April 9, 2001

THE DILEMMA ZONE AND VOLUME DENSITY OPERATION

It has been my experience that many traffic engineers and signal technicians are a little confused when it comes to upstream detection (detection in advance of the stop line). More than once I have been in the field and heard someone incorrectly refer to a set of upstream loops as "volume-density loops" or "dilemma zone loops" when, in reality, the upstream loops being discussed were neither. As you will discover by reading the remainder of this article, the following statements are all true:

- There is no such thing as complete dilemma zone protection.
- The purpose of volume-density operation is to increase the operational efficiency of a traffic signal.
- Volume-density operation can be used in conjunction with dilemma zone protection. However, the degree of dilemma zone protection will be reduced if the two are used together. A measure of safety is sacrificed to achieve the efficiency associated with volume-density operation.
- Volume-density operation can be used with any type of detection configuration, including both stop line detection and upstream detection.
- Although dilemma zone protection requires the use of upstream detection, the use of upstream detection does not guarantee dilemma zone protection.

There is no such thing as full dilemma zone protection. In the last issue of the IMSA Journal I presented a detection design that provides dilemma zone protection for vehicles travelling between 40 mph and 55 mph. That design handles a combined dilemma zone that begins 400 feet from the stop line and ends 110 feet from the stop line. This is a reasonable detection design for an approach having a posted speed limit of 45 mph since many motorists tend to exceed the speed limit by 5 to 10 mph. However, someone traveling more than 10 mph over the speed limit would not be fully protected since their dilemma zone would begin more than 400 feet in advance of the stop line. In addition, someone travelling slower than 40 mph could get caught in the middle of the dilemma zone since a vehicle going this slow would not span the 145 foot distance between the two loops within the 2.5 second extension time.

Dilemma zone protection is also lost on an approach when the signal phase for that approach either max's-out (if the signal is not in coordinated operation) or reaches the yield point (if the signal is coordinated). Even if there is constant demand on a particular approach, the associated signal phase will eventually run out of time and, when this happens, the signal will turn yellow. This will occur even if there are motorists in the dilemma zone.

The purpose of volume-density operation is to increase the operational efficiency of a traffic signal. Volume density operation is a special type of actuated signal control that, when properly used, improves the efficiency of the signal. The characteristic of volume density operation that results in this improved efficiency is the gradual reduction of the passage interval over time; referred to as "gap reduction". As the passage interval shrinks the probability of gap-out increases. This ensures that vehicles waiting on other approaches will promptly receive the green unless a tightly grouped stream of vehicles is being served on the approach that currently has the green indication. Volume density control is efficient since a thin stream of stragglers will not continue to extend the green.

Volume-density operation can be used in conjunction with dilemma zone protection. However, the degree of dilemma zone protection will be reduced if the two are used together. A measure of safety is sacrificed to achieve the efficiency associated with volume-density operation. Unfortunately, reduction of the passage interval reduces the safety benefit offered by dilemma zone protection as the passage time becomes too small to pass vehicles through the dilemma zone before gap-out occurs (see Figure 1). The end result is that, with volume-density operation active and the on-set of gap reduction, the signal can turn yellow while a motorist is right in the middle of the dilemma zone. Consequently, volume-density operation reduces the degree of dilemma zone protection.

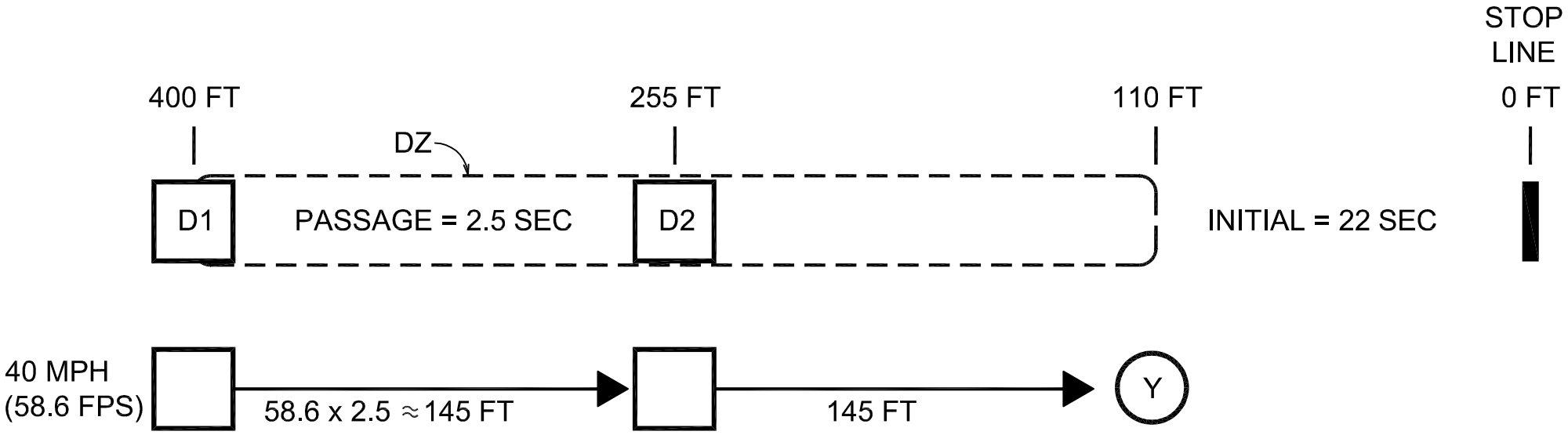
Volume-density operation can be used with any type of detection configuration, including both stop line detection and upstream detection. Although volume-density operation has been traditionally used with upstream detection, there is no reason why it cannot be used with stop line detection. The benefits of gap-reduction are achieved regardless of the location of the zone of detection with respect to the stop line. Consequently, referring to a set of upstream loops as volume-density loops is not correct. Volume-density operation is dependent on controller programming, not loop location.

Although dilemma zone protection requires the use of upstream detection, the use of upstream detection does not guarantee dilemma zone protection. Dilemma zone protection cannot be provided without the use of upstream detection. However, as shown in Figure 2, you can have upstream detection that does not provide any dilemma zone protection. Consequently, referring to a set of upstream loops as dilemma zone loops may not be correct.

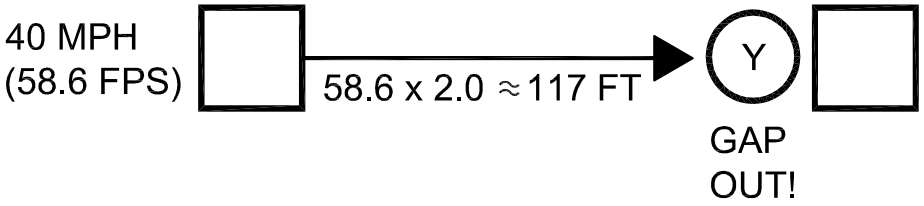
It should be noted that upstream detection can be of benefit even if no dilemma zone protection is provided. Upstream detection is often used on main street thru lanes to increase the efficiency of the signal. As is shown in Figure 3, if upstream loops are used instead of stop line loops the green indication is returned more quickly to the side street once the last main street vehicles passes. This increases the efficiency of the signal.

If you understand these concepts you will not make the mistake of calling upstream loops dilemma zone loops or volume-density loops unless they are really providing one of these two services.

FIGURE 1



WHEN PASSAGE REDUCES TO 2.0 SEC DUE TO VOLUME-DENSITY OPERATION:



AND SIGNAL TURNS YELLOW WITH
VEHICLE IN MIDDLE OF DILEMMA ZONE!

FPS = FEET PER SECOND
D1 = DETECTION AREA 1
D2 = DETECTION AREA 2
DZ = COMBINED DILEMMA ZONE FOR SPEEDS FROM 40 MPH TO 55 MPH

Y = LOCATION OF VEHICLE WHEN SIGNAL TURNS YELLOW DUE TO GAP-OUT

FIGURE 2

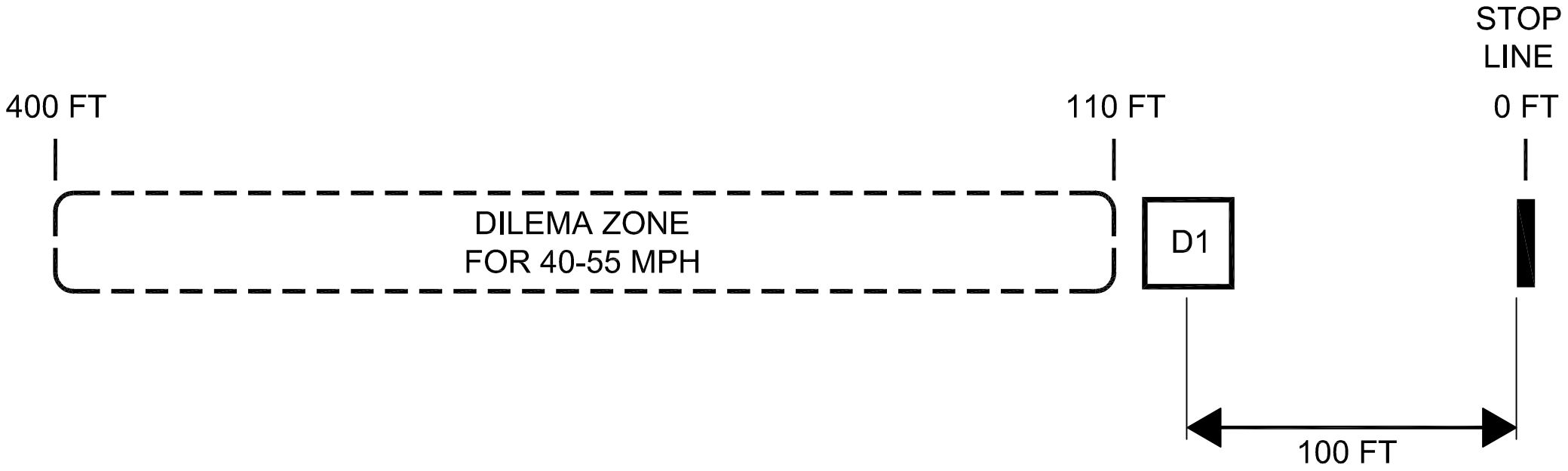
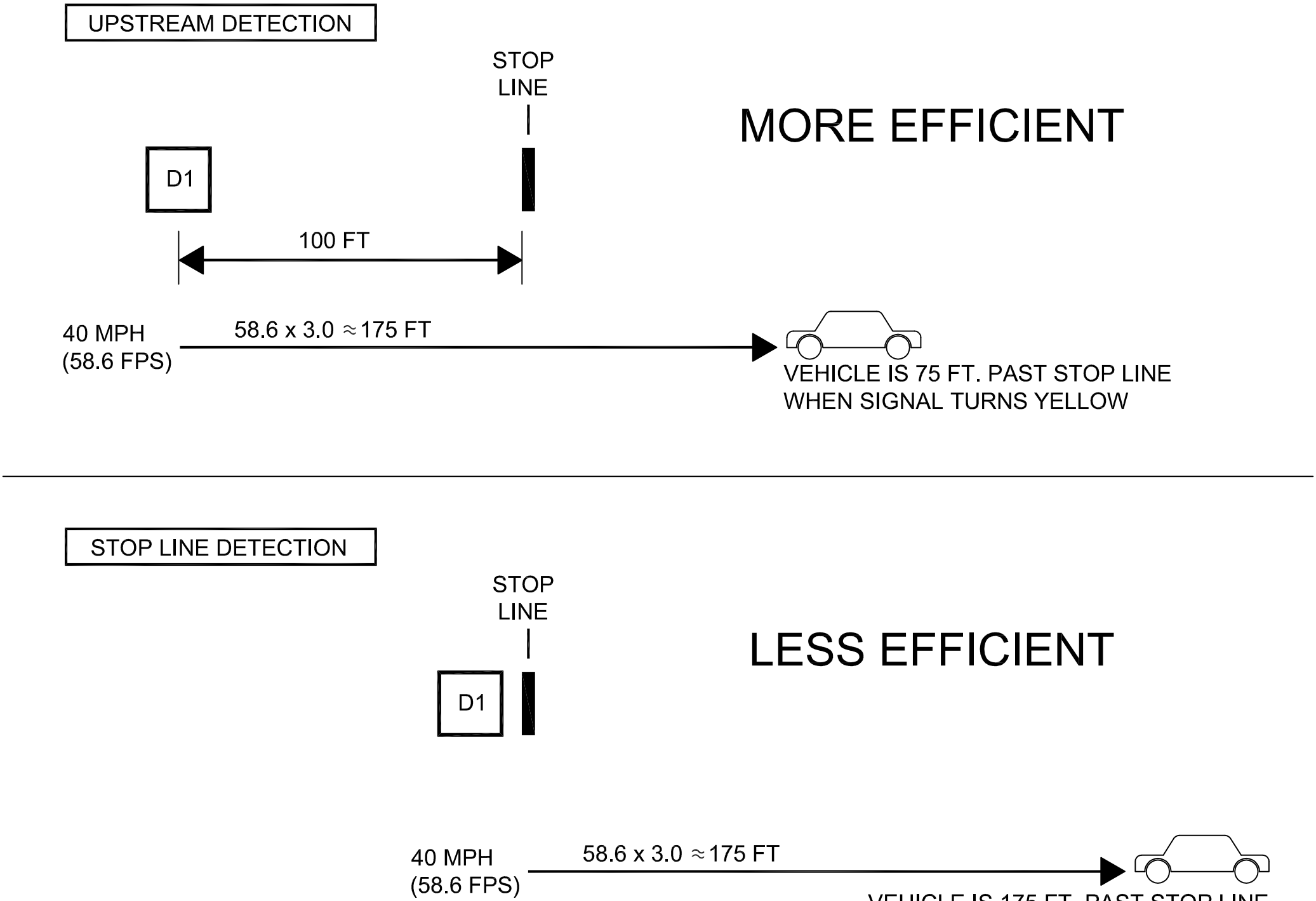


FIGURE 3


UPSTREAM DETECTION
STOP LINE
MORE EFFICIENT
D1
100 FT
40 MPH
(58.6 FPS)
58.6 x 3.0 ≈175 FT
VEHICLE IS 75 FT. PAST STOP LINE
WHEN SIGNAL TURNS YELLOW
STOP LINE DETECTION
STOP LINE
LESS EFFICIENT
D1
40 MPH
(58.6 FPS)
58.6 x 3.0 ≈175 FT
VEHICLE IS 175 FT. PAST STOP LINE
WHEN SIGNAL TURNS YELLOW