no improvements have taken place

→ Otherwise Pearson's Chi Square test is the result of contengency tables drawn in interest of comparing two independent data & thereby draw conclusions over it.

→ Null hypothesis plays a important role in Chi Square test, which has different degrees of freedom. Quite commonly it is taken as 5%. to have freedom of error.

— NOTE: Depending on event & data degrees of freedom Changes.

$$\chi^2 = \frac{\text{Observed values} - \text{Expected values}}{\text{Average Variance}}.$$

Eg: 1: In an Ordinary square junction of two roads, there were 20 accidents in a year, After provision of traffic signals, no. of accidents dropped down to 8 per year. In this sector of city where this junction is situated, general trend observed was that no. of accidents increased at a rate of 10% during the period covered by the above two observations. Test whether the improvements in the junction design has a significance effect of 5% level of degree if control ratio c = 01.1

Sol: Given

no. of accidents after improvement $a = 8$.

no. of accidents before improvement $b = 20$

control ratio $c = 1.1$.

$$\therefore \chi^2 = \frac{(a-bc)^2}{(a+b)c} = \frac{[8 - 20(1.1)]}{(8+20)(1.1)} = 6.36.$$ (Calculated Value) or Expected value.

→ As per null hypothesis chi square table, the value for degree of freedom of 5% is $\chi^2 = 3.841$. (observed value / Given value).

∴ As calculated value is greater than given value.

$$\chi^2_{(calculated)} > \chi^2 \text{ (observed)}$$

It is clear that there was an effective improvement in the junction design in reducing accidents.

———— X ————

Nonparametric Method

- The nonparametric approach is simple to apply and only assumes a Poisson distribution for the accidents.

To estimate the number of accidents, a_k expected to occur in an equivalent after period on a system that had k accidents in the before period, we need

N_k = number of systems with k accidents, and

N_{k+1} = number of systems with (k+1) accidents.

Now, $a_k = (k+1)*N_{(k+1)} / N_k$

Empirical Bayes Method

- The empirical Bayes method assumptions are (1) a Poisson distribution for the accidents, and (2) a Gamma distribution for the distribution of the averages in the population of systems.
- With these two assumptions, the number of systems with k accidents must obey the negative binomial distribution. The expected number of accidents, a'_k, in the after period on a system that had k accidents in the before period is

$$a'_k = (k+1)*N'_{(k+1)} / N'_k$$

Safety Performance Function (SPF)

- SPF is an equation used to predict the average number of crashes per year at a location as a function of exposure and, in some cases, roadway or intersection characteristics (e.g., number of lanes, traffic control, or median type) (1). For highway segments, exposure is represented by the segment length and annual average daily traffic (AADT) associated with the study section
- Application: SPFs are used to predict crash frequency for a given set of site conditions. The predicted crashes from the SPF can be used alone or in combination with the site-specific crash history (i.e., Empirical Bayes method) to compare the safety performance of a specific site under various conditions.
- The Empirical Bayes method is used to estimate the expected long-term crash experience, which is a weighted average of the observed crashes at the site of interest and the predicted crashes from an SPF

References

1. Traffic Engineering by Roger Roess, Elena and McShane 3rd Edition
2. Traffic and Highway Engineering by Garber and Hoel 4th Edition
3. Transport Planning and Traffic Engineering- CA O'Flaherty