# Elements of a Transportation System and their Characteristics

Dr. Manish Dutta
Assistant Professor
Department of Civil Engineering
Institute of Technology, Nirma University

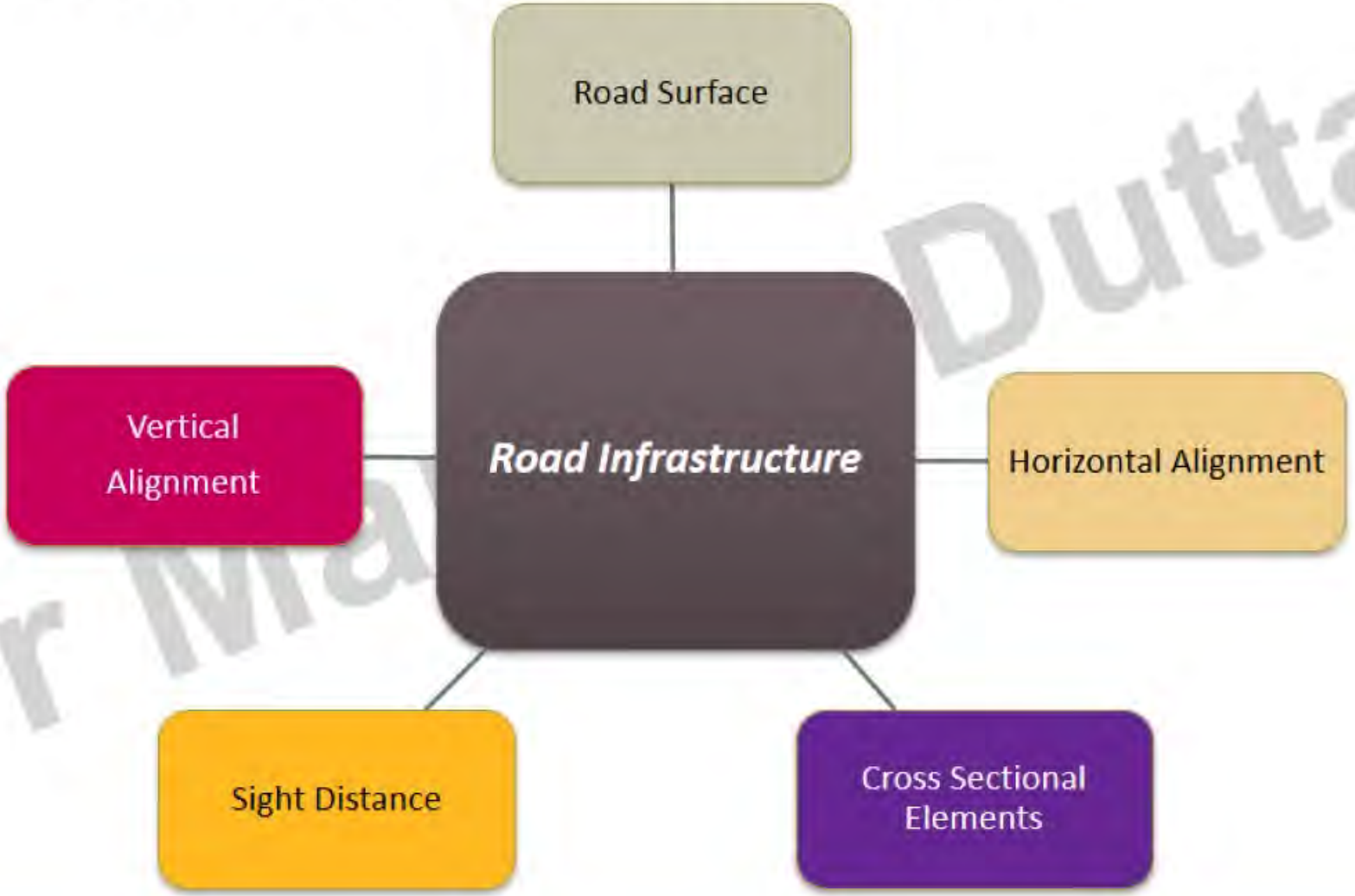
# Introduction

- To begin with understanding the functional and operational aspects of a transportation system it is important to understand how its various elements interact.
- A transportation system is heavily influenced by the characteristics of five critical elements, and the interaction between them:
  - ❑ *Road Infrastructure (streets, highways, crosswalks, sidewalks, etc)*
  - ❑ *Road Users (drivers, pedestrians, bicyclists, and passengers)*
  - ❑ *Vehicles (dimensions, turning radius, axle configuration, axle weight)*
  - ❑ *Traffic Regulation and Control (lane marking, signs and signals, bus timings)*
  - ❑ *Terminals (bus stops, metro stations, parking lots, etc)*

# Road Infrastructure

# Road Infrastructure

Various road infrastructure characteristics that affect the flow of traffic are:



# Road Infrastructure

Sight Distance

- Stopping Sight Distance
- Overtaking Sight Distance

Horizontal Alignment

- Geometric Characteristics of Horizontal Curves
- Spiral Transition Curves
- Compound Horizontal Curves
- Reverse Horizontal Curves

Vertical Alignment

- Grades
- Geometric Characteristics of Vertical Curves

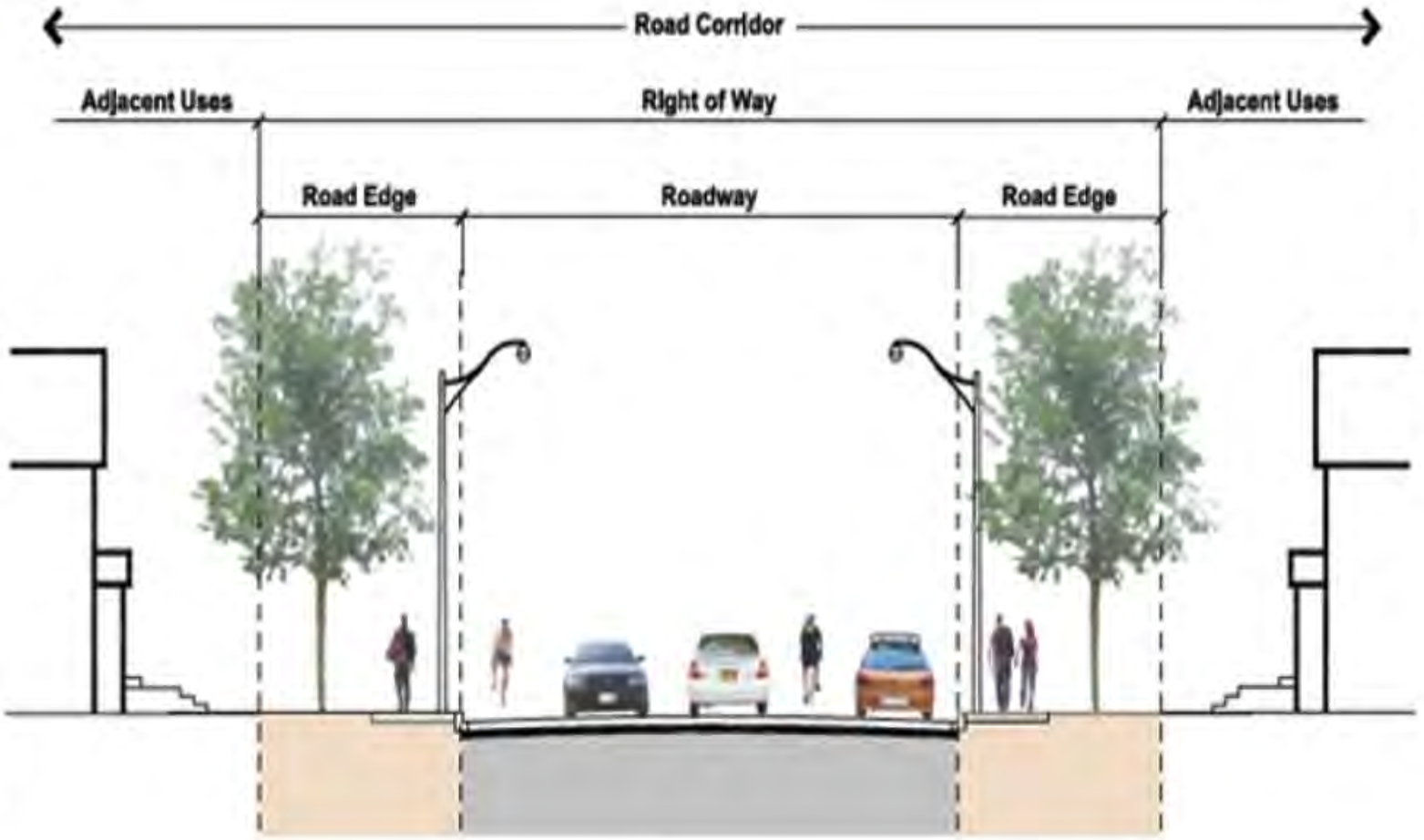
Cross-Section Elements

- Travel lanes
- Shoulders
- Side slopes
- Curbs
- Medians and median barriers
- Guardrails
- Drainage channels

Pavement Surface Characteristics

- Friction
- Unevenness
- Light Reflection
- Drainage

# Road Infrastructure




Cross Sectional Elements

# Road Infrastructure

## Road Surface

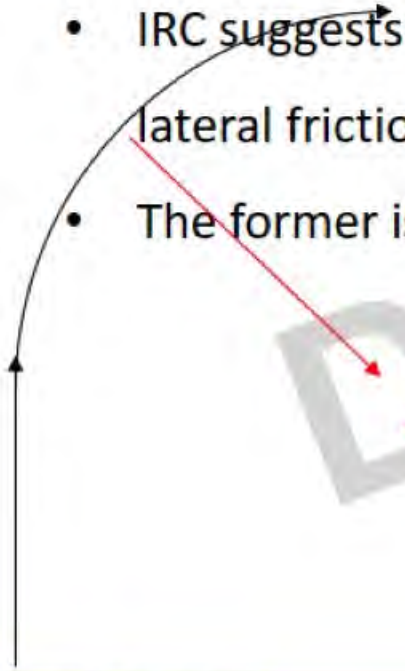
- For safe and comfortable driving four aspects of the pavement surface are important:
  1. The friction between the wheels and the pavement surface
  2. Smoothness of the road surface
  3. The light reflection characteristics of the top of pavement surface
  4. Drainage to water

## Road Surface

Friction:

- The frictional force that develops between the wheel and the pavement is the load acting multiplied by a factor called the coefficient of friction and denoted as ***f***
- The choice of the value of f is a very complicated issue since it depends on many variables
- IRC suggests the coefficient of longitudinal friction as 0.35-0.40 depending on the speed and coefficient of lateral friction as 0.15
- The former is useful in sight distance calculation and the latter in horizontal cu

$$F_r \text{ or } F = f_r \times N$$




# Road Infrastructure

## Road Surface

Friction:

- Friction between the wheel and the pavement surface is a crucial factor in the design of horizontal curves and thus the safe operating speed
- Further, it also affect the acceleration and deceleration ability of vehicles
- Lack of adequate friction can cause skidding or slipping of vehicles
- Skidding happens when the path traveled along the road surface is more than the circumferential movement of the wheels due to friction
- Slip occurs when the wheel revolves more than the corresponding longitudinal movement along the road

## Road Surface

Friction between the wheel and the pavement surface is a crucial factor in the design of horizontal curves and thus the safe operating speed. Further, it also affect the acceleration and deceleration ability of vehicles. Lack of adequate friction can cause ***skidding*** or ***slipping*** of vehicles.

- Skidding happens when the *path traveled along the road surface is more than the circumferential movement* of the wheels due to friction
- Slip occurs when the *wheel revol* *ding longitudinal r*


Skidding

## Road Surface

Various factors that affect friction are:

- ❑ **Type of the pavement (like bituminous, concrete, or gravel),**
- ❑ **Condition of the pavement (dry or wet),**
- ❑ **Condition of the tyre (new or old),**
- ❑ **Speed, load and tyre pressure of the vehicle.**
- ❑ **Extent of brake application and brake efficiency**
- ❑ **Temperature of tyre and pavement**

The **frictional force** that develops between the wheel and the pavement is the **load acting** multiplied by a factor called the **co-efficient of friction** and denoted as ***f***. IRC suggests the **co-efficient of longitudinal friction as 0.35-0.4** depending on the speed and **co-efficient of lateral friction as 0.15.** The former is useful in sight distance calculation and the latter in horizontal curve design.

# Road Infrastructure

## Road Surface

Skid Resistance Value

- Skid Resistance Value, SRV This is the value obtained from the actual road surface, measured using the Portable Skid Resistance Tester.
- The resistance to skidding of a road surface, i.e. SRV, is dependent on the PSV (polished stone value) of the aggregate in the wearing course material and the texture (roughness) of the surface of the wearing course material.
- **Skid Number Comments**
  - <30 Take measures to correct
  - ≥30 Acceptable for low volume roads
  - 31 - 34 Monitor pavement frequently
  - ≥35 Acceptable for heavily traveled roads
- **Polished Stone Value, PSV**
- This is a value of an individual aggregate, found by subjecting the aggregate to a standard polishing process and then testing the aggregate with the Portable Skid Resistance Tester.

# Road Infrastructure

## Road Surface


British Pendulum Tester

ASTM E303-22: Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester

# Road Infrastructure

## Road Surface

**METHODS OF MEASUREMENT SKID RESISTANCE**

- Stopping of test vehicle
- Braking of trailers towel by vehicle
- Braking of vehicle with test wheel
- Measuring side way force that develops when placed at an inclination side slips
- Portable laboratory test

- Stopping of test vehicle
  - f= v2 /2gd
  - v in m/sec
  - d distance travelled after braking
  - f friction factor

# Road Infrastructure

## Road Surface

- Measuring side way force that develops when placed at an inclination sid
  - **a test wheel that is set at 20°**
  - **2750 lit capacity**
  - **200 kg dead weight load**

- SFC= sideways force/vertical reaction between tyres and road

# Road Infrastructure

## Road Surface

# Road Infrastructure

**Problems**

- A test car of mass 1250 kg is travelling AT a speed of 72 kmph when it is suddenly bracked by locking the wheel.the vehicle comes to stop in a distance of 50 M. Calculate the friction factor. (ANS=0.41)
- A trailer wheel ,loaded to 300 kg is locked by braking. The horizontal force at a tyre road interface then developed 1200 N. Calculate skid number.(ANS =41)

# Road Infrastructure

## Road Surface

Unevenness

- It is always desirable to have an even surface, but it is seldom possible to have such
- Even if a road is constructed with high quality pavers, it is possible to develop unevenness due to pavement failures
- Unevenness affect the vehicle operating cost, speed, riding comfort, safety, fuel consumption and wear and tear of tyres

# Road Infrastructure

## Road Surface

Unevenness

- Unevenness index is a measure of unevenness which is the cumulative measure of vertical undulations of the pavement surface recorded per unit horizontal length of the road
- An unevenness index value less than 1500 mm/km is considered as good, a value less than 2500 mm/km is satisfactory up to speed of 100 kmph and values greater than 3200 mm/km is considered as uncomfortable even for 55 kmph
- It is measured by using **Bump Integrator** equipment

# Road Infrastructure

## Road Surface

- ✓ It is always desirable to have an even surface, but it is seldom possible to have such a one.
- ✓ Unevenness affect the vehicle operating cost, speed, riding comfort, safety, fuel consumption and wear and tear of tyres.
- ✓ enness which is the cumulative measure of vertical undulations of horiz

| Unevenness Value | Remark |
|---|---|
| < 1500 mm/km | good |
| < 2500 mm/km | satisfactory up to speed of 100 kmph |
| > 3200 mm/km | uncomfortable even for 55 kmph |

Bump Integrator

# Road Infrastructure

**Road Surface**

# Road Infrastructure

## Road Surface

Light Reflection

- White roads have good visibility at night, but caused glare during day time.
- Black roads has no glare during day, but has poor visibility at night.
- Concrete roads has better visibility and less glare.

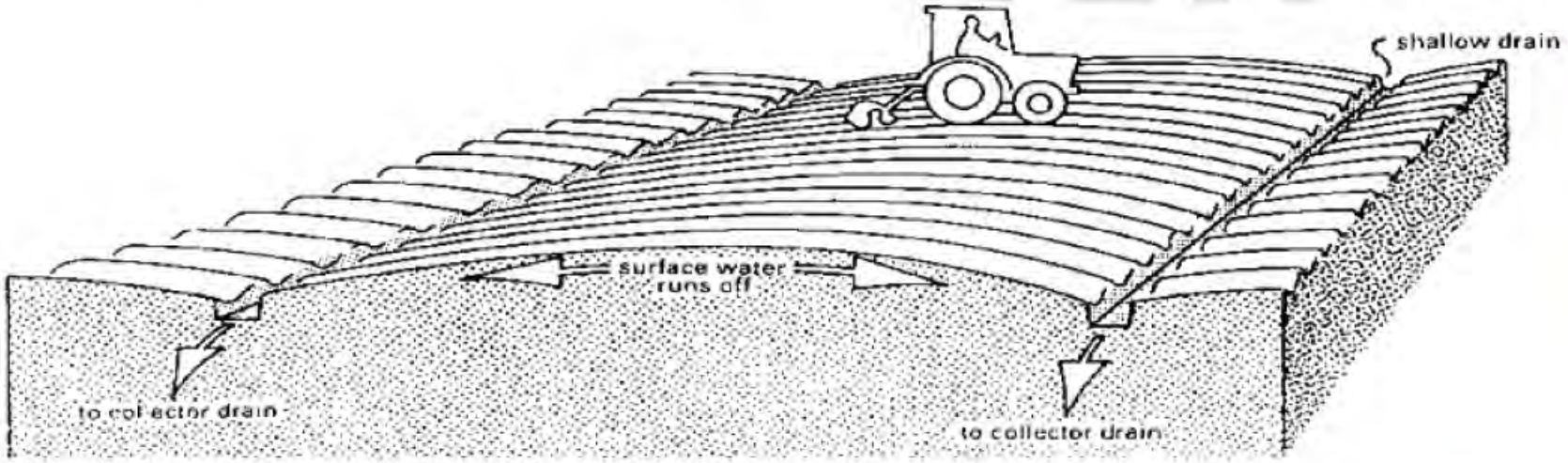
* It is necessary that the road surface should be visible at night and reflection of light is the factor that answers it.

# Road Infrastructure

## Road Surface

Drainage

The pavement surface should be absolutely impermeable to prevent seepage of water into the pavement layers. Further, both the geometry and texture of pavement surface should help in draining out the water from the surface in less time.




# Road Users

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  - *Terminals (bus stops, metro stations, parking lots, etc)*

# Road Users

- The psychology of human being is complex and have a wide range of characteristics, that influence the driving task.
- In a system where the driver is in complete control of vehicle operations, good traffic engineering requires a keen understanding of driver characteristics.
- Hence it is important for a traffic engineer to find ways to provide drivers with information in a clear and effective manner that induces safe and proper responses.
- The drivers characteristics of utmost importance may broadly be classified under four heads, that affects the reaction process.
  - ✓ *Physical*
  - ✓ *Mental*
  - ✓ *Psychological*
  - ✓ *Environmental*

# Road Users

## Physical Characteristics

- The permanent physical characteristics of the driver are *vision*, *hearing*, *strength* and the *general reaction to the traffic situations*.
- Understanding how information is received and processed is a key element in th controls.

***Vision:***

- The driver's visual landscape is both complex and rapidly changing.
- Approaching objects appear to expand in size, while other vehicles and stationary objects are in relative motion both to the driver and to each other.
- The typical driver essentially samples the available visual information and selects appropriate cues to make driving decisions.

# Road Users

## Physical Characteristics

### *Vision:*

Below listed factors reflect static and the dynamic nature of the driving task and the fact that most objects to be viewed by drivers are in relative motion with respect to the driver's eyes.

- *Acuity of vision*
- *Field of vision*
- *Colour Perception/Contrast Sensitivity*
- *Glare recovery and Depth Judgement*
- *Phoria*

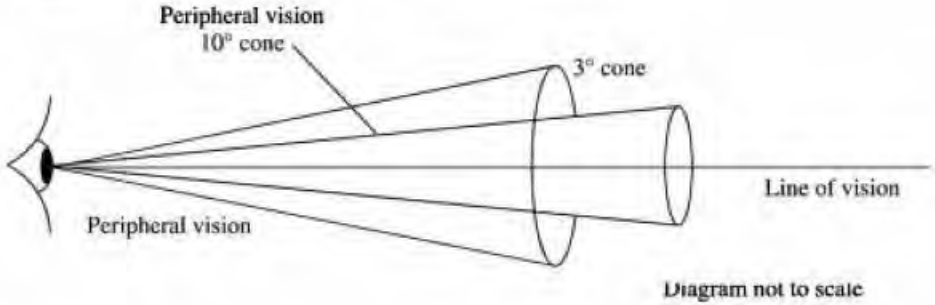
These visual characteristics influence the crash involvement rates of drivers. In India, there are no efficient standards and testing methods to assess the visual capabilities of drivers during their licensing process.

# Road Users

## Physical Characteristics

### *Visual Acuity*

- Visual Acuity refers to how well a person can see.
- A person with normal vision (6/6 vision) can read a letter of height 8.5mm from a distance of approximately 6m.
- With increase in distance, the letter size has to be increasec




### *Field of Vision*

- Field of accurate, clear vision is about a 3 degrees cone.
- However the vision is fairly satisfactory up to 10 degrees in general and 20 degrees in horizontal plane.
- In vertical plane the vision may be limited to 2/3 of that in horizontal plane.

# Road User Characteristics

## Physical Characteristics-Field of Vision

Road Side Signs


Overhead Signs

# Road Users

***Hearing:***

Hearing is an important element in the driving task (i.e., horns, emergency vehicle sirens, brakes squealing, etc.)

***Strength:***

Physical strength is an important factor in general, lack of strength may make parking manoeuvres difficult, particularly for heavy vehicles.

But the evolution of power-steering and power-braking systems has eliminated this as a major issue, with the possible exception of professional drivers of trucks, buses, and other heavy vehicles.

# Road Users

## Mental Characteristics

- It includes knowledge, skill, intelligence, experience and literacy.
- Knowledge of vehicle characteristics, traffic behavior, driving practice, rules of roads and psychology of road users will be quite useful for safe traffic operations.
- Reactions to certain traffic situations become more spontaneous with experience.
- Understanding the traffic regulation and special instruction and timely action depends on understanding and literacy.

# Road Users

## Psychological Characteristics

- One of the complex human factor that influences driving is psychology of the driver, that is not easily quantified to consider in design.
- It deals with enforcement and licensing procedures to restrict drivers who periodically display inappropriate tendencies, by violation experience.
- Attentiveness, anger, fear, anxiety, phobias, superstition, impatience and general attitude towards traffic rules and regulations effect the traffic performance to great extent.
- Distractions due to non-traffic events and worries reduce drivers' attentiveness to traffic situations.
- Impatience and disregard towards traffic rules and regulations can lead to dangerous driving.

# Road Users

## Environmental Characteristics

- The various environmental conditions affecting the behavior of road user are traffic stream characteristics, facilities to the traffic, atmospheric conditions and locality.
- The traffic stream may consist of mixed traffic or heavy traffic whereas facilities to overtake to the faster vehicles may be limited.
- The behavior of the driver varies from one traffic stream to another.
- Similarly the facilities of the traffic separators, multi-lanes etc. will effect the performance.
- Surrounding environment effect the performance of the traffic; one will get slower at market places and will be faster at the open places.

# Road Users

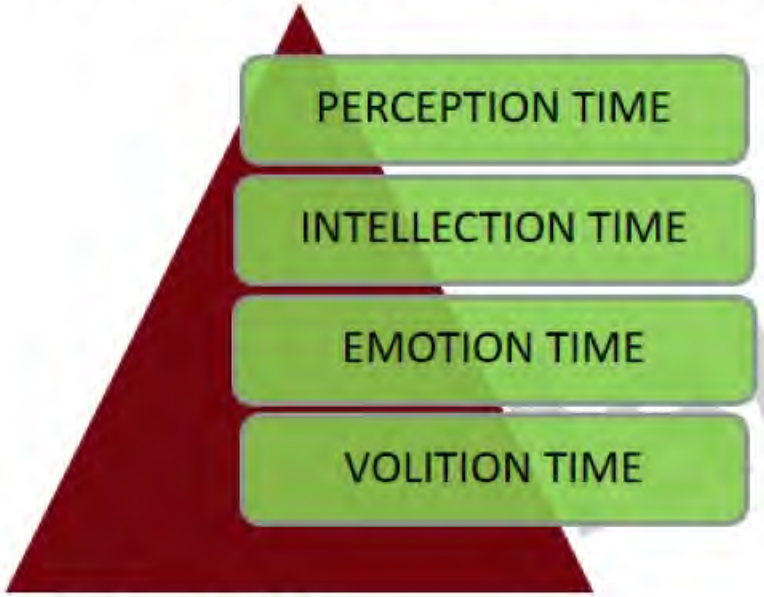
## Perception-Reaction Process

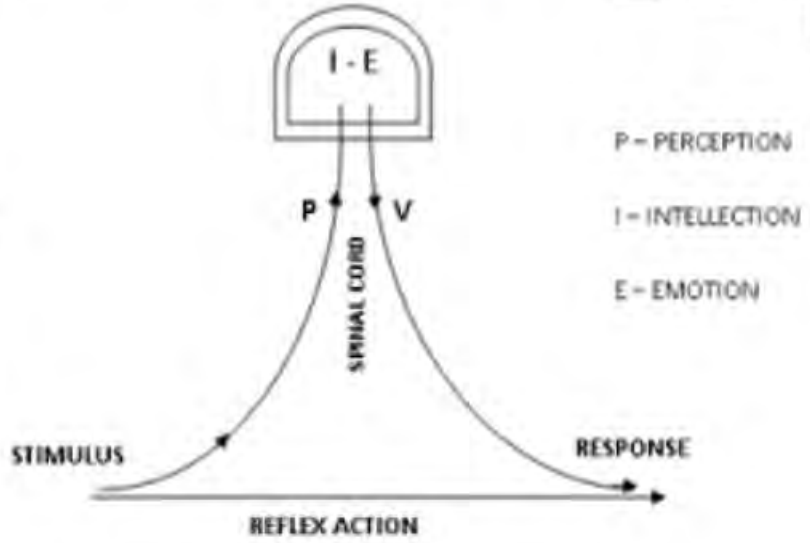
- The perception-reaction process is an outcome of the overall driver characteristics which are discussed in the previous slides.
- The most critical driver characteristic is perception-reaction time (PRT). During PRT, four distinct processes that the driver performs:
  - *Detection: In this phase, an object or condition of concern enters the driver's field of vision, and the driver becomes consciously aware that something requiring a response is present.*
  - *Identification: In this phase, the driver acquires sufficient information concerning the object or condition to allow the consideration of an appropriate response.*
  - *Decision: Once identification of the object or condition is sufficiently completed, the driver must analyse the information and make a decision about how to respond.*
  - *Response: After a decision has been reached, the response is now physically implemented by the driver.*
- The total amount of time that this process takes is called the perception-reaction time (PRT).

# Road Users

## PIEV Theory

- In some of the literature, the four phases are referred to as perception, identification, emotion, and volition, leading to the term "PIEV time", that is equivalent to PIEV time.




- AASHTO mandates the use of 2.5 seconds for most computations involving braking reactions.

# Road Users

**PIEV Theory**

***Perception time:*** It is the time required for the sensations received by the eyes or ears to be transmitted to the brain through the nervous system.

***Intellection time:*** It is the time required for understanding the situation.

***Emotion time:*** It is time elapsed during emotional sensations & disturbance such as fear, anger, etc. with reference to the situation.

***Volition time :***

Volition time is the time taken for the final action.

Total reaction time of driver may be vary from 0.5 sec to 4 sec

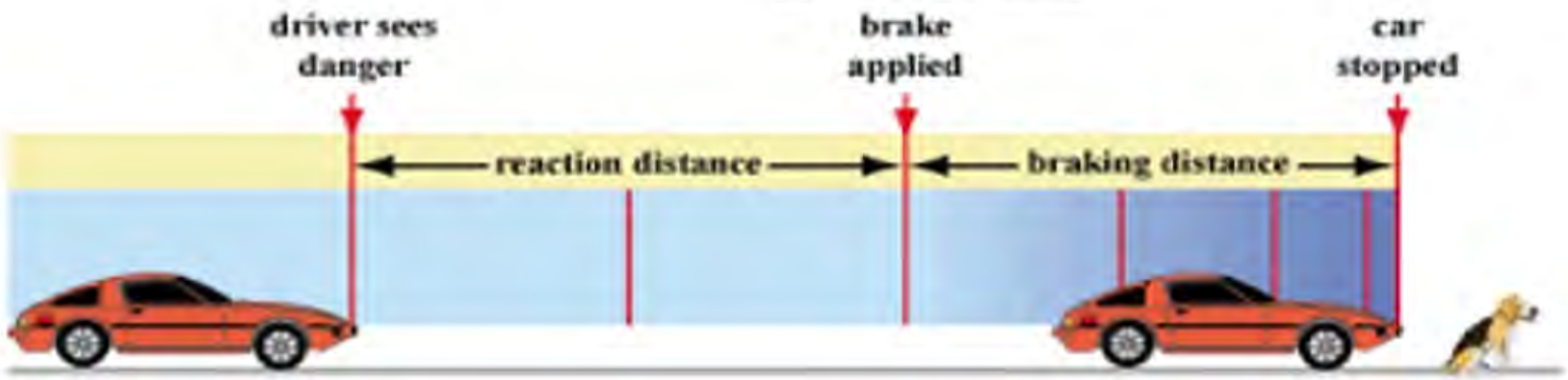
**Reaction time:** of the driver is the time taken from the instant the object is visible to the driver to the instant the brakes are effectively applied.

# Road Users

## Lag Distance

- Definition: The distance travelled by the vehicle during the total reaction time is known as lag distance.
- Lag distance = v * t
- Where, v = speed of vehicle in m/s, t = total reaction time (s) [as per IRC t = 2.5s]





# Road Users

**Problem**

A driver takes 3.2 s to react to a complex situation while traveling at a speed of 55 mi/h. How far does the vehicle travel before the driver initiates a physical response to the situation (i.e., putting his or her foot on the brake)?

# Vehicles

# Introduction

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  - ***Vehicles***
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  - *Terminals (bus stops, metro stations, parking lots, etc)*

# Vehicles

- It is quite important to study the various vehicular characteristics which affect the design and traffic performance, because it is possible to design, a road for a few specific types of vehicle but not for numerous types of vehicle.
- It will not be economically feasible to keep on increasing the geometric standards and thickness of pavement from time to time to meet the needs of vehicles whose weight and dimensions are increased.
- Vehicular characteristics are examined to decide geometric features and traffic control for safe and efficient movements of vehicle.
- Critical vehicle properties affect the design of roadways and traffic control are broadly classified into:
  - Static characteristics
  - Dynamic characteristics

# Vehicles

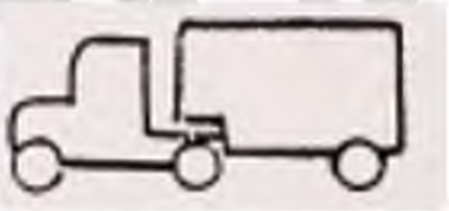
**Classification**

- *Static characteristics*
  - ✓ *Dimensions*
  - ✓ *Weight*
  - ✓ *Axle configuration*
- *Dynamic characteristics*
  - ✓ *Speed*
  - ✓ *Acceleration and deceleration (braking)*
  - ✓ *Turning: low-speed and high-speed*
  - ✓ *Power to weight ratio*
  - ✓ *Vehicular emission*

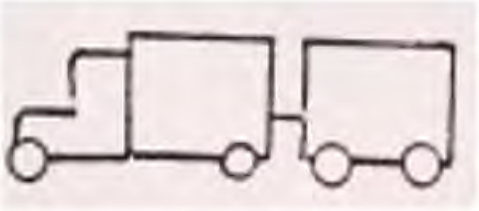
# Vehicles

**Some Definitions**

- Truck-Tractor/Tractor: A motor vehicle designed for drawing other vehicles, but not for a load other than part of the weight of the vehicle drawn.
- Semi-Trailer: A vehicle designed for carrying persons or property and drawn by a truck-tractor on which part of its weight and load rests.
- Truck: A motor vehicle used primarily for the transportation of goods.
- Trailer: A vehicle designed for carrying persons or goods and drawn by a motor vehicle which carries no part of the weight and load of the trailer on its own wheels.



Semi-Trailer



Trailer

# Vehicles

(1) Types of Axles:

- Axle usually denotes a common axis of rotation regardless of the number of wheels
- Axle load is the load transmitted by all wheels whose centres are in one transverse vertical plane i.e. on a single axle
- It may also include load transmitted by all wheels whose centres are included between two parallel transverse vertical planes, a specific distance apart (usually 1m)
- In both cases, the axle is termed as single axle
- If two or more axles are consecutively arranged, such that their centres are more than 1m apart but not more than 2.5 m and are individually attached to or articulated from a common attachment to the vehicles having a mechanism to equalize the load among the axles, the arrangement is known as tandem axle

# Vehicles

## Axle Configurations

Single Axle With Single Wheel
gal Axl[illegible]

Tandem Axle
gal Axle Load = 18t)

Single Axle With Dual Wheel
egal Axle Load = 10t)

Tridem Axle
gal Axle Load = 24t)

# Vehicles

(2) Vehicle Types:

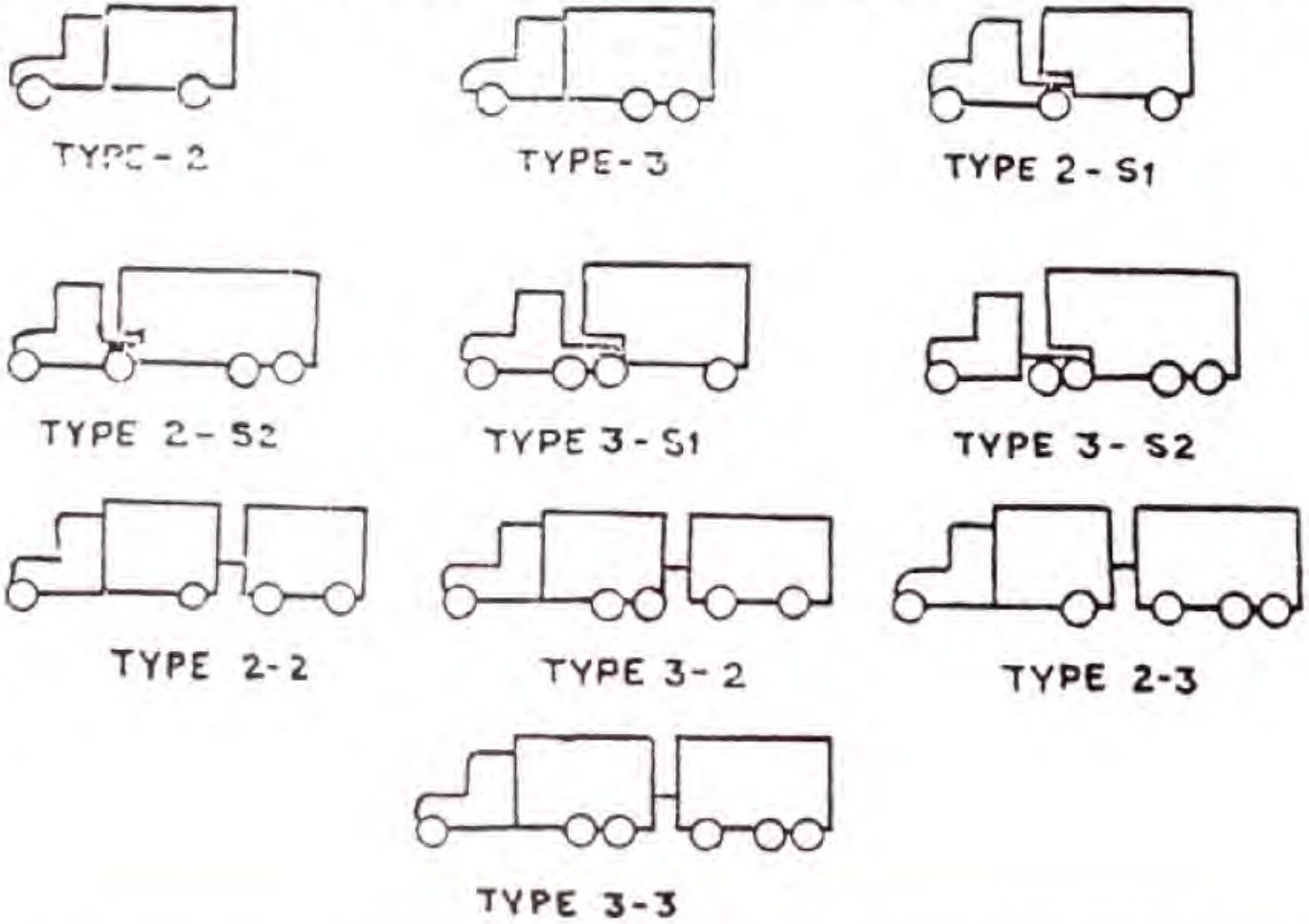
Commercial vehicles are usually categorized into the following three types as following:

1. Single unit truck, designated as Type 2 for 2-axled vehicles and Type 3 for 3-axled vehicles etc.
2. Semi-trailer, designated as Type 2-S wherein the first digit denotes the number of axles of the truck-tractor, the letter S denotes a semi-trailer and the number following S indicates the number of axles on the semi-trailer. It may be noted that in this type, part of the load of the trailer rests on the truck-tractor
3. Tractor-trailer or truck-trailer designated as Type 3-2 which is a combination of 3 axles for the tractor and 2 axles for the trailer. A trailer load is on its own wheels and no part of weight of its rests on the tractor drawing it

# Vehicles

## Vehicle Types (IRC 3-1983)

Based on axle configuration, and type of traction vehicle, vehicles are classified in IRC 3 (1983) as follows:



# Vehicles

## Vehicle Types – AASHTO 151

In general, motor vehicles are classified by AASHTO 151 into five main categories:

- *Passenger Cars*- all passenger cars, SUVs, minivans, vans, and pickup trucks.
- *Buses*- intercity motor coaches, transit buses, school buses, and articulated buses
- *Trucks*- single-unit trucks, tractor-trailer, and tractor-semi-trailer combination vehicles
- *Recreational Vehicles*- motor homes, cars with various types of trailers (boat, campers, motorcycles, etc.)
- *Motorcycles and bicycles* also use highway and street facilities but are not isolated as a separate category, as their characteristics do not usually limit or define design or control needs.

# Vehicles

## Vehicle Types – Indo-HCM

- Indo-HCM has classified vehicles into following categories for Indian road conditions:

| Motorized Vehicles | Non-motorized |
|---|---|
| • Motorized Two Wheelers<br>• Autorickshaws<br>• Standard Cars<br>• Large Cars<br>• Light Commercial Vehicles<br>• Buses<br>• Trucks (2 to 3 axles or multi-axle)<br>• Tractors or Tractor-Trailers | • Bicycles<br>• Cycle Rickshaws<br>• Animal Drawn Vehicles<br>• Handcarts |

# Vehicles

(3) Dimensions of Vehicles:

In 1954 the IRC first published the standards on Dimensions and Weights of Road Design Vehicles

| Maximum Dimensions of Road Vehicles | | |
|---|---|---|
| Dimension of Vehicle | Details | Maximum Dimension in m |
| Width | All vehicles | 2.5m |
| Height | a. Single Decked | 3.8m |
| | b. Double Decked | 4.75m |
| Length | a. Single unit truck with two r more axles (Type 2,3) | 11m |
| | b. Single unit bus with two or more axles (Type 2,3) | 12m |
| | c. Semi trailer tractor combinations (Type 2-S1, 2-S2, 3-S1, 3-S2) | 16m |
| | d. Tractor and trailer combinations (Type 2-2, 3-2, 2-3, 3-3) | 18m |

# Vehicles

## Dimensional Specifications (IRC-3-1983)

- Width: No vehicle shall have a width exceeding 2.5 m.
- Height: No vehicle other than a double-decker bus shall have a height exceeding 3.8 m for normal application and 4.2 m when carrying ISO series 1 freight containers. Double decker buses may, however, have a height not exceeding 4.75 m.
- Length: The maximum overall length of a single unit truck, exclusive of front and rear bumpers, having two or more axles, shall be 11 m.
- The maximum overall length of a single unit bus, exclusive of front and rear bumpers, having two or more axles shall be 12 m.
- The maximum overall length of a truck-tractor semi-trailer combination, exclusive of front and rear bumpers, shall be 16 m.
- The maximum overall length of a truck-trailer combination, exclusive of front and rear bumpers, shall be 18 m.
- No combination of vehicles shall comprise more than two vehicles.

# Vehicles

(4) Axle Loads:

- The national policy concerning the limits of Registered Laden Weights (RLW) as adopted in 1954 is as follows:
  - ✓ Maximum Single Axle Load – 10.2t
  - ✓ Maximum Tandem Axle Load – 19t
  - ✓ Distance between tandem axles is to be more than 1.016m
- Maximum Gross Vehicle Weight (GVW) of a single unit or combination vehicle not to exceed the value given by the following formula

$$W = 465\,(24 + 3.38\,L) - 14.6\,L^2$$

Where, W = GVW in kg, L = Distance between extreme axles in m



*******refer to **Revision of Safe Axle Weights for Transport Vehicles on codes and manuals folder**

# Vehicles

(4) Axle Loads:

- These limits on axle loads are based on considerations of pavement life and those on GVW or safety of bridge structures
- In 1959 the central government had granted an adhoc increase in the RLW of transport vehicles to the extent of 25% for post-1953 models and 12% for pre-1953 models
- Some states allow overloads up to 50% of the certified weights
- A survey by MOST reveals that 30 to 40 % of the transport vehicles were found to have axle loads heavier than 8.16t and 10 to 20% axles heavier than 10t
- Such increase in axle loads increase the distress by 1.5 to 2.3 times, thereby reducing the pavement life

# Vehicles

(4) Axle Loads:

- Though pavement design is still being done in India for an axle load of 8.17t, the Central Government, which has taken own powers to prescribe maximum Registered Laden Weight and maximum safe axle weight has noticed the limits as follow:
  - ✓ Single axle with two tyres – 10.2t
  - ✓ Single axle with four tyres – 10.2t
  - ✓ Tandem axle with eight tyres - 19t
- With above limits, it is now possible to have a combination of articulated and fully trailerised vehicles up to a gross vehicle weight of 52.2t

# Vehicles

***Dynamic Characteristics***

- ✓ *Speed*
- ✓ *Acceleration and deceleration (braking)*
- ✓ *Turning: low-speed and high-speed*
- ✓ *Power to weight ratio*
- ✓ *Vehicular emission*

# Vehicles

## Dynamics Characteristics

- Characteristics of vehicles affecting road design are speed, acceleration and braking characteristics and some aspects of vehicle design. The speed and acceleration depends upon the power of the engine and the resistant to be overcome and are important in all geometric design elements.
- ***Speed and Acceleration:*** The deceleration and braking characteristics guide safe vehicle operation. The stability of vehicle and its safe movement of horizontal curves are affected by the width of wheel base. The riding comfort on vertical curves depends on the design of suspension system of vehicles.
- ***Power of vehicle:*** The power of the heaviest vehicles and their loaded weights govern the permissible and limiting values of gradient on roads. From the total hauling capacity and power required to overcome the total tractive resistance it is possible to determine the speed and acceleration of the vehicle which in turn useful in traffic regulation, planning and design.

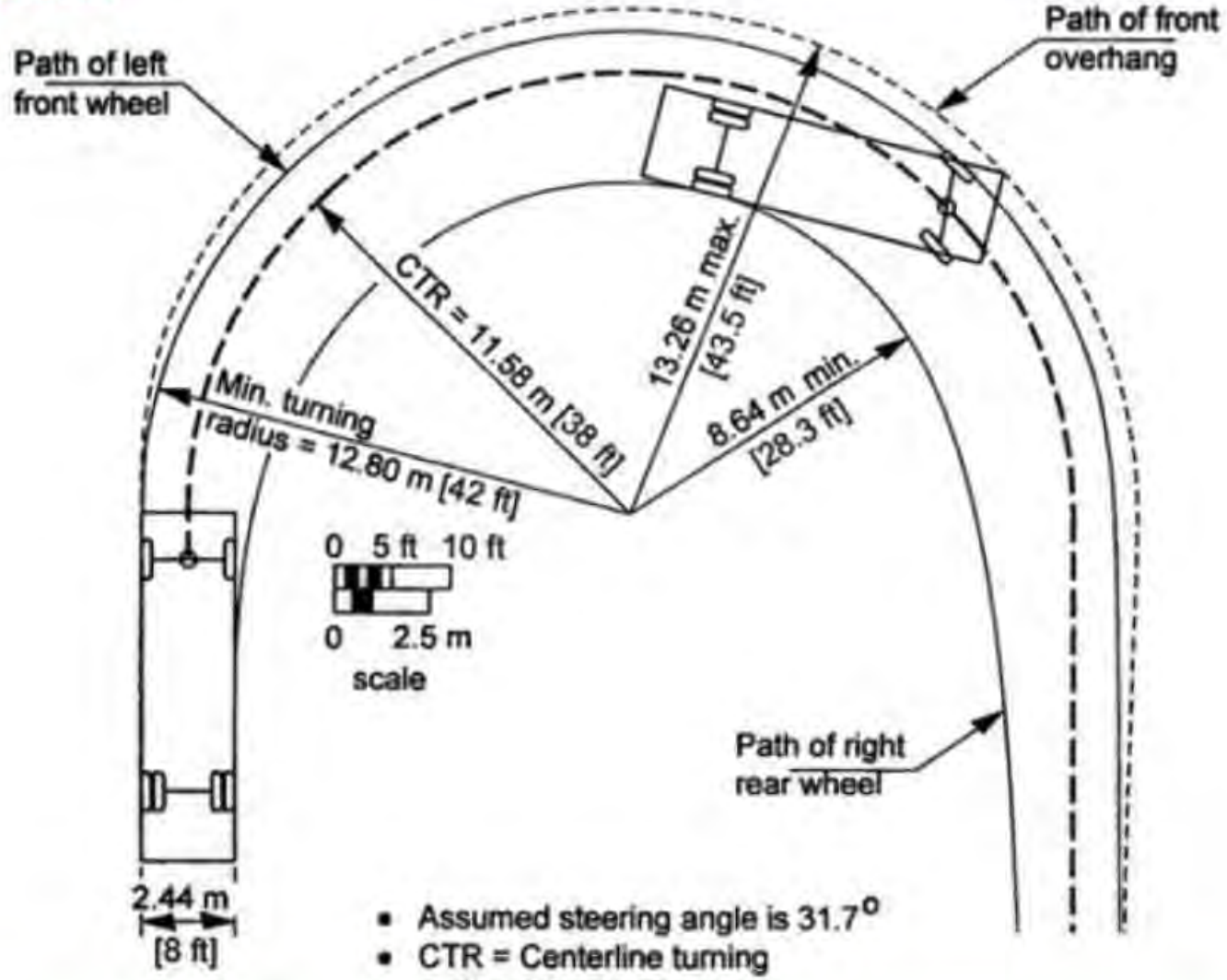
# Vehicular Characteristics

## Dynamics Characteristics

- The deceleration and braking characteristics of vehicles depend on design and type of braking system and its efficiency.
- The safety of vehicle operation, stopping distance, and the spacing between two consecutive vehicle in a traffic stream is affected by the braking capacity.
- Thus the road capacity and geometric design requirements also get indirectly affected.
- Braking tests are conducted to measure the skid resistance of pavement surface.

# Vehicles

## Minimum Turning Radius



# Vehicles

## Braking Test

- At least two of the following three measurements are needed during braking tests in order to determine the skid resistance of pavement.
  - Braking distance, *L* m
  - Initial speed, *u* m/s
  - Actual duration of brake application, *t* s
- After application of brakes, the work done against frictional force for stopping the vehicle will be equal to the kinetic energy of the vehicle.

$$\frac{1}{2}mu^2 = fWL$$

$$\frac{Wu^2}{2g} = fWL$$

$$\boxed{L = \frac{u^2}{2gf}}$$

Where f= coefficient of friction and g = acceleration due to gravity

# Vehicles

## Braking Test

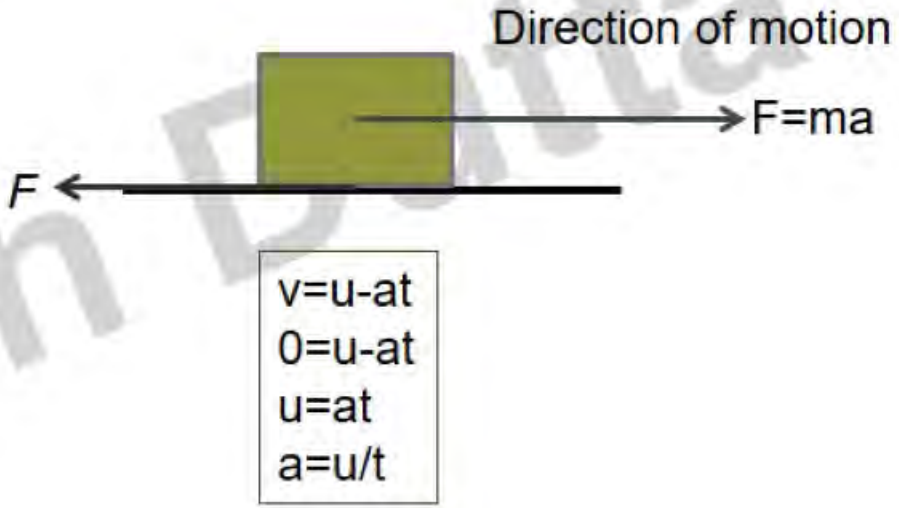
If initial speed and actual duration of application of brakes is known,

$$mg.f = ma$$

$$f = \frac{a}{g}$$

$$a = \frac{u}{t}$$

$$\boxed{f = \frac{u}{tg}}$$




where, a= deceleration of vehicle during skidding

# Vehicles

## Braking Test

If braking length and initial speed are measured,

$$0 = u^2 - 2aL$$

$$a = \frac{u^2}{2L}$$

$a = fg$

so, $fg = u^2/2L$

$f = u^2/2gL$

$v^2 = u^2 - 2aL$
$0 = u^2 - 2aL$
$a = u^2/2L$

## Braking Efficiency

- If sometimes the maximum skid resistance is already known, then braking efficiency can be found:

$$\eta = \text{breaking efficiency} = \frac{f \text{ obtained from breaking test}}{f_{max} \text{ known}}$$

- If braking efficiency is 50%, the wheels will skid through 50% of the braking distance, and rotate through the remaining distance.

# Vehicles

## Example

Determine the average skid resistance of the pavement surface. During a braking test, a vehicle travelling at a speed of 35 kmph was stopped by applying brakes fully and

(a) Skidmarks were 5.8m in length

(b) Vehicle stopped within 2 sec after application of break.

(c) Vehicles stopped within 1.5 sec and skid marks observed was 7.0 m long.

# Vehicles

## Design Vehicles

- Design vehicles are primarily employed in the design of turning roadways and intersection curbs, and are used to help determine appropriate lane widths, and lane-widening on curves.
- In general, the design should consider the largest vehicle and could easily accommodate 95% or more of the expected vehicle mix.
- Hence, the physical dimensions of design vehicles are also important considerations.

# Traffic Regulation and Control

# Introduction

- To begin with understanding the functional and operational aspects of a transportation system it is important to understand how its various elements interact.
- A transportation system is heavily influenced by the characteristics of five critical elements, and the interaction between them:
  - ❑ *Road Infrastructure (streets, highways, crosswalks, sidewalks, etc)*
  - ❑ *Road Users (drivers, pedestrians, bicyclists, and passengers)*
  - ❑ *Vehicles*
  - ❑ ***Traffic Regulation and Control (lane marking, signs and signals, bus timings)***
  - ❑ *Terminals (bus stops, metro stations, parking lots, etc)*

# Traffic Regulation and Control

Traffic regulation and control mechanism includes:

***Road Infrastructure***

- Speed Breakers
- Road Markings
- Road Studs
- Channelization
- Traffic Signs – Highways, Segments
- Manual Traffic Control
- Traffic Signals

***Policy***

- Bus Scheduling
- Regulating Office and School Timings
- Odd-Even Scheme
- BRT or Metro Rail Scheme

# Terminals

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  - ❑ ***Terminals (bus stops, metro stations, parking lots, etc)***

# Terminals

- Terminal facilities include:
  - Home Garages
  - On-street and Off-street parking area
  - Bus Stops, Bus Terminals, Intermediate Public Transport (IPT) Stands
  - Railway and Metro stations, etc
- To a traffic engineer, design of terminal facilities is important because it has considerable impact on traffic flow, performance of public transportation services, etc.

# Summary

- This chapter has summarized some of the key elements of driver, and vehicle characteristics that influence highway design and traffic control.
- Together with the characteristics of the roadway itself, these elements combine to create traffic streams.
- As will be seen, the characteristics of traffic streams are the result of interactions among and between these elements.
- The characteristics of human road users and their vehicles have a fundamental impact on traffic streams.