Sight Distances

Highway and Traffic Engineering

Objectives

1. Know 5 types of sight distance and important determinants

Important Sight Distances

1. Stopping
2. Decision
3. Passing
4. Intersection
5. Crossing RR

Sight Distance in Design

- For safety, should provide sight distance of sufficient length so that drivers can control the operation of their vehicles to avoid striking an unexpected object in the traveled way - STOPPING SIGHT DISTANCE (SSD)
- Certain 2-lane roads should have sufficient sight distance to enable drivers to occupy the opposing traffic lane for passing other vehicles without risk of crash - PASSING SIGHT Distance (PSD)

Green Book (AASHTO) Policy Question

- Sight distance assumes drivers are traveling at:
  - A. The posted speed limit
  - B. 10 mph above the speed limit
  - C. The 85% percentile spot speed of the facility
  - D. The design speed of the facility

Design Policy - Response

- Sight distance assumes drivers are traveling at:
  - A. The posted speed limit
  - B. 10 mph above the speed limit
  - C. The 85% percentile spot speed of the facility
  - **D. The design speed of the facility**

Green Book Question

- Stopping sight distance is composed of two distances, what are they?

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  - Distance traveled during perception/reaction time
  - Distance required to physically brake vehicle

Studies on Perception/Reaction Time

- 321 drivers (Johansson and Ruma): drivers expected to use brakes
  - Median: 0.66 sec
  - 90th percentile: >= 1.5 sec
- Unexpected, response time increased by ~ 1 sec
- Some drivers took over 3.5 seconds to respond even under simple test condition

Green Book Question

- AASHTO Green Book recommends 2.5 seconds, this is adequate for conditions that are more complex than the simple conditions used in laboratory and road tests, but is not adequate for what?

Class - Develop a Table to Track Variations in Policy Assumptions

Case	P – R Time	Accel. rate	Eye height	Object height	Notes
SSD	2.5	11.2	3.5	2.0	Object = tail light ht.
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Sight distance

- Distance a driver can see ahead at any specific time
- Must allow sufficient distance for a driver to perceive/react and stop etc when necessary

Stopping Sight Distance (SSD)

- Required for every point along alignment (horizontal and vertical) – Design for it, or sign for lower, safe speed
- Available SSD = f(roadway alignment, objects off the alignment, object on road height
- SSD = PRD + BD (with final velocity $V_2 = 0$)

Criteria for Sight Distance

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

- 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
  - AASHTO represents friction as a/g which is a function of the roadway, tires, etc
  - Can use when deceleration is known (usually not)

$$BD = \frac{V^2}{30\left[\frac{(a)}{(g)} \pm G\right]}$$

Where:

BD = braking distance (ft)

V = speed (mph)

a = deceleration rate (ft/s^2)

G = grade (decimal)

g = acceleration due to gravity =32.2 ft/s^2

Braking Distance

- Assumes a rate of deceleration, driver may brake harder
- $a = 11.2$ ft/sec^2 normal
- $a = 14.8$ ft/sec^2 emergency, use tables from AASHTO
- Friction is a function of pavement condition (wet, icy), tire, and roadway surface
- Depends on weight, but some assumptions are made to arrive at a standard equation

SSD Equation

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

SSD	in feet
U	speed in mph
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

SSD Example

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

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

SSD = 220.5 + _345.5 = 566 ft

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

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

Stopping (emergency) – SSD (Table 3-1)

Metric					US Customary				
Design speed (km/h)	Brake reaction distance (m)	Braking distance on level (m)	Stopping sight distance		Design speed (mph)	Brake reaction distance (ft)	Braking distance on level (ft)	Stopping sight distance	
			Calculated (m)	Design (m)				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

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

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

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

Discuss: Would this be an acceptable condition if the road is generally posted for 60 mph?

Stopping Sight Distance Example

- Consider analysis when vehicle skids across different surfaces (a/g is not equal to 0.35)
- Or final velocity is not zero at the end of the skid, as evidenced because the vehicle sustains crushing damage until the vehicle is stopped.

Stopping Sight Distance

With assumed acceleration, using friction

$$S = PRD + D_b$$

$$= 1.47ut + \frac{v_o^2 - v_f^2}{30(f \pm G)}$$

where:

terms are as before, except

v_o = original velocity

v_f = final velocity at impact

Stopping Sight Distance Example

Accident Reconstruction:

- Average Skid Mark = 47 feet
- Crush damage indicates 20 to 30 mph speed at impact
- f = 0.65 ,level roadway, and 40 mph posted speed.
- Was vehicle speeding?
- 47 feet skid represents what? BD?

If final speed is 30 mph …

$BD = 47 = (V_i^2 - 30^2)/30(0.65 + 0)$

$V_i = 42.6$ mph

If final speed is 20 mph ($V_i = 36.3$ mph)

- What if pavement changes to gravel after 47 feet and car slides another 30 feet (f = 0.7)? What is initial speed?

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

Source: Lynn Fricke, Northwestern Univ.

Decision Sight Distance

- SSD are sufficient to allow reasonable competent and alert drivers to come to a hurried stop under ordinary circumstances
- May be inadequate when drivers must make complex or instantaneous decisions, when information is difficult to perceive or when unexpected or unusual maneuvers are required
- Equations in book, use tables

Decision Sight Distance

- When situation is unexpected or driver makes unusual maneuvers or under difficult to perceive situations
- Requires higher P/R time
- Depends on type of maneuver made and roadway setting (urban vs. rural)
- Use table 3.3 from Text, (Green book)

Source: *A Policy on Geometric Design of Highways and Streets* (The Green Book).

Metric						US Customary					
Design speed (km/h)	Decision sight distance (m) Avoidance maneuver					Design speed (mph)	Decision sight distance (ft) Avoidance maneuver				
	A	B	C	D	E		A	B	C	D	E
50	70	155	145	170	195	30	220	490	450	535	620
60	95	195	170	205	235	35	275	590	525	625	720
70	115	235	200	235	275	40	330	690	600	715	825
80	140	280	230	270	315	45	395	800	675	800	930
90	170	325	270	315	360	50	465	910	750	890	1030
100	200	370	315	355	400	55	535	1030	865	980	1135
110	235	420	330	380	430	60	610	1150	990	1125	1280
120	265	470	360	415	470	65	695	1275	1050	1220	1365
130	305	525	390	450	510	70	780	1410	1105	1275	1445
						75	875	1545	1180	1365	1545
						80	970	1685	1260	1455	1650

Avoidance Maneuver A: Stop on rural road—t = 3.0 s
Avoidance Maneuver B: Stop on urban road—t = 9.1 s
Avoidance Maneuver C: Speed/path/direction change on rural road—t varies between 10.2 and 11.2 s
Avoidance Maneuver D: Speed/path/direction change on suburban road—t varies between 12.1 and 12.9 s
Avoidance Maneuver E: Speed/path/direction change on urban road—t varies between 14.0 and 14.5 s

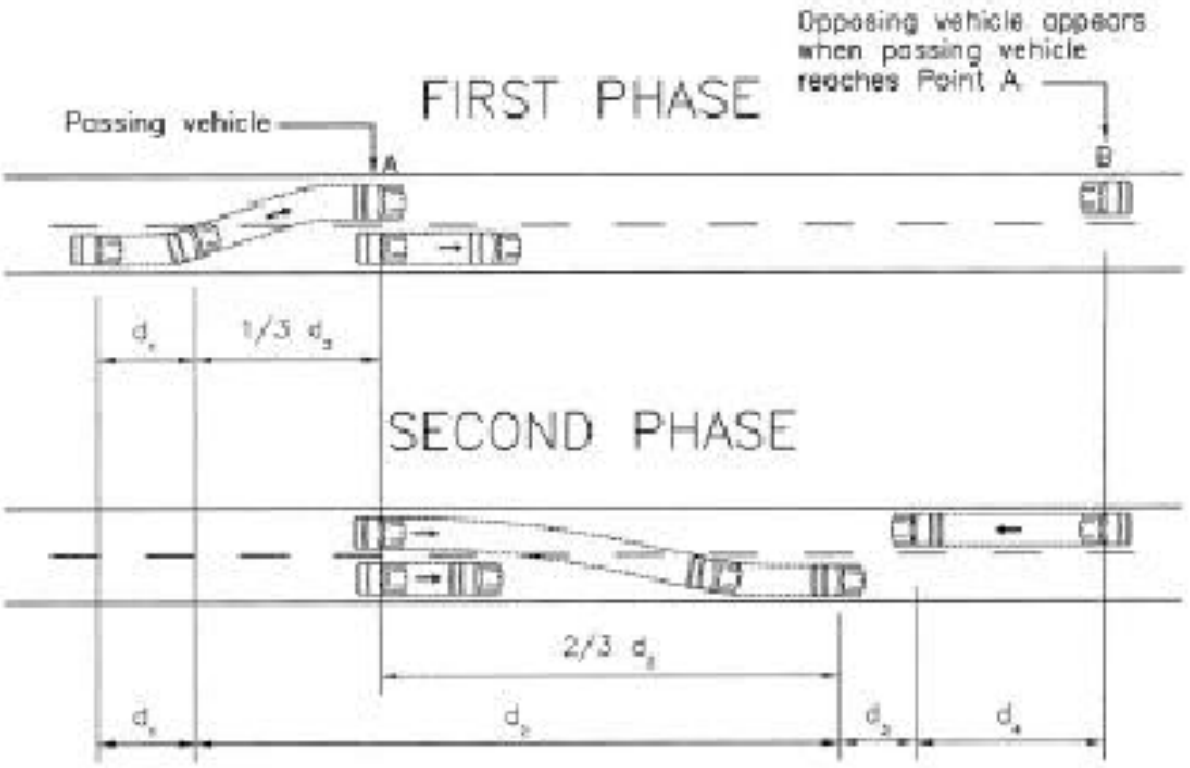
Exhibit 3-3. Decision Sight Distance

Passing Sight Distance

Assumptions (conservative?):

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

- d_1—Distance traversed during perception and reaction time and during the initia 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

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

$$d_1 = 1.47t_1\left(u - m + \frac{at_1}{2}\right)$$

where

t_1 = time for initial maneuver (sec)

u = average speed of passing vehicle (mph)

a = acceleration (mph/s)

m = difference between speeds of passing and passed vehicle

Passing Sight Distance

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

d_2 = distance traveled by vehicle while in left lane

$d_2 = 1.47ut_2$

where:

u = speed of passing vehicle (mph)

t_2 = time spent passing in left lane (sec)

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

PSD - observations

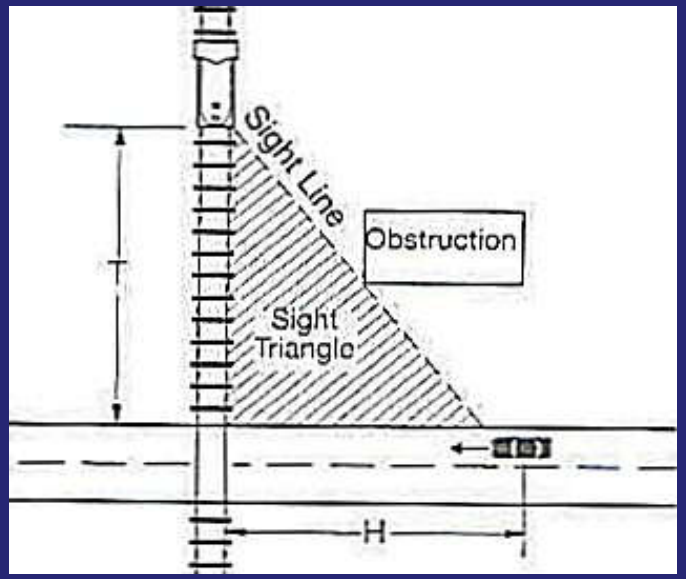
- Would new research be of value?:
  a = acceleration rates range from 1.40 to 1.5 mph/sec^2
  (could this element be ignored in d1?)
- What % of total distance is this portion of PSD?

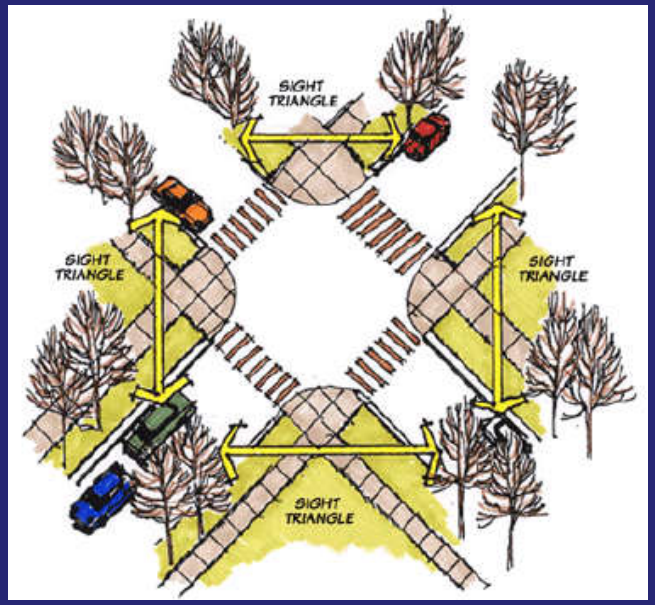
- Acceleration rates in the formula have not changed since 1954.

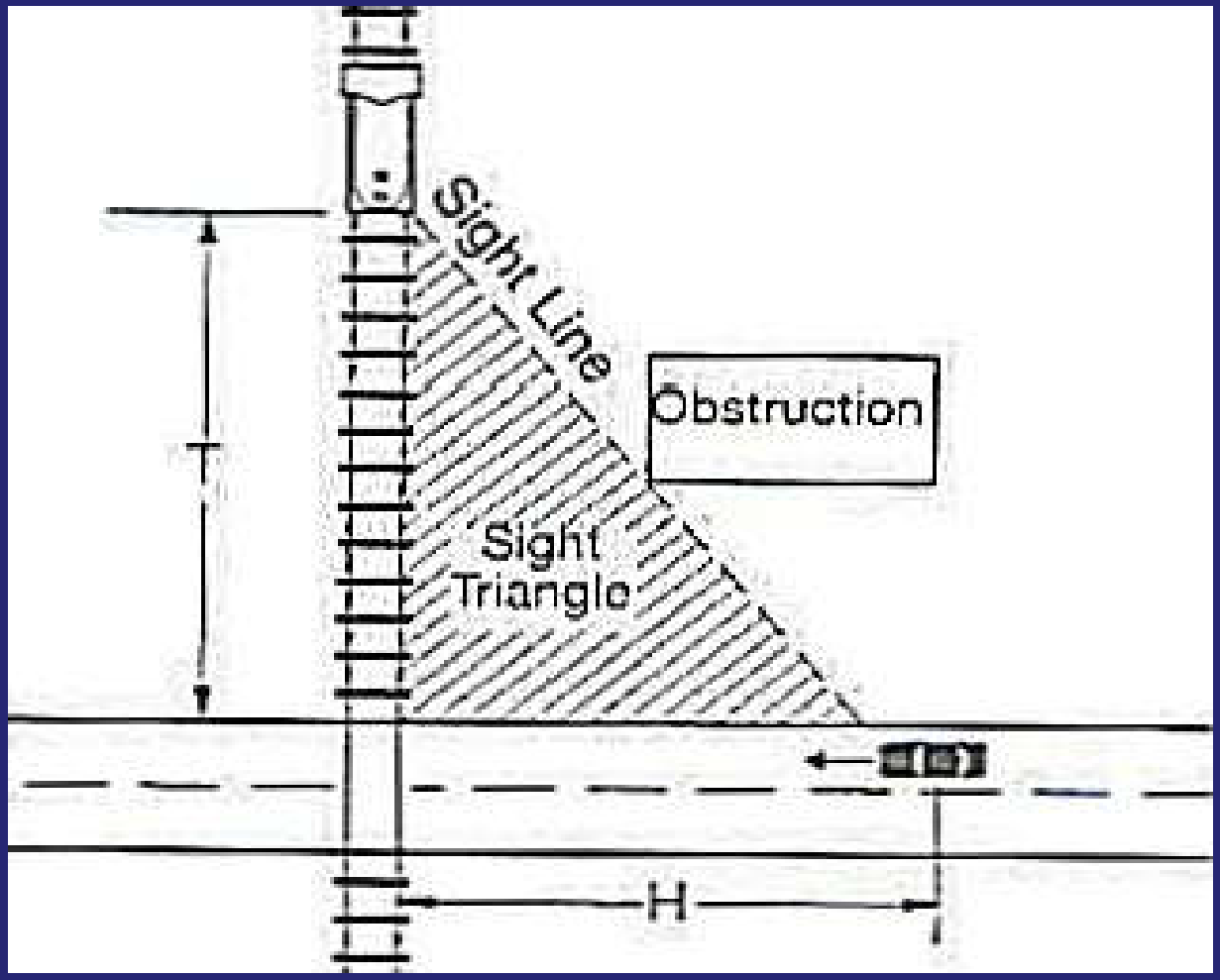
- Clearance interval distances, d3: apparently based on observation of driver behavior. Tabled values have not changed since 1954.

Important Sight Distances (cont.)

- Intersection (turning/crossing)
  - Stop, proceed, proceed from stop



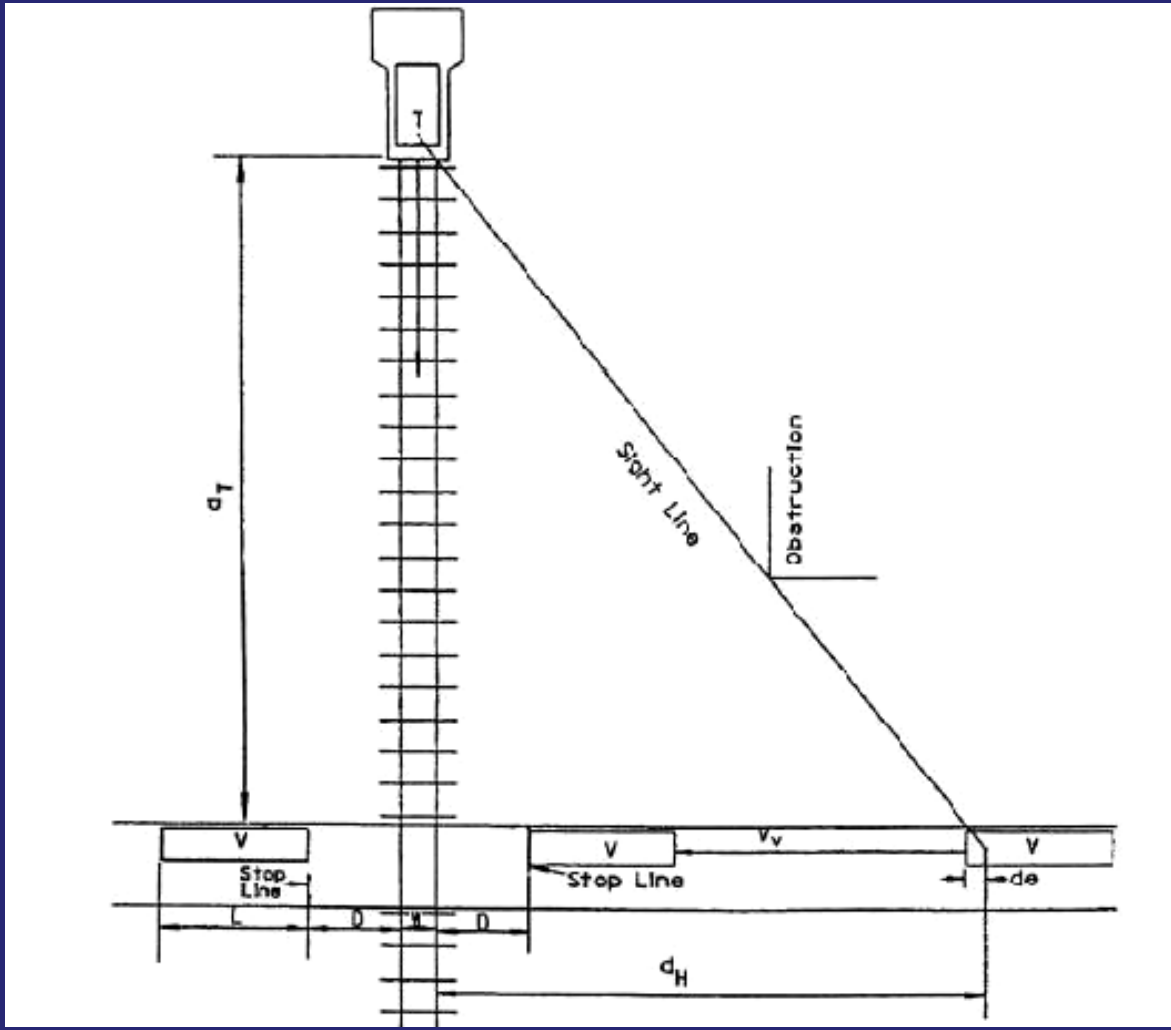




Crossing RR

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