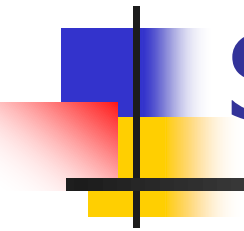
Geometric design deals with

1- Cross section elements
2- sight distance considerations
3- Horizontal alignment details
4- Vertical alignment details
5- Intersection elements



Sight Distances

Definition

حتى يتم تصميم طريق تتوافر فيه عناصر الأمان يجب أن تتوافر فيه مسافة رؤية واضحة أمام السائق على الطريق حنى يتمكن من تجنب الاصطدام بعوائق غير متوقعة وكذلك تمكنه من تخطى السيارات البطيئة أمامه فى حالة الطرق الغير مقسمة

The distance that a driver can see ahead at any specific time

Must allow sufficient distance for a driver to perceive/react and stop, swerve etc when necessary

Objectives

Know different types of sight distance and important determinants

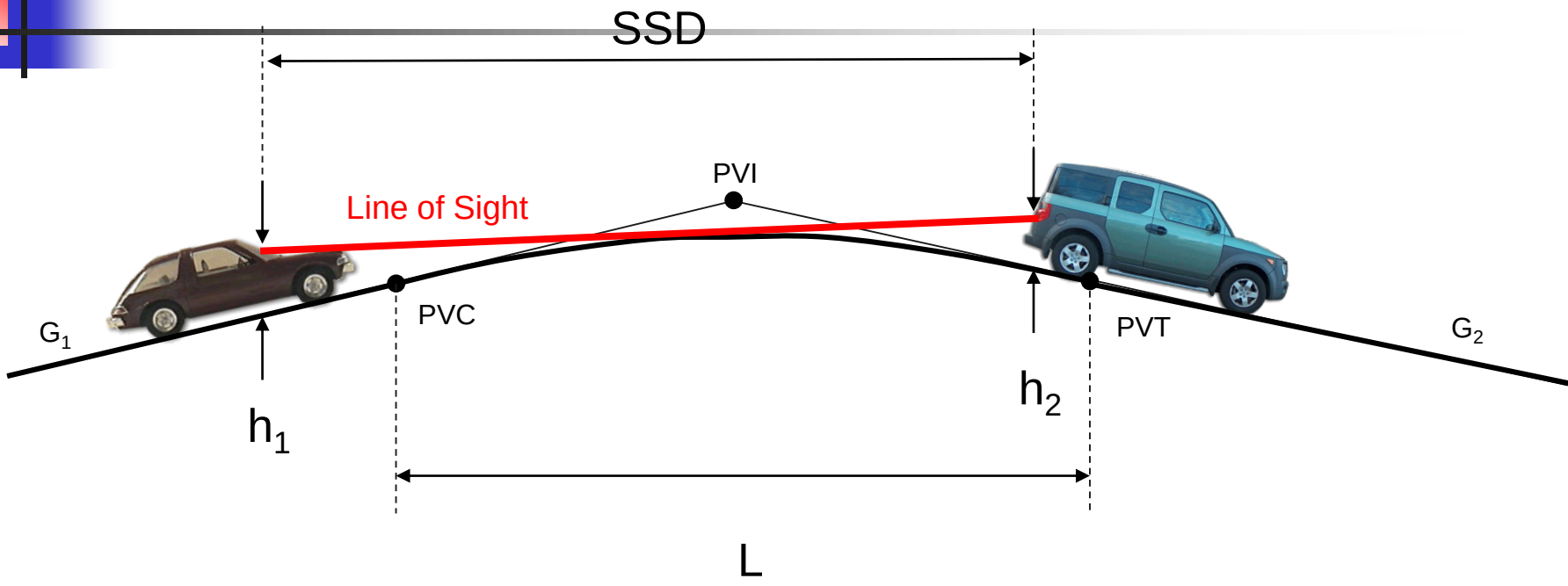
Important Sight Distances

1. Stopping or Absolute min. sight distance (SSD) = Object in a roadway
1. Safe overtaking or Passing sight distance (PSD) = Pass slow vehicles
1. Safe sight distance for entering uncontrolled intersections

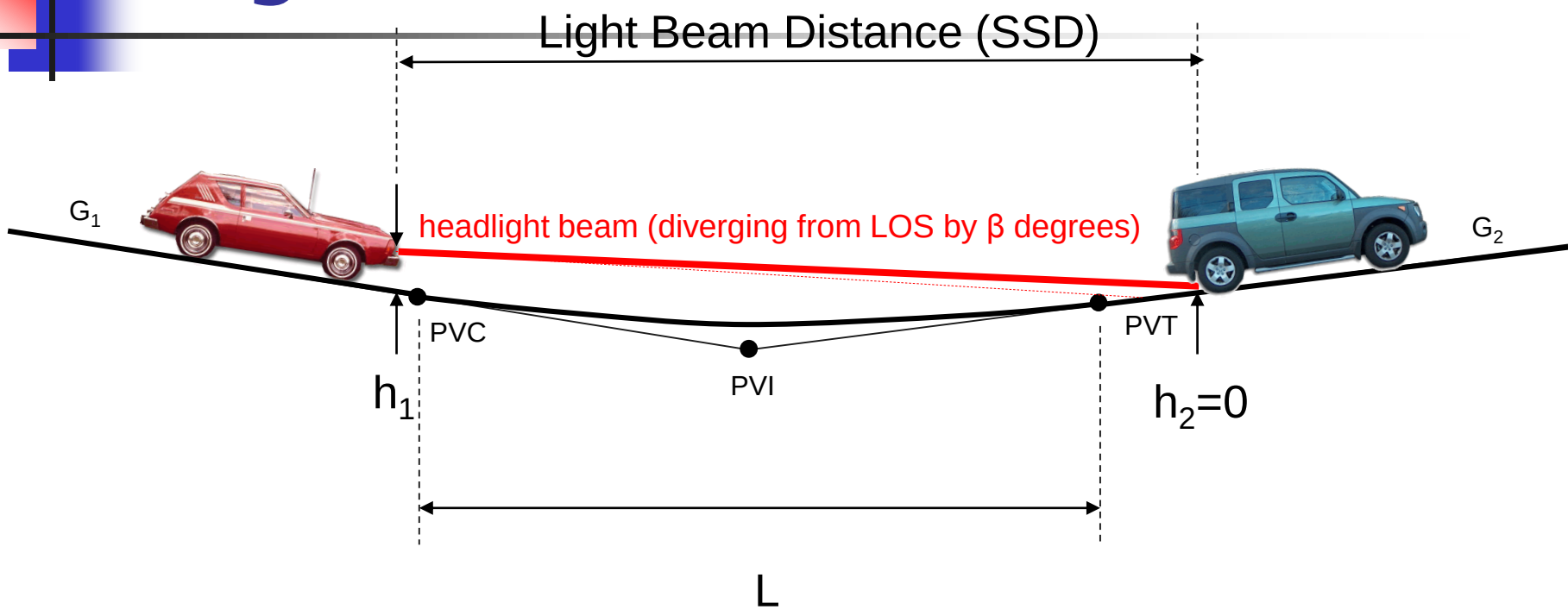
Criteria for Sight Distance

- Driver eye height: for passenger vehicle's = 3.5 ft above surface
- Height of object in roadway = 2 feet (SSD) Height of opposing vehicle = 3.5 feet (PSD)

Crest Vertical Curves



Sag Vertical Curves



Stopping Sight Distance

أقل مسافة من طول الطريق يمكن للسائق أن يوقف فيها سيارته قبل الاصطدام بهدف ثابت أو متحرك ظهر له فجأة ويتكون مدى الرؤية من مسافتين:

1- Perception/Reaction Distance (PRD)
مسافة الاستيعاب وإتخاذ القرار

2- Braking Distance (BD)
مسافة الفرملة

Perception reaction distance:

المسافة التى سارتها المركبة أثناء الفترة الزمنية التى إستغرقها السائق فى إستيعاب الموقف وفهمه وإتخاذ القرار بالوقوف المفاجئ

$$d_1 = 1.47vt$$

v – design speed, mph;
t – perception & reaction time, 2.5 s
d_1 - ft

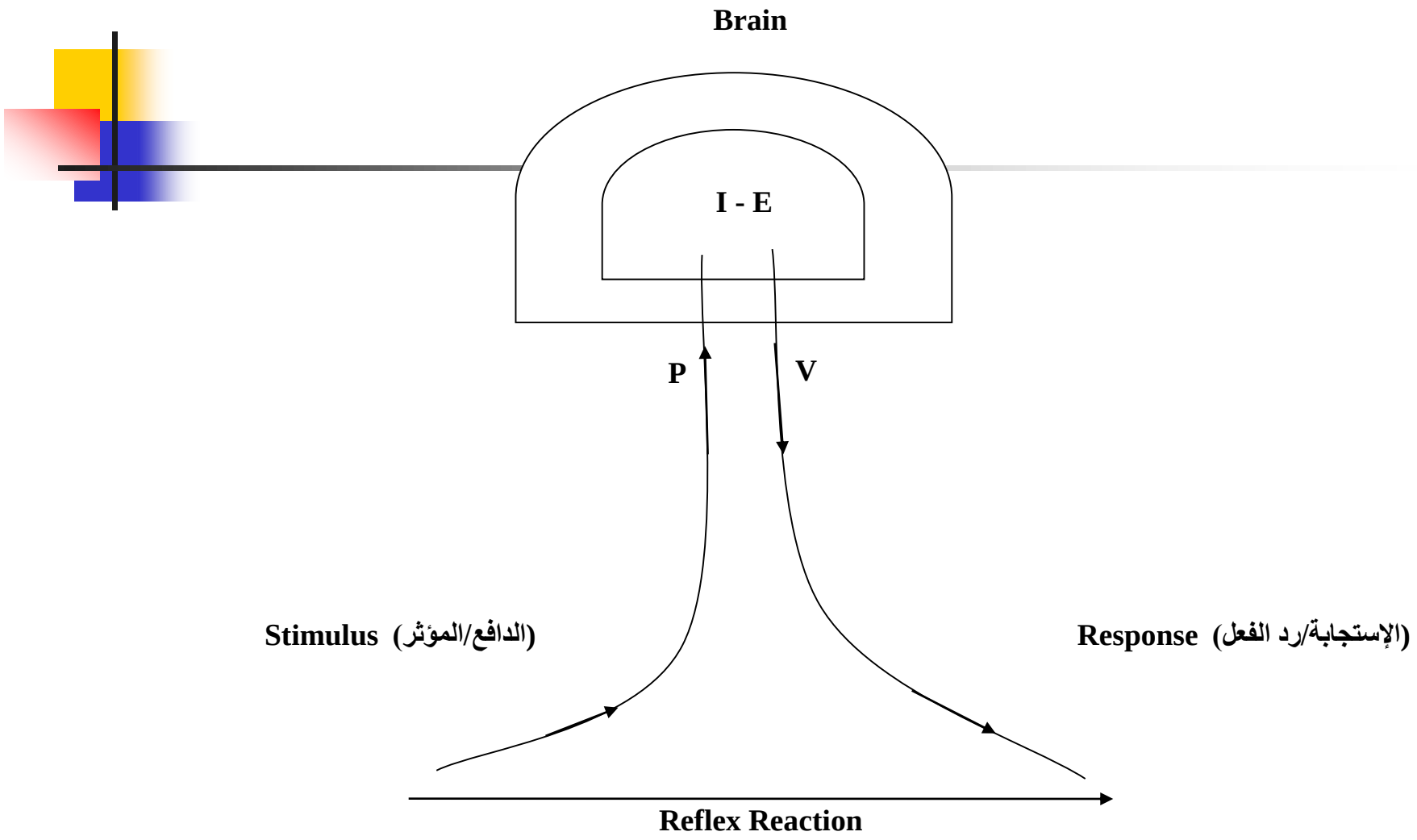
AASHTO Green Book

- AASHTO GB recommends 2.5 seconds, this is adequate for conditions that are more complex than the simple conditions used in laboratory and road tests.

PIEV Theory

According to this theory, the total reaction time of the driver is split into four parts, viz, time taken by the driver for:

- **Perception** (إدراك حسى)
- Intellection (الفكر)
- **Emotion** (إنفعال/إحساس)
- Volition (إرادة /إختيار)


Brain
I - E
P
V
Stimulus (الدافع/المؤثر)
Response (الإستجابة/رد الفعل)
Reflex Reaction

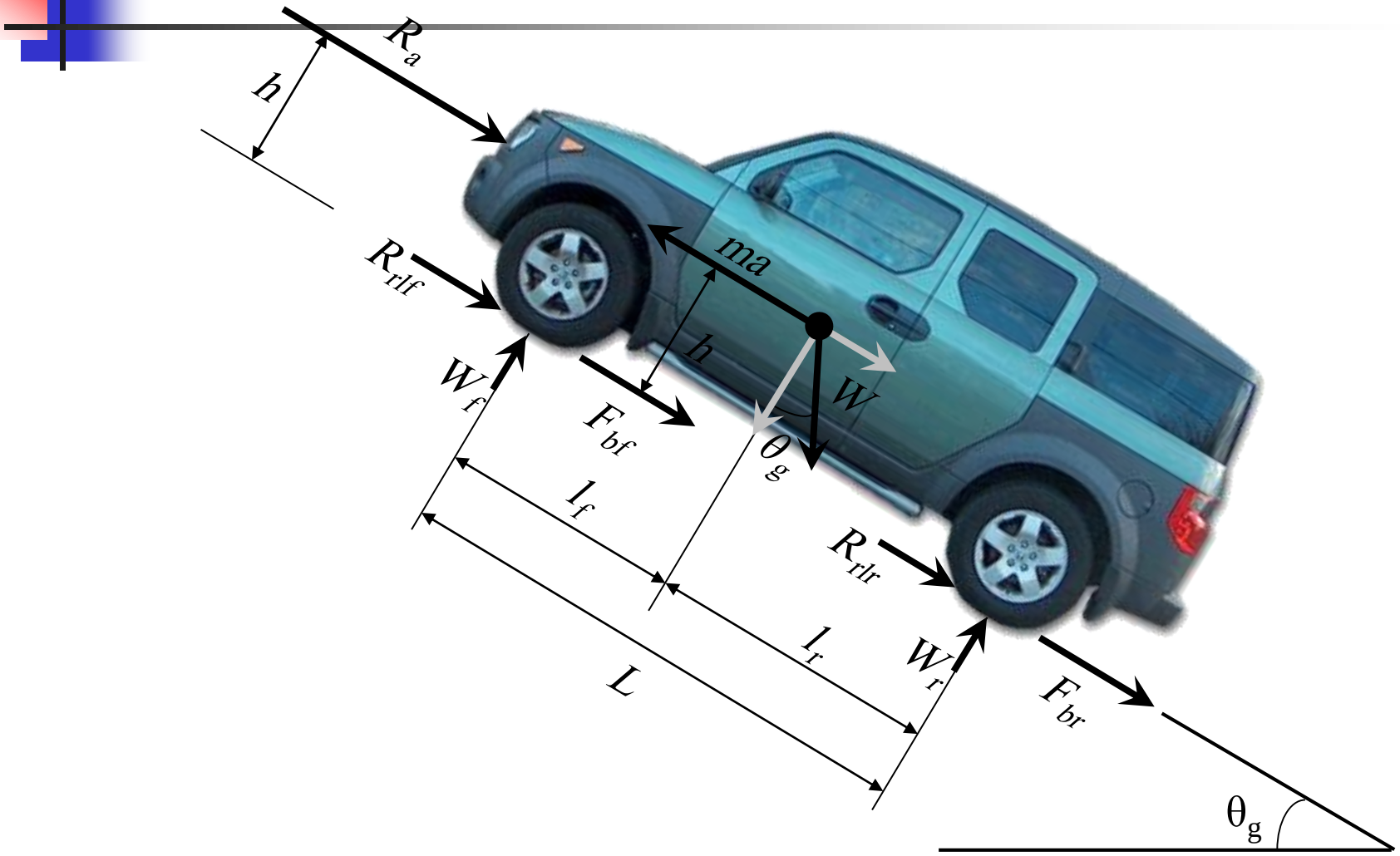
Braking distance:

المسافة التى تقطعها المركبة منذ لحظة الضغط على الفرامل وحتى وقوف المركبة وتتأثر بالعوامل الآتية:

- معامل الاحتكاك بين سطح الأسفلت وإطارات المركبات
- سرعة المركبة المتوسطة
- ميل الأرض(Gradient)

the distance required to stop after brake activation

Diagram



$$d = \frac{V_1^2 - V_2^2}{2g\left(\frac{a}{g} \pm G\right)}$$

For grade (G)

a/g = *f*

AASHTO Green Book

Deceleration rate: AASHTO: 11.2 ft/s^2

Deceleration is within capability of drivers to stay within their lane and control the vehicle when braking on wet surfaces and is comfortable for most drivers

in emergency

“a” may be larger than 14.8 ft/s2.

Braking distance: (cont…)

$$d_2 = \frac{v^2}{30 f}$$

the distance required to stop after brake activation

v – design speed, mph,

f – Coefficient of friction

d2 - ft

Typical values for friction

Values of friction vary widely with road surface type, age, condition. Examples:

Surface type	f (or a/g)
Concrete pavement -dry	0.60 to .75
Concrete pavement – wet	0.45 to .65
Asphalt pavement	0.55 to .70
Gravel	0.40 to .70
Ice	0.05 to .20
Snow	0.30 to .60

Typical values for friction

V (mph)	20	25	30	35	40	45	50	55	60	65	70
f	0.4	0.38	0.35	0.34	0.32	0.31	0.3	0.3	0.29	0.29	0.28

SSD Equation

$$SSD = 1.47vt + \frac{v^2}{30(\{a/g\} \pm G)}$$

SSD in feet

u speed in mph (may also see "v")

t perception/reaction time (in seconds)

a assumed deceleration rate (ft/sec^2)

g gravitational force (32.2 ft /sec^2)

G gradient in ft/ft

a/g *f* (Coefficient of friction)

for design: (G=0.0%)

Metric					US Customary				
			Stopping sight distance					Stopping sight distance	
Design speed (km/h)	Brake reaction distance (m)	Braking distance on level (m)	Calculated (m)	Design (m)	Design speed (mph)	Brake reaction distance (ft)	Braking distance on level (ft)	Calculated (ft)	Design (ft)
20	13.9	4.6	18.5	20	15	55.1	21.6	76.7	80
30	20.9	10.3	31.2	35	20	73.5	38.4	111.9	115
40	27.8	18.4	46.2	50	25	91.9	60.0	151.9	155
50	34.8	28.7	63.5	65	30	110.3	86.4	196.7	200
60	41.7	41.3	83.0	85	35	128.6	117.6	246.2	250
70	48.7	56.2	104.9	105	40	147.0	153.6	300.6	305
80	55.6	73.4	129.0	130	45	165.4	194.4	359.8	360
90	62.6	92.9	155.5	160	50	183.8	240.0	423.8	425
100	69.5	114.7	184.2	185	55	202.1	290.3	492.4	495
110	76.5	138.8	215.3	220	60	220.5	345.5	566.0	570
120	83.4	165.2	248.6	250	65	238.9	405.5	644.4	645
130	90.4	193.8	284.2	285	70	257.3	470.3	727.6	730
					75	275.6	539.9	815.5	820
					80	294.0	614.3	908.3	910

Note: Brake reaction distance predicated on a time of 2.5 s; deceleration rate of 3.4 m/s^2 [11.2 ft/s^2] used to determine calculated sight distance.

Exhibit 3-1. Stopping Sight Distance

Source: Green book, pp. 112

Effect of Grade on SSD – adjust d_2 only:

Metric	US Customary
$d = \frac{V^2}{254\left(\left(\frac{a}{9.81}\right) \pm G\right)}$	$d = \frac{V^2}{30\left(\left(\frac{a}{32.2}\right) \pm G\right)}$ (3-3)

G: Grade in percent

Inside GB equations of SSD:

Used: passenger car, object height: 2 ft., eye-height: 3.5 ft.
Truck: high eye-height compensate lower acceleration/deceleration rate, no Separate design needed except for downgrade condition.

for design: on grades

Metric							US Customary						
Design speed (km/h)	Stopping sight distance (m)						Design speed (mph)	Stopping sight distance (ft)					
	Downgrades			Upgrades				Downgrades			Upgrades		
	3%	6%	9%	3%	6%	9%		3%	6%	9%	3%	6%	9%
20	20	20	20	19	18	18	15	80	82	85	75	74	73
30	32	35	35	31	30	29	20	116	120	126	109	107	104
40	50	50	53	45	44	43	25	158	165	173	147	143	140
50	66	70	74	61	59	58	30	205	215	227	200	184	179
60	87	92	97	80	77	75	35	257	271	287	237	229	222
70	110	116	124	100	97	93	40	315	333	354	289	278	269
80	136	144	154	123	118	114	45	378	400	427	344	331	320
90	164	174	187	148	141	136	50	446	474	507	405	388	375
100	194	207	223	174	167	160	55	520	553	593	469	450	433
110	227	243	262	203	194	186	60	598	638	686	538	515	495
120	263	281	304	234	223	214	65	682	728	785	612	584	561
130	302	323	350	267	254	243	70	771	825	891	690	658	631
							75	866	927	1003	772	736	704
							80	965	1035	1121	859	817	782

Exhibit 3-2. Stopping Sight Distance on Grades

Source: Green book, pp. 115

SSD Example

Use basic assumptions to determine SSD at 60 mph on
a) 0% grade, b) 3% grade

$$SSD = 1.47\ V\ (2.5\ sec) + \frac{V^2}{30(\{11.2/32.2\} + 0.00)}$$

SSD = 220.5 + 345.5 = 556 ft

(compare to table 3-1 in GB – See next slide)

On a +3% grade, SSD = 220 +318 = 538 ft

Metric					US Customary				
			Stopping sight distance					Stopping sight distance	
Design speed (km/h)	Brake reaction distance (m)	Braking distance on level (m)	Calculated (m)	Design (m)	Design speed (mph)	Brake reaction distance (ft)	Braking distance on level (ft)	Calculated (ft)	Design (ft)
20	13.9	4.6	18.5	20	15	55.1	21.6	76.7	80
30	20.9	10.3	31.2	35	20	73.5	38.4	111.9	115
40	27.8	18.4	46.2	50	25	91.9	60.0	151.9	155
50	34.8	28.7	63.5	65	30	110.3	86.4	196.7	200
60	41.7	41.3	83.0	85	35	128.6	117.6	246.2	250
70	48.7	56.2	104.9	105	40	147.0	153.6	300.6	305
80	55.6	73.4	129.0	130	45	165.4	194.4	359.8	360
90	62.6	92.9	155.5	160	50	183.8	240.0	423.8	425
100	69.5	114.7	184.2	185	55	202.1	290.3	492.4	495
110	76.5	138.8	215.3	220	60	220.5	345.5	566.0	570
120	83.4	165.2	248.6	250	65	238.9	405.5	644.4	645
130	90.4	193.8	284.2	285	70	257.3	470.3	727.6	730
					75	275.6	539.9	815.5	820
					80	294.0	614.3	908.3	910

Note: Brake reaction distance predicated on a time of 2.5 s; deceleration rate of 3.4 m/s^2 [11.2 ft/s^2] used to determine calculated sight distance.

Exhibit 3-1. Stopping Sight Distance

Source: *A Policy on Geometric Design of Highways and Streets* (The Green Book). Washington, DC. American Association of State Highway and Transportation Officials, 2001 4th Ed.

SSD Example

Given: Available Sight distance = 430’ on a +3% grade

Find maximum speed if perception reaction time is assumed to be 2.5 seconds

$$430 \text{ feet} = 1.47\,V(2.5 \text{ sec}) + \frac{V^2}{30(\{11.2/32.2\} + 0.03)}$$

$$430 \text{ feet} = 3.68\,V + \frac{V^2}{30(0.378)}$$

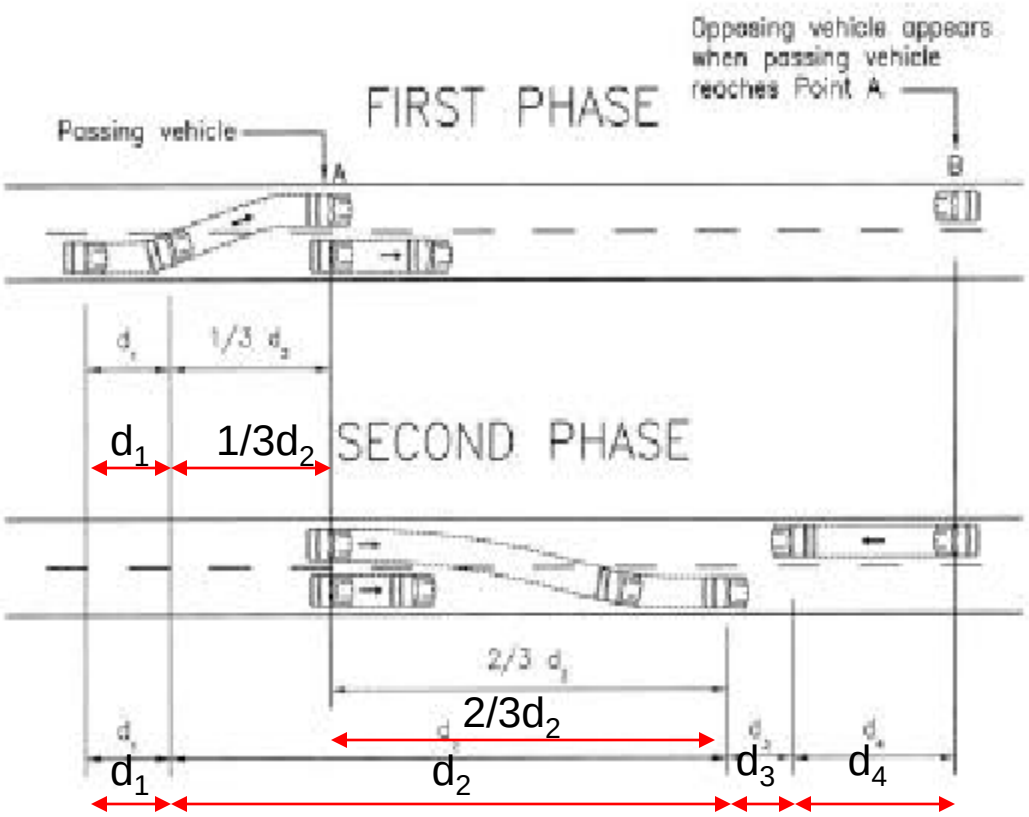
Solving for V, V = 52.0 mph (Set speed at 50 mph)

- A motorist traveling down a grade of 5% on a highway observes an accident at a distance of 635.5ft ahead of him involving an overturned truck that is completely blocking the road. He also read a warning sign at a distance of 500 ft from the truck. If the motorist was able to stop his vehicle 30 ft from the overturned truck, what was the travel speed when the driver first reacted with the accident? (Use t= 2.5 sec and f = 0.3).

Passing Sight Distance

إن التصميم الجيد لابد ان يوفر مسافات كافية على طول الطريق لتمكين المركبات المسرعة من تجاوز المركبات البطيئة التى تسير فى إتجاهها وتتكون مسافة الرؤية للتجاوز من مجموع المسافات الآتية:

Two phase passing maneuver



Source: Green book, pp. 119

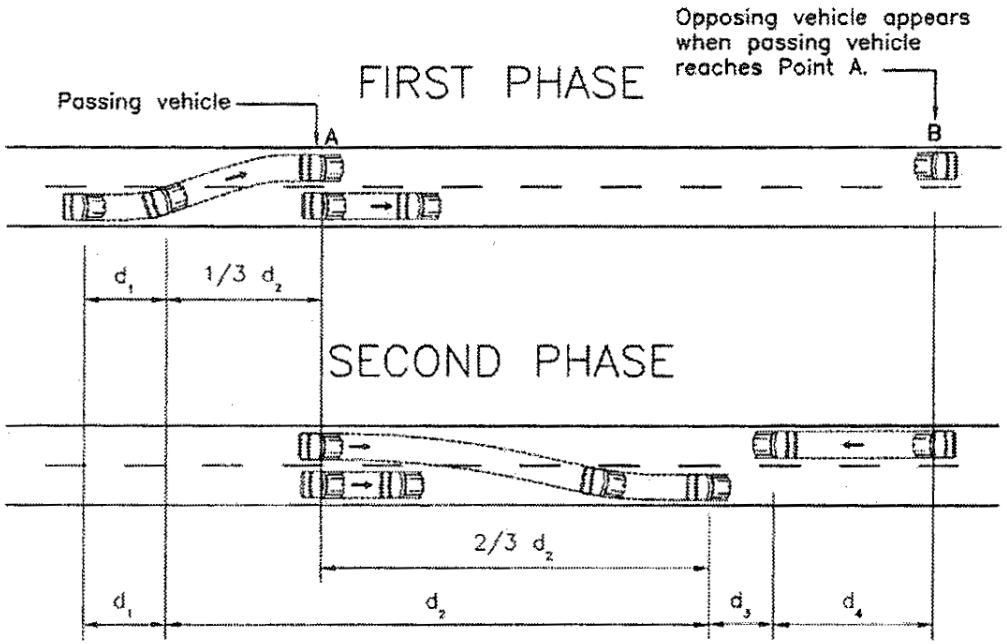
d1- مسافة إستيعاب الموقف وإتخاذ القرار والانتقال إلى الحارة العكسية -

d2- المسافة التى تحركتها العربة المتجاوزة خلال الحارة المقابلة العكسية

d3 - مسافة الخلوص بين المركبتين بعد إتمام عملية التجاوز -

d4_ المسافة التى تحركتها العربة المقابلة فى الاتجاه المقابل أثناء عملية المناورة

- d_1—Distance traversed during perception and reaction time and during the initial acceleration to the point of encroachment on the left lane.
- d_2—Distance traveled while the passing vehicle occupies the left lane.
- d_3—Distance between the passing vehicle at the end of its maneuver and the opposing vehicle.
- d_4—Distance traversed by an opposing vehicle for two-thirds of the time the passing vehicle occupies the left lane, or 2/3 of d_2 above.



Source: *A Policy on Geometric Design of Highways and Streets* (The Green Book). Washington, DC. American Association of State Highway and Transportation Officials, 2001 4th Ed.

Exhibit 3-4. Elements of Passing Sight Distance for Two-Lane Highways

Assumptions

1. Vehicle being passed travels at uniform speed
2. Speed of passing vehicle is reduced behind passed vehicle as it reaches passing section
3. Passing vehicle accelerates during the passing maneuver and velocity of the passing vehicle is 10 mph greater than that of the passed vehicle
4. Enough distance is allowed between passing and oncoming vehicle when the passing vehicle returns to its lane

Passing Sight Distance

$$D_{passing} = d_1 + d_2 + d_3 + d_4$$

d_1 = distance traveled during P/R time to point where vehicle just enters the left lane

$$d_1 = 1.47 t_1 \left(v - m + \frac{a t_1}{2} \right)$$

where

t_1 = time for initial maneuver (sec) (from 3:5 sec.)

V = average speed of passing vehicle (mph)

a = acceleration (mph/s)

acceleration rates range from 1.40 to 1.5 mph/sec

m = difference between speeds of passing and passed vehicle (10 mph)

Passing Sight Distance

$D_{passing} = d_1 + d_2 + d_3 + d_4$

d2 = distance traveled by vehicle while in left lane

$d2 = 1.47vt_2$

where:

v = speed of passing vehicle (mph)

t_2 = time spent passing in left lane (sec)

(from 9:11 sec. = 10 sec. as avge.)

Passing Sight Distance

$D_{passing} = d_1 + d_2 + d_3 + d_4$

d_3 = clearance distance varies from 110 to 300 feet

d_4 = distance traveled by opposing vehicle during passing maneuver

d_4 usually taken as 2/3 d_2

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.

Source: Green book, pp. 120

Metric					US Customary				
Design speed (km/h)	Assumed speeds (km/h)		Passing sight distance (m)		Design speed (mph)	Assumed speeds (mph)		Passing sight distance (ft)	
	Passed vehicle	Passing vehicle	From Exhibit 3-6	Rounded for design		Passed vehicle	Passing vehicle	From Exhibit 3-6	Rounded for design
30	29	44	200	200	20	18	28	706	710
40	36	51	266	270	25	22	32	897	900
50	44	59	341	345	30	26	36	1088	1090
60	51	66	407	410	35	30	40	1279	1280
70	59	74	482	485	40	34	44	1470	1470
80	65	80	538	540	45	37	47	1625	1625
90	73	88	613	615	50	41	51	1832	1835
100	79	94	670	670	55	44	54	1984	1985
110	85	100	727	730	60	47	57	2133	2135
120	90	105	774	775	65	50	60	2281	2285
130	94	109	812	815	70	54	64	2479	2480
					75	56	66	2578	2580
					80	58	68	2677	2680

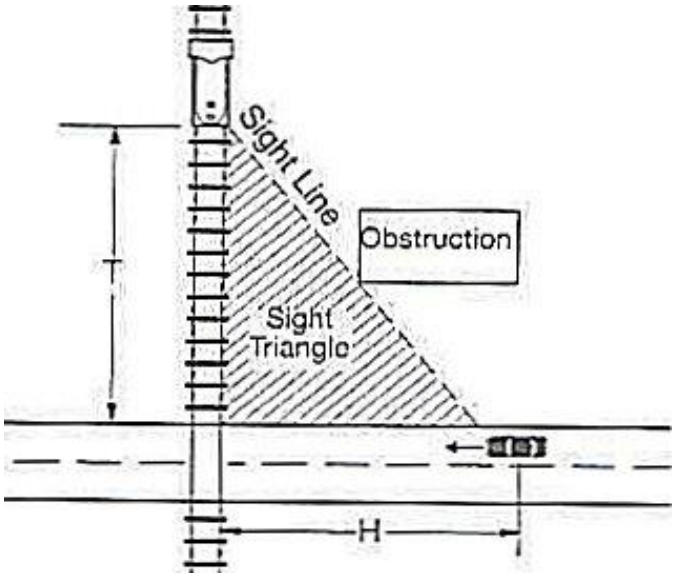
Exhibit 3-7. Passing Sight Distance for Design of Two-Lane Highways

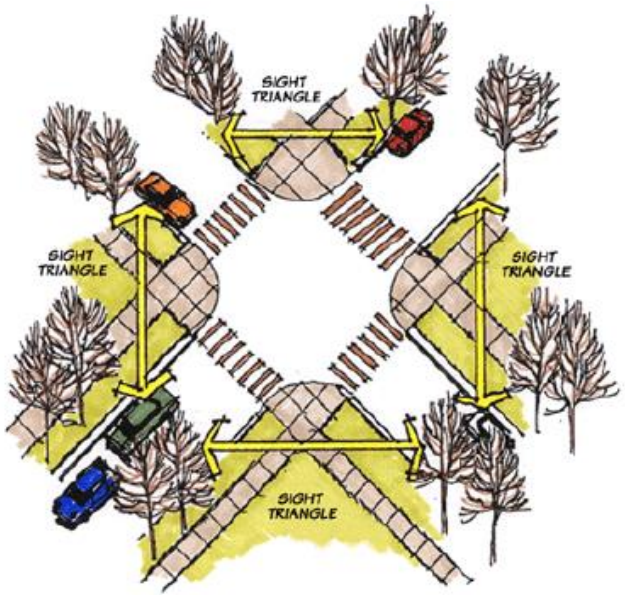
Source: Green book, pp. 124

Important Sight Distances (cont.)

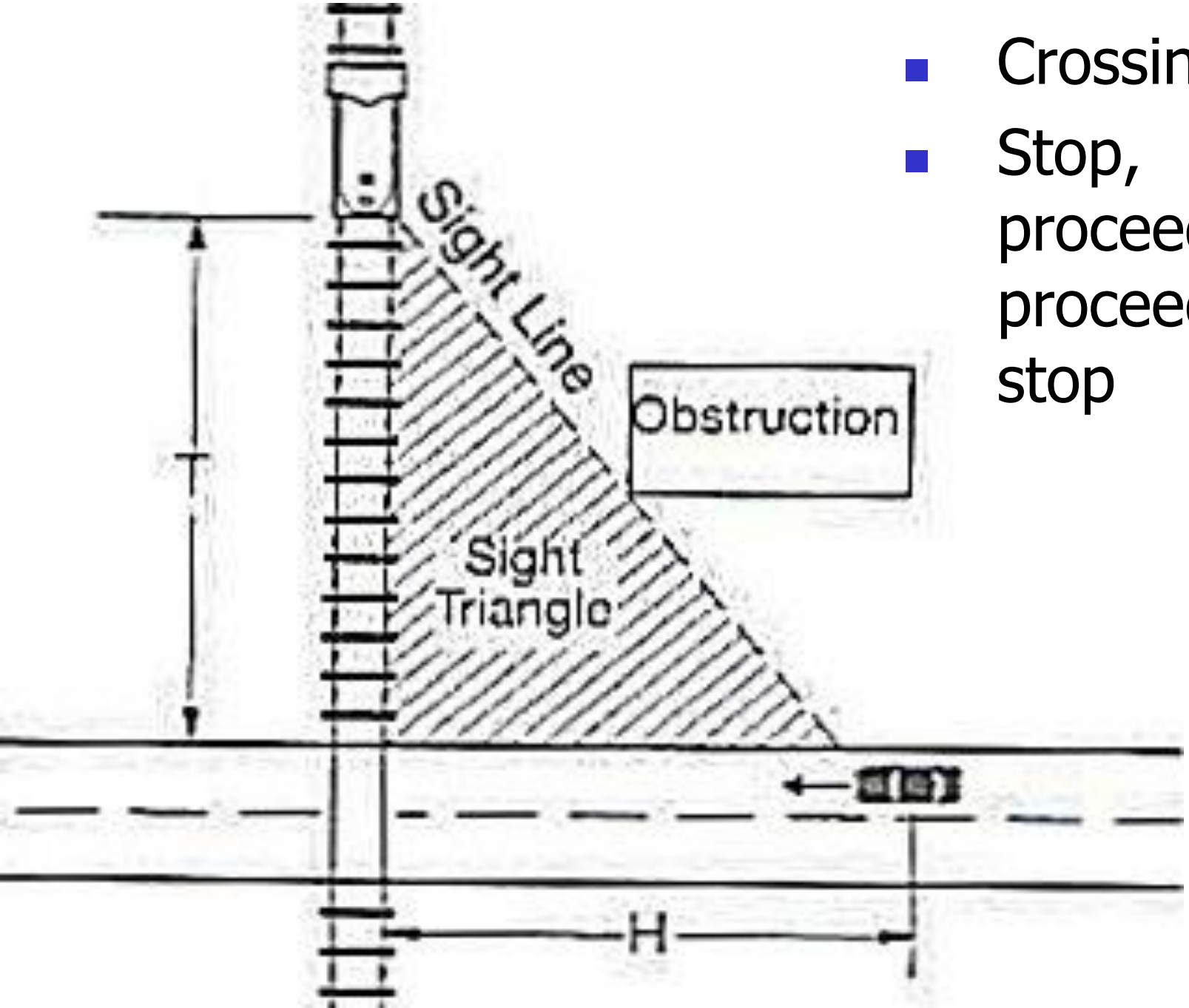
Intersection (turning/crossing)-

Crossing RR

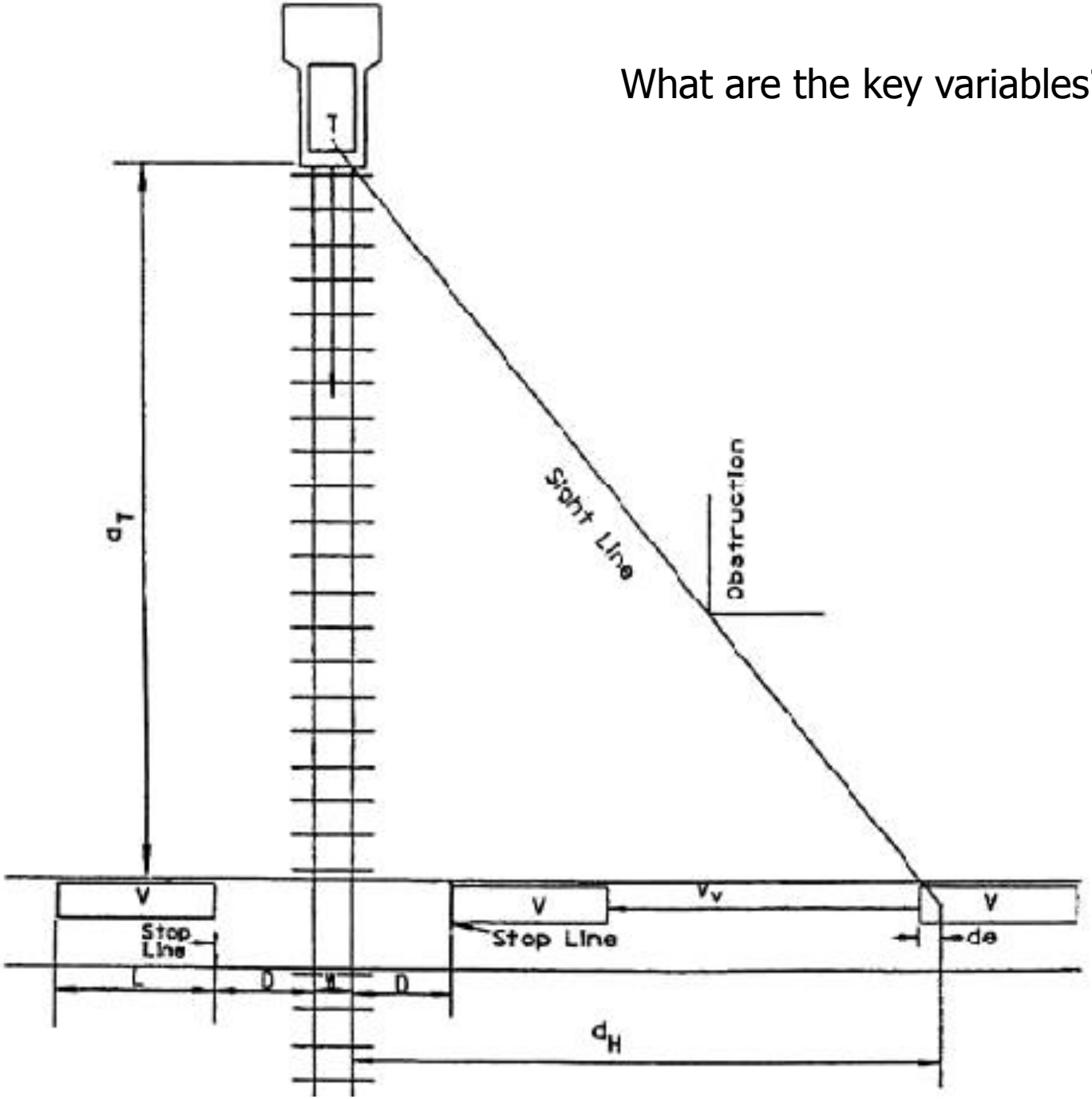




- Crossing RR
- Stop, proceed, proceed from stop



What are the key variables?



Key issues in safe crossing

Speeds
Distance from front of vehicle to driver's eye
Distance from rail to front of vehicle
Assumptions about PR time and braking distance
Width of crossing
Distance from end of vehicle after crossing
Length of vehicle
Acceleration capability of road vehicle

Offset of obstruction from the road and the rail line

In the shown Figure: **How could you control the speed on Road (B) to satisfy the stopping condition and maintain the design speed on Road (A)**