CE 486
Urban Transportation Planning
Lec. 8
Vehicle Characteristics

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Vehicle Characteristics

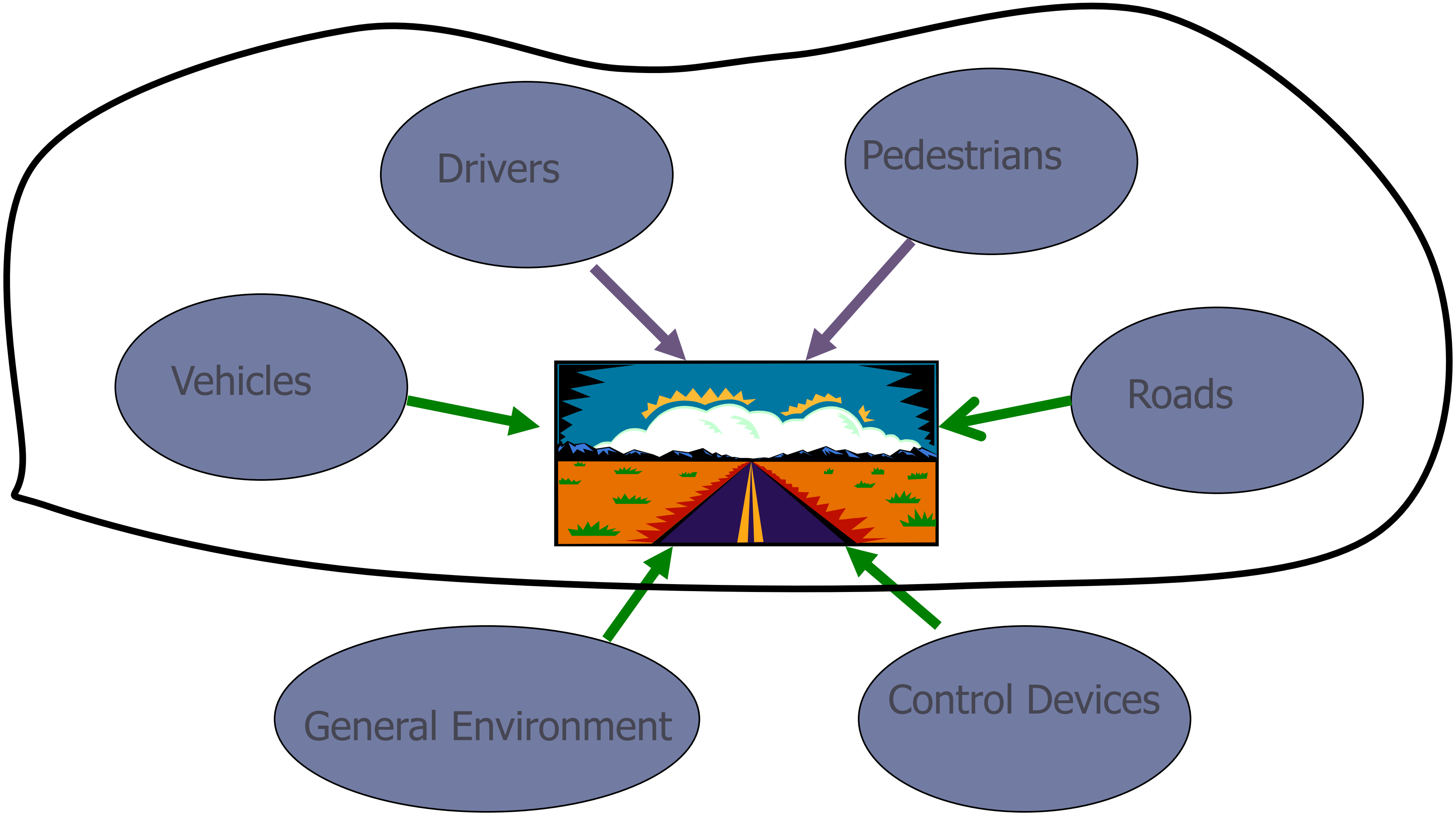
Introduction

Components of network mode of transportation

- The **four** main components of the network mode of transportation are the driver, the pedestrian, the vehicle, and the road.

- The **bicycle** is also becoming an important component in the design of urban highways and streets.

Four components affecting the traffic system



Introduction

Importance of knowledge of characteristics

- To provide **efficient** and **safe** highway transportation,
  a knowledge of the **characteristics** and **limitations** of each of these components is essential.
- It is also important to be aware of the **interrelationships** that exist among these **components** in order to determine the **effects**, if any, that they have on each other.
- Their characteristics are also of primary importance when traffic engineering measures such as **traffic control devices** are to be used in the highway mode.

VEHICLE CHARACTERISTICS

- Criteria for the geometric design of highways are partly based on the static, kinematic, and dynamic characteristics of vehicles.
- Static characteristics include the weight and size of the vehicle, while kinematic characteristics involve the motion of the vehicle without considering the forces that cause the motion.
- Dynamic characteristics involve the forces that cause the motion of the vehicle.

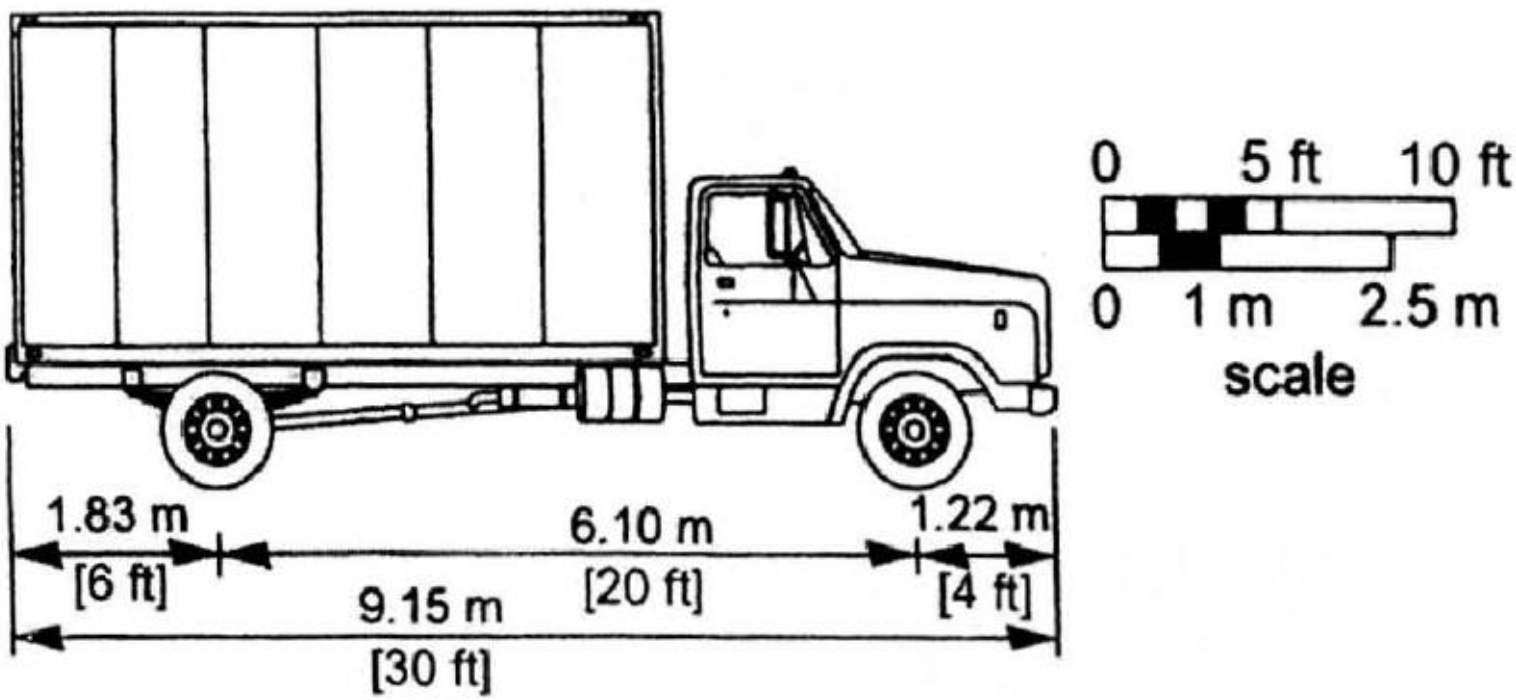
Static Characteristics

- The size of the design vehicle for a highway is an important factor in the determination of design standards for several physical components of the highway.
- These include lane width, shoulder width, length and width of parking bays, and lengths of vertical curves.
- The axle weights of the vehicles expected on the highway are important when pavement depths and maximum grades are being determined.

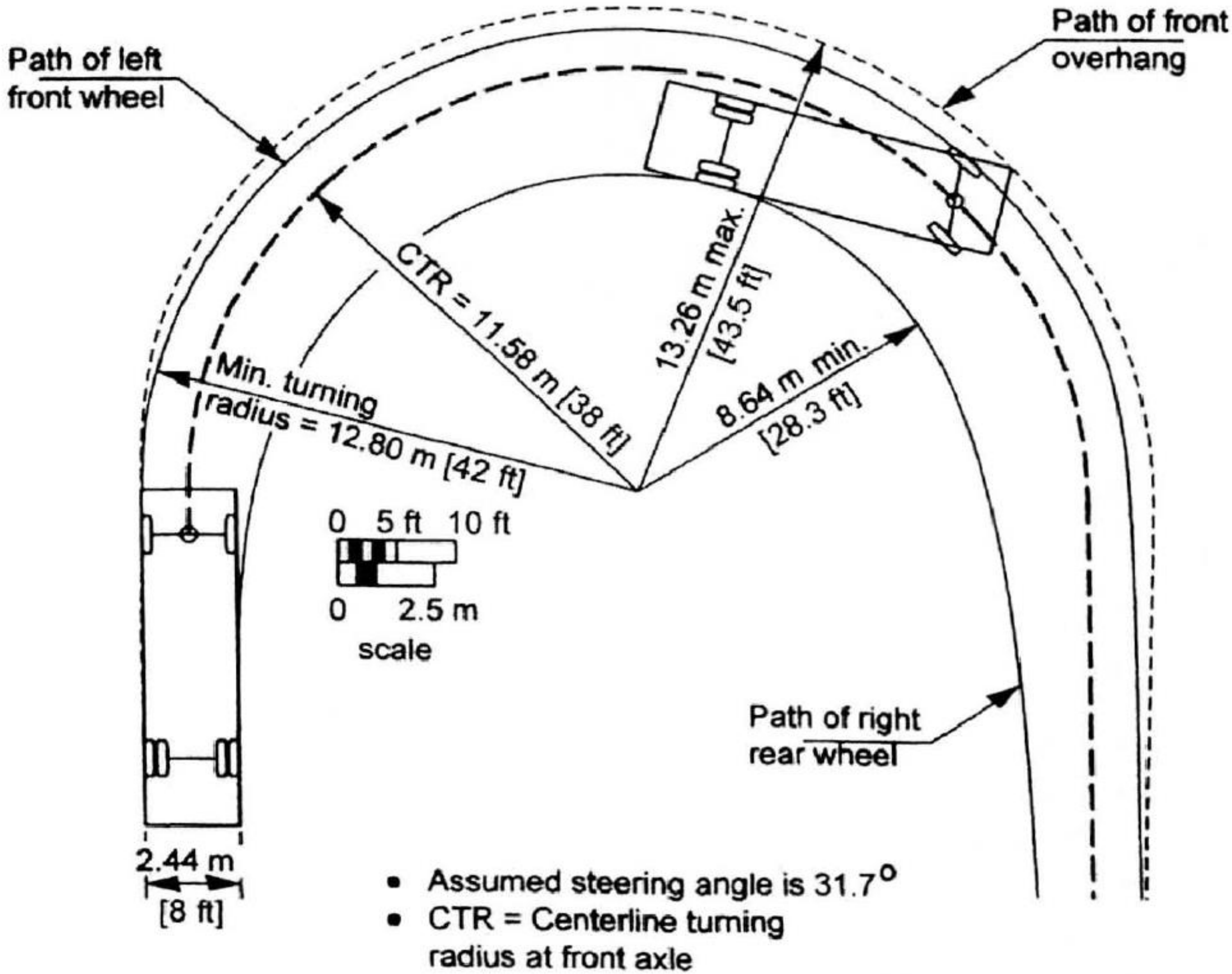
1. Static Characteristics

AASHTO also has suggested the following guidelines for selecting a design vehicle:

- For a parking lot or series of parking lots, a passenger car may be used
- For intersections on residential streets and park roads, a single-unit truck could be considered
- For the design of intersections of state highways and city streets that serve bus traffic but with relatively few Large trucks, a city transit bus may be used



0
5 ft
10 ft
0
1 m
2.5 m
scale
1.83 m
[6 ft]
6.10 m
[20 ft]
1.22 m
[4 ft]
9.15 m
[30 ft]



Minimum Turning Path for Single-Unit (SU) Truck Design Vehicle

2 Kinematic Characteristics

Definition

- kinematic characteristics involve the motion of the vehicle without considering the forces that cause the motion.
- The primary element among kinematic characteristics is the acceleration capability of the vehicle

Acceleration, Velocity, Distance and Time Equations:

Acceleration Assumed Constant:

$$a = dv/dt$$

$$v = \int a\,dt$$

$$v = v_0 + at$$

$$x = \int v\,dt$$

$$x = x_0 + v_0 t + 1/2at^2$$

Another useful formula:

$$v^2 = v_0^2 + 2ax$$

Acceleration, Velocity, Distance and Time Equations:

Acceleration as a Function of Velocity:

α is the maximum acceleration rate

$$\frac{du_t}{dt} = \alpha - \beta u_t$$

β is the change in acceleration with respect to time

u_t is the velocity at any time t

$$u_t = \frac{\alpha}{\beta}(1 - e^{-\beta t}) + u_0 e^{-\beta t}$$

x is the displacement at any time t

$$x = \left(\frac{\alpha}{\beta}\right)t - \frac{\alpha}{\beta^2}(1 - e^{-\beta t}) + \frac{u_0}{\beta}(1 - e^{-\beta t})$$

3 Dynamic Characteristics

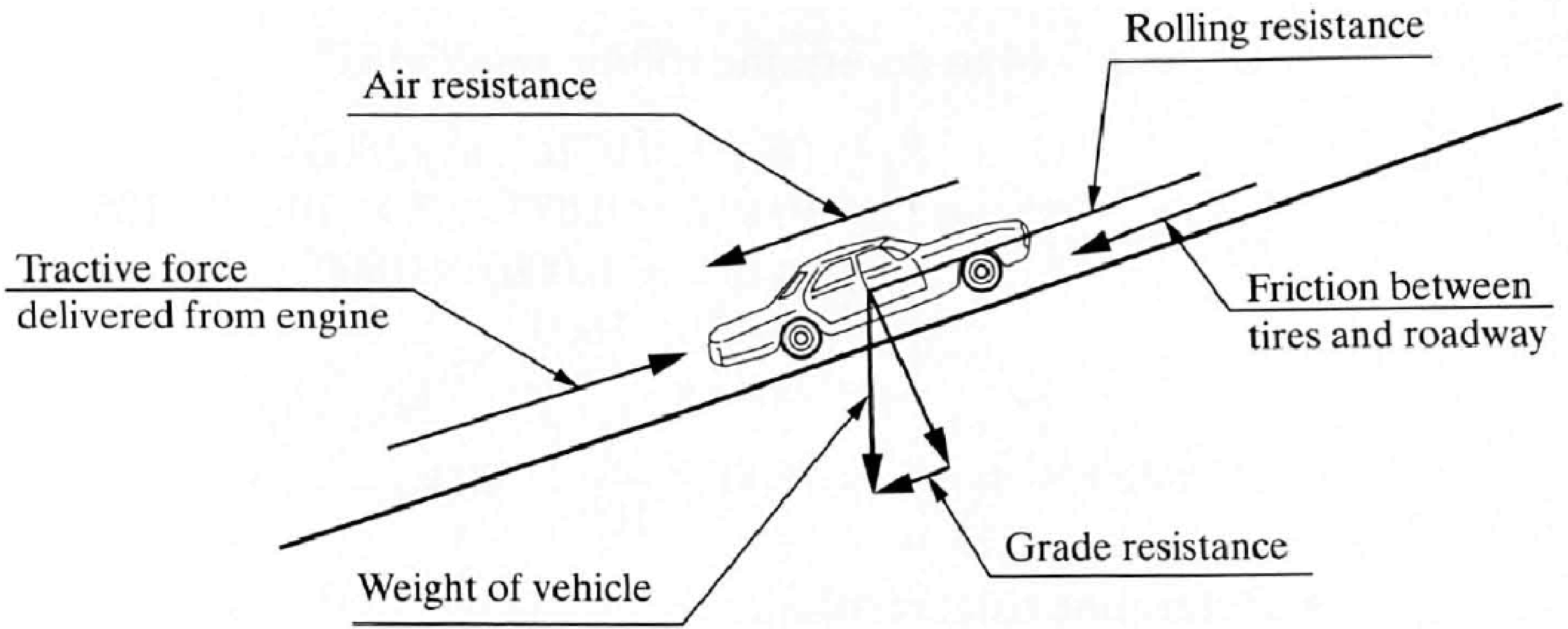
Several forces act on a vehicle while it is in motion: air resistance, grade resistance, rolling resistance, and curve resistance

Power requirements

- Power is the rate at which work is done. It is usually expressed in horsepower (a U.S. unit of measure), where 1 horsepower is 746 W.
- The performance capability of a vehicle is measured in terms of the horsepower the engine can produce to overcome air, grade, curve, and friction resistance forces and put the vehicle in motion.

Power requirements

forces act on the moving vehicle.



Forces Acting on a Moving Vehicle

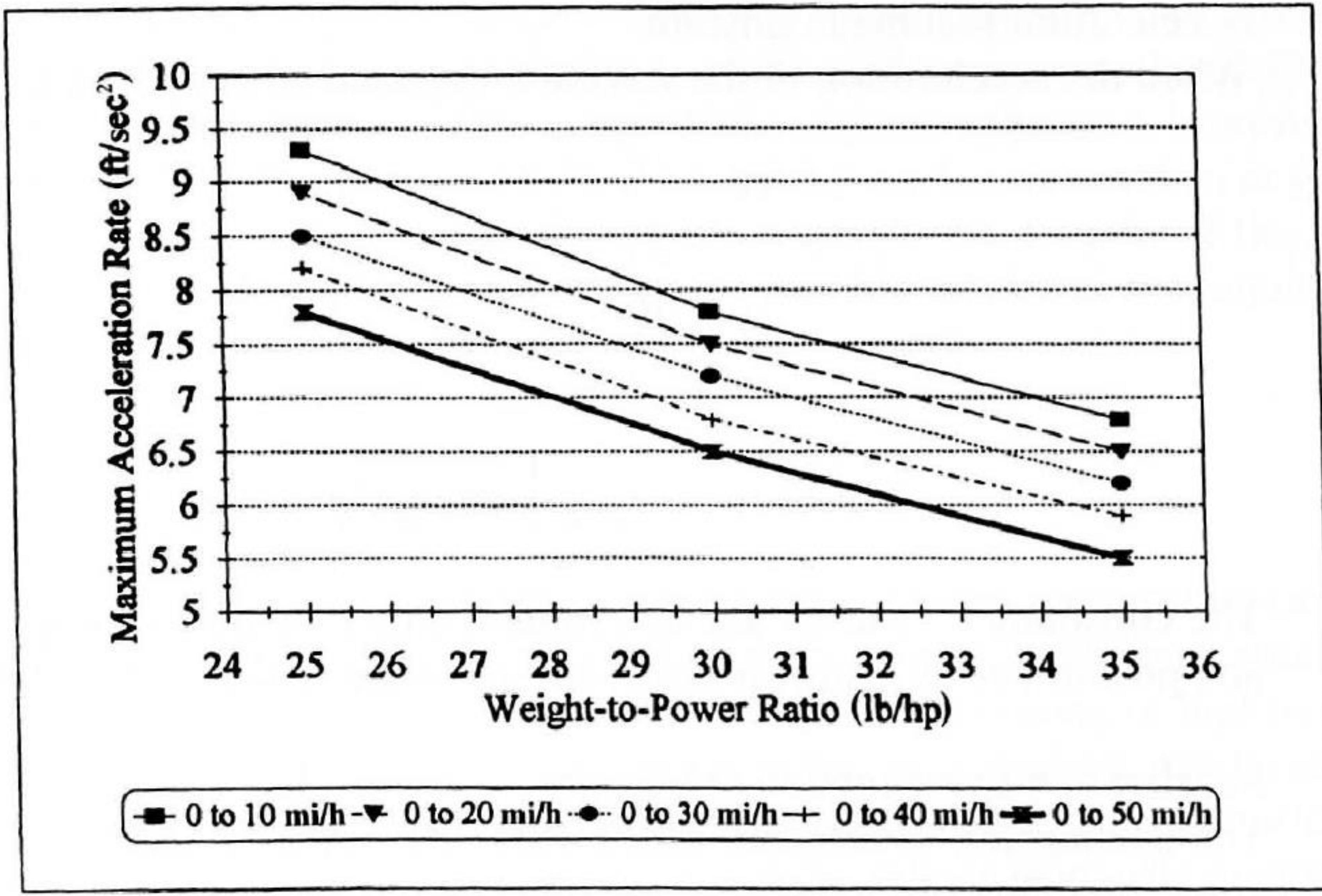
Power requirements

- The power delivered by the engine is:

$$P = \frac{2.91\, Ru}{746}$$

where

P = horsepower delivered (hp)
R = sum of resistance to motion (N)
u = speed of vehicle (km/h)

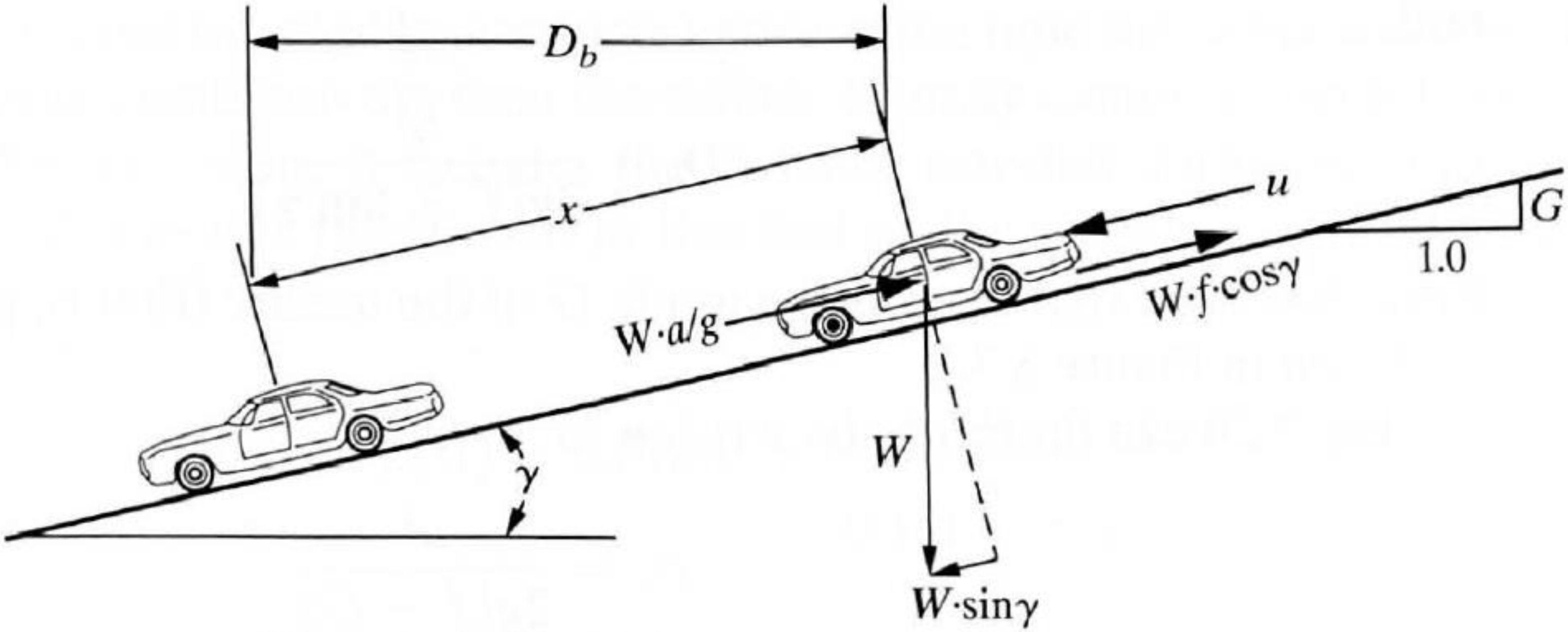


(a) Passenger Cars

Braking distance

- The action of the forces on the moving vehicle and the effect of perception-reaction time are used to determine important parameters related to the dynamic characteristics of the vehicles.
- These include the braking distance of a vehicle and the minimum radius of a circular curve required for a vehicle traveling around a curve with speed u where $u > 16$ km/h.

Braking distance



W = weight of vehicle

f = coefficient of friction

g = acceleration of gravity

a = vehicle acceleration

u = speed when brakes applied

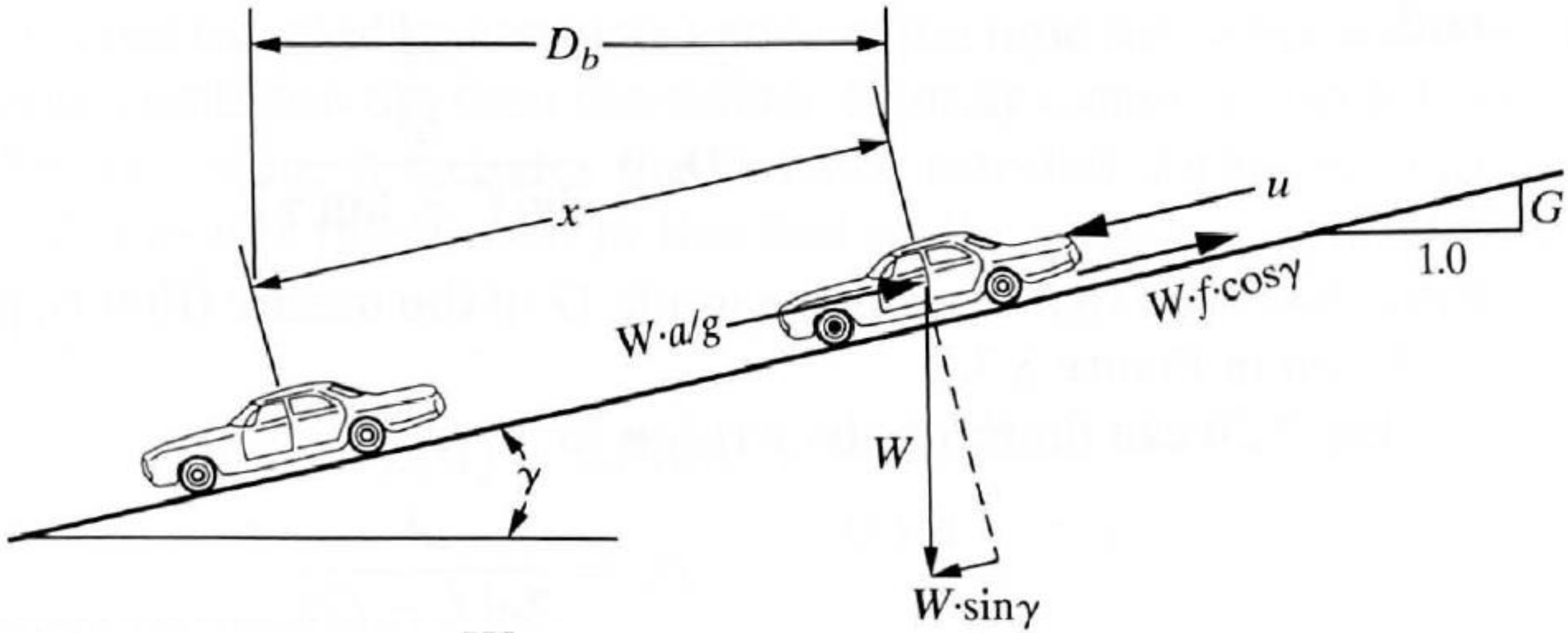
D_b = braking distance

γ = angle of incline

$G = \tan\gamma$ (% grade/100)

x = distance traveled by the vehicle along the road during braking

Frictional force on the vehicle $= W f \cos\gamma$



$$W \sin\gamma - W f \cos\gamma = \frac{W a}{g}$$

$$a = -u^2/2x$$

$$W \sin\gamma - W f \cos\gamma = -\frac{W u^2}{2 g x}$$

$$D_b = x \cos\gamma$$

$$\frac{W u^2}{2 g D_b}\cos\gamma = W f \cos\gamma - W \sin\gamma$$

$$\frac{u^2}{2 g D_b} = f - \tan\gamma$$

$$D_b = \frac{u^2}{2g(f - \tan\gamma)}$$

$$D_b = \frac{u^2}{2g(f - G)}$$

If g is taken as 9.81 m/sec^2

u is expressed in km/h

$$D_b = \frac{u^2}{254(f - G)}$$

- A general equation for the braking distance can therefore be written as:

$$D_b = \frac{u^2}{254(f \pm G)}$$

Estimation of Velocities

It is sometimes necessary to estimate the speed of a vehicle just before it is involved in a crash. This may be done by using the braking-distance equations if skid marks can be seen on the pavement. The steps taken in making the speed estimate are as follows:

Step 1. Measure the length of the skid marks for each tire and determine the average. The result is assumed to be the braking distance Db of the vehicle.

Estimation of Velocities

Step 2: Determine the coefficient of friction f by performing trial runs at the site under similar weather conditions, using vehicles whose tires are in a state similar to that of the tires of the vehicle involved in the accident. This is done by driving the vehicle at a known speed U_k and measuring the distance traveled D_k while braking the vehicle to rest.

Alternatively, a value of 0.35 for a/g can be used for f_k

Estimation of Velocities

Step 3: Use the value of f_k obtained in step 2 to estimate the unknown velocity u_u just prior to impact; that is, the velocity at which the vehicle was traveling just before observing the crash.

If it can be assumed that the application of the brakes reduced the velocity u_u to zero, then u_u may be obtained from

$$D_b = \frac{u_1^2 - u_2^2}{254\left(1\frac{a}{g} \pm G\right)}$$

$$D_b = \frac{u_u^2}{254(f_k \pm G)} \qquad D_b = \frac{u_u^2}{254\left(\frac{u_k^2}{254D_k} \mp G \pm G\right)} = \left(\frac{u_u^2}{u_k^2}\right)D_k \quad u_u = \left(\frac{D_b}{D_k}\right)^{1/2} u_k$$