2017

Iteris Vector Camera and Detector Strategies

Iteris has come out with the Vector Camera, combining Radar Detection for far detectors with the high quality video detection of the Iteris video detection camera for stop bar detectors. This advanced camera package, combined with features of the Siemens controller, provides a huge advance in driver safety over other detection systems.

- Michael Grunewald, PE, PTOE
  Advanced Traffic Systems Manager
  MoboTrex

May 9, 2017

Iteris Vector Camera and Detection Strategies

Video Detection – In the Beginning

In the infancy of video detection (about 20 years ago), traffic engineers found many good reasons to not try video detection. Detection quality was iffy. Far detection and stop bar detection at the same time was impractical.

The promise of video detection: replace all detector loops and underground conduit for those loops with one video detection camera (per approach). It didn't really measure up to expectations.

But customers did find locations to use video detection. And, with some tradeoffs, it had its useful locations.

Over time, the video detection became better each year, and – surprise – the traffic signal industry changed. Stopbar detection with the video detectors became pretty solid. And often, engineers put in just video detection. They gave up on installing far detection on the main road. It just became too complex to argue with the planning office you needed both detector loops for far detection and video detection for the stopbar detectors. And some agencies continued to install the conduit, cable, pullboxes, and loops they needed for their far detection systems.

My observation is that, Hey, hold the phone! The Vector camera system is the delivery of that long-awaited promise. Here, in one camera package, replace all detector loops – stop bar and far detection – with one video detection package! And it's for real this time!

Why can't I just use Video Detection for my Far Detectors?

Video Detection has a rule of thumb: Height to distance is a ratio of 1:10. So for every 10 foot increment I want visibility from the camera, I need to raise the camera another foot. For a 45 mph approach, a 5-second dilemma zone detector would be placed at about 330 feet from the stop bar. The camera's mounting location is on the mast arm on the far side of the intersection, so my viewing distance is the width of the intersection to the stop bar (probably 120 feet) plus 330 feet.

So to be able to place that 5-second dilemma zone detector, my video camera mounting height must be at least 45', better 50'.

Now here come the problems.

- My typical combination mast arm lighting arm is at a height of 35'. I can order a 50' combo arm. But it will look out of place.
- My city owns 35' bucket trucks. How am I going to maintain a highway light and video camera at 50' mounting height?
- The video image itself is an issue.
    - The focal length of a lens has an issue. It can get good focus near or far – not both at the same time.
    - As you add distance to the camera, the number of pixels that represent a vehicle becomes so small that the algorithm has a hard time catching every vehicle.
    - There needs to be some distance from the top of the view monitor to the first detector for the algorithm to track the anomaly into the detection zone.
    - With such a flat viewing angle and long view length, it is very likely that the camera will be blinded, portions of the day, by direct sunlight entering the lens.

Iteris has accepted that for video detection, their camera is designed for stop bar detection. Iteris recommends their camera be mounted at about 22 feet above pavement at the roadway stripe dividing the nearest left turn lane from the adjacent through lane.

What does the Radar Detection give me?

Vector's radar detection is good for the range of ~200 feet to 600 feet distant from the camera – right in the area where the video detection stops. The Vector provides up to 5 very-easy-to-program trip lines. A vehicle passing over that trip line is detected – just like a far detector loop.

In addition, because the format is radar, we can also condition the trip line for speed parameters. Min speed – slower than this, no detect. Max speed – faster than this, no detect.

In the example above, a 45 mph dilemma zone detector at 450 feet from the camera mounting. One Trip line. No problem.

What is the Dilemma Zone?

The dilemma zone was defined back in the 1950s by an engineer with a Federal grant. His experiment: send a bunch of engineering students out with stopwatches and give them this assignment: Watch for the traffic signal to turn yellow. Then, for every vehicle, measure how far that vehicle was from the stop bar when the light changed to yellow and record whether that driver chose to stop or to go through the intersection.

From a large data set, the engineer defined two points. First point: where 90% of drivers would choose to go through the intersection. Second point: where 90% of the drivers would choose to stop on the yellow indication. These two points were the boundaries for the dilemma zone.

Outside the dilemma zone, the driver's decision – stop or go – was pretty clear. Inside the dilemma zone, the driver's decision was fuzzy. The driver was in a dilemma to choose which was the more correct decision.

So boiling down the data, the engineer defined the dilemma zone boundaries in terms of time, rather than distance. Given the driver was approaching at the 85th percentile speed of traffic, the dilemma zone boundaries were 2.6 seconds and 4.2 seconds from the stop bar. So, if the driver was 2.6 seconds from the stopbar when the light changed to yellow, 90% of those drivers would continue through the intersection If the driver was 4.2 seconds from the intersection when the light turned yellow, 90% of those drivers would choose to stop on the yellow indication.

So where to place the far detector to make it a dilemma zone detector? The problem with the 85th percentile speed is that it can vary dramatically during the day. A corridor posted 45 mph speed limit may have an 85th percentile speed of 52 mph during some time periods and an 85th percentile speed of 25 mph in other time periods. Which is my 85th percentile design speed?

A common industry tact is to apply the posted speed limit as your design speed and place the detection at 5 seconds travel time at the posted speed limit. In application, this design, combined with good passage values creates a very good dilemma zone protection for drivers.

Now my speed limit is in mph. I want to measure in feet. And my target time unit is seconds. For exact conversion, 30 mph = 44 fps. Dirty, but easy, 1 mph ~ 1.5 fps.

So for my example above, 45 mph = 66 fps. Five second dilemma zone detector location: 330 feet from the stop bar.

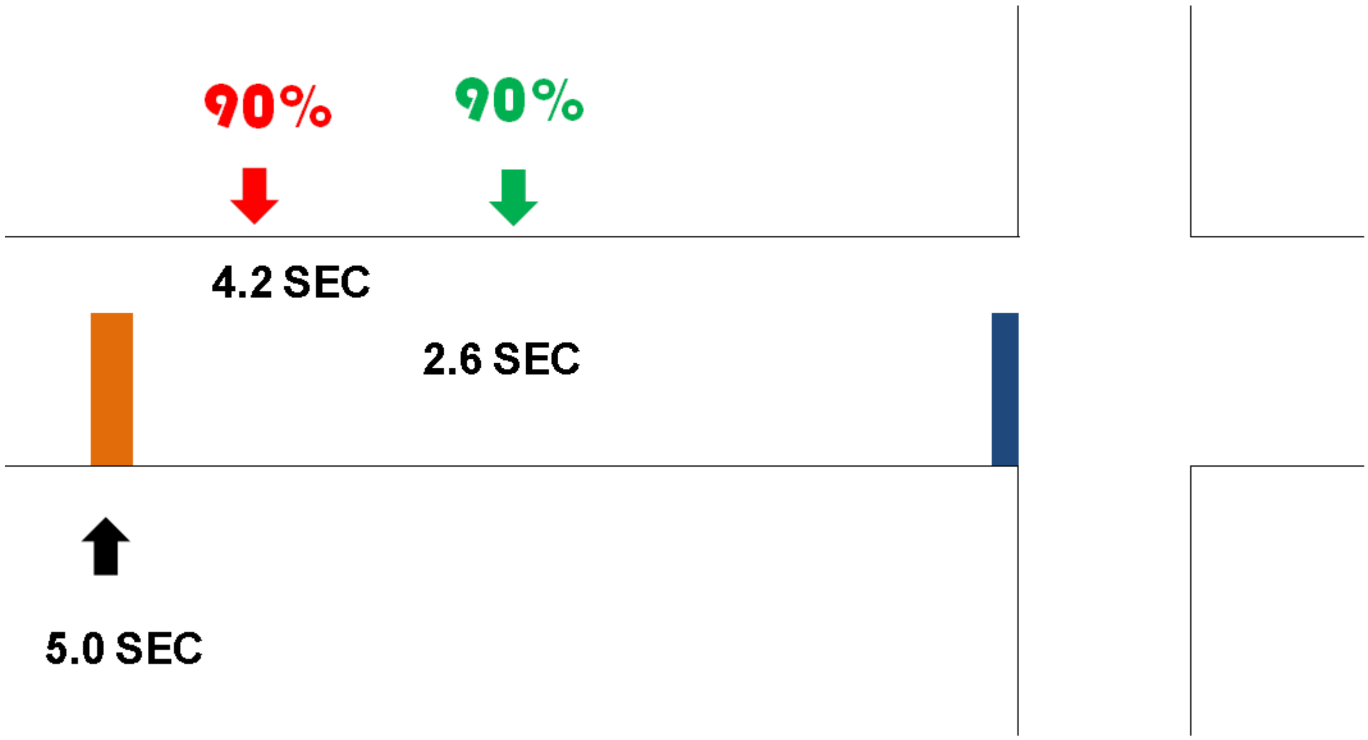

Figure 1: Dillema Zone definition. The Dilemma zone begins at a point where 90% of drivers would choose to stop if shown a yellow indication. The Dilemma zone ends at a point where 90% of the drivers would choose to proceed if shown a yellow indication. A Dilemma Zone detector extends the active green display long enough to let the last driver arrive at a point beyond the Dilemma Zone when the yellow is displayed. [Note: Design vehicle is passenger car.]

In practice, designing the dilemma zone detector at 5 seconds travel time and then installing passage times and minimum gap times for a crisp yellow cut off does create a very safe intersection. When drivers are given a yellow light and no driver is in a dilemma zone, the stopping decision for each driver is very clear cut. The net result of crisp timing parameters with dilemma zone detectors conforming to this detector theory is a very safe intersection – reduction in both crossing accidents and rear-end accidents.

What are Crisp Dilemma Zone Timing Parameters?

I have used the following vehicle extension parameters in timing intersections under my authority when I was a traffic signal engineer for the Illinois DOT. These values are my opinion of how a traffic signal works the safest and most efficient. The intersections where I placed these parameters were typically boundary intersections outside of city borders. If you use these values, please visually evaluate them for a long time period. You may find that some slight modification is appropriate based upon your driver population.

The two values to consider are Vehicle Extension and Minimum Gap. Depending on your traffic signal controller manufacturer, they may use slightly different terminology but they will have the same feature.

Vehicle Extension is the beginning detector Passage time. Vehicle Extension is a timer that begins timing from its full value down to zero upon the vehicle leaving the detector zone. Upon the vehicle extension timer reaching zero, the traffic signal may change to yellow if there is a conflicting demand for green time.

Gap Time is a substitute value for Vehicle Extension. After the traffic signal has been green for a programmed amount of time [the Time Before Reduction value], the controller will start imposing an active gap timer to the phase in substitute for the beginning vehicle extension timer. Over a period of time [the Time to Reduce value], the controller will continue to reduce the gap timer each second until the active gap timer is equal to the programmed Minimum Gap Value.

How do Vehicle Extension Timers and Minimum Gap Timers relate to the Dilemma Zone detector?

A reasonable Vehicle Extension time would seem to be 5 seconds. That is the travel time from the Dilemma Zone detector to the stop bar. However, that estimate assumes the approaching driver has a clear path to the stop bar. When the light first turns green, it is likely that stopped drivers are queued at the stopbar and this approaching driver must slow. So a passage time greater than 5.0 seconds is reasonable. Recommended Vehicle Extension Time: 5.5 seconds

Now as the light remains green, queued traffic will clear and the driver will be able to travel at the speed limit from the dilemma zone detector to the stop bar. With the vehicle extension timer programmed at 5.5 seconds, the active green does not change to yellow until the last driver is well beyond the stopbar. For the driver on the sideroad, the intersection has been clear for way longer than seemed necessary for a safe green display. From the sideroad driver's perspective, the signal was too slow to offer up my turn for the green light.

So what would be a better gap time? Well, the 90% dilemma zone boundary for going is at 2.6 seconds from the stop bar. But we do not want 10% of the drivers to stop. When the light changes to yellow, we want those drivers to be past the point of even considering stopping.

Where would that location be where a driver has no decision to stop? The traffic signal definition for perception-reaction time is 1.0 second. That is, the design driver, when presented with a decision, will take 1.0 second of time between the decision point being presented and the driver implementing their decision. So if the driver is even beyond that point, then the driver cannot decide to stop at all. Recommended Minimum Gap Time 4.2 seconds.

So with a Minimum Gap Value of 4.2 seconds, the last driver will be at the stop bar or very close to the stopbar when the signal changes to yellow. The sideroad driver will see the light change to yellow as the last crossing driver enters the intersection. When the sideroad driver receives the green, the intersection has been clear for a short amount of time, but enough to feel safe and well-serviced.

Recommended Starting Values Dilemma Zone Passage

Vehicle Extension – 5.5 seconds
Minimum Gap – 4.2 seconds
Time Before Reduction – 20 seconds
Time to Reduce – 1 second

Truck Dilemma Zone

For reproducible results, all traffic engineering studies have been homogenized for these conditions:

- All vehicles are passenger cars
- Sunny, daytime conditions
- Dry pavement
- Level, high quality driving surface

That may be nice for a study, but it is not the real world we drive in. So, with any traffic study results, we need to take a conservative approach with implementing their conclusions.

As I'd stated, the 5 second dilemma zone detector works well in most cases. However, exceptions occur on roadways where the population of semi-tractor-trailer units rises to a significant proportion of traffic – say more than 6% of the vehicle population.

A semi with trailer has a different dilemma zone boundary than a passenger car. For the semi with trailer, the dilemma zone boundary begins at 6.2 seconds travel time from the stop bar.

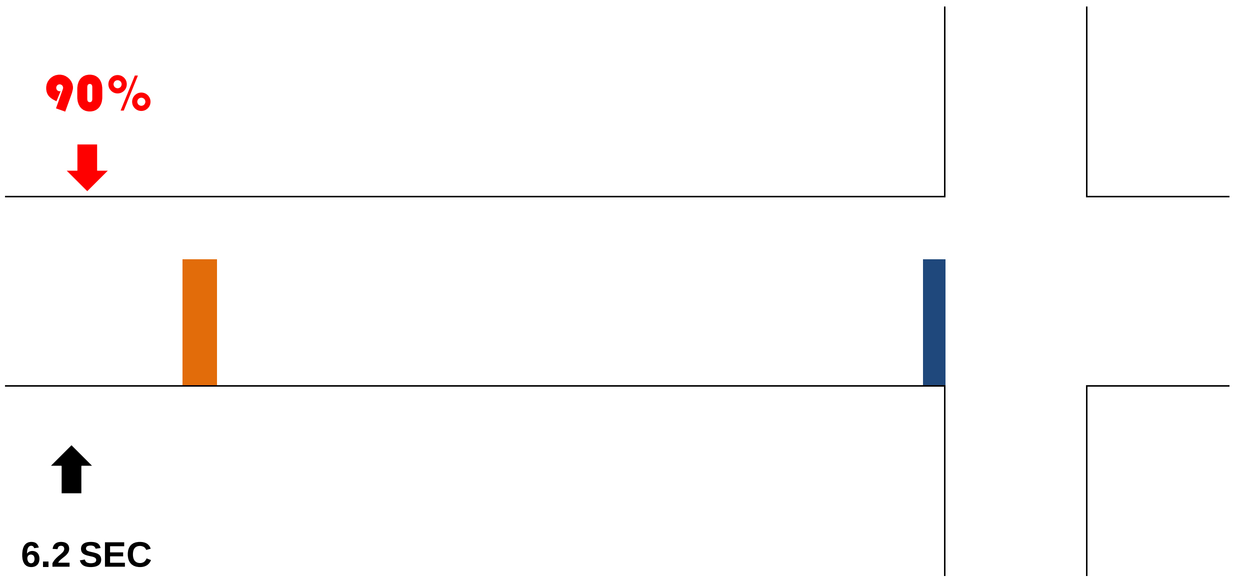

Figure 2: Dilemma Zone Semi-tractor-trailer. For the semi-truck, the Dilemma zone point where 90% of drivers would choose to stop begins at 6.2 seconds travel time from the stop bar.

So Figure 3 shows the recommended design for an approach using semi-truck dilemma zone detector protection with an Iteris Vector Camera.

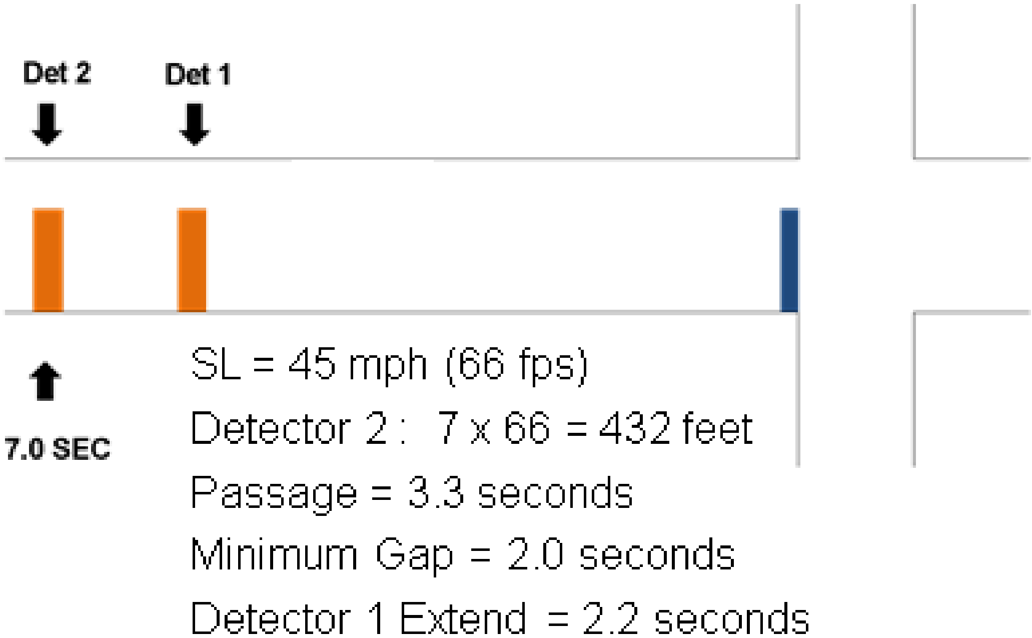

Figure 3: Proposed Dilemma Zone Design for design vehicle Semi-tractor-trailer using the Iteris Vector Camera.

So which dilemma zone detection pattern should I use? In general, the passenger car dilemma zone is usually the best fit. Most intersections are overwhelmingly passenger cars and the tradeoff of guaranteed inefficiency (truck design) versus a potential, but very infrequent condition of a semi-truck getting caught in a dilemma zone is just not practical.

That is where the Iteris Vector Camera shines. While making the generally-best decision of the 5-second dilemma zone, an intersection will slip through the design process that actually warranted the semi-truck dilemma zone design. If your design medium is detectors loops, the cost and difficulty of going back and making the intersection right are often too much to overcome.
With the Vector Camera, going back and making the upgrade decision is as simple as a half-hour of point and click between camera and reprogramming setting on the controller. Truly impressive that implementing this secondary design at the right place, right time, at no cost is just that easy.

Red Protect

Red Protect is a detector channel mode option available in the Siemens EPAC controllers beginning in firmware version 3.34g and newer. The concept of Red Protect is that if a Red Protect detector is on at the moment that the phase changes from yellow to the all red display, the controller will stop time for the time that the Red Protect detector(s) is on – up to the Red protect max extend value that the user has programmed.

So what is Red Protect supposed to do? If a distressed vehicle has made the decision to go through the signal and the light has turned red before the distressed driver crosses the stop bar, extend the all red time to protect that vehicle to avoid a potential accident.

So we're protecting drivers who intentionally violate the all red time? That's a natural reaction that misses the point. High speed right angle accidents are the most deadly type of car crash. Cars are not nearly as capable of protecting a person in a door collision crash as in a head-on collision. We are not protecting the violator. It is the unsuspecting driver releasing from the sideroad we are protecting from a deadly side-collision.

In our world of traffic signals, red violations occur for numerous reasons .

- Threatened by following vehicle
- Not familiar with the area
- Looking at road signs for directions
- Distractions by passengers
- Looking at your phone
- Bad decision
- And others

Why hasn't Red Protect come up earlier? A traffic signal controller recognizes one of two inputs – detector on or detector off. The detector channel of the traffic signal controller has no sensitivity to discriminate between a distressed vehicle – one who is not intending to stop – and a typical vehicle - one slowing to a stop for the red light. What the market has been missing has been a detector that could determine a distressed vehicle versus a normal vehicle. Enter radar detection.

The Iteris Vector camera allows the user to set up to five distinct radar trip lines. With the radar trip lines in the Vector camera, we can set filters. Vehicles greater than a design trip speed – detect. Vehicles slower than a design speed – no detect. We can use vehicle speed – at the moment the red display begins – to evaluate our drivers: Is that a normal vehicle? Is that a distressed vehicle?

Red Protect Zones

Any of the 80 detector channels in the Siemens controller can be used as the red protect detector.

```
VEH DET CONTROL .49.50.51.52.53.54.55.56
  ASSIGNED PHASE  0  2  2  2  0  0  0  0
  OPERATION MODE  0  8  8  8  0  0  0  0
  SWITCHED PHASE  0  0  0  0  0  0  0  0
 MODE: 0-VEH  1-PED 2-ONE 3-SBA  4-SBB
       5-PPL  6-PPT 7-AND 8-RDPT 9-BIKE
 SWITCHED: TO PH # (AP=Y/R & SP=GRN)
```

```
VEH DET TIMING
VEH DET...49..50..51..52..53..54..55..56
 EXT/10:   0  30  30  30   0   0   0   0
 DEL/10:   0   0   0   0   0   0   0   0
 QLIMIT:   0   0   0   0   0   0   0   0
 FAIL  : 255 255 255 255 255 255 255 255
```

Figure 4: Red Protect Detectors programmed into the controller. These screenshots are from the Special Detectors screen under Phase Data in the Siemens controller. Detectors 50, 51, and 52 are set to Red Protect on phase 2 with a max red protect value of 3.0 seconds.

How red protect functions in the Siemens controller: The red protect detectors are functioning all the time. However, the Siemens controller ignores them – until the moment that the phase associated with the red protect detector changes from yellow to all red. If a red protect detector is active at that moment, the controller stop times in all red for the length of time that the red protect detector set is a positive detection – up to a maximum red protect extend time programmed by the user. As a safety, detector diagnostics is changed for the red protect mode detectors. A failed red protect detector fails off instead of failing on.

When the traffic signal has completed its yellow, we would expect two things – first, vehicles beyond the stop bar have no issue; second, vehicles before the stop bar are slowing to a stop. So our expectations define our detection area for distressed vehicles – first, a distressed vehicle must be before the stopbar; second, a distressed vehicle is not going slow.

So that is what our red protect detectors are going to look for – vehicles before the stopbar that are going too fast when their traffic signal has finished its yellow display.

Red Protect Detector Pattern Objectives:

1. Discriminate between a distressed vehicle and normal vehicle.
2. Protect vehicles travelling at a speed up to 20 mph over the posted speed limit.

Example: Speed Limit 40 mph. Max Red Protect = 3.0 seconds.

To get the intended speed range without accidentally detecting moderately fast vehicles, we will use three speed zones. To avoid unnecessary red protect actuations, we will allow that a vehicle 0.5 seconds away from the stop bar at the moment of all red will clear the intersection safely.

The first speed trip line the driver crosses will be at a distance of (3.0 +0.5) seconds at a design speed of 60 mph (90 fps). Distance = 315 feet. Validation Speed: 50 mph or faster. Width of trip line: 10 feet. Radar detection Extend of 0.5 seconds.

The third trip line will be at a distance of (3.0 +0.5) seconds at a design speed of 40 mph (60 fps). Distance = 225 feet. Validation Speed: 40 mph or faster. Width of trip line: 6 feet. Radar detection Extend of 3.0 seconds.

Halfway between will be the second trip line.

The second trip line will be at a distance of (3.0 +0.5) seconds at a design speed of 40 mph (60 fps). Distance = 270 feet. Validation Speed: 45 mph or faster. Width of trip line: 15 feet.

Width of the trip line: A fudge factor to allow the extend of 0.5 seconds plus the design vehicle travel speed to cover the distance to the next trip line.

A summary of the design is shown in Figure 5.

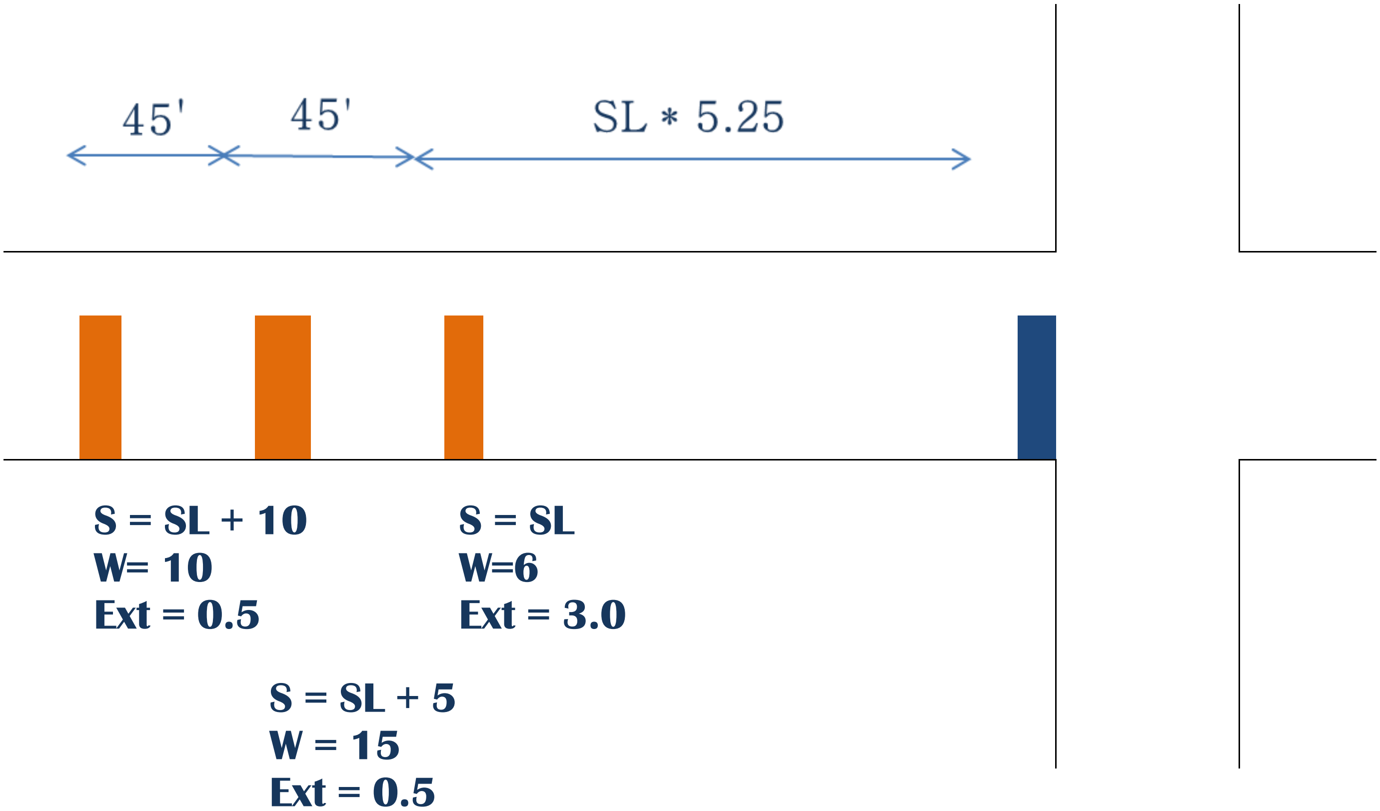

Figure 5. Summary of proposed red protect design. Given: Max Red Protect set at 3.0 seconds and posted speed limit (SL) of 40 mph. If Max Red Protect is set at 3.0 seconds and the speed limit is different, this design template will require only modifications to the trip line widths to remain valid.

Conclusion

The Iteris Vector Detection system is the camera of the future. In one camera package, replace all detectors you would have created with expensive underground conduit and detector loops. Replace stop bar loops with high quality video detection. Replace Dilemma Zone detectors with precise radar trip lines. Gain ability to implement Red Protect detection at no cost. This all-in-one camera package should be the engineer's first choice for traffic signal detection.