# Minimizing the impact of latest MUTCD on traffic signal operation

Jose Guedes, T.E.

California adopted its version of the 2009 Manual on Uniform Traffic Control Devices (MUTCD) in 2012, and later updated in November 2014. With each new version, additional requirements on traffic signal timing parameters, such as minimum yellow timing, pedestrian clearance and bicycle minimum green timing are introduced. The latest update of the California MUTCD (2014) added new requirements for establishing the minimum value of yellow clearance: The 85th percentile speed should be used to determine the yellow interval; If a $85^{th}$ percentile speed is not available, then the yellow time should be determined by the use of the posted speed plus 7 mph. The 2014 CA-MUTCD offers two tables to be used in determining the yellow clearance time: one based on $85^{th}$ percentile speeds, and the second one based on posted speeds or prima facie speed

For cities in Southern California where intersections are normally wider, these requirements have led cities to increase such parameters, which, in turn, have led to increases in signal coordination cycle times and overall increase in delays. Many cities, in trying to minimize the impact, have decided to follow the MUTCD to the letter, and implement only the Standards ("shall" statements), but not the "should". So, if you are a traffic engineer working for a city that has decided to implement all the new MUTCD requirements, what can you do?

There are hardware and software approaches that can be used to minimize the impact of MUTCD requirements on the signal operation. Hardware solutions are based on the latest detection technologies: video and radar. Video detection can be used to detect vehicles and bicycles. Once you provide separate detection inputs for vehicle and bicycle, the latest traffic signal controllers can determine which minimum green timing to use. You will still have to account for bike timing in your coordination split times, but now you can count on not having to use the longer minimum green at every cycle. The second technology, radar, can be used to track vehicles and bicycles movement in the intersection.
The 2014 version of CA-MUTCD allows the use of the previous 4.0 ft/sec crossing speed if passive pedestrian detection is being used, i.e., a detection that does not depend on pedestrian manual input. With this method, the signal controller will keep the "flashing don't walk" (FDW) interval on until the pedestrian actually clears the crosswalk.

Software approaches can be divided in two groups: The ones associated with the processing of the vehicle/pedestrian/bike detection input in the controller, and second, the controller timing parameters. Traffic signal controllers already distinguish between vehicles and pedestrians, but only the latest software recognizes bikes, and very few can extend pedestrian clearance. This is an area where traffic signal controller manufacturers are working on, so we can expect new controller software options in the near future. Once you can differentiate detection inputs, you can use the appropriate timing parameters, such as "minimum green", and "extension".

Controller timing parameters that can contribute to "wasted time" are: minimum green, yellow clearance, all-red, detection extension, detection lock, and pedestrian clearance. These parameters need to be set to the minimum values that will provide for a safe operation of the traffic signal. A good example is the vehicle extension. For speeds over 45 mph, if the signal detection is set up as call+extension at both the advance and limit line (crosswalk) loops, then each vehicle passing the crosswalk will hold the green for at least another 4.5 seconds, where a 2 second would suffice.

The reduction of each of these parameters by half a second to one second, can lead to significant reduction in overall signal delay.

Let's look at each individual parameter.

We will use as an example a city in Orange County, California, that has always been cautious when determining pedestrian clearance timing. We will look at a signalized intersection with 50 mph approaches, and pedestrian crossing distances varying from 108 ft. to 120 ft. Existing FDW is based on 4 ft./sec, measured from curb to curb (street width), and Yellow clearance is not considered as part of pedestrian clearance. An All-Red interval of 2.0 sec. is used citywide (at all signal phases).

## Pedestrian Intervals

Pedestrian intervals are a combination of "Walk" time, Flashing "Don't Walk" (FDW), and a
Buffer interval. The 2014 CA-MUTCD specifies:

Walk = 7 seconds (minimum)
FDW = calculated at 3.5 ft/sec
Buffer = 3 seconds

In our example, city engineers would like to use a pedestrian crossing distance measured from bottom of ADA ramp to bottom of ADA ramp. The table below shows the current and proposed crossing distances:

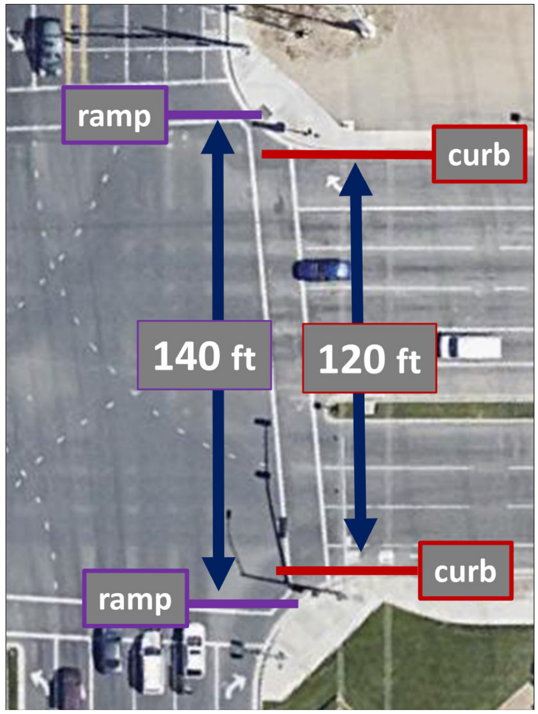
| Direction | Current distance (curb to curb or street width) | Proposed distance (ADA ramp to ADA ramp) |
|---|---|---|
| NB | 120 | 140 |
| SB | 108 | 123 |
| EB | 116 | 127 |
| WB | 110 | 127 |

Based on the new proposed distances and a pedestrian crossing speed of 3.5 ft/sec, the new FDW will be:

| Direction | Current FDW at 4.0 ft/sec (curb to curb or street width) (sec) | Proposed FDW at 3.5 ft/sec (ADA ramp to ADA ramp) (sec) |
|---|---|---|
| NB | 30 | 40 |
| SB | 27 | 36 |
| EB | 29 | 37 |
| WB | 28 | 37 |

The MUTCD does not specify exactly how to determine the pedestrian crossing distance, so it is up to each agency to establish a policy on pedestrian crossing distance. In our experience with signal timing projects, the shortest crossing distance method we have used is the "Curb to Curb" (or street width). Figure 1 shows the "ramp to ramp" and "curb to curb" methods.

**Figure 1 - Pedestrian Crossing Distance alternatives**




The MUTCD provide many options for the buffer interval, as defined in Figure 4E-2 of the manual.

City engineers decided to use part of yellow clearance time to cover the buffer period. The FDW was then decreased by 5 sec (Yellow clearance).

| Direction | Current FDW at 4.0 ft/sec (curb to curb or street width) (sec) | Proposed FDW at 3.5 ft/sec minus Yellow (sec) (ADA ramp to ADA ramp) |
|---|---|---|
| NB | 30 | 35 |
| SB | 27 | 31 |
| EB | 29 | 32 |
| WB | 28 | 32 |

Had the City kept its current “curb to curb” crossing distance, the new FDW would have been almost identical to existing, as show in the following table:

| Direction | Current FDW at 4.0 ft/sec (curb to curb or street width) | Proposed FDW at 3.5 ft/sec minus Yellow (curb to curb) |
|---|---|---|
| NB | 30 | 30 |
| SB | 27 | 26 |
| EB | 29 | 29 |
| WB | 28 | 27 |

It would still be possible to further lower the values of the calculated FDW interval by also subtracting the value of "All-Red" interval (2 sec).

## Bicycle minimum green

Our example city has on-street bike lanes at all major and minor arterials and city staff wants to make sure that bicycles are provided adequate minimum green times. To enhance the safety of bicyclists, the City decided to remove the All-red value from the calculation of the bicycle minimum green, giving bicycles another 2 seconds to complete the crossing.

$$G_{min} + \mathrm{Y} + R_{clear} \geq 6\ \mathrm{sec} + (\mathrm{w}{+}6\ \mathrm{ft})/14.7\ \mathrm{ft/sec}$$

For our example intersection, the bicycle crossing distances are:

| Direction | Bicycle crossing distance (ft.) | City adopted Minimum Bicycle Green Time - Gmin (sec.) | MUTCD Gmin (sec) |
|---|---|---|---|
| NB LT | 145 | 12 | 10 |
| NB Thru | 140 | 11 | 9 |
| SB LT | 155 | 13 | 11 |
| SB Thru | 127 | 10 | 8 |
| EB LT | 152 | 13 | 11 |
| EB Thru | 137 | 11 | 9 |
| WB LT | 140 | 12 | 10 |
| WB Thru | 130 | 10 | 8 |

In this example, using the MUTCD formula would have yielded lower minimum green times.

The only way to further reduce the minimum green would be to use a hardware solution. Video detection and bicycle loops provide the opportunity to detect vehicles and bicycles separately, allowing the traffic signal controller to use the bicycle minimum green only when bikes are detected, and a shorter minimum green when only cars are detected. Another alternative is the use of radar based detection which can keep track of bicycles and vehicles moving through the intersection. The radar detector can be programmed for left and through movements, and will hold the detection until the vehicle/bike clears the intersection.

## Yellow clearance

The 2014 California MUTCD defines:

- The minimum yellow change interval for through traffic movement shall be determined by using the 85th percentile speed of free-flow traffic rounded up to the next 5 mph increment. Where the posted or prima facie speed limit is higher than the rounded value, use the posted or prima facie speed limit for determination of the minimum yellow change interval for the through traffic movement. See Table 4D-102(CA) sub-heading “a”.

- If the 85th percentile speed data is not available, the minimum yellow change interval for through traffic movements shall be determined by adding 7 miles per hour to the posted or prima facie speed limits of 30 mph or higher, and by adding 10 miles per hour to the posted or prima facie speed limits of 25 mph or less. See Table 4D- 102(CA) sub-heading “b”.

a - For Speed determined by 85th Percentile

| SPEED (Determined by 85th Percentile Speed)* | MINIMUM YELLOW INTERVAL |
|---|---|
| mph | Seconds |
| 25 or less | 3.0 |
| 30 | 3.2 |
| 35 | 3.6 |
| 40 | 3.9 |
| 45 | 4.3 |
| 50 | 4.7 |
| 55 | 5.0 |
| 60 | 5.4 |
| 65 | 5.8 |

*See Section 4D.26 Standard under paragraph 14b

b - For Posted or Prima Facie Speed

| POSTED SPEED or UNPOSTED PRIMA FACIE SPEED | MINIMUM YELLOW INTERVAL* | MINIMUM YELLOW INTERVAL* |
|---|---|---|
| mph | Seconds | Seconds |
| 15 | N/A | 3.0 |
| 20 | N/A | 3.2 |
| 25 | N/A | 3.6 |
| 30 | 3.7 | N/A |
| 35 | 4.1 | N/A |
| 40 | 4.4 | N/A |
| 45 | 4.8 | N/A |
| 50 | 5.2 | N/A |
| 55 | 5.5 | N/A |
| 60 or higher | 5.9 | N/A |

*Speed values for Table 4D-102b (CA) are inclusive of the 7 MPH added for speeds equal to 30 MPH or higher and 10 MPH for speeds equal to or lower than 25 MPH for determining the minimum values of the yellow intervals.

A comparison of tables 4D-102(CA) "a" and "b" shows that the use of the 85th percentile speed will yield a shorter yellow interval by 0.5 second. It is not a significant difference, but using the yellow intervals determined by the Post Speeds could be just enough of an increase to require a longer cycle length during signal coordination.

Comparison of tables 4D-102(CA) “a” and “b”

| Speed | Yellow interval – based on 85$^{th}$ Percentile | Yellow interval – based on Posted Speed (no 85$^{th}$) |
|---|---|---|
| 15 | 3.0 | 3.0 |
| 20 | 3.0 | 3.2 |
| 25 | 3.0 | 3.6 |
| 30 | 3.2 | 3.7 |
| 35 | 3.6 | 4.1 |
| 40 | 3.9 | 4.4 |
| 45 | 4.3 | 4.8 |
| 50 | 4.7 | 5.2 |
| 55 | 5.0 | 5.5 |
| 60 | 5.4 | 5.9 |
| 65 | 5.8 | 5.9 |

## All-red interval

An All-red interval is used to clear the intersection before the next conflicting movement starts. Excessive All-red intervals add to delay and lost time, and drivers learn of the extra time and start abusing it. The equation to estimate the All-red time takes into account the vehicle speed, and distance to be traveled to clear the intersection. The faster the vehicle speed is, the less time it will require to clear the intersection. And, the wider the intersection, the longer the vehicle will take to clear the intersection.

The equation for the red interval is:

$$r = \frac{W + L}{v}$$

In our example, the longest crossing distance (W) is 140 ft. , the speed (v) is 50 mph (73 ft/sec), and the length of vehicle L is 20 ft.:

$$r = \frac{140 + 20}{73} = 2.2$$

The calculated All-red value matches the existing 2.0 sec All-red.

## Vehicle extension

A detection input received by the controller activates a countdown timer that holds the signal phase green for a set amount of time, usually the time required for the vehicle to go from the advance detector to the crosswalk or limit line. If a detector exists at the limit line (a.k.a. presence detector) then the countdown timer is re-started.

In our example, the detection extension is set to 5 seconds, and both advance and limit line detectors are used. The limit line detector extends the green time for another 5 seconds, which allows the vehicle to travel approximately 345 feet (at 50 mph). Since the intersection width is approximately 140 ft., by the time the signal turns yellow, the car is already 200 ft. beyond the intersection. In this example , a 2 second extension at the limit line would be sufficient to clear the intersection (50 mph = 73 ft/sec; 2 sec = 146 ft).

If advance detector input is separate from the limit line detector input, one way to minimize the excess extension at the limit line is to use the extension setting in the advance detector card in the cabinet or in the controller. The advance detector card extension can be set to 3 seconds, and the controller phase extension set to 2 seconds, for a total of 5 seconds for advance detection. The detector card will hold each call for 3 seconds, and then the phase extension timer will start counting down for another 2 seconds. The limit line detectors will only re-start the 2 second extension. If the controller is capable of individual advance detector input, then the same can be accomplished inside the controller, by programming the advance detectors to hold the call for 3 seconds.

## Detector lock

Controllers allow the detector actuation that happen during yellow or red to be locked, or maintained, until the signal turns green, when the detection is released. This feature is normally used at major

arterials, or at locations where advance detectors are working and limit line ones are not (or other similar situations, such as multiple consecutive loops).
Locked detector calls can cause signal phases to be serviced without a vehicle present. This is frequently observed at locations where the Detector Lock is allowed during yellow time. Vehicles going through yellow can leave a locked detection behind for the next cycle.

Detector lock option should be turned off where detectors are working properly.

## Conclusion

Minimizing the impact of the many MUTCD requirements on the traffic signal operation requires the use of multiple approaches:

1. Exploit some of MUTCD's not clearly defined concepts, such as the method to measure pedestrian crossing distances – use the shortest distance possible;
2. Understand MUTCD's formulas and options, and always reduce the timing parameters by using all available options, such as reducing the Bicycle minimum green and the Pedestrian Clearance, by subtracting both Yellow and All-red intervals.
3. Use hardware solutions, such as video detection and radar-based detection , to reduce minimum greens
4. Fine-tune other timing parameters, such as Vehicle Extension and Detector Lock, to further limit the amount of wasted time during signal operation