Baystate Roads Program
Local Technical Assistance Program (LTAP)
Tech Notes

Tech Note #37 -- 2004

Passing Sight Distance

As Massachusetts continues to resurface the state road network, solid centerlines are replacing yellow dashed centerlines. What does this mean for the Massachusetts commuter?

Dashed lines are important tools in road design as they provide drivers with guidance in determining when they might have an opportunity to pass another vehicle safely. Passing zones exist for the engineering purposes of moving traffic more efficiently on a two-lane road and showing drivers where the sight distance is adequate for a passing maneuver. With the large network of scenic roads available in Massachusetts and the state's high tourist rate which swells during certain seasons, passing zones allow locals and visitors the opportunity to safely pass other vehicles.

Passing zones and passing lanes alleviate untold amounts of frustration every year and are an integral part of the highway system. Where space is available, passing lanes are an excellent way to minimize risky behavior and maximize level of service by allowing trucks to climb a hill at their own pace while allowing passenger vehicles to travel at higher speeds. Passing zones are used where the space and capital are not always available to add a passing zone.

Road designers designate potential passing zones during the initial design of a roadway. This allows for potential passing / no-passing zones to be marked in the field if the zones are determined to be necessary. The available sight distance at these potential passing areas is then checked in the field during construction. Because passing maneuvers depend on the behavior of individual drivers, certain assumptions are made. The minimum sight distance should accommodate the passing abilities of a high percentage of drivers.

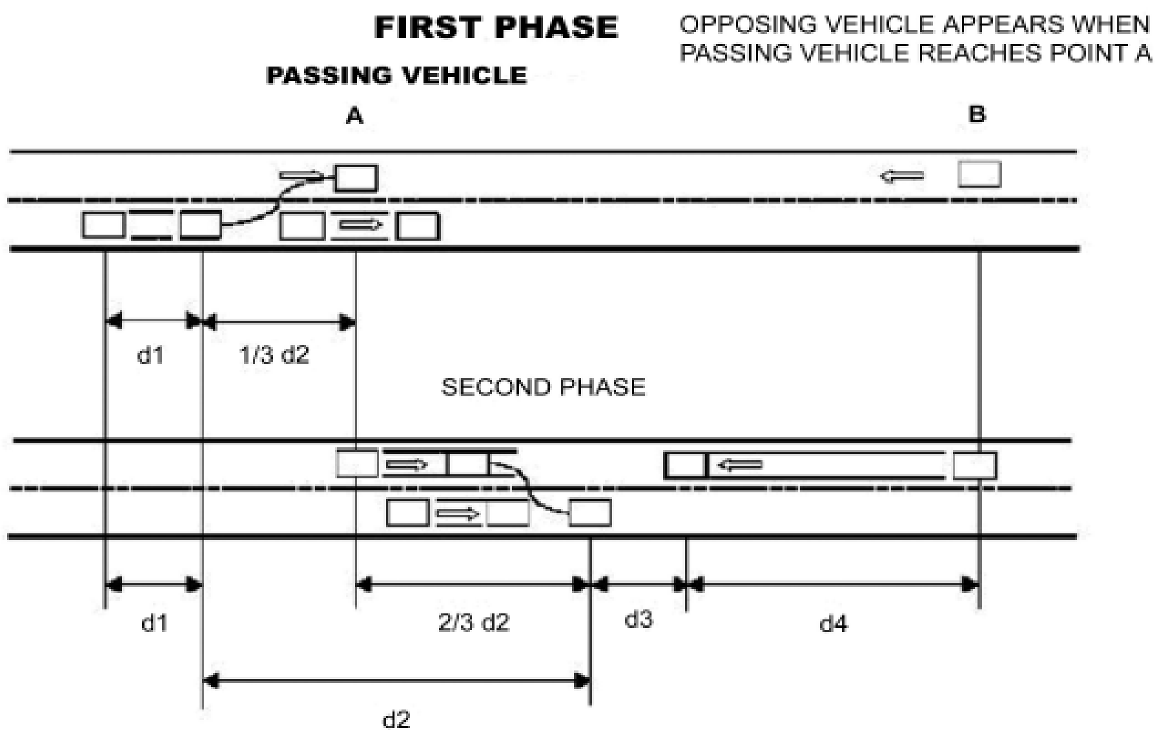

Figure 1. Elements of Passing Sight Distance for Two-Lane Highways (Exhibit 3-4 from the AASHTO Green Book)

The minimum passing sight distance is made up of the following four distance components:

•d1 - Distance traversed during perception reaction time and during the initial acceleration to the point of encroachment on the left lane
•d2 - Distance traveled while the passing vehicle occupies the left lane
•d3 - Distance between the passing vehicle at the end of its maneuver and the opposing vehicle
•d4 - Distance traversed by an opposing vehicle for two-thirds of the time the passing vehicle occupies the left lane, or 2/3 of d2 above.

Because the purpose of these specific distances might not be obvious at this point, a short discussion of each of these components can be found below. In addition, Figure 1 gives a graphical explanation of these distances, while Table 1 gives a numerical breakdown.

d_1: Initial Maneuver Distance

$d_1 = 1.47t_1(v - m + at_1/2)$

where:
t_1 = time of initial maneuver, s;
a = average acceleration, mph/s;
v = average speed of passing vehicle, mph;
m = difference in speed of passed vehicle and passing vehicle, mph.

The perception-reaction-acceleration distance isn't hard to understand. The only aspect of this distance that might be confusing is the simultaneous nature of perception and acceleration. Some drivers will begin accelerating before they enter the passing section and will continue to accelerate while they scan the opposing lane for traffic.

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
Initial maneuver:								
a= average acceleration[a]	2.25	2.3	2.37	2.41	1.4	1.43	1.47	1.5
t_1 = time (sec)[a]	3.6	4.0	4.3	4.5	3.6	4	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	10.7	11.3
d_2 = distance traveled	145	195	251	314	477	643	827	1030
Clearance length:								
d_3 = distance traveled	30	55	75	90	100	180	250	300
Opposing vehicle:								
	97	130	168	209	318	429	552	687
Total distance, d1+d2+d3+d4	317	446	583	726	1040	1468	1918	2383

Note: In the metric portion of the table, speed vales 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.

Table 1. Elements of Safe Passing Sight Distance for Design of Two-Lane Highways (Exhibit 3-5 from AASHTO Green Book)

These drivers tend to accelerate at a reduced rate. Other drivers will avoid accelerating until they have determined that the opposing lane is clear, but they will accelerate at a higher rate once they have decided to pass. The net effect is that the perception-reaction-acceleration distance is identical for both types of drivers. The distance d_1 and the corresponding time t_1 were measured for several different passing vehicle speeds. More recent research has confirmed that the accepted values are conservative.

d_2: Occupancy Distance

$d_2 = 1.47vt_2$
where:
t = time passing vehicle occupies the left lane, s;
v = average speed of passing vehicle, mph

The distance traveled during the occupancy of the left lane is also easy to understand. Since the speed of the passing vehicle was assumed to be 10 mph faster than the overtaken vehicle, it is necessary to know the time the passing vehicle occupies the left lane to calculate distance d_2. Values for this time interval were measured for several different passing vehicle speeds. These measured values were then used to develop design values for d_2.

d_3: Clearance Distance

A maneuver that feels safe will require that a certain length of roadway is present between the passing vehicle and the opposing vehicle when the passing vehicle returns to the relative safety of the right lane. The clearance distance that drivers require depends on their personality. A timid driver might require several hundred feet of clearance distance, while a more aggressive driver might consider exchanging side mirrors a perfectly acceptable practice. The clearance distance is determined from a graph in Figure 2 (Exhibit 3-6, *AASHTO Green Book*), with studies having shown that the clearance distance is normally between 100 and 300 feet.

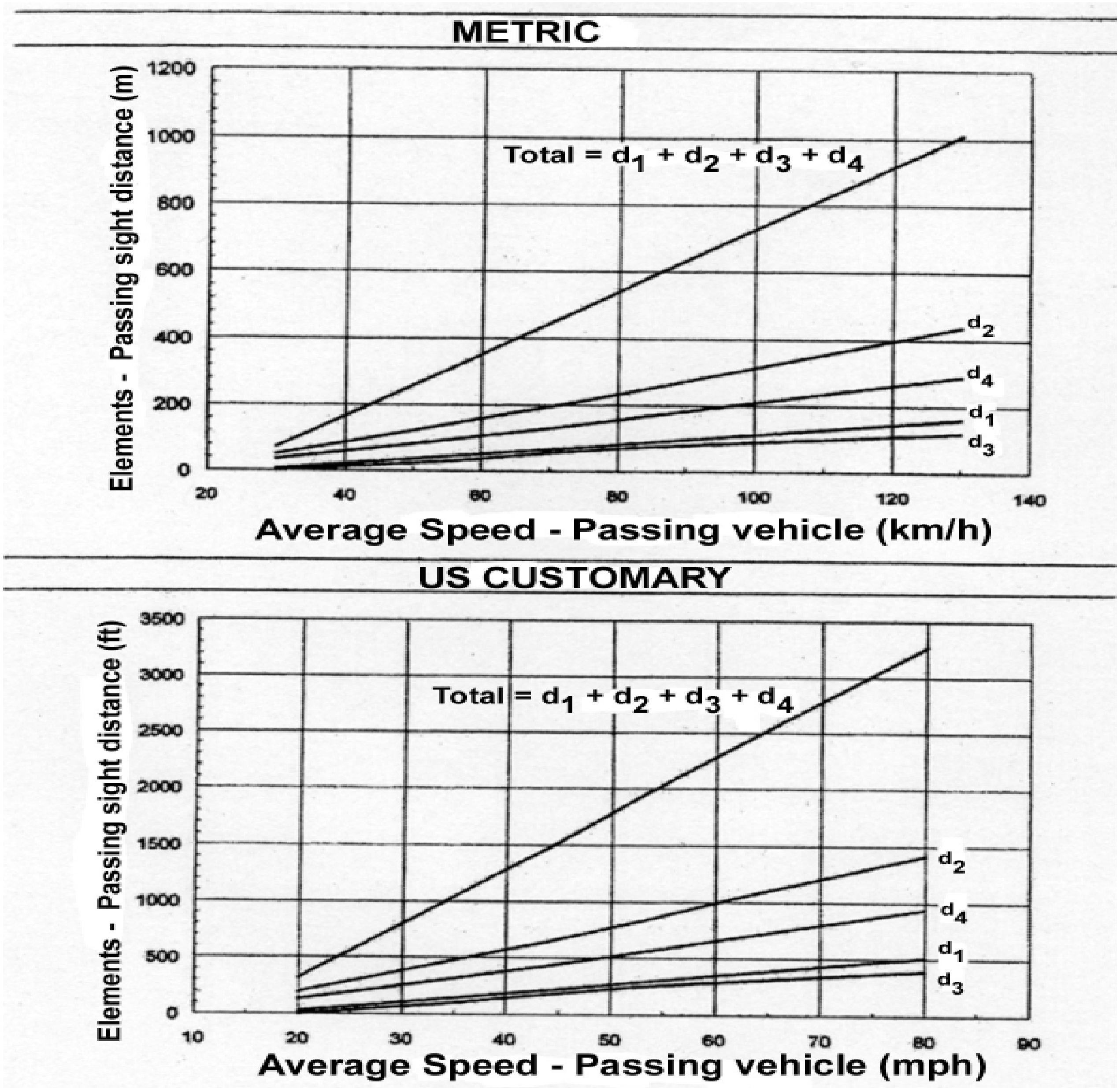

Figure 2. Total Passing Sight Distance and Its Components - Two-Lane Highways (Exhibit 3-6 from AASHTO Green Book)

d_4: Encroachment Distance

$d_4 = 2d_2/3$

This is the distance that an approaching vehicle moves during a passing maneuver. The encroachment distance is calculated by multiplying the speed of the opposing vehicle (normally assumed to be the speed of the passing vehicle) by $2/3t_2$, where t_2 is the time the passing vehicle occupies the left lane.

Imagine a passing section on a rural two-lane highway, with a speed limit of 50 mph. The passing zone is terminated by a sharp reduction in grade that prevents the passing driver from seeing any vehicles beyond the end of the passing section. This is typical of roads found all over Massachusetts, especially central and western portions of the state. Assume that the length of the passing section is equal to the sum of the distances d_1 and d_2. The passing vehicle driver could pass the slower vehicle before leaving the passing section, but can't see beyond the passing section for opposing vehicles that might conflict during the maneuver.

The question now is how much extra sight distance would the driver need to safely avoid conflict with an opposing vehicle while passing?

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	73	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

Table 2. Passing Sight Distance for Design of Two-Lane Highways (Exhibit 3-7 from AASHTO Green Book)

If it is assumed the driver can abort the maneuver if an opposing vehicle appears during interval t_1 or during the first third of the interval t_2, the sight distance can be reduced.

Assume that the passing section length is equal to the passing sight distance as defined in reality ($d = d_1 + d_2 + d_3 + d_4$). If an opposing vehicle appears just after the first third of the interval t_2 is over, the passing car can still safely pass the slower car and return to the right lane before the opposing vehicle becomes a threat. This is because the opposing vehicle is a distance $2/3d_2 + d_3 + d_4$ away from the passing vehicle. By the time that the passing vehicle has traveled the remaining $2/3d_2$ and returned to the right lane, the opposing car will have traveled d_4, and the clearance distance, d_3, will separate them. This is why we add the distances d_3 and d_4 to the passing sight distance. The distance d_4 is calculated by multiplying the speed of the opposing vehicle (normally assumed to be the speed of the passing vehicle) by $2/3t_2$.

From Table 1 (Exhibit 3-5, *AASHTO Green Book*), values are obtained for each component of the passing sight distance. For a 50 mph highway there are two options, one with a speed range of 40 to 50 mph and the other with a range of 50 to 60 mph. For increased safety a conservative estimate should be made, therefore, the higher range should be selected.

The table provides the following values:

d1 = 289 feet;
d2 = 827 feet;
d3 = 250 feet;
d4 = 552 feet

Plugging these values into the expression above provides the sight distance required for the driver of the passing vehicle to feel secure in the ability to complete the maneuver before having a conflict with another vehicle. That distance is:

Passing Sight Distance = d1 + d2 + d3 + d4 = 1918 feet

The American Association of State Highway and Transportation Officials (AASHTO) recommends minimum passing sight distances between 710 and 2,680 feet for two-lane highways for design speeds ranging from 20 to 80 mph.The minimum recommended sight distance for a passing maneuver, which can be found in Table 2 (Exhibit 3-7, *AASHTO Green Book)* is slightly less at 1,835 feet.

Passing zones should be as long as possible and should be placed as frequently as available sight distances allow. Passing opportunities have a profound effect on the level-of-service performance of two-lane highway segments. Two measures of effectiveness when evaluating highway segments are average travel speed and percentage of time spent following another vehicle. The fewer passing zones there are in a stretch of road, the more these two measures degrade.

Along with the effort to maintain the streets through resurfacing, pavement markings must also be maintained. Drivers generally take these markings for granted until they are obscured. This should be especially clear to anyone who has driven through construction zones where lane markings have been laid out, only to be ground down and moved again, until there is a maze of partial lane markings across the roadway.

Before carrying out scheduled overlay operations, all pavement markings should be clearly measured and labeled. This allows for precise placement of the new markings and ensures that the size of passing zones does not fluctuate.

References:

(1) From *A Policy on Geometric Design of Highways and Streets*, 2001, American Association of State Highway and Transportation Officials, Washington, DC. Used by permission. Publications may be purchased from the AASHTO bookstore at 1-800-231-3475 or online at: http://bookstore.transportation.org

(2) Laboratory Manual, University of Idaho, Boise, ID, 1998.