Advanced Traffic Engineering

TE-504A

Lecture-3

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DTEM

Course Outline

Human Vehicular and Traffic Characteristics; Composition and measurement of traffic volume; Measurement of speeds, Speed zoning and restrictions; Travel time and delay studies; Types of parking facilities and Design of car parks; Accident patterns and characteristics, Collision and condition diagrams; Types and functions of traffic control devices, traffic sign, marking; Traffic signal: design of signal timing; Determination of highway capacity and Levels of service.

Transportation Engineering

- **Transportation Engineering is defined as a discipline applying technology and scientific principles to the planning, functional design, operation, and management of facilities for all modes of transportation**
- **Transportation mode includes: land, rail, water, air and pipe**

Traffic Engineering

- Traffic engineering is a branch of civil engineering that uses engineering techniques to achieve the safe and efficient movement of people and goods on roadways
- It focuses mainly on research and construction of the infrastructure necessary for safe and efficient traffic flow, such as road geometry, sidewalks and crosswalks, segregated cycle facilities, shared lane marking, traffic signs, road surface markings and traffic lights.

Traffic Engineering

It is the phase of transportation engineering that deals with the planning, geometric design and traffic operations of roads, streets and highways, their networks, terminals, abutting lands, and relationships with other modes of transportation

Scope of Traffic Engineering

- **Surface transportation**
- **Relationships and connection with other modes of transportation**

Major modes of Surface Transportation

- **Automobile,**
- **Bus,**
- **Truck and**
- **Bike**

Goal of Traffic Engineering

- **To provide means 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**
- **Movement --- Mobility**

Basic Components in Traffic Engineering

1. **Road users including**
   Drivers,
   Cyclists and
   Pedestrians
2. **Vehicles**
3. **Roads and highways**
4. **Control devices**

Basic Components in Traffic Engineering

Five critical components interact in a traffic system:

1. Road users-drivers, pedestrians, bicyclists, and passengers

2. Vehicles-private and commercial

3. Roads and highways

4. Traffic control devices

5. The general environment

Traffic Control

Traffic controls could be easily designed if all drivers reacted to them in exactly the same way.

Safety could be more easily achieved if all vehicles had uniform dimensions, weights, and operating characteristics.

Drivers and other road users have widely varying characteristics.

Simple subjects like reaction time, vision characteristics, and speed become complex because no two road users are the same.

Road User Characteristic

- **Visual**
- **Fields of Vision**
  - ❖ **Acute or clear vision cone**
  - ❖ **Fairly clear vision cone**
  - ❖ **Peripheral vision**
- **Perception-reaction time (PRT)**
  - ❖ **Detection**
  - ❖ **Identification**
  - ❖ **Decision.**
  - ❖ **Response**

- **Reaction Time**
- **Reaction Distance**
- **Expectancy**
  - ❖ **Continuity.**
  - ❖ **Event.**
  - ❖ **Temporal.**
- **Age**
- **Complexity of reaction**
- **Presence of alcohol and/or drugs in the driver's system**

Road User Characteristics

Visual

The test is a standard chart-reading exercise that measures static visual acuity -that is, the ability to see small stationary details clearly.

Road User Characteristics

Fields of Vision

Acute or clear vision cone-3 to 10 around the line of sight; legend can be read only within this narrow field of vision.

Fairly clear vision cone-10 to 12 around the line of sight; colour and shape can be identified in this field.

Peripheral vision -This field may extend up to 90 to the right and left of the centreline of the pupil, and up to 60 above and 70 below the line of sight. Stationary objects are generally not seen in the peripheral vision field, but the movement of objects through this field is detected.

Fields of Vision

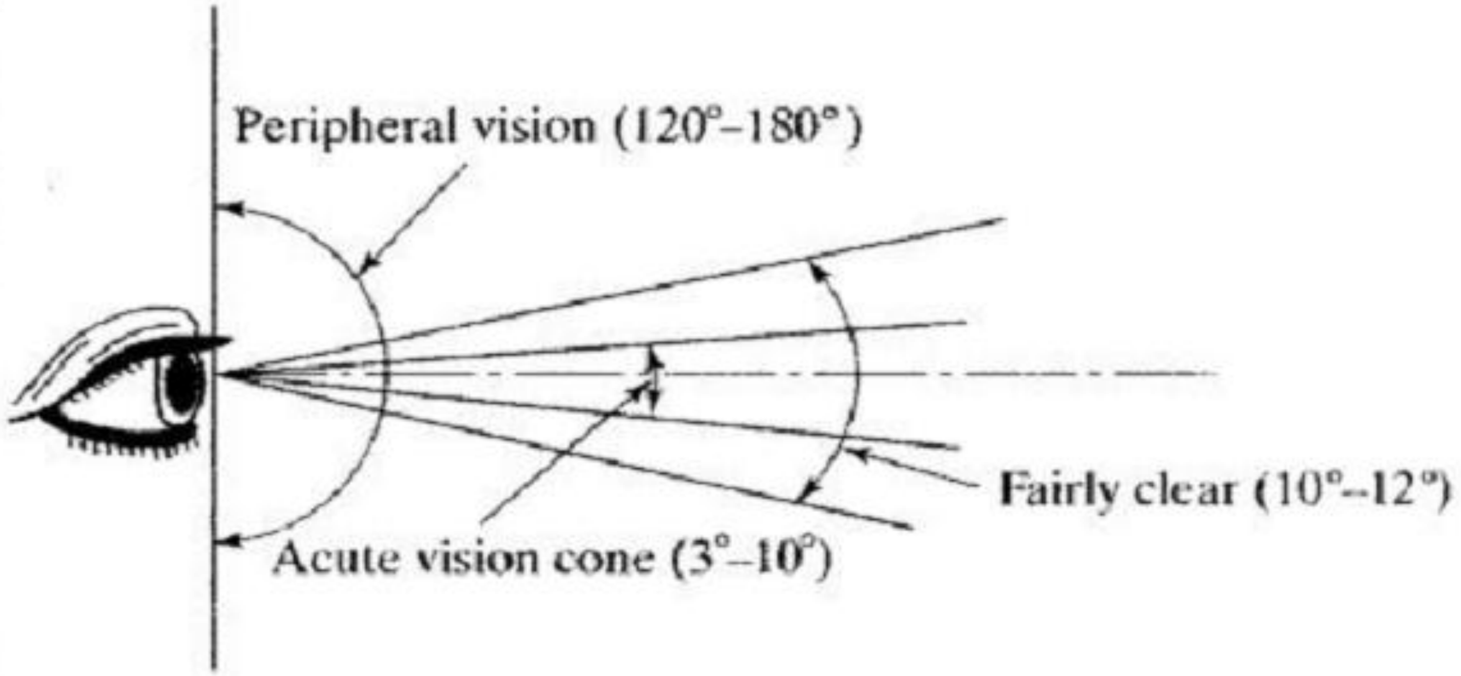


Figure : Illustration of Fields of Vision

Visual Factors in Driving Task

Visual Factor	Definition	Sample Related Driving Task(s)
Accommodation	Change in the shape of the lens to bring images into focus.	Changing focus from dashboard displays to roadway.
Static Visual Acuity	Ability to see small details clearly.	Reading distant traffic signs.
Adaptation	Change in sensitivity to different levels of light.	Adjust to changes in light upon entering a tunnel.
Angular Movement	Seeing objects moving across the field of view.	Judging the speed of cars crossing drivers' paths.
Movement in Depth	Detecting changes in visual image size.	Judging speed of an approaching vehicle.
Color	Discrimination between different colors.	Identifying the color of signals.
Contrast Sensitivity	Seeing objects that are similar in brightness to their background.	Detecting dark-clothed pedestrians at night.
Depth Perception	Judgment of the distance of objects.	Passing on two-lane roads with oncoming traffic.
Dynamic Visual Acuity	Ability to see objects that are in motion relative to the eye.	Reading traffic signs while moving.
Eye Movement	Changing the direction of gaze.	Scanning the road environment for hazards.
Glare Sensitivity	Ability to resist and recover from the effects of glare.	Reduction in visual performance due to headlight glare.
Peripheral Vision	Detection of objects at the side of the visual field.	Seeing a bicycle approaching from the left.
Vergence	Angle between the eyes' line of sight.	Change from looking at the dashboard to the road.

Road User Characteristics

Perception-reaction time (PRT)

The perception time includes the detection, identification, and decision elements involved responding to a action, whereas the reaction time is the time it takes to initiate the physical response.

Some references refer it to the Perception Identification Emotion Volition time or PIEV, which is comparable in concept to the PRT.

Perception- Reaction Time

The time of critical driver characteristic is perception-reaction time (PRT). During perception and reaction, the driver must perform four distinct processes :

- **Detection. In this phase, an object or condition of concern enters the driver's field of vision, and the road users 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 analyze 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.**

Reaction Time

For signal timing purposes, the Institute of Transportation Engineers recommends a PRT time of 1.0 second

The American Association of State Highway and Transportation Officials (AASHTO) mandates the use of 2.5 seconds for most computations involving braking reactions

Reaction Distance

Reaction distance is the distance the vehicle travels while the driver goes through the process.

In the example of a simple braking reaction, the PRT begins when the driver first becomes aware of an event or object in his or her field of vision and ends when his or her foot is applied to the brake.

During this time, the vehicle continues along its original course at its initial speed. Only after the foot is applied to the brake pedal the vehicle begins to slow down in response to the stimulus.

The reaction distance is simply the PRT multiplied by the initial speed of the vehicle.

Expectancy

- **Continuity. Experiences of the immediate past are generally expected to continue. Drivers do not, for example, expect the vehicle they are following to suddenly slow down.**
- **Event. Things that have not happened previously will not happen. If no vehicles have been observed entering the roadway from a small driveway over a reasonable period of time, the driver will assume that none will enter now.**
- **Temporal. When events are cyclic, such as a traffic signal, the longer a given state is observed, drivers will assume that it is more likely a change will occur.**

Other Factors Affecting PRT

- **Age,**
- **Fatigue,**
- **Complexity of reaction, and**
- **Presence of alcohol and/or drugs in the driver's system**

Vehicle Characteristics

- **Size**
- **Weight**
- **Axle configuration**
- **Power to weight ratio**
- **Turning ratio**
- **Turning path**
- **Pollution created**
- **Design vehicle**

Size ,Weight, Axle Configuration

A vehicle has three dimension: length , width, height

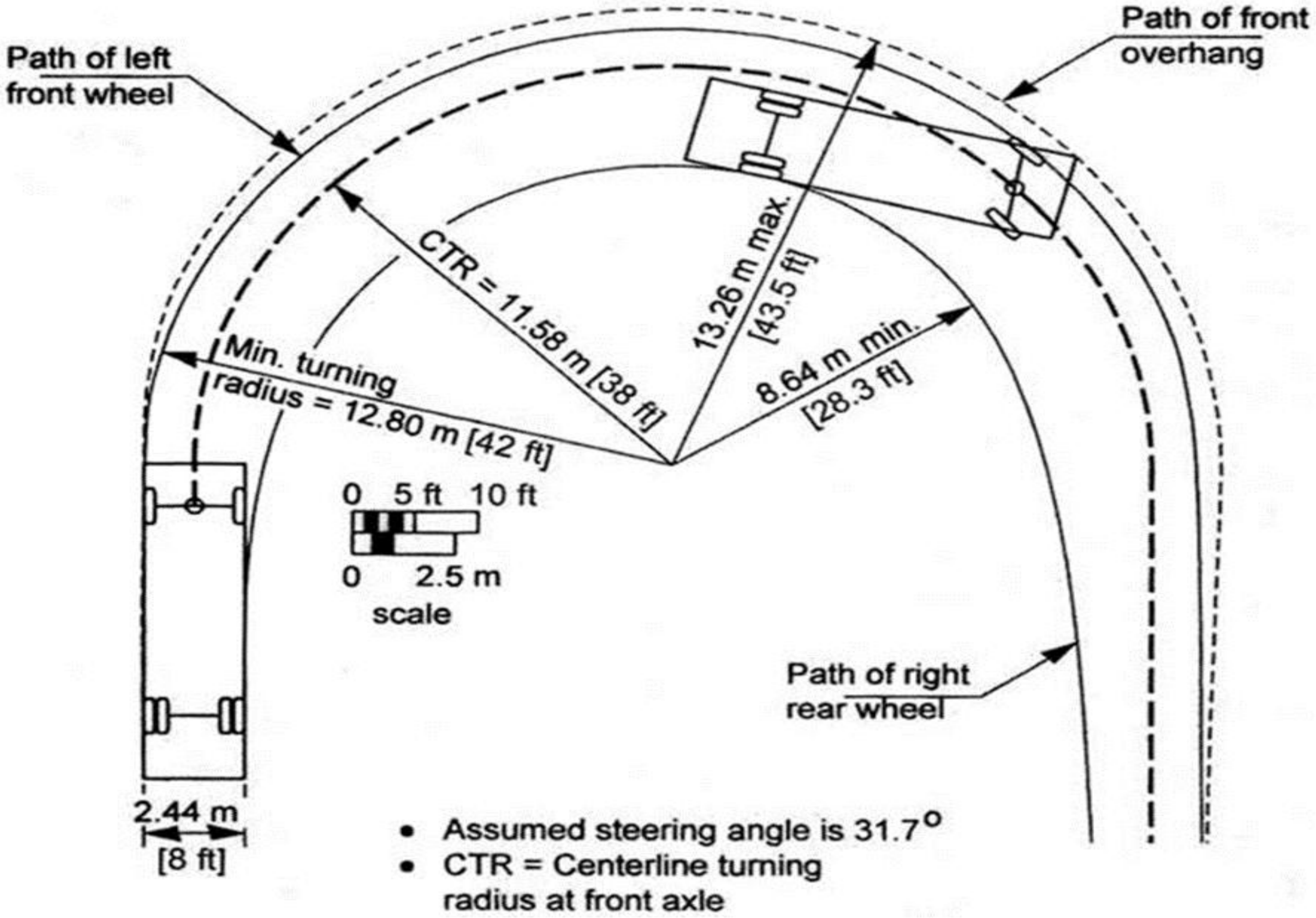
The height of vehicles are more important considered in placing of signals and designing over passes and under passes.

Weight of the vehicle plays an important role in design of both flexible and rigid pavement. The weight of vehicle is transferred through axle, it is important to design a pavement.

Power to Weight ratio of vehicle

- **Human powered vehicles – cycles, rickshaw have low powered to weight ratio and their acceleration characteristic, speed on slopes are low.**
- **Motorized vehicle - have high power to weight ratio**
- **Heavy vehicles- have poor power to weight ratio**
- **Power to Weight ratio is important factors as it relates to operating efficiency of vehicles**

Turning radius and turning path



Minimum Turning Radius

Minimum turning radius is the radius of the circle that will be traced by the front wheel if the vehicle moved with its steering maximum extend.

Big vehicle have bigger turning radius and small vehicle have smaller radius.

Turning path

Since when vehicle turns, the rear wheel are fixed and the vehicle body extends beyond the tyres, the effective width of vehicle on a turn is increased

The width of the road on curves is increased in order to accommodate the increase effective width of vehicle

Vehicle Pollution

- **Release hydrocarbons.**
- **Hydrocarbons react with nitrogen oxide in the presence of sunlight to produce ozone**
- **It releases major components of nitrogen which is the main cause of acid rain**
- **Carbon monoxide reduces the flow of blood streams**
- **Green house gases also emitted-carbon dioxide**
- **Noise pollution-age of vehicle, tyre type etc.**

Design Vehicle

Types of Vehicles:

- **Motorized two wheeler**
- **Motorized three wheeler**
- **Passenger cars**
- **Buses**
- **Trucks**
- **Slow non motorized vehicle like cycles**

Engineer needs to choose a type of vehicle-based on the characteristic of vehicle, the road must be designed

AASHTO- The American Association of State Highway and Transportation Officials (AASHTO) gives the guidelines for design of roads

Vehicle characteristic

- **Design vehicle**

  Selection of design vehicle can have a good effect on use of roadway facilities such as turning radius, turning pocket length, U-turn from left-turn-bay, and design of parking.

- **Acceleration performance of vehicle**

  Determination of length of acceleration lane when merging, dual objectives of greater power and improved fuel efficiency

Power performance of vehicle

Resistance to motion of a vehicle

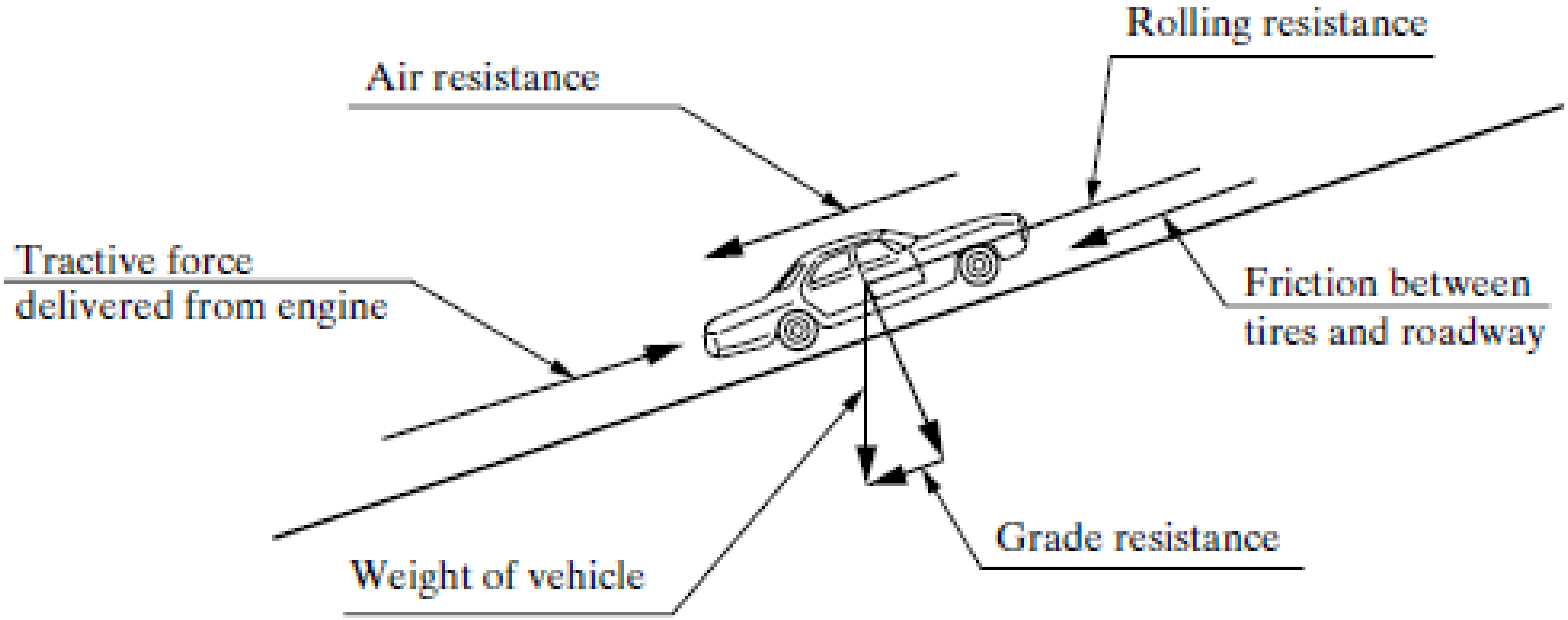
The power developed by the engine should be sufficient to over come all resistance to motion at desired speed and to accelerate an any desired rate to the desired speed

- Rolling resistance
- Air resistance
- Grade resistance
- Inertia force during acceleration and de acceleration
- Transmission losses

Tractive resistance

$$P_p = P_f + P_a + P_i + P_j$$

Forces acting on a moving vehicle



Rolling Resistance

When the vehicle wheels rolls over the road surface ,the irregularities and roughness of the surface causes deformation of the tyres, and some times the road surface may go deformation

Rolling resistance Pf = m x f x g

- m = mass of the vehicle in kg
- f = coefficient of rolling resistance
- Pf = rolling resistance in N
- G = acceleration due to gravity in m /sec^2

Values of Rolling

Types of surfacing	Co efficient of rolling resistance
CEMENT CONCRETE AND ASPHALT SURFACING	0.01 to 0.02
ROAD WITH SMOOTH CHIPPING , GRAVEL SURFACE TREATED WITH BITUMINOUS BINDER	0.02 to 0.0025
ROAD WITH SMOOTH CHIPPING , GRAVEL SURFACE NOT TREATED WITH BITUMINOUS BINDER	0.03 to 0.04
COBBLESTONE PAVEMENT	0.04 to 0.05
EARTH ROADS, SMOOTH AND COMPACT	0.03 to 0.06
PLOUGHED FIELD ,SWAMPY GROUND	0.15 to 0.30

Rolling resistance

Rolling resistance depend on speed also

$$fv = fo\ [\ 1 + 0.01\ (V\text{-}50)]$$

fv = coefficient of rolling resistance at speed V

V = speed in K.P.H

fo = coefficient of rolling resistance

Air Resistance

- Resistance caused against side of vehicles body
- Wheel causes power loss
- It exert reaction pressure against the front of the vehicle

$$\mathbf{Pa = Ca \times A \times} V^2$$

- Pa = air resistance in N
- A= projected front area
- V= velocity of speed in m/sec
- Ca = coefficient of air resistance
- G = acceleration due to gravity 9.81 m/sec^2

Coefficient of Air Resistance

TYPE OF VECHICLE	FRONTAL AREA m^2	MASS in kg	COEFFICIENT
CAR	1.63	1065	0.42
AMBASSADOR CAR	2.15	1365	0.39
JEEP	2.38	1200	0.37
TATA TRUCK	5.37	6120	0.48
ASHOK LEYLAND	5.37	8125	0.48
MARUTI CAR	1.54	880	0.40

Grade Resistance

When a vehicle which has to moving on a level stretch at a particular speed has to move up in incline, addition work has to be done.

Pi= (m x i x g) /100 (+ or -)

Pi = grade resistance

Inertia Forces during Acceleration and Reacceleration

Inertia force

Force = mass x acceleration

$$Pj = m \times a = m \times (dv/dt)$$

m = mass of vehicle in kg

Pj = Inertia force

Transmission Losses

- Losses in power from the engine to gear system. The vehicle has a system of gear to alter the speed.
- At starting of vehicle high power is needed and speed is low.
- For high power engine for climbing a hill the speed is reduced

Power requires of a vehicle

The mechanical power developed by the engine is transmitted to the driving wheels by transmission system.

- **Rear axle torque Ta = k x Tc x Gt x Ga**

- Tc = engine torque
- Gt = transmission gear ratio
- Ga =rear axle gear ratio = 0.80 to 0.90
- K = efficiency of transmission system

Power requires of a vehicle

Pp = (rear axle torque/radius of rolling tyre) Pp = tractive force

Pp = (K x Te x Gt x Ge) / rw Power output = Ppx v

v= speed in m/sec

v = (V x 1000)/3600=V/3.6

Power output= (Pp x V)/3.6

Power output= (Pv x 0.377 x rw x n)/(Gt x Ga)

Engine power in watts= (Pv x 0.377 x rw x n)/(Gt x Ga x k)

Tractive resistance

Tractive resistance

$$\mathbf{Pp = Pf + Pa + Pi + Pj}$$

Pa = Air resistance in N

Pf = Rolling resistance in N

Pi = grade resistance

Pj=inertia force due to acceleration and de acceleration.

Problem

A passenger car weighing 2 tones is requires to accelerate at a rate of 3 /sec ^{2} in the first gear from a speed of 10 K.P.H the gradient is + 1 percentage and the road has a black topped surface. The frontal projection area of the car is 2.0 m^2. The car tyres have a radius of 0.33 m. The real axle gear ratio is 3.82 :1 and the first gear ratio is 2.78 :1. Calculate the engine horsepower needed and the speed of engine. Make suitable assumption

SOLUTION:

Tractive resistance

$$\mathbf{Pp = Pf + Pa + Pi + Pj}$$

$$\mathbf{Pf = m \times f \times g}$$

f= 0.02 assume

$$Pf = 2000 \times 9.81 \times 0.02$$

$$= 392.4\ N$$

$$\mathbf{Pa = Ca \times A \times v^2}$$

Ca = 0.39

A= 2.15 m^2

V=10 KMPH

$$\mathbf{Pa = 0.39 \times 2.15 \times (15/3.6) \times (15/3.6)}$$

$$= 14.5\ N$$

Pi = (m x i x g) /100

= 2000 x 9.81 x (1/100)

= 196.3 N

Pj= m x a

= 2000 x 3

= 6000N

Pp= Pf+ Pa+Pi+Pj

= 392.4 +14.5+196.2+6000

= 6603.1 N

Power output = Pp x v

= Pp x (V/3.6)

= 6603.1 x 10/3.6

= 183441.9 W

= 183441.9/735 = 24.95 hp

Assume transmission efficiency of 0.90

The engine horse power V

= 24.95/0.90 = 27.72 hp

V= 0.377 x rw x n/Gt x Ga

rw= ro x λ

λ= tyre deformation factor = 0.935

= 0.935 x 0.33

= 0.308 m

N = (10 x 2.78 x 3.82)/(0.377 x 0.308)

= 915 R.P.M

Braking system

Braking system is more important for safety

The safe stopping distance is the distance travelled during the perception and reaction time and the distance required to stop the vehicle after the brakes are applied.

The braking distance

$$\mathbf{d = V^2/254f}$$

- V= speed in K.P.H
- f = coefficient of friction between the tyres and the pavement

Braking system

The braking character of the vehicle influence the skidding of the vehicle

Acceleration rate is governed by vehicle transmission system, weight and horse power

Acceleration rate

- **Medium passenger car = 3-8 K.P.H per sec**
- **Trucks and busses = 1-4 K.P.H per sec**

Deceleration rates

The maximum deceleration is related to the coefficient of friction between the tyres and the pavement

Force required to decelerate= F= m x d

F= force required to decelerate in N

M = mass of vehicle in kg

d = deceleration in m /sec ^{2}

$$d = F/m$$

But

f = F/(m x g)

f = coefficient of friction

d = f x g d =9.81

Deceleration rate

	Deceleration in m/s^2	**f**
Comfortable to passenger	2.62	0.27
Undesirable but not alarming to passenger	3.39	0.34
Severe and uncomfortable to passenger	4.26	0.43

Deceleration rate

When the vehicle is travelling at a particular speed is suddenly allowed to move by switch off the engine and putting the gear neutral and deceleration in caused

Pp = Pf +Pa +or -Pi+or -Pj

Pp=0 and i=0 Pj=Pa+Pf

$m(dv/dt)=Cv \times A \times v^2 + (m \times f \times g)$

$(dv/dt)= (Cv \times A \times v^2)/m + (f \times g)$

Problem

A ambassador car travelling at a speed of 60 K.M.H on a WBM road in good condition is suddenly allowed to coast by switching off the engine and putting the gear in neutral. What is the deceleration caused.

Solution:

$$(dv/dt) = (Cv \text{ x } A \text{ x } v2)/m + (f \text{ x} g)$$

Cv =0.39 kg/m^2

A =2.15 m^2

M =1365 kg

For WBM f= 0.025

$$(dv/dt)=(0.39 \text{ x } 2.15)/1365 \text{ x } (60/3.6) \text{ x } (60/3.6) + 0.025 \text{ X } 9.81=0.42 \text{ m sec}^2$$

Skidding

Road accident are very commonly caused in pavement which results due to skidding of vehicle.

When a driver moving at speed applies the vehicle brakes suddenly, stability of vehicle is the friction that develops in the tyre pavement interference.

Skidding

If the friction that can be mobilized is greater than the deceleration force , the vehicle comes to safe halt.

If the pavement is wet the friction developed is much smaller than the deceleration force.

In USA the skid resistance is denoted by skid number which is 100 times the friction factor

$$\mu = \alpha / g$$

α = acceleration or deceleration of the vehicle

g= acceleration of gravity.

Factors affecting skid resistance

- Pavement
- Effect of water on the surface
- Speed
- Tyre characteristics

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 Resistance Value

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

Measurement of skid resistance

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.

The testing procedure and description of the process is set out in, B.S. 812:Part 114.

Methods of Measurement of 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

Methods of Measurement of skid resistance

Stopping of test vehicle

- $f = v^2 / 2gd$
- v in m/sec
- d distance travelled after braking f friction factor

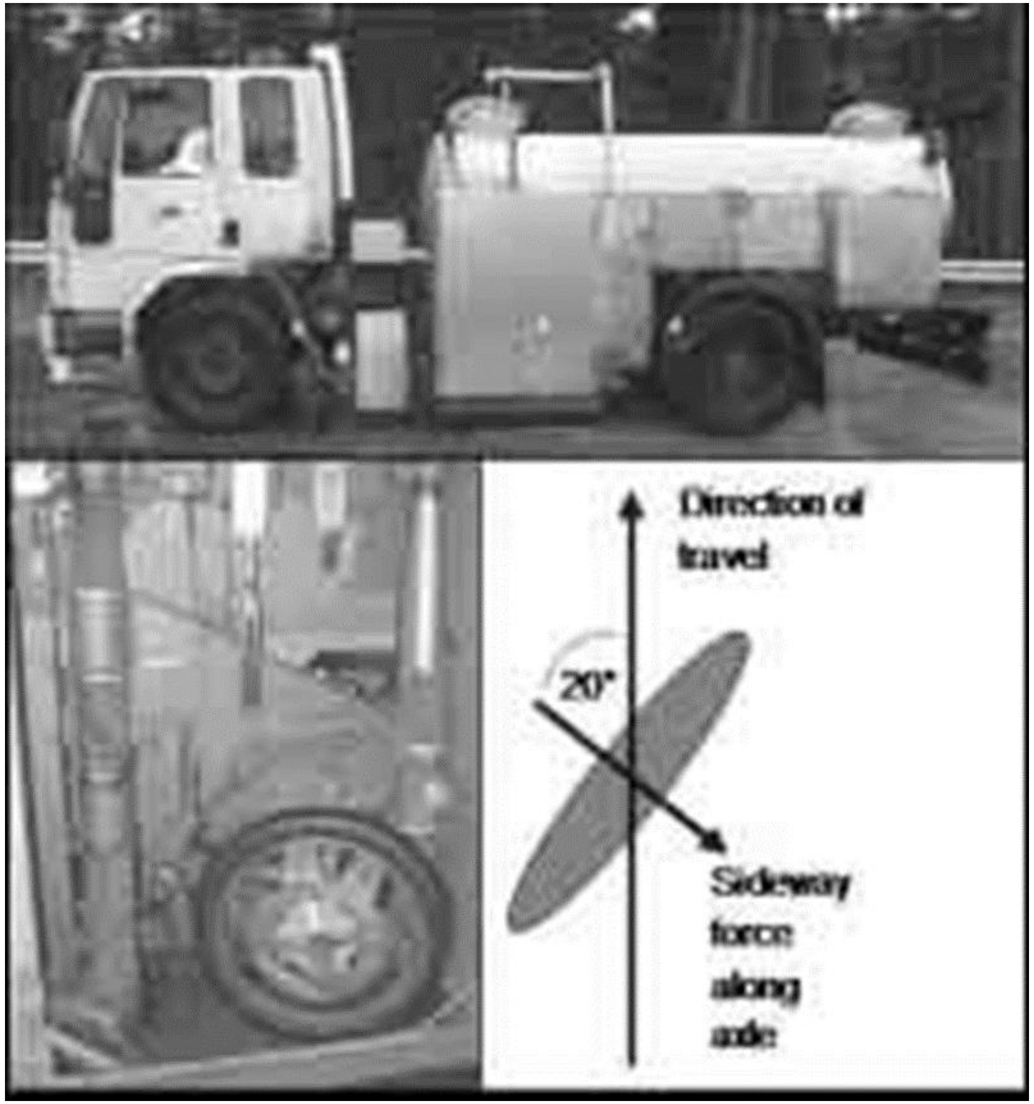
Braking of trailers towel by vehicle

- SN=100 x f =100 x (F/W)
- F=force at tyre pavement interface
- W=load normal to the

Methods of Measurement of skid resistance

- Measuring side way force that develops when placed at an inclination side slips
  - **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


Direction of travel
20°
Sideway force along axle

Problem

- 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)