1.3.5 Other elements

- **Sidewalks** are usually provided on roads in urban areas, but are uncommon in rural areas. Nevertheless, the provision of sidewalks in rural areas should be evaluated during the planning process to determine sections of the road where they are required. Sidewalks should have a minimum clear width of 1.25 m in residential areas and a range of 1.25 m to 2.5 m in commercial areas.
- **Cycle tracks** are provided in urban areas when the volume of cycle tracks is high Minimum width of 2 meter is required, which may be increased by 1 meter for every additional track.

1.4 Right -of -Way (ROW)

Right of way (ROW) or land width is the width of land acquired for the road, along its alignment. It should be adequate to accommodate all the cross-sectional elements of the highway and may reasonably provide for future development. Sufficient right – of- way should be acquired in order to avoid the expense of purchasing developed property, with varying widths depending on local conditions. The right – of – way for a 2- lane highway in rural areas is recommended to have a minimum width of 30 m, with 37 m desirable. A minimum right-of-way width of 45m, and a desirable width of 76m are recommended for divided highways. Widths of 60 to 90 m have been used for divided highways without frontage roads. For Iraqi Expressway No One, a right- of- way width of 260 m has been provided, which included service roads.

The right of way width is governed by:

- Width of formation: It depends on the category of the highway and width of roadway and road margins.
- Height of embankment or depth of cutting: It is governed by the topography and the vertical alignment.

- Side slopes of embankment or cutting: It depends on the height of the slope, soil type etc.
- Drainage system and their size which depends on rainfall, topography etc.
- Sight distance considerations: On curves, there is restriction to the visibility on the inner side of the curve due to the presence of some obstructions like building structures etc.
- Reserve land for future widening: Some land has to be acquired in advance anticipating future developments like widening of the road.

1.5 Site Distance

In highway alignment design, the sight distance is a fundamental consideration that should be provided throughout the alignment. The safe and efficient operation of vehicles on the road depends very much on the visibility of the road ahead of the driver. Thus, the geometric design of the road should be done such that any obstruction on the road length could be visible to the driver from some distance ahead. This distance is called to be the sight distance. Sight distance available from a point is the actual distance along the road surface, over which a driver from a specified height above the carriage way has visibility of stationary or moving objects. Three sight distance situations are considered for design:

- ✓ Stopping sight distance (SSD) or the absolute minimum sight distance
- ✓ Intermediate sight distance (ISD) is defined as twice SSD
- ✓ Overtaking sight distance (OSD) for safe overtaking operation
- ✓ Head light sight distance is the distance visible to a driver during night driving under the illumination of head lights
- ✓ Safe sight distance to enter into an intersection.

The most important consideration in all these is that at all times the driver traveling at the design speed of the highway must have sufficient carriageway distance within his line of vision to allow him to stop his vehicle before colliding with a slowly moving or stationary object appearing suddenly in his own traffic lane.

The computation of sight distance depends on:

- **Reaction time of the driver.** Reaction time of a driver is the time taken from the instant the object is visible to the driver to the instant when the brakes are applied. The total reaction time may be split up into four components. In practice, all these times are usually combined into a total perception-reaction time suitable for design purposes as well as for easy measurement. Many of the studies shows that drivers require about 1.5 to 2 secs under normal conditions. However, taking into consideration the variability of driver characteristics, a higher value is normally used in design. A reaction time of **2.5 sec** is considered adequate for design purposes.
- **Speed of the vehicle.** The speed of the vehicle very much affects the sight distance. Higher the speed, more time will be required to stop the vehicle. Hence it is evident that, as the speed increases, sight distance also increases.
- **Efficiency of brakes**. The efficiency of the brakes depends upon the age of the vehicle, vehicle characteristics etc. If the brake efficiency is 100%, the vehicle will stop at the moment the brakes are applied. However, practically, it is not possible to achieve 100% brake efficiency. Therefore, the sight distance required will be more when the efficiency of brakes are less. Also for safe geometric design, we assume that the vehicles have only 50% brake efficiency.
- **Frictional resistance between the tyre and the road**. The frictional resistance between the tyre and road plays an important role to bring the vehicle to stop. When the frictional resistance is more, the vehicles stop

immediately. No separate provision for brake efficiency is provided while computing the sight distance. This is taken into account along with the factor of longitudinal friction. It is has generally specified the value of longitudinal friction in between 0.35 to 0.4.

- **Gradient of the road**. Gradient of the road also affects the sight distance. While climbing up a gradient, the vehicle can stop immediately; therefore, sight distance required is less. On the other hand, on descending a gradient, gravity also comes into action and more time will be required to stop the vehicle therefore, the requirement of Sight distance will be more in this case.

1.5.1 Stopping Sight Distance (SSD)

Stopping sight distance (SSD) is the minimum sight distance available on a highway at any spot having a sufficient length to enable the driver to stop a vehicle traveling at design speed, safely without collision with any other obstruction. In design consideration, the (site) safe stopping distance is one of the important measures in traffic engineering. It is the distance of vehicle travels from the point at which a situation is first perceived to the time of deceleration is complete. Drivers must have adequate time if they are to suddenly respond to a situation. The stopping sight distance is the sum of lag distance (or Perception-reaction distance) and braking distance as shown in Figure 1.12. These two components can be computed separately: Perception-reaction distance ($d_{reaction}$) travelled during perception-reaction time, and braking distance ($d_{braking}$) travelled after applying brakes.

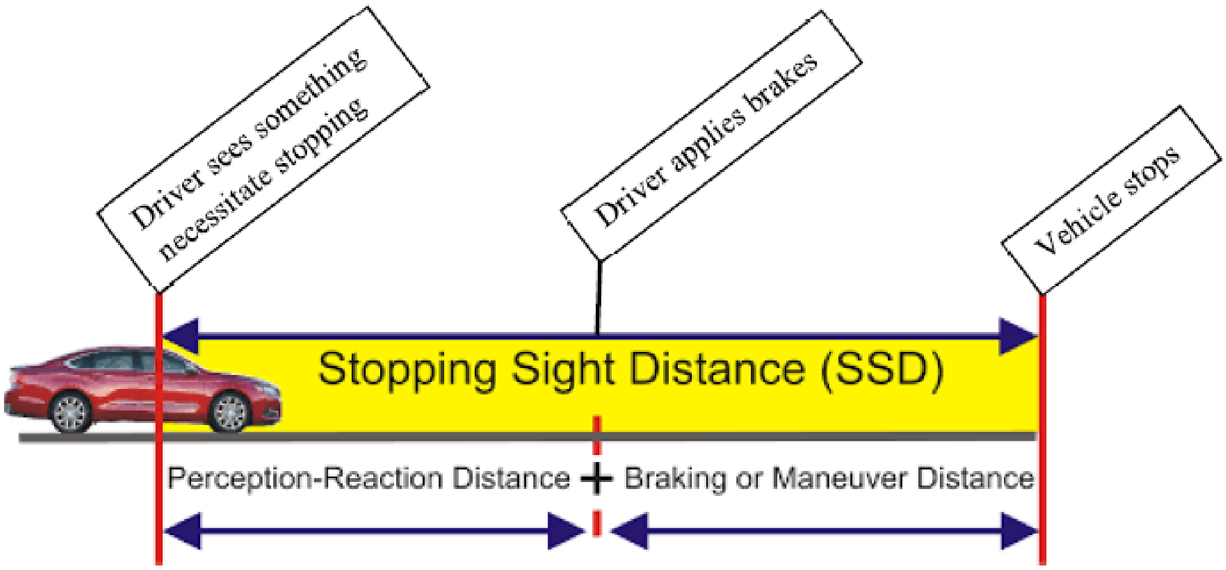

Figure 1.12: Diagrammatic representation of stopping sight distance components

- ***Perception-reaction distance***

  As defined previously, a reaction time is the interval from the instant that the driver recognizes the potential hazard that need a stop until the instant that the driver actually applies the brakes. Vehicle speed and roadway environment probably also influence reaction time. Normally, a driver traveling at or near the design speed is more alert than one traveling at a lesser speed. A perception-reaction time of 2.5 sec. is considered adequate for design purposes. Perception-reaction distance in meters is calculated from the following equation.

$$\text{Reaction Distance} = v.t \quad \ldots\ldots\ldots\ldots \quad (1)$$

Where: **v** is speed **(m/s)** and t is reaction time **(sec)**

$$\text{Reaction Distance} = 0.278\, V.t \quad \ldots\ldots\ldots\ldots \quad (2)$$

Where: **V** is speed **(Km/h)** and t is reaction time **(sec)**

- ***Braking distance***

  Braking distance (D_B) in meters is computed from one of the following equations

$$D_B = 0.039\,\frac{v^2}{a} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\textit{For flat terrain}\ldots \quad (3)$$

$$D_B = \frac{v^2}{254\left[\left(\frac{a}{9.81}\right)\pm G\right]} \quad \ldots\ldots\ldots\ldots\ldots \textit{ For non-flat Terrain}\ldots \quad (4)$$

Where V is speed in (Km/h), a is deceleration rate in (m/sec^2), G is grade of road in % and –ve and +ve signs should be used for downgrade and upgrade, respectively.

Therefore,

$$SSD = 0.278\ V.t + 0.039\,\frac{v^2}{a} \quad \ldots\ldots\textit{For flat terrain}\ldots\ldots\ldots \quad (5)$$

$$SSD = 0.278\ V.t + \frac{v^2}{254\left[\left(\frac{a}{9.81}\right)\pm G\right]} \quad .\ \textit{For non-flat Terrain}\ldots \quad (6)$$

1.5.2 Overtaking (Passing) Sight Distance (OSD or PSD)

The overtaking sight distance is the minimum distance open to the vision of the driver of a vehicle intending to overtake the slow vehicle ahead safely against the traffic in the opposite direction. The overtaking sight distance or passing sight distance is measured along the centre line of the road over which a driver with his eye level 1.2m above the road surface can see the top of an object 1.2m above the road surface. The factors that affect the OSD are:

- Velocities of the overtaking vehicle, overtaken vehicle and of the vehicle coming in the opposite direction.
- Spacing between vehicles, which in-turn depends on the speed
- Skill and reaction time of the driver
- Rate of acceleration of overtaking vehicle
- Gradient of the road.

It should be noted that passing sight distance only applies to two-lane, two-way highways because highways with additional lanes are not constrained by the risk posed by opposing traffic. The minimum passing sight distance for two-lane highways is determined as the sum of the following four distances as presented in Figure 1.13**:**

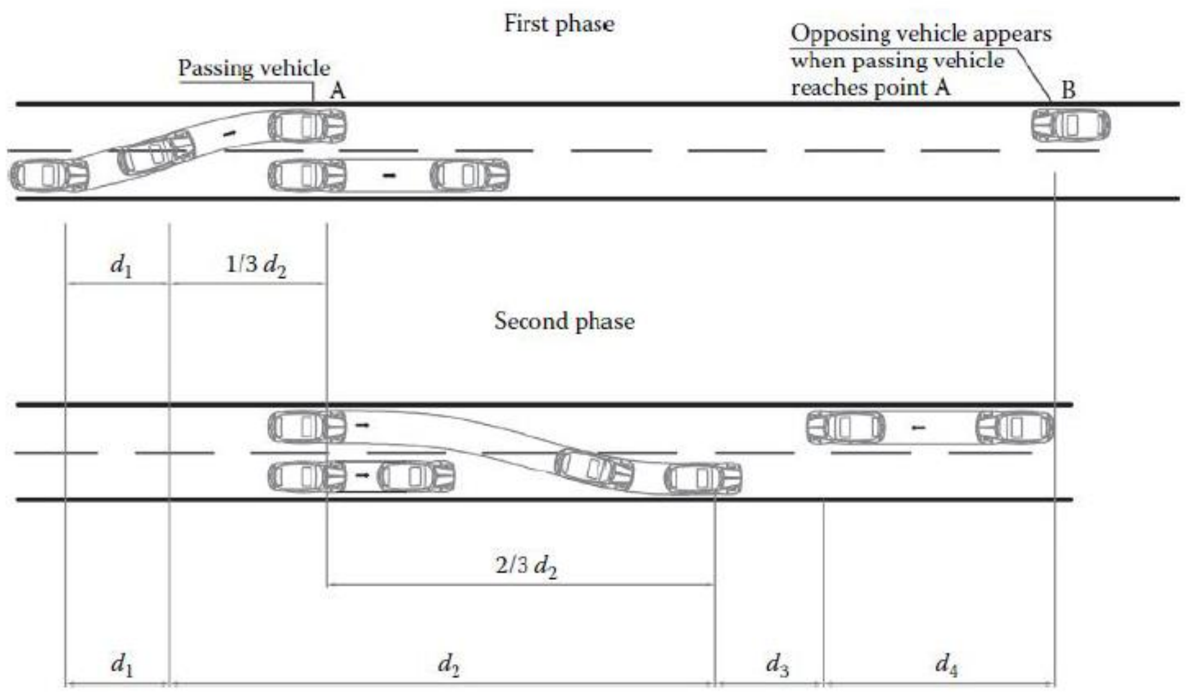

Figure 1.13: Passing sight distance elements

Therefore,

$$PSD = d_1 + d_2 + d_3 + d_4 \quad \ldots\ldots (7)$$

Where d_1 is a distance traversed during perception-reaction time and during the initial acceleration to the point where the passing vehicle just enters the left lane.

$$\mathbf{d_1 = 0.278\, t_1 \,[V - m + (a\, t_1 /2)]}$$

Where: t_1 is time of initial manoeuvre, s; a is average acceleration, km/h/s;) V is average speed of passing vehicle, km/h; m is difference in speed of passed vehicle and passing vehicle, taken as = 15 to 19 km/h.

$\mathbf{d_2}$ is distance travelled during the time the passing vehicle is traveling in the left lane.

$$\mathbf{d_2 = 0.278\, V\, t_2}$$

Where: t_2 is time passing vehicle occupies the left lane, in sec (9.3s to 11.3s); and V is average speed of passing vehicle, in km/h.

$\mathbf{d_3}$ = distance between the passing vehicle and the opposing vehicle at the end of the passing manoeuvre (such as, clearance distance). This distance at the end of the passing manoeuvre is assumed to be between 30 m to 75 m

$\mathbf{d_4}$ is distance moved by the opposing vehicle during two thirds of the time the passing vehicle is in the left lane (usually taken to be 2/3 d_2). $\mathbf{d_4 = 2/3 \times d_2}$

Table 1.3: PSD as recommended by AASHTO

Component of passing maneuver	Metric				US Customary			
	Speed range (km/h)				Speed range (mph)			
	50-65	66-80	81-95	96-110	30-40	40-50	50-60	60-70
	Average passing speed (km/h)				Average passing speed (mph)			
	56.2	70.0	84.5	99.8	34.9	43.8	52.6	62.0
Initial maneuver:								
a = average acceleration[a]	2.25	2.30	2.37	2.41	1.40	1.43	1.47	1.50
t_1 = time (sec)[a]	3.6	4.0	4.3	4.5	3.6	4.0	4.3	4.5
d_1 = distance traveled	45	66	89	113	145	216	289	366
Occupation of left lane:								
t_2 = time (sec)[a]	9.3	10.0	10.7	11.3	9.3	10.0	10.7	11.3
d_2 = distance traveled	145	195	251	314	477	643	827	1030
Clearance length:								
d_3 = distance traveled[a]	30	55	75	90	100	180	250	300
Opposing vehicle:								
d_4 = distance traveled	97	130	168	209	318	429	552	687
Total distance, $d_1 + d_2 + d_3 + d_4$	317	446	583	726	1040	1468	1918	2383

[a] For consistent speed relation, observed values adjusted slightly.

Note: In the metric portion of the table, speed values are in km/h, acceleration rates in km/h/s, and distances are in meters. In the U.S. customary portion of the table, speed values are in mph, acceleration rates in mph/sec, and distances are in feet.

1.5.2 Sight Distance at Intersection

At intersections where two or more roads meet, visibility should be provided for the drivers approaching the intersection from either sides. They should be able to perceive a hazard and stop the vehicle if required. Stopping sight distance for each road can be computed from the design speed. The sight distance should be provided such that the drivers on either side should be able to see each other. This is illustrated in the Figure 1.14.

Design of sight distance at intersections may be used on three possible conditions:

- ✓ Enabling approaching vehicle to change the speed
- ✓ Enabling approaching vehicle to stop
- ✓ Enabling stopped vehicle to cross a main road.

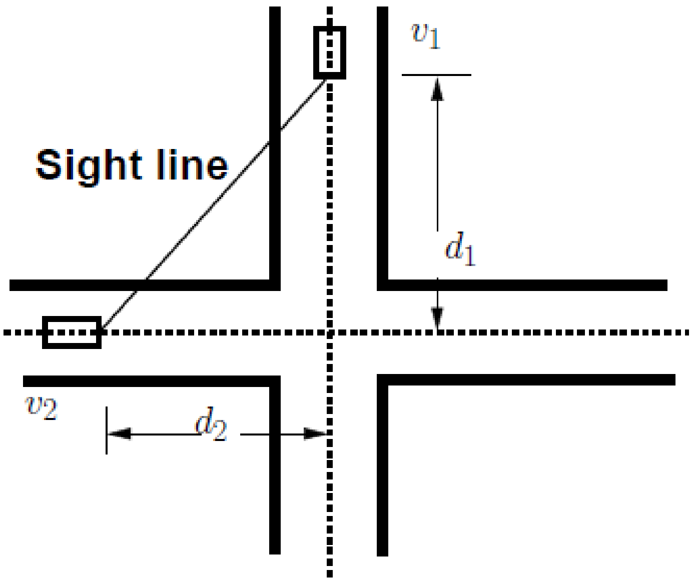

Figure 1.14: Sight distance at intersections

Example 2: For a Two-lane, Two-way (TLTW) highway, find: a- minimum sight distance to avoid head-on collision of two cars approaching at 90 km/h and 60 km/h? b- For the same conditions but the road has grade of downhill 3% (car of speed 90 km/h moves downward)? Use t =2.5 sec, a =3.5 m/sec^2

a)

For first car having speed of 90Km/h

SSD= $0.278*90*2.5 + \frac{90^2}{254\left[\left(\frac{3.5}{9.81}\right)\pm 0\right]} = 152\text{m}$

For first car having speed of 60Km/h

SSD= $0.278*60*2.5 + \frac{60^2}{254\left[\left(\frac{3.5}{9.81}\right)\pm 0\right]} = 81.5\text{m}$

Required total distance = 152+81.5 = <u>233.5m</u>

b)

For first car having speed of 90Km/h

SSD= $0.278*90*2.5 + \frac{90^2}{254\left[\left(\frac{3.5}{9.81}\right)-0.03\right]} = 160.14\text{m}$

For first car having speed of 60Km/h

SSD= $0.278*60*2.5 + \frac{60^2}{254\left[\left(\frac{3.5}{9.81}\right)-0.03\right]} = 85.1\text{m}$

Required total distance = 160.14+85.1 = <u>245.24m</u>

Example 3: A motorist traveling at 105 km/h on an expressway intends to leave the expressway using an exit ramp with a maximum speed of 55 km/h. At what point on the expressway should the motorist step on his brakes in order to reduce his speed to the maximum allowable on the ramp just before entering the ramp, if this section of the expressway has a downgrade of 3%? Use deceleration rate value as 3.4 m/sec^2

$$D_B = \frac{v1^2 - v2^2}{254\left[\left(\frac{a}{9.81}\right) \pm G\right]}$$

$$D_B = \frac{105^2 - 55^2}{254\left[\left(\frac{3.4}{9.81}\right) - 0.03\right]} = 99.5m$$

Example 3: Compute the safe passing sight distance of two lanes two-direction highway if the speed of passing vehicle was 85 km/ h and its acceleration was 0.65 m/s^2 and the clear distance between passing and opposing vehicles equal to 73meters and time of initial manoeuvre is 4 sec? use any standard values if needed?

PSD= $d_1 + d_2 + d_3 + d_4$

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

$d_1 = 0.278 \times 4\ [85 - 16 + (0.65\times3.6\times 4/2)] = 81.93 = 82m$

$d_2 = 0.278\times V\times t_2$ to find d_2 assume t_2 as 10 seconds

$d_2 = 0.278\times85\times 10 = 236.3m$

d3 =73m

$d_4 = 2/3 \times d_2 = 2/3 \times 236.3 = 157.54m$

PSD=82 + 236.3 + 73 + 157.54=548.84=549m

Questions:

1- Find head light sight distance and intermediate sight distance for a vehicle having a speed of 65 Km/h (Hint: a=3.5 m/sec^2). Assume any standard value you would require.

2- Overtaking and overtaken vehicles are at 70 and 40 km/h respectively. Find PSD. (Hint: a=0.99 m/sec^2) Assume any standard value you would require.