Factors Influencing Highway Design

- Functional classification
- Design hourly traffic volume and vehicle mix
- Design speed
- Design vehicle
- Cross section of the highway, such as lanes, shoulders and medians
- Presence of heavy vehicles on steep grades
- Topography of the area that the highway traverses
- Level of service
- Available funds
- Safety
- Social and environmental factors

These factors are often interrelated

Geometric Design

Geometric design is intimately related to the capabilities and limitations of the roadway user and his vehicle, who will use the road and how often are also most important. Toward that end, traffic volume, speed, and composition are three major items to be considered in striving to provide safe, efficient, and economic traffic operations.

The geometric design of highways includes the visible elements of highway or street. It deals with the grade line or profile, horizontal alignment, the several components of the cross section, sight distances, & intersections.

In preparing the design of a new highway or the redesign of an old one, the highway engineer must give attention to the following basic considerations:

1. The design must be adequate for the estimated future traffic volume, both average daily traffic and design peak hour, for the character of vehicles and for the design speed.
2. The design must be safe for driving and should instill confidence in majority of drivers.
3. The design must be consistent, and must avoid surprise changes in alignment, grade, or sight distance.
4. The design must be complete. It must include the necessary roadside treatment & provide essential traffic control devices, such as markings & signs, and proper lighting.
5. The design must be as economical as possible relative to initial costs and maintenance costs.

Elements of Geometric Design

The design of highways necessitates the determination of specific design elements which include:

1. The number of lanes,
2. Lane width,
3. Median type (if any) and width,
4. Length of acceleration and deceleration lanes for on- and off-ramps,
5. Needing for truck climbing lanes for steep grades,
6. Curve radii required for vehicle turning,
7. The alignment required to provide adequate stopping and passing sight distance

The most of geometric features depends primarily on available sight distance.

Sight distance

It is the length of highway visible a head to the driver. It is important to consider to provide clear sight to enables the driver to see in both the horizontal and vertical planes. The available sight

distance on a roadway should be sufficiently long to enable a vehicle traveling at or near the design speed to stop before reaching a stationary object.

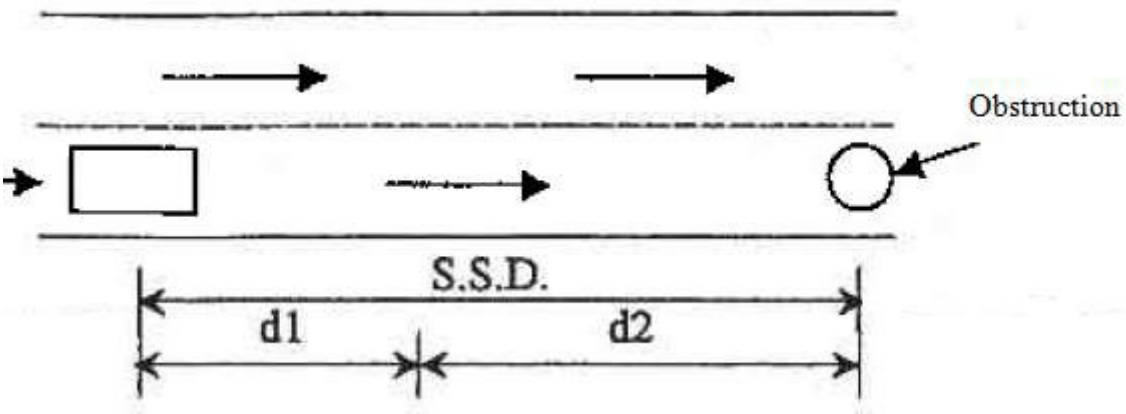
The components of the safer sight distance are three distances:

1. Stopping sight distance (SSD). it is provided for all types of highways
2. Decision sight distance. It is provided for complex location
3. Passing (overtaking) sight distance (PSD). It is provided for two-lane two-way highway to overtake slow vehicles.

1- ***Stopping Sight Distance (SSD)***: Minimum distance required for alerting driver to stop a vehicle traveling at the design speed, after seeing an object in the vehicle's bath without hitting that object. It is disaggregated into lag distance (Reaction distance) (d_1) and braking distance (d_2).

Thus:

SSD = d_1 (d lag) + d_2 (d breaking)



a. **Lag distance (d_1)**: Lag distance. It is the distance traveled during perception & reaction time.

Perception = ½ sec. (Urban area)

= 1 ½ sec. (Rural area)

Break Reaction= 1 sec.

t= perception-reaction time = 1 ½ - 2 ½ sec.

The combined perception and reaction time, t, can vary widely depending on the driver. However, in Iraq, a value of 1.5 seconds is taken for urban area and 2.5 seconds for rural area. When the designated area is not specified, the value of 2.5 seconds will be used for safe and comfortable design.

$$d_1\left(lag\ (m)\right) = v\left(\frac{m}{sec}\right) * t\ (sec)$$

1 (km/h) = 1000 m / 3600 sec =0.278 (m/sec)

$d_1 = 0.278\ V * t$

Where:

d_1 = lag distance (m)

V = speed (Km/hr)

t = perception-reaction time (sec)

**

d_1 (ft) = 1.47 V (mi/hr) * t (sec)

1 mile = 5280 ft

1.47 = 5280 ft / 3600 second

Where:

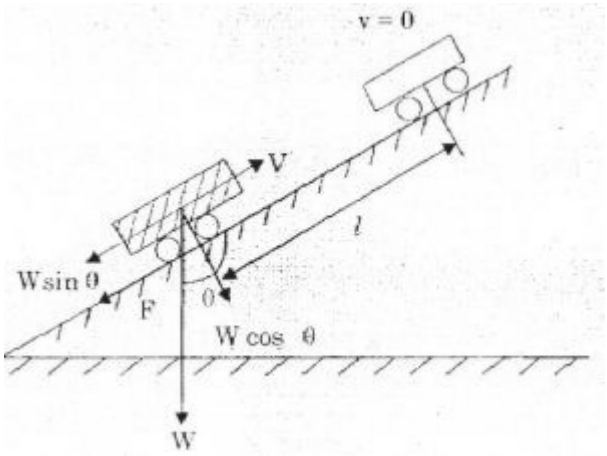
d_1 = lag distance (ft)

V = speed (mile/hr)

t = perception-reaction time (sec)

b. Braking distance (d_2): it is the distance travelled after applying the brake.

$$d_{breaking} = \frac{V^2}{254\,(f_b \pm g)}$$



Where:

D_b : (m)

V = initial speed in (Km/hr)

f_b = coefficient of friction due to braking

$$upgrade\ force = F + X$$

When ɵ is small

$$F = w.\cos\theta.f_b = w.f_b$$

$$x = w.\sin\theta = w.\tan\theta = w.g$$

$$\therefore upgrade\ force = w\,(f_b + g)$$

$$upgrade\ force = w\,(f + g)$$

$$Downgrade\ force = w\,(f_b - g)$$

$$In\ general\ force = w\,(f \mp g)$$

Work = force * distance = change in kinetic energy

$$= w\,(f_b + g).\,d_b = \frac{1}{2}\frac{w}{9.81}(v_o^2 - 0)$$

g = 9.81 m / sec^2

$$d_b = \frac{(0.278)^2\,V^2}{2 * 9.81\,(f_b + g)}$$

254 = 2 * 9.81 / (0.278 * 0.278)

$$d_b = \frac{V^2}{254\,(f_b + g)}$$

** f_b (unit – less)*

= 0.55 - 0.62 (dry pavement condition)

= 0.28 - 0.4 (wet pavement condition)

= 0.1 (muddy)

= 0.05 (icy)

** g :- longitudinal grade (unit – less) = (0 – 0.09)*

g ≤ 0.05 (high speed)

g ≤ 0.09 (low speed)

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$$d_b = \frac{V^2}{30\,(f_b + g)}$$

Where:

D_b : (ft)

V = initial speed in (mi/hr)

$$In\ general\ force = w\,(f \mp g)$$

Work = force * distance = change in kinetic energy

$$= w\,(f_b + g).\,d_b = \frac{1}{2}\frac{w}{32.2}(v_o^2 - 0)$$

g = 32.2 ft / sec^2

$$d_b(ft) = \frac{(1.47)^2 V^2}{2 * 32.2 (f_b + g)}$$

30 = 2 * 32.2 / (1.47 * 1.47)

$$d_b = \frac{V^2}{30 (f_b + g)}$$

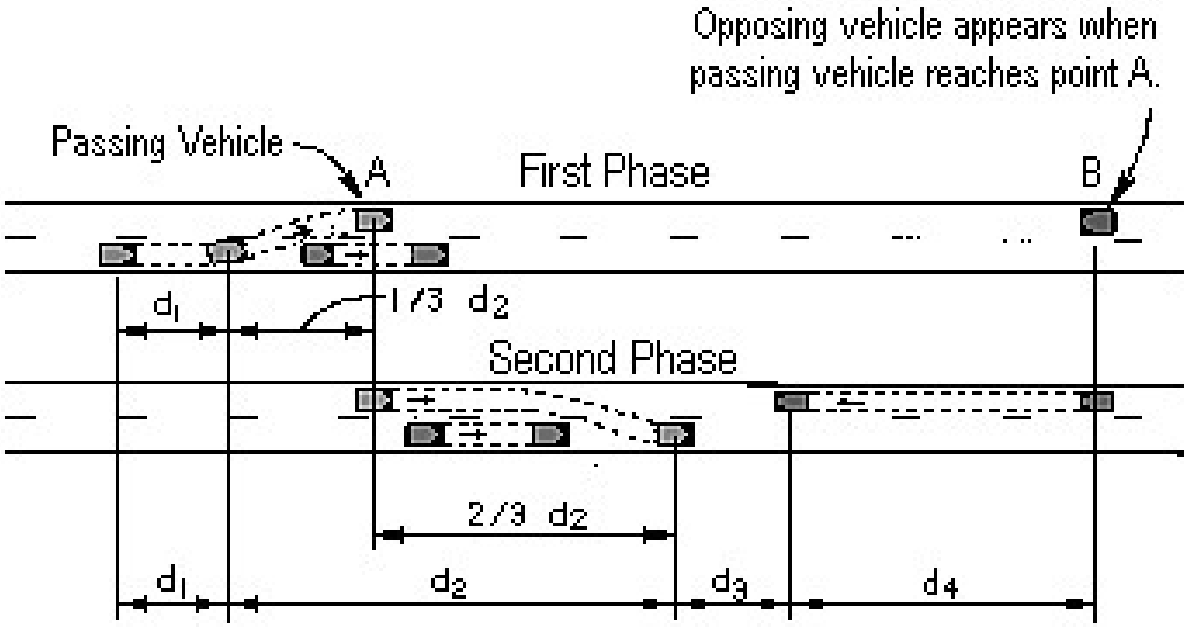
$$\mathbf{Min\ S\ (stopping) = 0.278\ Vt + \frac{V^2}{254 (f_b + g)}}$$

2. Decision Sight Distance (DSD)

It is the distance needed to avoid maneuver (stopping, speeding, or path change). It is considered in the design of roads at complex locations (visual noise area) like intersection, interchange or where there is a change in the cross section.

Maneuver	Description	DSD (m) when speed=100kph	Time needed to pass the DSD (sec)
A	Stopping in rural area	225	3
B	Stopping in urban area	415	9.1
C	Speed or path change in rural area	315	10
D	Speed or path change in suburban area	365	12
E	Speed or path change in urban area	405	14

3. *Passing Sight Distance (PSD)*: minimum distance required on two-way two-lane highways to give the opportunity to pass slow moving vehicles safely. It must be provided at intervals, otherwise capacity decreases and accidents may occur.



The PSD is determined as the sum of the following four distances:

PSD (Min S passing) = $d_1 + d_2 + d_3 + d_4$

1. d_1: distance traveled during perception and acceleration time (initial maneuver distance).

$d_1 = 0.278\ t_1\ [V + (a.t_1)/2]$

Where:

V: average speed of overtaking vehicle (Km/hr)

t_1: preliminary delay time (3.5-4.5) sec ≈ 4 sec

a: acceleration rate 0.5 - 1 Km/hr/sec for trucks
3-8 Km/hr/sec for ordinary car (passenger car)
16-24 Km/hr/sec for sport car

2. d_2: distance traveled in the opposite direction

$d_2 = 0.278\ V_2\ t_2$

Where:

d_2 = overtaking distance (m)

V_2= average speed of overtaking vehicle (Km/hr)

t_2: time of occupying opposing lane (9.5-11.5) sec ≈ 10 sec

3. d_3: safety distance(clearance distance) = 100m

   It is the distance between the passing vehicle at the end of its maneuver and the opposing vehicle.

4. d_4: It is the distance traversed by an opposing vehicle in the opposing lane (m). It is equal to the two-thirds of the time the passing vehicle occupies the left lane

   $d_4 = 2/3\ d_2$