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ESTABLISHED 1850

November 10, 2009

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Senior Transportation Engineer
Executive Secretary, CTCDC
1120 N Street, MS36
Sacramento, CA 95814

Subject: Request to place on the CTCDC agenda as a public hearing and action item, proposed modifications to Section 4D.105(CA) Bicycle/Motorcycle Detection.

The City of Vacaville has dozens of intersections where the implementation of the new signal timing guidelines in MUTCD Section 4D.105(CA) will make the intersections less efficient, increase fuel consumption, increase automotive emissions, increase transit headways, result in unnecessary stops and delays to the motoring public, and reduce traffic safety. I request that the CTCDC conduct a public hearing and take action to revise MUTCD Section 4D.105(CA).

The collision records for the City of Vacaville show that since 2005, only one quarter of bicycle related collisions occur at traffic signals, and of those, cyclists are at fault about 90% of the time. This means that less than 5% of all bicycle collisions could be related to motor vehicle driver error at traffic signals, with cyclists and motorists currently operating under the existing standards for setting green, yellow and all-red intervals at traffic signals.

I have taken a look at how the new signal timing guidelines would impact over a dozen existing intersections and have looked for ways to modify the language in Section 4D.105 to meet the intent of providing bicyclists a reasonable time period to avoid conflict zones within signalized intersections, while minimizing the negative impacts on all of the other intersection users. I am currently formulating new signal timing for over a dozen intersections in Vacaville where a roadway overlay project has triggered the need to replace all of the detection zones. In doing so I find that the CTCDC and the State's Bicycle Advisory Committee did not clarify such issues as:

- Do the new guidelines apply to left turn phases?
- Is the last conflicting lane, the last through lane or right turn lane?
- Should the bicyclists' path of travel be measured from the limit line or the end of the Reference Bicycle-Rider detection zone?
- Can supplemental detection zones be used to shorten the bicyclists' path of travel conflict exposure time?
- How does traffic signal phase sequencing effect bicycle conflicts?

- Can mean bicyclist speed be used where and when slower cyclists who travel at the 90th percentile slowest speed are not likely to be present?
- How should traffic signal timing be set when provisions in Section 4D.105(CA) conflict with other signal timing policies in the MUTCD?
- How should Traffic Engineers balance the traffic signal timing guidelines in Section 4D.105(CA) against the negative impact this timing would have on traffic safety, the environment, the economy, transit operations, and the overall transportation network?
- What discretion do Traffic Engineers have in setting signal timing based on all of the factors mentioned above?

I apologize for the length of this letter and the number of attachments. It is my understanding that there are some interested parties that wanted some clear examples of how the new timing policy would effect real intersections. I have included aerial photos of several intersections and have overlaid my interpretations of the new guidelines and how the guidelines would affect signal timing at these locations. I have also included proposed changes to MUTCD Section 4D.105(CA) and Table 4D-109(CA) that should preserve the intent of providing cyclists with adequate intersection passage time, while minimizing the negative impact the new guidelines would have on the environment, transit operations and other roadway users. I have organized the attachments to provide my recommended revisions to the MUTCD first, and then the reasoning and background data for these changes afterwards.

It would be greatly appreciated if this item can be placed on the December 2009 CBAC agenda and also the January 2010 CTCDC agenda. Thank you in advance for reconsidering these issues.

Jeff Knowles
Deputy Director of Public Works
City of Vacaville
CTCDC Member, League of California Cities

The existing federal MUTCD language is shown in blue, the California Supplement language is shown in red, and my proposed changes are shown in italicized, underlined green:

~~Section 4D.105(CA) Bicycle Detectors~~
~~Option:~~
~~Bicycle detectors may be required at traffic-actuated signal installations.~~
~~The loop detector logo shown on Department of Transportation's Standard Plan A24C may be used to show a bicyclist where to stop in a bike lane or traffic lane to be detected.~~
~~Support:~~
~~See Figure 4D-111(CA) for suggested locations of bicycle detectors and Department of Transportation's Standard Plans for typical bike lane pavement markings.~~
~~Efforts need to be made to ensure that signal detection devices are capable of detecting a bicycle. Detectors for traffic-actuated signals need to be located in the bicyclist's expected path, including left-turn lanes and shoulders. Marking the road surface to indicate the optimum location for bicycle detection is helpful to the bicyclist. Video detection is an effective alternate technique to loop detection.~~

Section 4D.105(CA) Bicycle/Motorcycle Detection
Standard:
All new limit line detector installations and modifications to the existing limit line detection on a public or private road or driveway intersecting a public road (see Section 1A.13 for definitions) shall either provide a Limit Line Detection Zone in which the Reference Bicycle-Rider is detected or be placed on permanent recall or fixed time operation. Refer to CVC 21450.5.
All new and modified bike path approaches to a signalized intersection shall be equipped with either a Limit Line Detection Zone or a bicyclist pushbutton, or else the phase serving the bike path shall be placed on permanent recall or fixed time operation. A bicyclist pushbutton, if used, shall be located on the right side of the bike path and where it can be reached from the bike path. See Section 9B.10 for bicycle regulatory signs.
At new signalized intersections or when the advance detection is being replaced at existing signalized intersections, phases with advance detection only shall be placed on permanent recall.

Support:
The requirement to detect the Reference Bicycle-Rider in the Limit Line Detection Zone is technology-neutral.
Option:
The detection zone in a bike lane may be narrower than 6 ft. See Figure 4D-111(CA).
A Bicycle Detector Symbol may be used. See Sections 9B.12 and 9C.05.
A bicyclist pushbutton may be used to supplement the required limit line detection.
Supplemental detection zones, new technology, or various signal controller settings may be utilized to reduce the time a bicyclist is exposed to conflicting vehicular traffic.
Support:
See Section 9B.10 for bicycle regulatory signs.
Guidance:
If more than 50% of the limit line detectors need to be replaced at a signalized intersection, then the entire intersection should be upgraded so that every lane has a Limit Line Detection Zone.
The Reference Bicycle-Rider or the equivalent should be used to confirm bicycle detection under the following situations:
A. A new detection system has been installed;
B. The detection configuration has been modified.

Support:

CVC Section 21202(a) requires bicyclists traveling "at a speed less than the normal speed of traffic" to ride "as close as practicable to the right-hand curb or edge of the roadway" with exceptions, including when the bicyclist is "approaching a place where a right turn is authorized." This exception was intended to provide the bicyclist the flexibility to avoid having to ride against the right hand curb or edge of the road where a potential conflict would be created with a right turning motorist.

A Limit Line Detection Zone provides for the detection of both bicycles and vehicles, including motorcycles.

Guidance:

~~Where~~ *When a new traffic actuated signal is constructed, or when more than 50% of the limit line detectors are replaced at an existing traffic actuated signal,* ~~a Limit Line Detection Zones that detects the Reference Bicycle-Rider has been provided,~~ minimum bicycle timing should be provided as follows:

For ~~all~~ *through* phases, the sum of the minimum green, plus the yellow change interval, plus any red clearance interval should be sufficient to allow a bicyclist riding a bicycle 6 ft long to clear the last conflicting *through* lane at a speed of *19.1* ft/sec plus ~~an additional effective~~ start-up time ~~of 6 seconds~~ *before a conflicting motor vehicle enters the bicyclist's path of travel*, *approximated by* ~~according~~ the formula *Bike* Gmin + Y + Rclear ~~≥ 6 sec + (W + 6 ft)/14.7 ft/sec~~ *4.2 sec + (W + 6 ft) / 19.1 ft / sec – Vehicle Green*, where

Gmin = Length of minimum green interval (sec)

Y = Length of yellow interval (sec)

Rclear = Length of red clearance interval (sec)

W = Distance from *the Reference Bicycle-Rider detector* ~~limit line~~ to far side of last conflicting *through* lane (ft)

Vehicle Green = Motor vehicle travel time to bicycle path of travel =0.8 + square root of ((D – 0.16)/4), where

D = the distance from the limit line to the bicyclist's path of travel

Note: A value of less than 4.2 seconds must be used when W + 6 is under 61 feet.

Support:

Bicyclist crossing times are shown in Table 4D-109(CA). The speed of *19.1* ft/sec represents the final crossing speed and the ~~effective start-up time of 6~~ *4.2* seconds ~~represents the time lost in reacting to the green light and then accelerating to full speed.~~ *is an adjustment that compensates for the shorter distance traveled during start-up and acceleration. This value must be reduced when W + 6 is less than 61 feet.*

Option:

A limit line detection system that can discriminate between bicyclists and vehicles may be used to extend the length of the minimum green.

Supplemental Reference Bicycle-Rider detection zones, new technology, or various signal controller settings may be utilized to reduce the time (Gmin + Y + Rclear) and/or travel distance (W) that bicyclists are exposed to conflicting vehicular traffic.

If bicycle volumes, intersection characteristics, or the bicycle collision history does not require the bicycle timing described above, a shorter minimum phase length may be used.

When younger bicyclists who typically travel slower than 13 mph (19.1 feet per second), routinely ride during a phase, a bicycle travel speed of 10 mph (14.7 feet per second) with an acceleration rate of 1.5 feet per second^2 should be considered in determining the minimum phase length.

Table 4D-109(CA) *Suggested* Minimum Bicycle Timing (English Units)

Distance from *Reference Bicycle-Rider detection zone* to far side of the last conflicting *through* lane (in feet)

Motor Vehicle Travel Distance to Bicycle Path of Travel (in feet)	100	110	120	130	140	150	160	170	180	190	200
10	7.4	7.9	8.4	8.9	9.5	10.0	10.5	11.0	11.6	12.1	12.6
20		7.2	7.8	8.3	8.8	9.3	9.9	10.4	10.9	11.4	12.0
30			7.3	7.8	8.3	8.8	9.4	9.9	10.4	10.9	11.4
40				7.4	7.9	8.4	8.9	9.5	10.0	10.5	11.0
50					7.5	8.0	8.6	9.1	9.6	10.1	10.7
60					7.2	7.7	8.2	8.7	9.3	9.8	10.3
70						7.4	7.9	8.4	9.0	9.5	10.0
80						7.1	7.6	8.1	8.7	9.2	9.7
90							7.3	7.9	8.4	8.9	9.4
100							7.1	7.6	8.1	8.7	9.2
110								7.4	7.9	8.4	8.9
120								7.1	7.7	8.2	8.7
130									7.4	8.0	8.5
140									7.2	7.7	8.3
150									7.0	7.5	8.1
160										7.3	7.9
170										7.1	7.7
180											7.5
190											7.3

Min Green + Yellow + All Red $\geq$ 4.2 sec + (W + 6) / 19.1 ft / sec - motor vehicle travel time
W = Distance from bicycle detection zone to far side of last conflicting through lane (typically 1
feet from the lane line)
Bicycle perception reaction time = 1.0 sec
Bicycle acceleration rate of 3.0 ft / sec^2
Maximum bicycle speed of 19.1 ft / sec (15 mph)
The length of the bicycle is 6 feet
Motor vehicle perception reaction time = 0.8 sec
Motor Vehicle acceleration rate of 8.0 ft / sec^2
Maximum Motor Vehicle speed within intersection of 35 mph
Note: The 4.2 second adjustment compensates for the shorter distance traveled during start-up and acceleration. This value is reduced when w + 6 is less than 61 feet.

Table 4D-109B(CA) Optional 10 MPH Bicycle Timing

Distance from *Reference Bicycle-Rider detection zone* to far side of the last conflicting *through* lane (in feet)

Motor Vehicle Travel Distance to Bicycle Path of Travel (in feet)	70	80	90	100	110	120	130	140	150	160	170	180	190	200
10	8.7	9.4	10.1	10.7	11.4	12.1	12.8	13.5	14.1	14.8	15.5	16.2	16.9	17.5
20	8.0	8.7	9.4	10.1	10.8	11.4	12.1	12.8	13.5	14.2	14.8	15.5	16.2	16.9
30	7.5	8.2	8.9	9.6	10.3	10.9	11.6	12.3	13.0	13.7	14.3	15.0	15.7	16.4
40	7.1	7.8	8.5	9.2	9.8	10.5	11.2	11.9	12.6	13.2	13.9	14.6	15.3	16.0
50		7.4	8.1	8.8	9.5	10.1	10.8	11.5	12.2	12.9	13.5	14.2	14.9	15.6
60		7.1	7.8	8.4	9.1	9.8	10.5	11.2	11.8	12.5	13.2	13.9	14.6	15.2
70			7.5	8.1	8.8	9.5	10.2	10.9	11.5	12.2	12.9	13.6	14.3	14.9
80			7.2	7.8	8.5	9.2	9.9	10.6	11.2	11.9	12.6	13.3	14.0	14.6
90				7.6	8.3	8.9	9.6	10.3	11.0	11.7	12.3	13.0	13.7	14.4
100				7.3	8.0	8.7	9.4	10.0	10.7	11.4	12.1	12.8	13.4	14.1
110				7.1	7.8	8.4	9.1	9.8	10.5	11.2	11.8	12.5	13.2	13.9
120					7.5	8.2	8.9	9.6	10.2	10.9	11.6	12.3	13.0	13.6
130					7.3	8.0	8.7	9.3	10.0	10.7	11.4	12.1	12.7	13.4
140					7.1	7.8	8.4	9.1	9.8	10.5	11.2	11.8	12.5	13.2
150						7.6	8.2	8.9	9.6	10.3	11.0	11.6	12.3	13.0
160						7.4	8.0	8.7	9.4	10.1	10.8	11.4	12.1	12.8
170						7.2	7.8	8.5	9.2	9.9	10.6	11.2	11.9	12.6
180							7.6	8.3	9.0	9.7	10.4	11.0	11.7	12.4
190							7.4	8.1	8.8	9.5	10.2	10.8	11.5	12.2
200							7.3	7.9	8.6	9.3	10.0	10.7	11.3	12.0

Min Green + Yellow + All Red $\geq$ 5.9 sec + (W + 6) / 14.7 ft / sec - motor vehicle travel time

W = Distance from bicycle detection zone to far side of last conflicting through lane (typically 10 feet from the lane line)

Bicycle perception reaction time = 1.0 sec

Bicycle acceleration rate of 1.5 / sec^2

Maximum bicycle speed of 14.7 ft / sec

Design Bicycle is 6 feet long

Motor vehicle perception reaction time = 0.8 sec

Motor Vehicle acceleration rate of 8.0 ft / sec^2

Maximum Motor Vehicle speed within intersection of 35 mph

Note: The 5.9 second adjustment compensates for the shorter distance traveled during start-up and acceleration. This value is reduced when w + 6 is less than 72 feet.

Section 4D.105(CA) and Table 4D-109(CA) Options that Accomplish Bicycle Clearance Goal

Add the following as an additional Option to the bicycle detection Standard:
Supplemental detection zones, new technology, or various signal controller settings may be utilized to reduce the time a bicyclist is exposed to conflicting vehicular traffic.

Add the following as an additional Option to the bicycle timing Guidance:
Supplemental Reference Bicycle-Rider detection zones, new technology, or various signal controller settings may be utilized to reduce the time (Gmin + Y + Rclear) and/or travel distance (W) that bicyclists are exposed to conflicting vehicular traffic.

Support

The minimum bicycle phase length provisions in Section 4D.105(CA) do not reflect professional traffic engineering practice, are inconsistent with other sections of the MUTCD, and will significantly impact the movement of people, goods and service, increase fuel use and automotive emissions, increase congestion and reduce the level of service along arterial roadways. Section 4D.105(CA) for all practical purposes extends the green time for minor side streets and left turn phases, thus increasing red time for arterial roadways and heavy arterial left turn movements. By increasing minimum green time it will often increase signal cycle lengths and that will also result in longer queues with more left turn traffic overflowing left turn storage pockets into the adjacent #1 through lane, thus negatively impacting traffic safety.

The signal timing provisions in MUTCD Section 4D.105(CA) are not consistent with the following provisions on the MUTCD and it is unclear how local Traffic Engineers are to balance the guideline in new Section 4D.105(CA) and these other MUTCD provisions:

MUTCD Section 4D.113(CA) states, “The proportion of green time, or split, allotted to each phase during a signal cycle, should be as close as practicable to the proportion of critical lane traffic volumes on the respective approaches.” New MUTCD Section 4D.105(CA) increases green time for minor vehicle movements disproportionately to the 1-2 percent of all traffic that bicycles represent. The new timing standard applies 24 hours a day, even late at night when bicycles represent an even smaller proportion of vehicles on the road.

MUTCD Section 4D.06 refers to minimizing the use of exclusive left turn phasing that “will reduce the green time available for other phases, alternate means of handling left turn conflicts should be considered first.” New MUTCD Section 4D.105(CA) does not allow for any options or discretion on the part of professional engineers to reduce the impact the new bicycle minimum phase will have on overall traffic signal operations.

MUTCD Section 4B.05, speaks to the point of making sure that changes to an intersection do not degrade capacity at the intersection, including pedestrian signal timing impacts related to roadway widening. Section 4d.105(CA) includes no provisions to minimize the impact it will have on intersection and overall system capacity and operations.

I have reviewed the minutes from the CTCDC meeting of May 14, 2009 and note that the committee did discuss the negative impact this new minimum bicycle timing would have on signal timing and the environment. But the minutes reflect that there was no discussion of how this new timing conflicts with other sections of the MUTCD, the negative impact it would have on traffic safety, or the impact it would have on Transit Operations. New Section 4D.105(CA) does not include any options for the use of new technology or other means to provide adequate clearance time for bicyclists while minimizing the impact to the environment, traffic safety and other roadway users.

The signal timing provisions in MUTCD Section 4D.105(CA) utilize green time to provide a clearance interval for bicyclists. The MUTCD does not establish minimum green times for vehicles, or provide any guidance, standards, or options for setting minimum green time. I do not know of any professional engineering practice that utilizes green time as a clearance interval for vehicles, because a vehicle can legally enter an intersection at any time during the green interval. Thus the green interval is an ineffective clearance interval. The use of green time as a clearance interval treats bicyclists more like pedestrians than vehicles, but the CVC considers a bicycle a vehicle and the purpose of MUTCD Section 4D.105(CA) is to set up traffic signal vehicle detection to treat bicycles and motorcycles as vehicles. Nothing in CVC 21450 requires the green interval of traffic signal be increased as required by MUTCD Section 4D.105(CA).

Signal timing for pedestrians terminates the pedestrian's legal right to enter the intersection once the "WALK" interval terminates. A combination of flashing don't walk, yellow and all-red is then used to provide a clearance interval for pedestrians to finish crossing the street. But cyclists can enter the intersection at any time during the green or yellow signal interval. Thus the formula used in new MUTCD Section 4D.105(CA) does not create a realistic clearance interval. The formula only provides limited benefit to cyclists that are present at the limit line the moment the light first turns green, and provides no benefit to those cyclists who arrive latter in the green, while it negatively impacts all other traffic at the intersection 24 hours a day, seven days a week.

The MUTCD does establish minimum yellow intervals. MUTCD Section 4D.10 states, "The exclusive function of the yellow change interval shall be to warn traffic of an impending change in the right-of-way assignment." The yellow interval is not a clearance interval. But the signal timing provisions in MUTCD Section 4D.105(CA) utilize yellow time to provide a clearance interval for bicyclists. Yellow time relates directly to perception/reaction time and stopping distance. Since stopping time makes up most of the duration of the yellow interval calculation and bicyclists need less stopping time than motor vehicles do, the yellow interval should not be increased to accommodate the detection of bicyclists at traffic signals. Bicyclists can also enter a signalized intersection during any portion of the yellow interval. That is why the yellow interval is not used as a clearance interval when following "professional traffic engineering practice" as called for in CVC Section 21450.

The MUTCD in Section 4D.10 states that, "The yellow interval may be followed by a red clearance interval to provide additional time before conflicting traffic movements, including pedestrians, are released." Further on it states, "When used, red clearance intervals normally range from 0.1 to 2.0 seconds." This is the only clearance interval in the MUTCD for vehicles. The MUTCD states that the vehicular clearance interval "may" be used, while new

MUTCD Section 4D.105(CA) says the new bicycle clearance time “should” be used, and Table 4D-109(CA) refers to “Minimum Bicycle Timing.”

The Minimum Bicycle Timing in MUTCD Section 4D.105(CA) reflects the time it take for a bicyclist to clear the intersection if it enters the intersection one seconds after the light first turns green. It does nothing for a cyclist who enters the intersection later during the green interval or even legally during the yellow interval. This section utilizes green and yellow interval time inappropriately. CTCDC discussion indicated that the majority of the committee felt this timing reflected the intent of the legislature and that the committee had no discretion in this area.

- I reviewed the hearing summaries from both the State Senate and Assembly and found no mention of the legislature dictating how signal timing should be modified.
- I spoke with staff of the Transportation and Housing Committee who told me that there was very little discussion during the hearings about the need to change signal timing. I was told the primary focus of the hearings was on providing bicycle and motorcycle detection. I was also told that the legislature purposefully omitted suggesting any signal timing change details as their intention was to delegate the resolution of those issues to Caltrans and the CTCDC.
- I spoke with staff from one State Senator’s office who sat on the Transportation and Housing Committee and she said much the same thing as the committee staff person.

This new legislation resulted in CVC Section 21450. Paragraph (b) of this code states that a “traffic-actuated signal shall, to the extent feasible and in conformance with professional traffic engineering practice, be installed and maintained so as to detect lawful bicycle or motorcycle traffic on the roadway.” Caltrans and the CTCDC have full discretion to utilize their professional engineering judgment to formulate signal timing provisions and guidelines that balance the needs of cyclists and all other facility users, consistent with the other provisions contained in the MUTCD.

Section 4D.105(CA)
When bicycle timing is recommended

Change bicycle timing guidance as follows:

~~Where~~ *When a new traffic actuated signal is constructed, or when more than 50% of the limit line detectors are replaced at an existing traffic actuated signal,* ~~a Limit Line Detection Zones that detects the Reference Bicycle-Rider has been provided,~~ minimum bicycle timing should be provided as follows:

Add an additional Option to the bicycle timing guidance:

If bicycle volumes, intersection characteristics, or the bicycle collision history does not require the bicycle timing described above, a shorter minimum phase length may be used.

Support

The background of the Caltrans Policy Directive TR-0011 states, "that the guidance only apply to new and modified traffic actuated signals with more than 50% of the limit line detectors to be replaced."

This statement seems to be describing the CTCDC's intent, but that is not what CA MUTCD Section 4D.105(CA) actually says. The section as written recommends bicycle timing be used whenever bicycle detection is installed. The language change I recommend above would reduce Section 4D.105(CA)'s impact on the environment, traffic safety and other roadway users by reducing the number of locations where the new bicycle timing is guidance is implemented.

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BACKGROUND

POLICY DIRECTIVE

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Screen capture:

bicycle signal timing guidance would have on existing signal operation, so it recommended that the guidance only apply to new and modified traffic actuated signals with more than 50% of the limit line detectors to be replaced.

The March 1995 ITE Journal article entitled, "Signal clearance timing for bicyclists" addresses many of the problems associated with extending yellow and all-red signal timing intervals. It goes on to state that "In practice, they will be of greatest benefit at intersections where one or more of the following is true:

- Bicycle clearance-time accidents have occurred.
- Physical characteristics (such as width) and bicyclist volume make such accidents likely, as evaluated either by the risk assessment method proposed above or simply by inspection.
- A bike -laned street or a signed bicycle route crosses a major street."

The MUTCD provides guidance that WALK time be set at 7 seconds, but provides an Option that allows WALK time to be reduced where such reductions are merited. Adding a similar option to Section 4D.105(CA) would allow engineers to use their discretion in utilizing minimum bicycle phase lengths where needed, and avoid the negative impacts of this guidance where such timing is not needed.

Caltrans Policy Directive TR-0011 states,

Screen Capture:

DEFINITIONS

When used in this Traffic Operations Policy Directive, the text shall be defined as follows:

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Guidance – a statement of recommended, but not mandatory, practice in typical situations, with deviations allowed if engineering judgment or engineering study indicates the deviation to be appropriate. All Guidance statements text appears in underline type. The verb should is typically used. Guidance statements are sometime modified by Options.

Providing an additional Option to the bicycle timing guidance seems to clarify the intent of that guidance and make it clear that this guidance is not mandatory and that local engineers can use engineering judgment to determine if a deviation from this practice is appropriate.

Section 4D.105(CA) and Table 4D-109B(CA) Varying Bicyclist Acceleration and Travel Speeds

Modify the bicycle timing guidance to apply to mean bicycle travel speeds (13 mph, 19.1 ft/sec) and acceleration rates (3 ft/sec^2).

4.2 sec + (W + 6 ft) / 19.1 ft / sec

Provide an option to utilize slower bicycle speeds and acceleration rates when calculating phase lengths when selected phases are routinely utilized by slower cyclists. This is similar to the option in the MUTCD to use slower pedestrian travel speeds at locations where slower pedestrians are likely to be present.

When younger bicyclists who typically travel slower than 13 mph (19.1 feet per second), routinely ride during a phase, a bicycle travel speed of 10 mph (14.7 feet per second) with an acceleration rate of 1.5 feet per second^2 should be considered in determining the minimum phase length.

This combination of Guidance and Option minimizes the negative impacts of bicycle timing on the environment, traffic safety and other roadway users by allowing less restrictive signal timing far from schools and at night when slower moving bicyclists are less frequent. Typically young cyclists do not utilize left turn phases and lanes at major intersections and so the use of the faster travel speed and acceleration rate would reduce left turn phasing inefficiencies which still providing extended green time at unusually wide intersections.

Table 4D-109(CA)
Suggested Minimum Bicycle Timing

The table below shows the travel time in seconds for bicyclist to accelerate at 3.0 feet per second^2 to 13 mph (19.1 feet per second) from a standing stop, including 1.0 second of delay from the time the light first turns green to the time the cyclist begins to pedal. The time shown is for the distance "W" plus an additional 6 feet so that the bicycle will completely clear the last through travel lane.

Distance from Bicycle Detection Zone to far side of the last conflicting through lane (in feet) = W

	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
Travel Time in Seconds	7.1	7.6	8.2	8.7	9.2	9.7	10.3	10.8	11.3	11.8	12.4	12.9	13.4	13.9	14.5	15.0

Min Green + Yellow + All Red $\geq$ 4.2 sec + (W + 6) / 19.07 ft/sec

W = Distance from bicycle detection zone to far side of last conflicting through lane (typically 10 feet from the lane line)

Bicycle perception reaction time = 1.0 sec

Bicycle acceleration rate of 3.0 ft/sec^2

Maximum bicycle speed of 19.07 ft/sec (13 mph)

Design Bicycle is 6 feet long

Note: The 4.2 second adjustment compensates for the shorter distance traveled during start-up and acceleration. This value is reduced when w + 6 is less than 61 feet.

The following table below shows the travel time in seconds for motorist to accelerate at 8.0 feet per second^2 to 35 mph (51.3 feet per second) from a standing stop, including 0.8 second of delay from the time the light first turns green to the time the motorist depresses the gas pedal. The time shown is for the distance "D" as measured from the limit line to the conflicting bicyclist's path of travel.

Motor Vehicle Travel Distance to Bicycle Path of Travel (in feet)	Seconds
10	2.4
20	3.0
30	3.5
40	4.0
50	4.3
60	4.7
70	5.0
80	5.3
90	5.5
100	5.8
110	6.0
120	6.3
130	6.5
140	6.7
150	6.9
160	7.1
170	7.3
180	7.5
190	7.7
200	7.9

Motor vehicle perception reaction time = 0.8 sec
Motor Vehicle acceleration rate of 8.0 FT/sec^2
Maximum Motor Vehicle speed within intersection of 35 mph

The minimum amount of time a bicyclists needs to avoid a collision is equal to the amount of time it takes for the bicyclist to clear the last conflicting through lane, minus the amount of time it takes for a conflicting motor vehicle to reach the cyclist's path of travel.

For example, if it takes 12.9 seconds for a bicyclist to start, accelerate and clear the last through lane 160 feet from the bicycle detection zone, and it takes a motorist 3.0 seconds to travel 30 feet from the limit line to the cyclist's path of travel, then if the motorist gets a green light 9.9 seconds after the bicyclist gets a green light, the two vehicle will avoid a collision even if neither party ever observed the other party approaching.

In addition, the MUTCD Section 4D.04 states that traffic facing a circular green, or green arrow is permitted to enter an intersection, "But vehicular traffic, including vehicles turning right or left, shall yield the right-of-way to other vehicles, and to pedestrians lawfully within the intersection…". New MUTCD Section 4D.105(CA) and the CTCDC discussion about related signal timing fails to treat bicycles as vehicles and ignores the fact that all vehicles must yield to any other vehicle already lawfully within the intersection.

Distance from Bicycle Detection Zone to far side of the last conflicting through lane (in feet)

Motor Vehicle Travel Distance to Bicycle Path of Travel (in feet)	100	110	120	130	140	150	160	170	180	190	200
10	7.4	7.9	8.4	8.9	9.5	10.0	10.5	11.0	11.6	12.1	12.6
20		7.2	7.8	8.3	8.8	9.3	9.9	10.4	10.9	11.4	12.0
30			7.3	7.8	8.3	8.8	9.4	9.9	10.4	10.9	11.4
40				7.4	7.9	8.4	8.9	9.5	10.0	10.5	11.0
50					7.5	8.0	8.6	9.1	9.6	10.1	10.7
60					7.2	7.7	8.2	8.7	9.3	9.8	10.3
70						7.4	7.9	8.4	9.0	9.5	10.0
80						7.1	7.6	8.1	8.7	9.2	9.7
90							7.3	7.9	8.4	8.9	9.4
100							7.1	7.6	8.1	8.7	9.2
110								7.4	7.9	8.4	8.9
120								7.1	7.7	8.2	8.7
130									7.4	8.0	8.5
140									7.2	7.7	8.3
150									7.0	7.5	8.1
160										7.3	7.9
170										7.1	7.7
180											7.5
190											7.3
200											7.1

Min Green + Yellow + All Red $\geq$ 4.2 sec + (W + 6)/19.1 ft/sec - motor vehicle travel time

W = Distance from bicycle detection zone to far side of last conflicting through lane (typically 10 feet from the lane line)

Bicycle perception reaction time = 1.0 sec

Bicycle acceleration rate of 3.0 FT/sec^2

Maximum bicycle speed of 19.1 ft/sec (13 mph)

The length of the bicycle is 6 feet

Motor vehicle perception reaction time = 0.8 sec

Motor Vehicle acceleration rate of 8.0 FT/sec^2

Maximum Motor Vehicle speed within intersection of 35 mph

Note: The 4.2 second adjustment compensates for the shorter distance traveled during start-up and acceleration. This value is reduced when w + 6 is less than 61 feet.

Table 4D-109B(CA)
Option - Minimum Bicycle Timing for Slow Cyclists

The table below shows the travel time in seconds for bicyclist to accelerate at 1.5 feet per second^2 to 10 mph (14.7 feet per second) from a standing stop, including 1.0 second of delay from the time the light first turns green to the time the cyclist begins to pedal. The time shown is for the distance "W" plus an additional 6 feet so that the bicycle will completely clear the last through travel lane.

Distance from Bicycle Detection Zone to far side of the last conflicting through lane (in feet) = W

50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
9.6	10.4	11.1	11.8	12.4	13.1	13.8	14.5	15.2	15.8	16.5	17.2	17.9	18.6	19.2	19.9

Min Green + Yellow + All Red $\geq$ 5.9 sec + (W + 6) / 14.7 ft/sec
W = Distance from bicycle detection zone to far side of last conflicting through lane (typically 10 feet from the lane line)
Bicycle perception reaction time = 1.0 sec
Bicycle acceleration rate of 1.5 FT/sec^2
Maximum bicycle speed of 14.7 FT/sec
Design Bicycle is 6 feet long
Note: The 5.9 second adjustment compensates for the shorter distance traveled during start-up and acceleration. This value is reduced when w + 6 is less than 72 feet.

Section 4D.105(CA) and Table 4D-109(CA)
Limit Line versus Reference Bicycle-Rider Detection Zone

Substitute the phrase "Reference Bicycle-Rider Detection Zone" where Section 4D.105(CA) and table 4D-109(CA) use the phrase "limit line" when measuring the distance a bicyclist must travel to clear the last conflicting motor vehicle lane.

Existing technology provides engineers with options to provide additional vehicle detection beyond the limit line that can increase vehicle green time for slow moving vehicles. I have worked for agencies that install vehicle detectors 2 feet beyond the limit line. Crosswalk striping changes often change the location of the detectors relative to the limit line. Measuring the bicycle clearance distance from the limit line regardless of the location of the bicycle detectors and supplemental detectors limits the ability of engineers throughout the state to optimize traffic signal performance.

For example, I have installed two brands of video detection that can be used to not only set up detection in advance and at the limit line, but can also set up detection zones within the intersection that only operate during the green interval for a given phase. Thus during the green interval for a left turn phase, I could set up a video detection zone that holds the green until the first vehicle is 20 or 40 feet into the intersection. This could eliminate the need for any additional minimum green time for the average motor vehicle, while extending the green for slow accelerating trucks and bicycles.

Table 4D-109(CA) as Adopted
Shortened Traveled Distance During Acceleration

Modify references to "time lost" throughout the section, previously referring to 6 seconds and now proposed to be 4.2 seconds.

Support:

Bicyclist crossing times are shown in Table 4D-109(CA). The speed of *19.1* ft/sec represents the final crossing speed and the ~~effective start-up time of 6~~ *4.2* seconds ~~represents the time lost in reacting to the green light and then accelerating to full speed.~~ *is an adjustment that compensates for the shorter distance traveled during start-up and acceleration. This value must be reduced when W + 6 is less than 61 feet.*

The 6 second time period (recommended to be reduced to 4.2 seconds) was referred to in 4D.105(CA) as time lost during start-up and acceleration. But it is actually an approximate time equivalent substitution for the shorter distance traveled during start-up and acceleration and only applies when the distance traveled is far enough to allow a bicyclist to accelerate to the assumed final speed. A shorter formula time adjustment is required when the travel distance is less than the full acceleration distance. The previous language seemed to indicate that bicycle start-up and acceleration time occurred within a 6-second period. This created confusion when trying to understand the original formula.

Table 4D-109(CA) as Adopted
Conflicting motor vehicle travel time and distance

The formula used to formulate table 4D-109(CA) appears to not account for the travel time required for a motor vehicle to reach the point of conflict with a cyclist's path of travel.

In the May 2009 CTCDC staff report and in the ITE article Signal clearance timing for bicyclists, ITE March 1995, the authors discuss bicycle travel and clearance times, but they do not discuss the travel time and distance for any conflicting motor vehicles. The last pages of this letter include over a half a dozen examples of bicycle left turn and through paths of travel and travel times at wide intersections. In all of the examples I found, the stopped conflicting motor vehicles had much farther to travel to collide with a cyclist than they did to strike a pedestrian in the near-side crosswalk. In examining the various conflict points, I also found that conflicting right turn movements should be excluded when calculating minimum phase length as in most cases right turns on red are permitted and thus extending bicycle green times to avoid right turn conflict would not be effective.

I recommend that the formula to calculate minimum bicycle passage time include the following assumptions for the conflicting motor vehicle travel time:

- Motor Vehicle Perception/Reaction time of 0.8 seconds when a new green interval is displayed.
- Motor Vehicle Acceleration rate of 8 feet per second^2.
- Motor Vehicle final travel speed of up to 35 mph within the intersection.

Suggested Minimum Phase Length Formula:

The travel time for a cyclist to clear the last conflicting through lane from a standing start, minus the travel time for a motor vehicle to reach the bicyclists' path of travel in the last conflicting through lane. (Where the last through lane is more than 10 feet wide, the distance is typically measured 10 feet to the right of the left lane line.)

So if it takes 16 seconds for a bicycle to clear the last conflicting through lane, and it takes 3 seconds for a motor vehicle to reach the point of conflict along the cyclist's path of travel, the suggested minimum phase length would be 16 – 3 = 13 seconds. Newly adopted Table 4D-109(CA) does not factor into the phase length calculation any time for the motor vehicle from the time the green interval is first displayed to the driver. A potential collision between these two vehicles involves both vehicles' travel time to the point of contact.

Real life examples of how the table above would affect signal timing are shown on the following aerial photographs of existing wide intersections taken from several different cities. The examples show the critical path of bicycles going through or turning left at these intersections and the paths of travel of the conflicting motor vehicles.

Crossing Wide Arterial Roadways

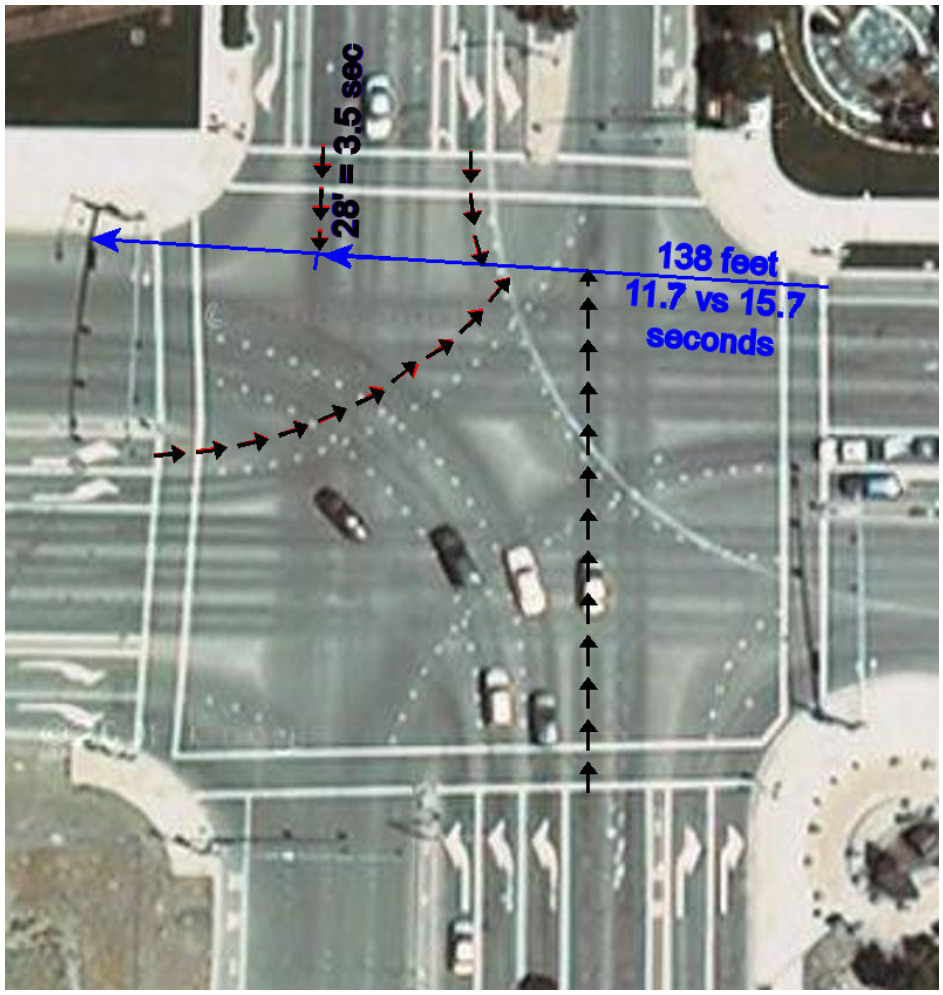
(Example: Dublin Blvd at Tassajarra Blvd)

Westbound bicycle path of travel = 138 feet to last conflicting southbound through lane. It takes a cyclist 11.7 seconds to clear this distance accelerating at 3.0 ft/sec^2 with a maximum speed of 13mph. It takes a cyclist 15.7 seconds to clear this distance accelerating at 1.5 ft/sec^2 with a maximum speed of 10mph. The existing Table 4D-109(CA), shows a minimum time of 15.9 seconds for 140 feet, but this is a little long due to formula rounding choices (the 6 seconds in the original formula was rounded up from 5.86 seconds).

The last conflicting lane is either the #3 southbound through lane or the southbound right turn lane. I recommend a language change to section 4D.104(CA) to specify the last conflicting through lane. Most right turns can be made on a red light. Since the minimum bicycle phase length is 11.7 to 15.9 seconds long, it is impossible to prevent the southbound right turn movement during this period of time without posting "No Right Turn On Red" restrictions. Requiring the minimum phase length to be long enough for the bicyclist to clear the far side of the southbound right turn path of travel would add an additional 3.6 seconds of minimum green time to the westbound through movement.

Note that a westbound bicycle is much farther from conflicting through traffic than a pedestrian in the crosswalk. It would take a stopped vehicle 3.5 seconds to reach the cyclist's path of travel accelerating at 8 ft/sec^2 after a 0.8 second perception / reaction time lag from the beginning of green.

This is also an example of the need to allow for engineering discretion. Note that the southbound through conflict only exists if the westbound through phase is followed by the southbound through phase. If the northbound left turn and through phases follow the westbound through phase, the conflict is with the #1 northbound through lane. Due to the shorter westbound travel distance to the conflict point, there would be no need to extend the westbound bicyclist's phase length.



Crossing Wide Arterial Roadways – Left Turns

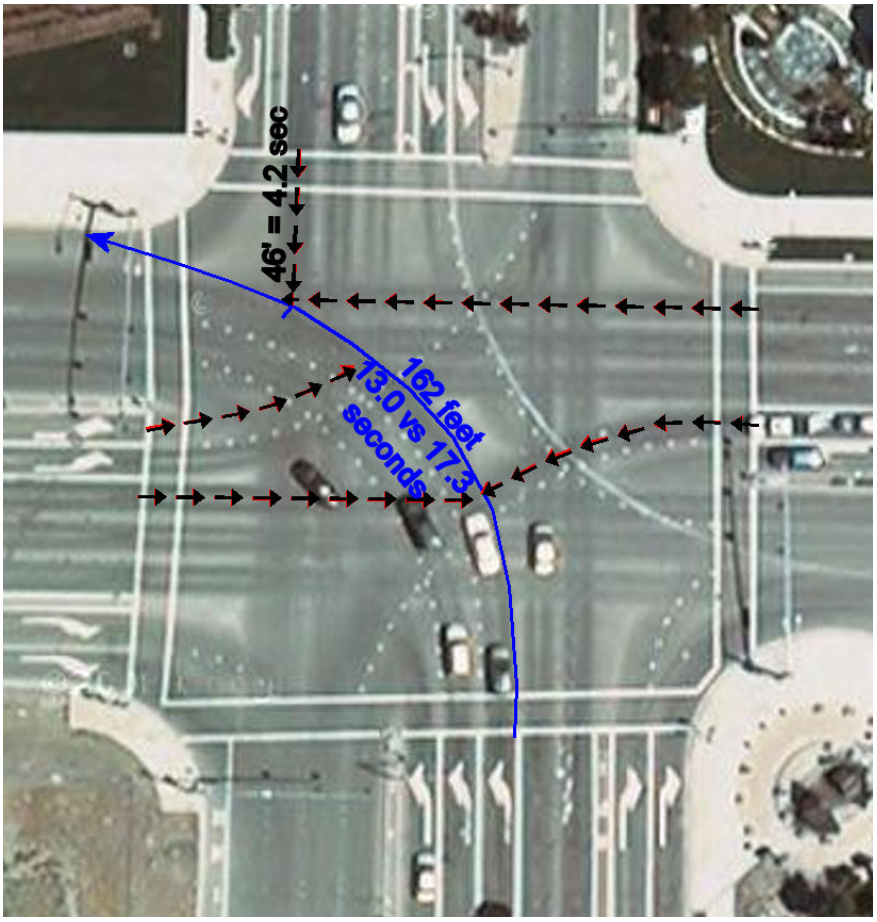
(Example: Dublin Blvd at Tassajarra Blvd)

Northbound left turn bicycle path of travel = 162 feet to last conflicting southbound through lane. It takes a cyclist 13.0 seconds to clear this distance accelerating at 3.0 ft/sec^2 with a maximum speed of 13mph. It takes a cyclist 17.3 seconds to clear this distance accelerating at 1.5 ft/sec^2 with a maximum speed of 10mph. The existing Table 4D-109(CA), shows a minimum time of 17.3 seconds for 160 feet.

The last conflicting lane is either the #3 southbound through lane or the southbound right turn lane. I recommend a language change to section 4D.104(CA) to specify the last conflicting through lane. Most right turns can be made on a red light. Since the minimum bicycle left turn phase length is 13.0 to 17.3 seconds long, it is impossible to prevent the southbound right turn movement during this period of time without posting "No Right Turn On Red" restrictions. Requiring the minimum phase length to be long enough for the bicyclist to clear the far side of the southbound right turn path of travel would add an additional 3.6 seconds of minimum green time to the northbound left turn phase.

Note that a bicycle making a northbound left turn is much farther from conflicting through traffic than a pedestrian in the crosswalk. It would take a stopped vehicle 4.2 seconds to reach the cyclist's path of travel accelerating at 8 ft/sec^2 after a 0.8 second perception / reaction time lag from the beginning of green.

Note that the southbound through conflict only exists if the northbound left turn phase is followed by the southbound through phase. If the northbound left turn phase lags, it will be followed by the eastbound left or westbound through phases that shorten the cyclist's exposure to conflicting traffic and lengthen the conflicting vehicle's travel times. A Traffic Engineer needs to be able to use professional judgment in balancing all of these factors and options when setting the minimum phase length.



Section 4D.105(CA) and Table 4D-109(CA)
Do the new minimum phase length guidelines apply to left turn phases?

Much of the basis for the new signal timing guidelines in Section 4D.105(CA) are derived from an article in the March 1995 ITE Journal entitled Signal clearance timing for bicyclists. That article never uses the word "left" or makes any mention of "left turn" phases or turning movements. It appears that left turn acceleration times and mean travel speeds where not studied for this article and were not included in the CTCDC subcommittee's bicycle timing research for AB 1581.

Base on my experience as the City Traffic Engineer for 3 cities and as a long-distance cyclist, the typical cyclist who makes left turns from signalized left turn lanes has above average acceleration times and travel speeds. The ITE article and the CTCDC AB1581 staff report noted the slowest travel speeds and acceleration rates were found at those locations with elementary school aged riders. The crown of the street as traversed in the rightmost through lane also impeded acceleration times.

Another issue raised in the ITE article as a reason to justify minimum bicycle phase lengths was that of limited sight distance.

Signal clearance timing for bicyclists, ITE March 1995

"These conflicts typically occur when a bicyclist traveling on a minor street that carries slow and infrequent traffic and has a short signal phase, crosses a wide, usually multilane major street or arterial that carries high-speed traffic. (We refer to these as the minor and major streets, but in some cases the "minor street" may also be a major street.) Most often, the conflict occurs at the far side of the intersection, in the outside lane of the major street. A motorist on the cyclist's right starts up or speeds up in this lane as the light turns green, while traffic still clearing the intersection is hidden by vehicles waiting in the inside lanes."

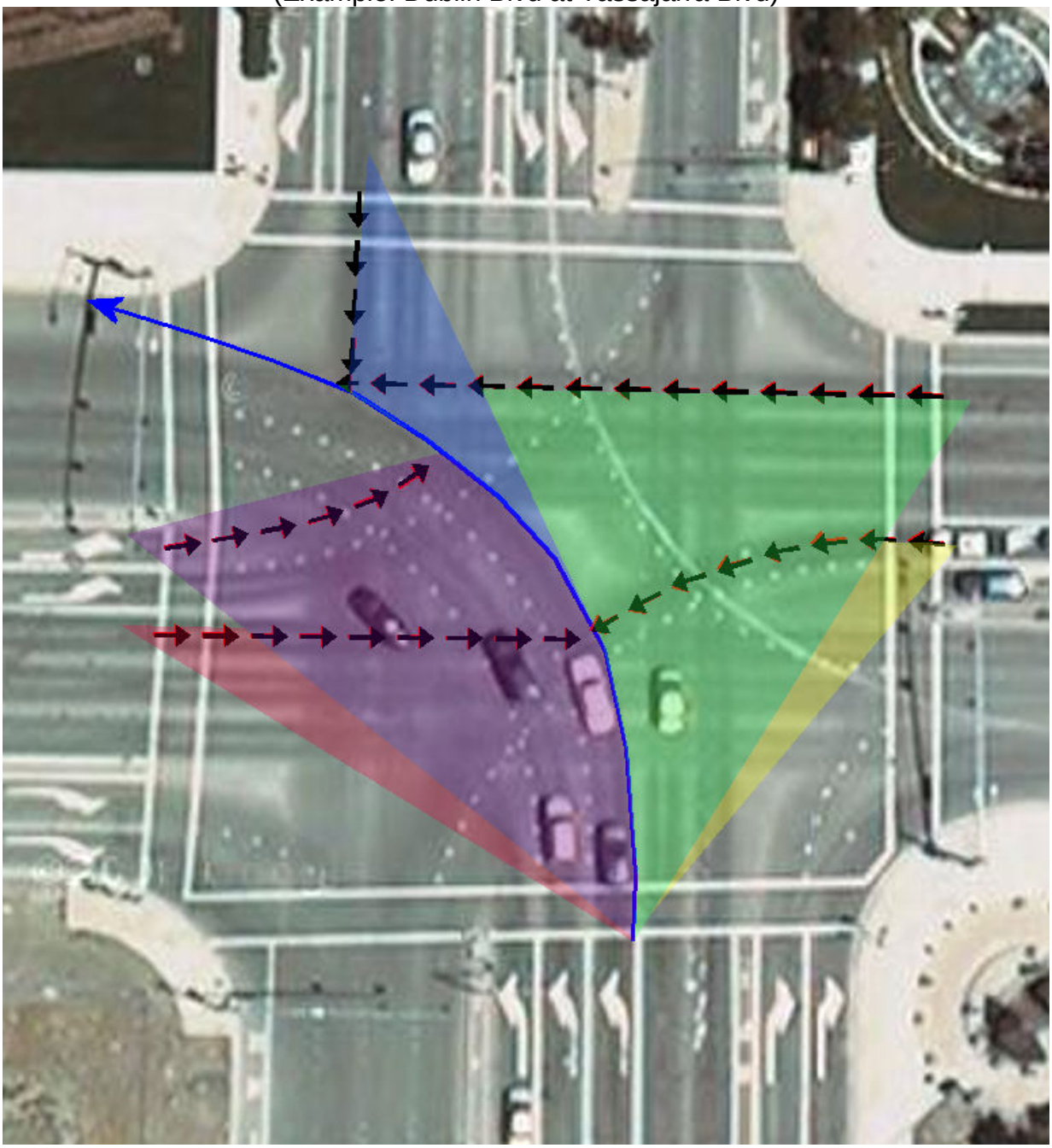
The passage I underlined above is from the first paragraph of the referenced ITE article. Nothing in this article indicates that the authors of the article were looking at left turn movements. They never even used the word "left" in their article. In fact several passages indicate that they were not looking at bicycles turning left from an arterial roadway, and that they were primarily looking at movements on the far right side of the road where visibility is restricted.

As shown in the following diagram, left turn movements generally pass through the center of the intersection where visibility is completely unrestricted by any stopped vehicles. Cyclists using left turn lanes typically have the fastest acceleration rates and travel speeds due to both the nature of the rider and the reduced roadway crown differential crossed by left turning vehicles.

Additional research is needed before the new minimum phase length guidelines are applied to left turn phases due to the unrestricted visibility drivers have of cyclists making left turns, the speed of left turning cyclists at wide intersections, and the provisions of CVC 21451 that requires any driver facing a green signal indication to "yield the right-of-way to other traffic and to pedestrians lawfully within the intersection"

Crossing Wide Arterial Roadways – Left Turn Visibility

(Example: Dublin Blvd at Tassajarra Blvd)



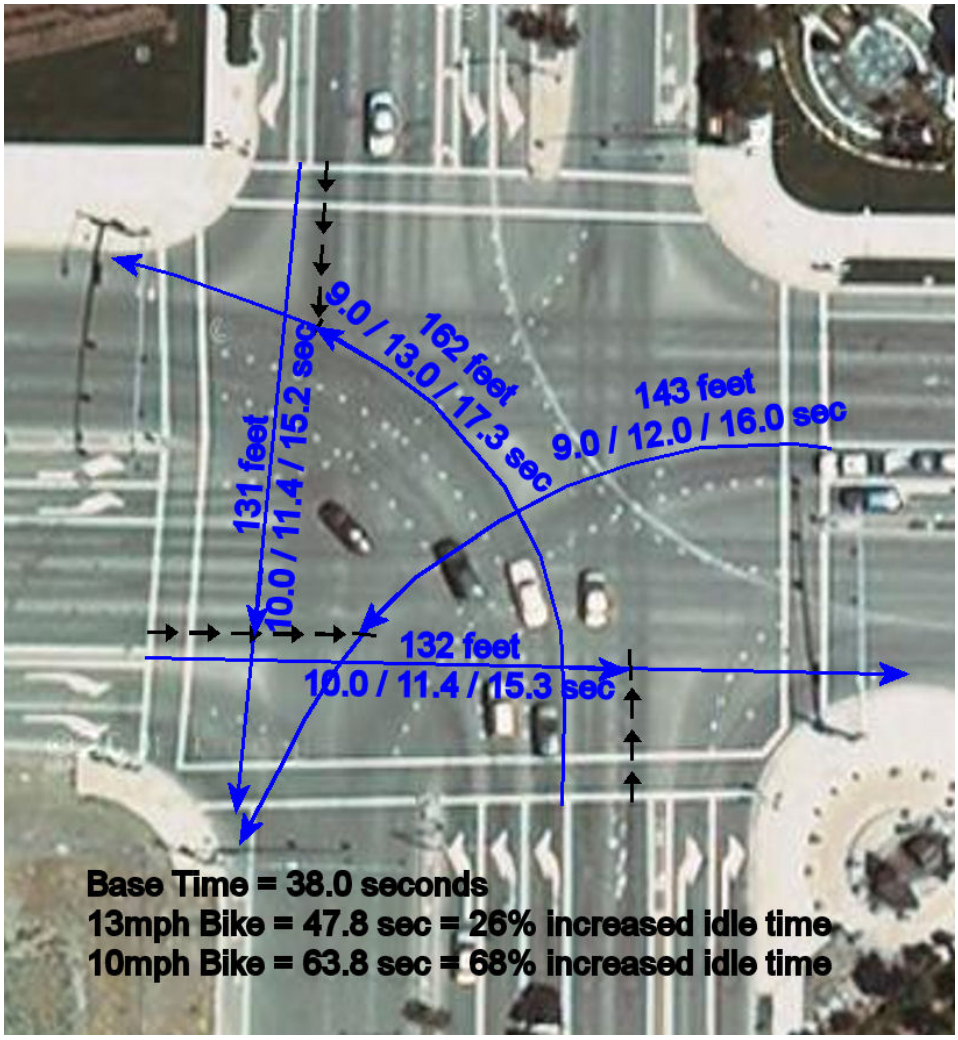
Crossing Wide Arterial Roadways – Cumulative Effect

(Example: Dublin Blvd at Tassajarra Blvd)

Every issue in Traffic Engineering involves achieving a balance between competing demands. The need to safely move motor vehicles, bicycles and pedestrians through an intersection must balance safety needs, circulation needs, and environmental impacts.

The implementation of the new guidelines for minimum bicycle phases on just one phase of an intersection could increase the cycle length along an entire corridor, thus increasing driver frustration, fuel use, automotive emissions, while also reducing traffic safety by causing traffic to back out of left turn pocket into the #1 through lanes.

The diagram on this page shows the extent to which the new Section 4D.105(CA) guidelines impact the critical movements at an intersection. The base timing for an intersection like this one provides a minimum green of 5.0 seconds per phase, 3.0 seconds of yellow per left turn and 4.0s seconds per through movement and 1.0 seconds of all red clearance time per phase for a total of 38 seconds of combined minimum phase lengths. This pre-4D.105(CA) time is shown as the first split under the travel distance in feet.



The last time split shown in this diagram represents the new phase minimum required by Section 4D.105(CA) which increases minimum green time by 25.8 seconds. This represents 68% more red time during which no vehicles are entering the intersection and everyone is stopping or idling unnecessarily.

The middle split shows the minimum phase length if the acceleration speed is assumed to be 3.0 ft/sec^2 with a maximum bike speed of 13mph.

The ***Traffic Signal Timing Manual*** published by ITE and the FHWA states that longer minimum green times (over 4 seconds) tend to increase overall delay. It also says, "Cycle lengths that are too long may increase congestion rather than reducing it due to the impacts of long waiting queues on side streets and the arterials alike." The document indicates that longer cycle lengths tend to increase pedestrian delay, "which may reduce the compliance of pedestrians or increase midblock

crossings (to avoid the signal)." The document shows that drivers expect shorter minimum green for left turn phases than for through phases, while MUTCD Section 4D.105(CA) has exactly the opposite effect.

The aerial photograph above and the other examples that follow show that often during the day there is very little demand for green time beyond the minimum green interval. This is also true at night when volumes are lighter and few if any bicycles are on the road. And yet there in no mention in section 4D.105(CA) of engineers having the discretion to shorten these minimum phase lengths when few if any bicycles are present. The ability to use discretion in setting bicycle timing is even more critical than in setting pedestrian timing as pedestrian timing is only in effect when a pedestrian activates a pedestrian push button. But most modern vehicle detection cannot distinguish between a bicycle and a motor vehicle, so the bicycle minimum phase lengths would remain in effect 24 hours a day, 7 days a week, for all vehicles when bicycles represent 2% or less of daily traffic. Bicyclists represent an even lower percentage of overall traffic at night, but Section 4D.105(CA) makes no provisions to adjust minimum phase lengths at night. Very few of the slower, elementary school age riders are present at night and yet Section 4D.105(CA) does not even permit the use of faster bicycle acceleration rates and travel speeds at night.

Impacts to Transit Operations

Local Transit Systems like the one operated by Vacaville. Struggle to increase ridership by improving routes and reducing headway times, while also minimizing costs and fares. Section 4D.105(CA) increases red time along arterial roadways which are the backbone of the Transit System Route Network. Increasing unnecessary stops and delays is detrimental to transit systems throughout the state. Fuel costs and wear and tear on transit vehicles due to increased starts and stops have a significant impact on transit costs and fare box to operating cost ratios that are critical to maintaining federal funding for this service. Section 4D.105(CA) must be modified to balance the needs of cyclists, and focus the application of bicycle timing in ways that minimize the impacts to the majority of transportation infrastructure users.

Section 4D.105(CA) must be modified to allow Traffic Engineers to adjust signal timing in ways that are more consistent with other MUTCD provisions.

MUTCD Section 4D.113(CA) states, "The proportion of green time, or split, allotted to each phase during a signal cycle, should be as close as practicable to the proportion of critical lane traffic volumes on the respective approaches." New MUTCD Section 4D.105(CA) increases green time for minor vehicle movements disproportionately to the 1-2 percent of all traffic that bicycles represent. The new timing standard applies 24 hours a day, even late at night when bicycles represent an even smaller proportion of vehicles on the road.

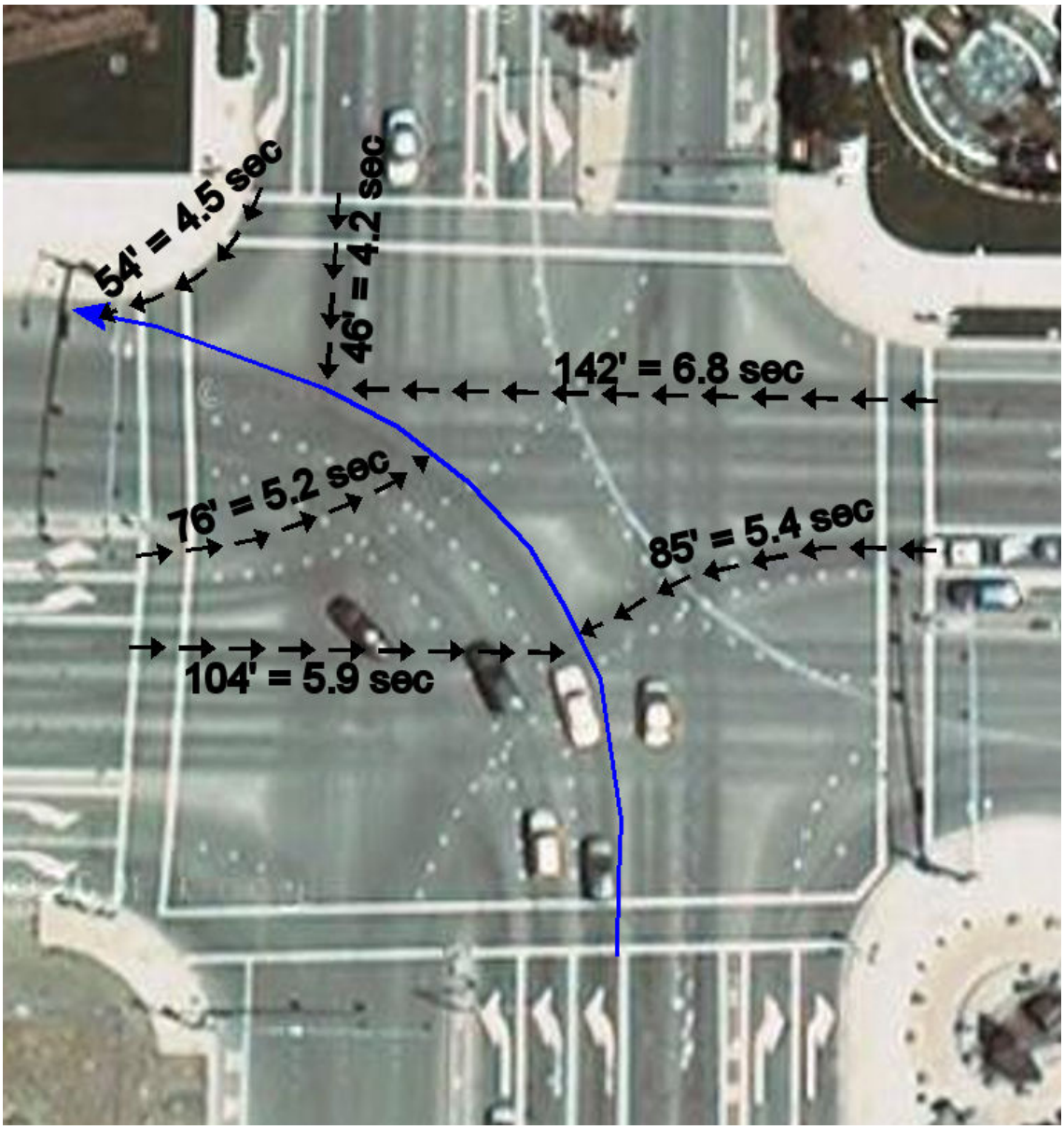
MUTCD Section 4B.05, speaks to the point of making sure that changes to an intersection do not degrade capacity at the intersection, including pedestrian signal timing impacts related to roadway widening.

MUTCD Section 4D.06 refers to minimizing the use of exclusive left turn phasing that "will reduce the green time available for other phases, alternate means of handling left turn conflicts should be considered first." New MUTCD Section 4D.105(CA) does not allow for any options or discretion on the part of professional engineers to reduce the impact the new bicycle minimum phase will have on overall traffic signal operations.

Crossing Wide Arterial Roadways – Conflicting Vehicles

(Example: Dublin Blvd at Tassajarra Blvd)

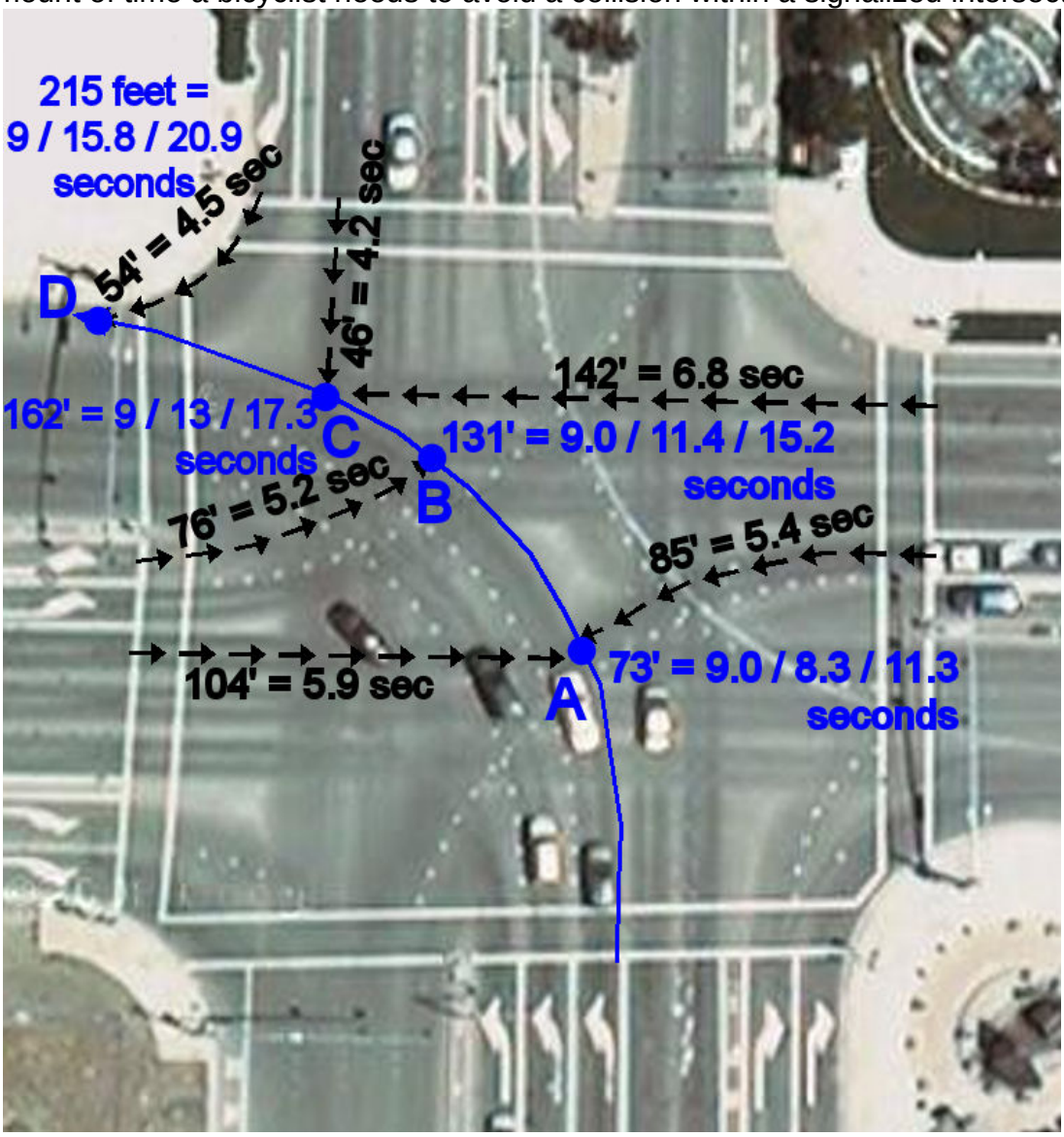
Another issue not addressed in the ITE article on bicycle clearance time, the CTCDC staff report on AB1581, or new section 4D.105(CA) of the MUTCD is the second component of any bicycle collision: the motor vehicle. The discussion of pedestrian versus motor vehicle conflicts in crosswalks where the pedestrian may be only 1 foot away from the front of a car at the time the light turns green for a conflicting car is quite different from the relative position of a bicycle and a car at the moment the light turns green for the car. In the majority of cases, a car must travel at least 15 feet before it enters the bath of travel of a bicyclists, and in some cases the car must travel over 100 feet before a conflict exists. Section 4D.105(CA) and the supporting staff report ignore the travel time of the conflicting motor vehicle when calculating the minimum phase length needed by a bicyclist to avoid a collision with an approaching motor vehicle.



The motor vehicle travel times in the preceding diagram assume the following:

- The vehicle is stopped at the limit line at the time the light turns green.
- The driver has a 0.8 second perception/reaction time before beginning to accelerate.
- The vehicle accelerates at 8.0 feet per second^2
- The maximum speed attainable by the motor vehicle is 35 mph.

Many different variables can be assumed when accounting for a conflicting motor vehicle's travel time. The factors listed above represent the fastest approach for a stopped vehicle in Synchro 7. The bottom line is that considering the significant impact the section 4D.105(CA) would have on the environment, automotive emissions, green house gasses, fuel consumption, increased transportation costs, transit service, and traffic safety, factors such as the travel time of conflicting motor vehicles must be included when calculating the minimum amount of time a bicyclist needs to avoid a collision within a signalized intersection.



As in previous examples, the bicyclist's travel time to clear conflict points A, B, C and D assume the following:

- For the distance in feet shown, the first number represents the pre-Section 4D.105(CA) phase length.
- The second travel time shown assumes 1.0 seconds of perception/reaction time, an acceleration rate of 3.0 ft/sec^2, and a maximum speed of 13mph.
- The third travel time shown assumes 1.0 seconds of perception/reaction time, an acceleration rate of 1.5 ft/sec^2, and a maximum speed of 10mph.

Conflict Point A:

1) If the northbound bike left turn is followed by the eastbound through phase, the standard 9-second phase length (5 sec green+3 sec yellow+1 sec all-red) would provide enough time for a cyclist at either speed assumption to clear point A prior to the conflicting motor vehicle reaching the cyclist's path of travel.
2) If the northbound bike left turn is followed by the westbound left turn phase, the standard 9-second phase length would provide enough time for a cyclist at either speed assumption to clear point A prior to the conflicting motor vehicle reaching the cyclist's path of travel.

Conflict Point B:

1) If the northbound bike left turn is followed by the eastbound left turn phase, the standard 9-second phase length would provide enough time for a cyclist accelerating at 3.0 ft/sec^2 to clear point B prior to the conflicting motor vehicle reaching the cyclist's path of travel. It takes the cyclist 11.4 seconds to clear point B, but at that point in time the motor vehicle is still 2.8 seconds away from reaching the conflict point. This is because it takes the conflicting motor vehicle 5.2 seconds to reach the cyclist's path of travel. (11.4 – 9.0 = 2.4 seconds. 5.2 – 2.4 = 2.8 seconds).

1b) If the northbound bike left turn is followed by the eastbound left turn phase, the standard 9-second phase length would NOT provide enough time for a cyclist accelerating at 1.5 ft/sec^2 to clear point B prior to the conflicting motor vehicle reaching the cyclist's path of travel. It would take the cyclist 15.2 seconds to clear point B, but a motorist could reach the conflict point only 14.2 seconds after the beginning of the cyclist's green light (9.0 + 5.2 = 14.2 seconds) If the CTCDC still finds the 1.5 ft/sec^2 acceleration rate to be required on a 24/7 basis, then at least one additional second of phase time would be needed, or supplemental detection could be used to shorten the bicyclist's travel distance from the last reference bicycle-rider detection zone to the point of conflict. But utilizing the motor vehicle's travel time in the phase length equation does significantly reduce the impact of providing minimum bicycle timing. The standard 9.0 second left turn phase would be increased to 10.0 seconds instead of 15.2 seconds.

Conflict Point C:

1) If the northbound bike left turn is followed by the westbound through phase, the standard 9-second phase length would provide enough time for a cyclist accelerating at 3.0 ft/sec^2 to clear point C prior to the conflicting motor vehicle reaching the cyclist's path of travel. It takes the cyclist 13 seconds to clear point C, but at that point in time the motor vehicle is still 2.8 seconds away from reaching the conflict point. This is because it takes the conflicting

motor vehicle 6.8 seconds to reach the cyclist's path of travel. (13 – 9.0 = 4 seconds. 6.8 – 4 = 2.8 seconds)

1b) If the northbound bike left turn is followed by the westbound though phase, the standard 9-second phase length would NOT provide enough time for a cyclist accelerating at 1.5 ft/sec^2 to clear point C prior to the conflicting motor vehicle reaching the cyclist's path of travel. It would take the cyclist 17.3 seconds to clear point C, but a motorist could reach the conflict point only 13.2 seconds after the beginning of the cyclist's green light (9.0 + 4.2 = 13.2 seconds) If the CTCDC still finds the 1.5 ft/sec^2 acceleration rate to be required on a 24/7 basis, then at least 3.9 additional seconds of phase time would be needed, or supplemental detection could be used to shorten the bicyclist's travel distance from the last reference bicycle-rider detection zone to the point of conflict. But even in this case utilizing the motor vehicle's travel time in the phase length equation significantly reduces the impact of providing minimum bicycle timing. The standard 9.0 second left turn phase would be increased to 10.5 seconds instead of 17.3 seconds.

2) If the northbound left turn is followed by the southbound through phase, the standard 9-second phase length would provide enough time for a cyclist accelerating at 3.0 ft/sec^2 to clear point C prior to the conflicting motor vehicle reaching the cyclist's path of travel. It takes the cyclist 13 seconds to clear point C, but at that point in time the motor vehicle is still 0.2 seconds away from reaching the conflict point. This is because it takes the conflicting motor vehicle 4.2 seconds to reach the cyclist's path of travel. (13 – 9.0 = 4 seconds. 4.2 – 4 = 0.2 seconds)

As part of this discussion please note that CVC 21451 requires the following: "(a) A driver facing a circular green signal shall proceed straight through or turn right or left or make a U-turn unless a sign prohibits a U-turn. Any driver, including one turning, shall yield the right-of-way to other traffic and to pedestrians lawfully within the intersection or an adjacent crosswalk." As discussed previously, a bicyclist making a left turn from a left turn lane travels along a path easily observed by drivers who must adhear to the requirements of CVC 21451.

2b) If the northbound left turn is followed by the southbound though phase, the standard 9-second phase length would NOT provide enough time for a cyclist accelerating at 1.5 ft/sec^2 to clear point C prior to the conflicting motor vehicle reaching the cyclist's path of travel. It would take the cyclist 17.3 seconds to clear point C, but a motorist could reach the conflict point only 15.8 seconds after the beginning of the cyclist's green light (9.0 + 6.8 = 15.8 seconds) If the CTCDC still finds the 1.5 ft/sec^2 acceleration rate to be required on a 24/7 basis, then at least 1.5 additional seconds of phase time would be needed, or supplemental detection could be used to shorten the bicyclist's travel distance from the last reference bicycle-rider detection zone to the point of conflict. But utilizing the motor vehicle's travel time in the phase length equation does significantly reduce the impact of providing minimum bicycle timing. The standard 9.0 second left turn phase would be increased to 13.1 seconds instead of 17.3 seconds.

Conflict Point D:

Conflict point D involves the southbound right turn movement. As discussed previously, it is pointless to contemplate increasing the northbound left turn phase minimum time from 9.0 seconds to 20.9 seconds as required in MUTCD Section 4D.105(CA) when the southbound right turn may be made on red at any time during the 20.9 second long northbound left turn phase.

I have attached aerial photographs of several wide arterial intersections around California that would be significantly impacted by MUTCD Section 4D.105(CA) as written. Changing the language to assume 3.0 ft/sec acceleration rates in the left turn lanes and subtracting the conflicting vehicle travel times would minimize these impacts. The examples also show that utilizing a 1.5 ft/sec acceleration rate for through movements at wide intersections when slower cyclists are likely to be present, and subtracting the conflicting vehicle travel time would minimize impacts under these circumstances while still providing a reasonable minimum bicycle phase length.

It should be noted that these intersections, and intersections like them do not operate in isolation. These intersections typically operate as part of a coordinated signal system. New signal timing requirements that increase the cycle lengths at these intersections force similar changes at all of the other intersections at are coordinated with these intersections. This results in system wide impacts to fuel use, greenhouse gas emissions, driver frustration, traffic safety degradation, increased congestion, less efficient transit service and other impacts not addressed by either the CTCDC's AB 1581 staff report or the ITE article on bicycle clearance times.

Crossing Wide Arterial Roadways

Example: Alamo Drive at Peabody Road

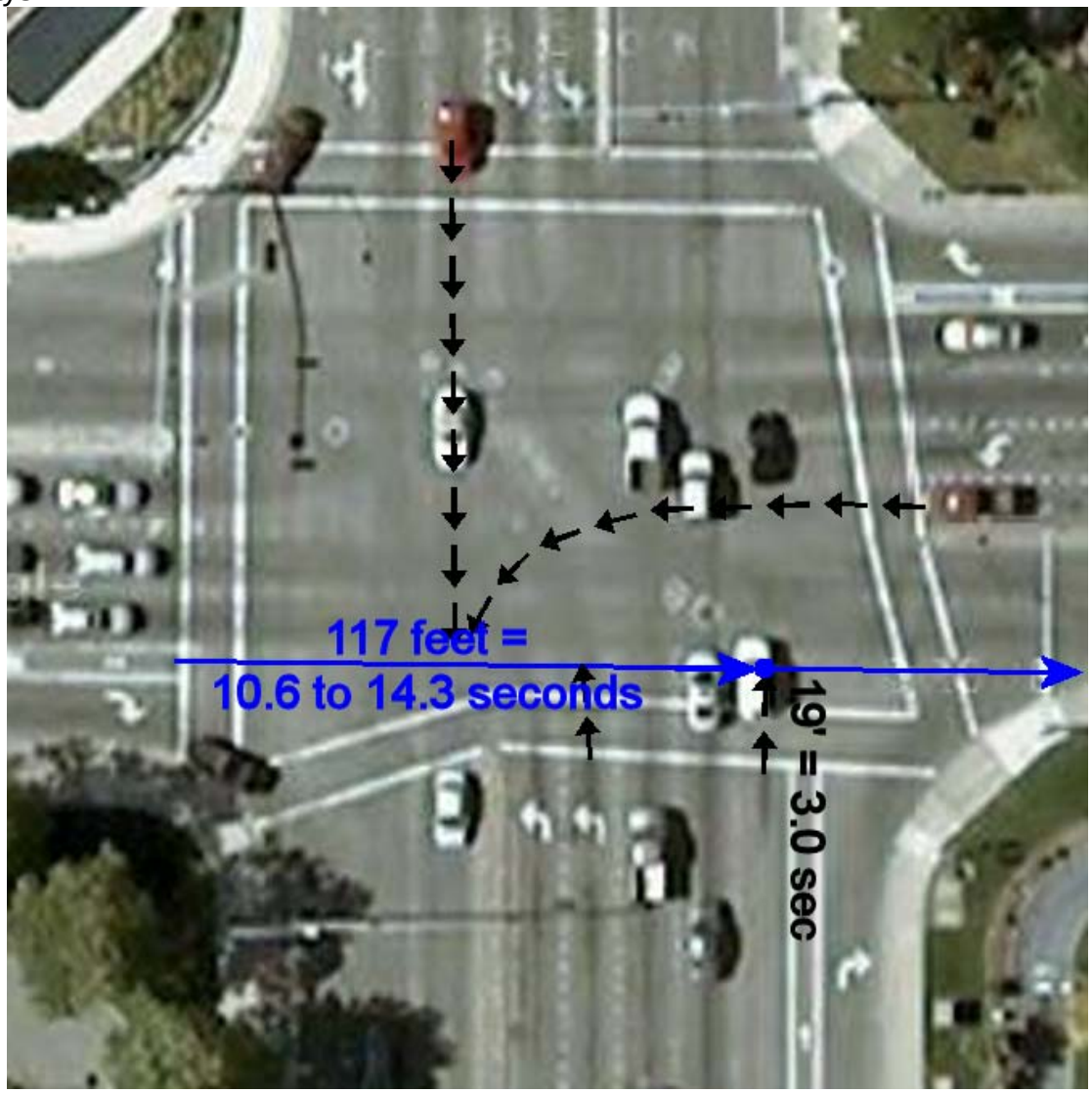
Westbound bicycle path of travel, distance and travel time in blue

Conflicting motor vehicle paths of travel, distance and travel time in black

An eastbound bicyclist takes 10.6 to 14.3 seconds to clear 117' while the conflicting northbound through vehicle takes 3.0 seconds to reach the point of conflict:

10.6 to 14.3 minus 3.0 = 7.6 to 11.3 seconds of Green+Yellow+all-Red

No additional time is needed for those cyclists who can accelerate at 3.0 ft/sec^2. 2.3 additional seconds may be needed for slower cyclists. However if the northbound left turn follows the eastbound through phase it takes 2.6 seconds less for a slow cyclist to clear the #2 northbound left turn lane than it does to clear the #3 northbound through lane. This emphasizes the need to provide local engineers with discretion to use engineering judgment when setting minimum phase lengths. Also the light traffic in the photo shows that often only standard minimum green time is needed to clear standing queues even on major arterial roadways.



Wide Crossing Arterial Roadways

Example: Alamo Drive at Peabody Road

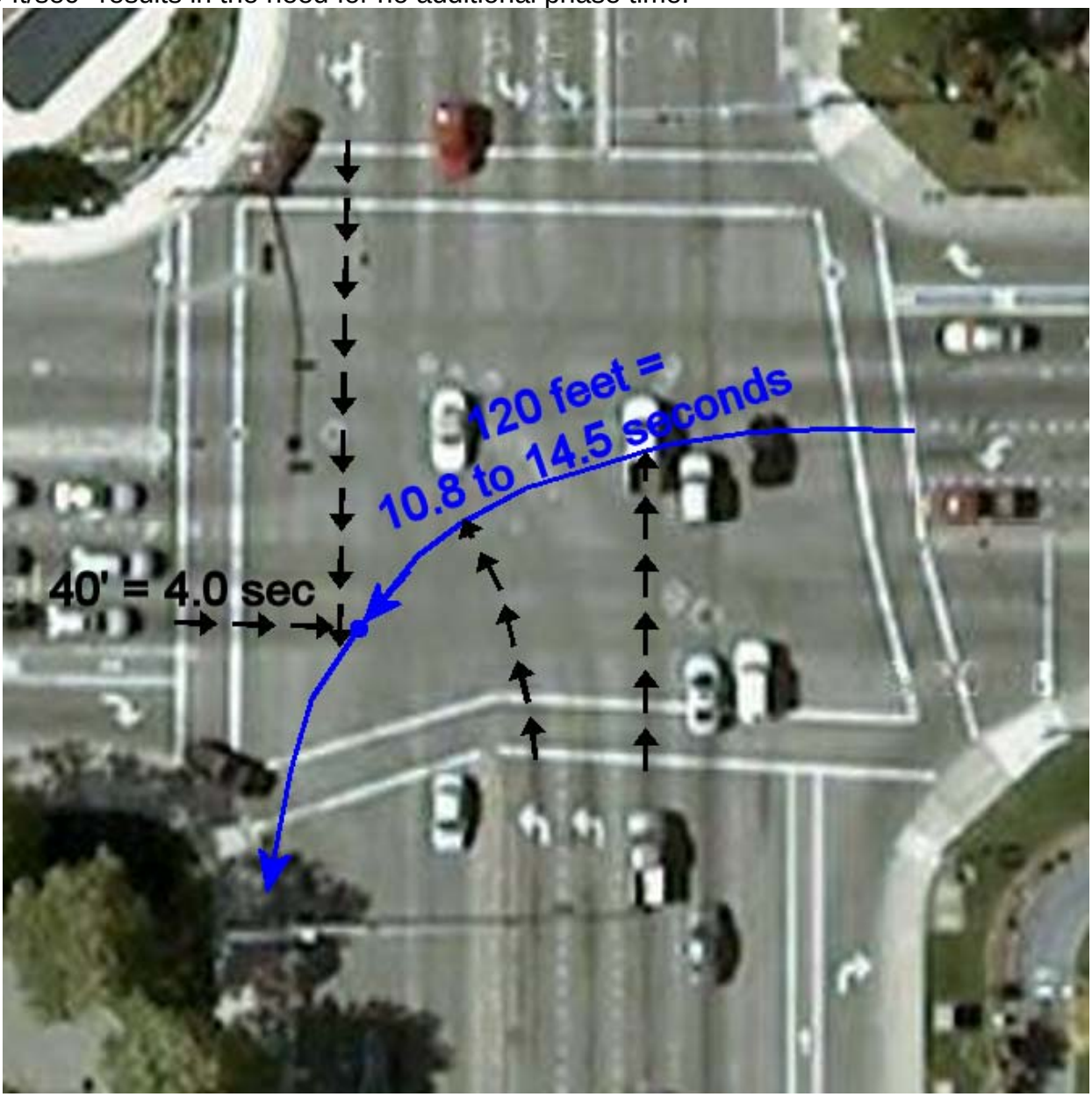
Westbound left turn bicycle path of travel, distance and travel time in blue

Conflicting motor vehicle paths of travel, distance and travel time in black

A bicyclist making a westbound left turn takes 10.8 to 14.5 seconds to clear 120 feet while the conflicting eastbound through vehicle takes 4.0 seconds to reach the point of conflict:

10.8 or 14.5 minus 4.0 = 6.8 or 10.5 seconds of Green+Yellow+All-Red

Additional time is only needed if a very slow rate of acceleration is assumed for this double left turn lane. This is an example where slower elementary school aged cyclists are not expected to be using the #2 left turn lane, and thus the more reasonable acceleration rate of 3.0 ft/sec^2 results in the need for no additional phase time.



Crossing Wide Arterial Roadways

Example: Hopyard Road at Las Positas

Westbound bicycle path of travel, distance and travel time in blue

Conflicting motor vehicle paths of travel, distance and travel time in black

A westbound bike takes 10.8 to 14.5 seconds to clear 121' while the conflicting southbound through vehicle takes 3.6 seconds to reach the point of conflict:

10.8 to 14.5 minus 3.6 = 7.2 to 10.9 seconds of Green+Yellow+All-Red

No additional time is needed for those cyclists who can accelerate at 3.0 ft/sec^2. 1.9 additional seconds may be needed for slower cyclists. However if the southbound left turn follows the westbound through phase it takes 2.6 seconds less for a slow cyclist to clear the #2 southbound left turn lane than it does to clear the #3 southbound through lane. This again emphasizes the need to provide local engineers with discretion to use engineering judgment when setting minimum phase lengths. Also the light traffic in the photo shows that often only standard minimum green time is needed to clear standing queues even on major arterial roadways. This is an example of where significantly increasing minimum green times would significantly and needlessly increase stops and delay at these types of intersections, and at all of the other intersections along Hopyard Road that are coordinated with this intersection.

Crossing Wide Arterial Roadways

Example: Hopyard Road at Las Positas

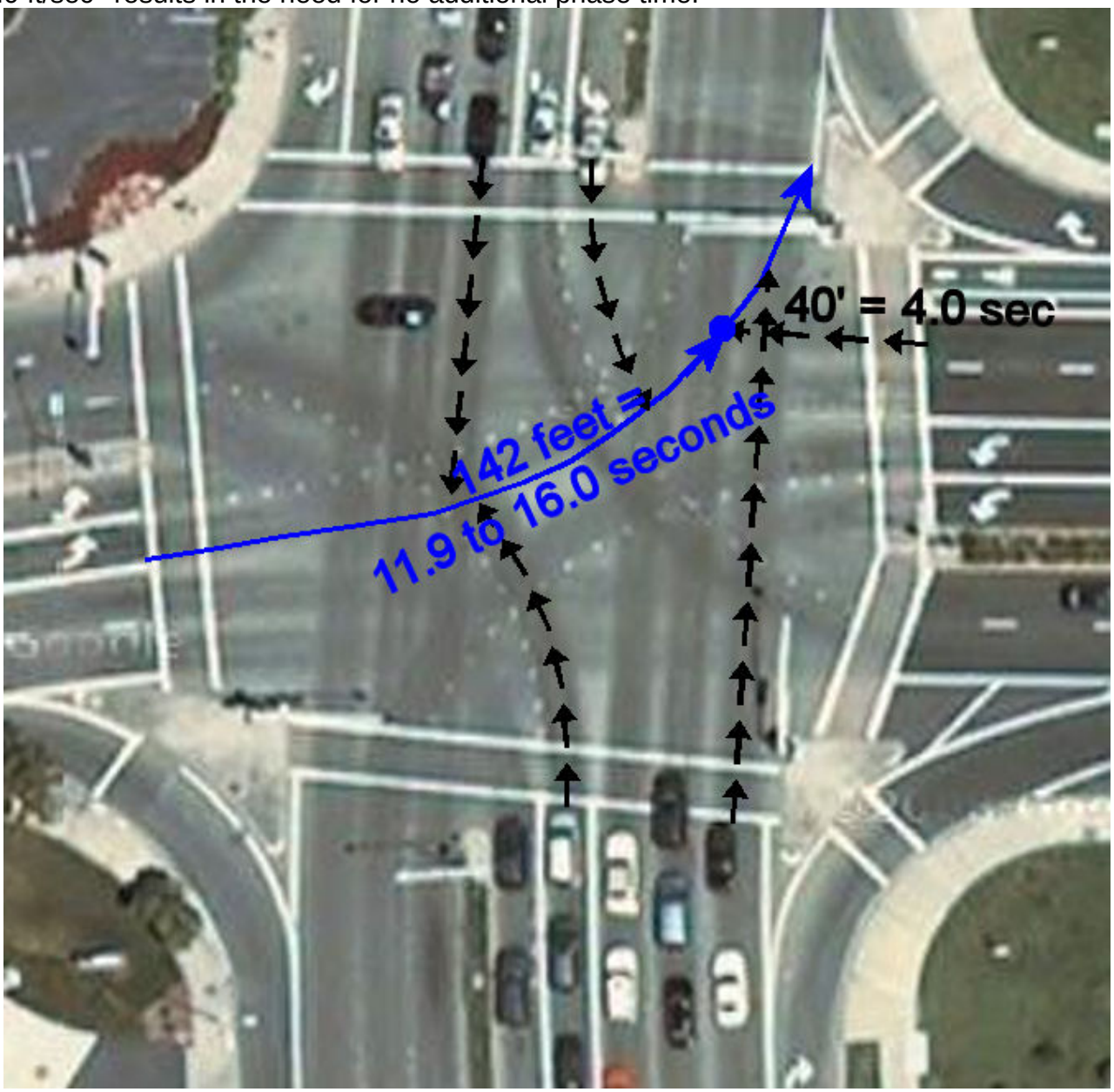
Eastbound left turn bicycle path of travel, distance and travel time in blue

Conflicting motor vehicle paths of travel, distance and travel time in black

A bicyclist making an eastbound left turn takes 11.9 to 16.0 seconds to clear 142 feet while the conflicting westbound through vehicle takes 4.0 seconds to reach the point of conflict:

11.9 to 16.0 minus 4.0 = 7.9 to 12.0 seconds of Green+Yellow+All-Red

Additional time is only needed if a very slow rate of acceleration is assumed for this double left turn lane. This is another example where slower elementary school aged cyclists are not expected to be using the #2 left turn lane, and thus the more reasonable acceleration rate of 3.0 ft/sec^2 results in the need for no additional phase time.



Crossing Wide Arterial Roadways

Example: Hopyard Road at Stoneridge Drive

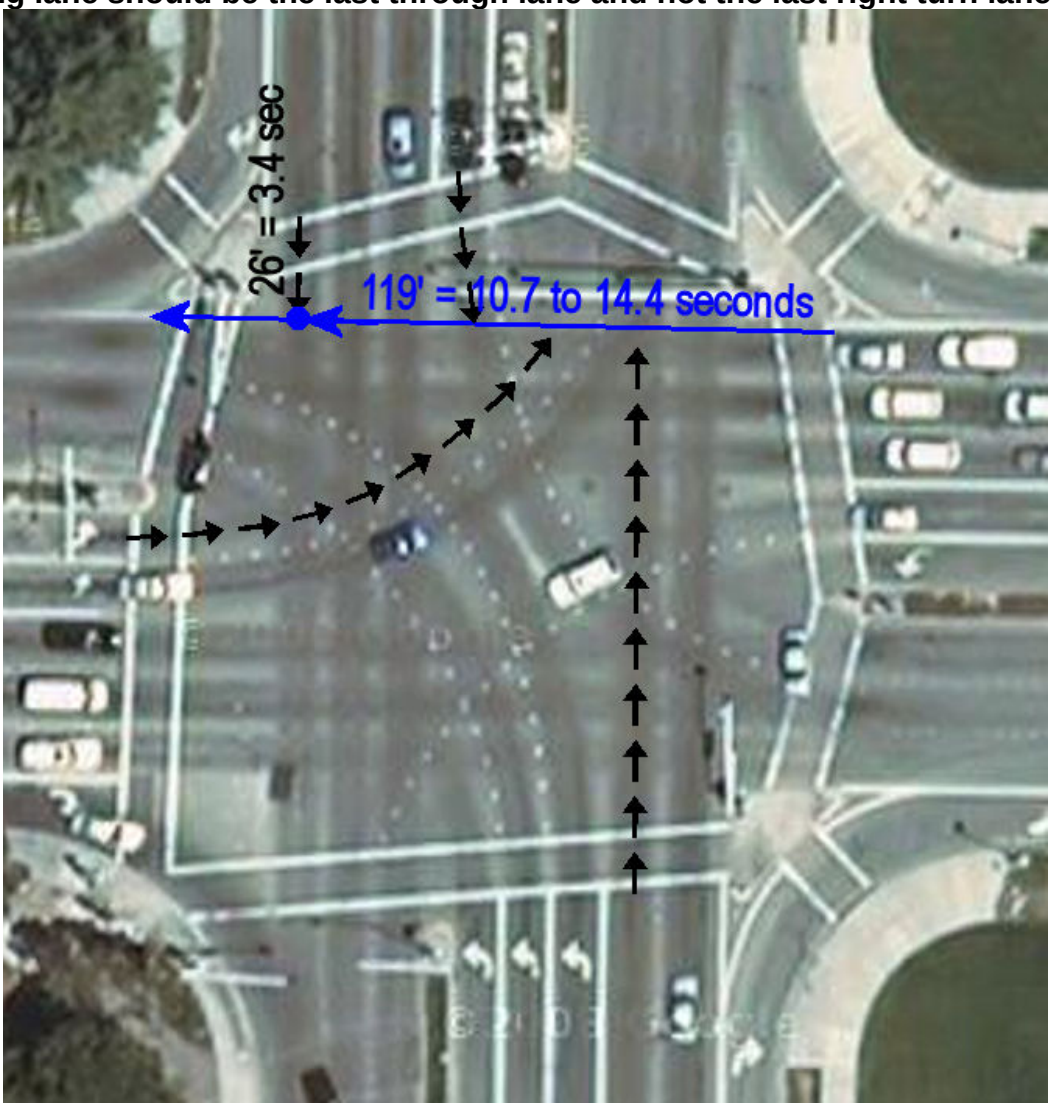
Westbound bicycle path of travel, distance and travel time in blue

Conflicting motor vehicle paths of travel, distance and travel time in black

A westbound bicyclist takes 10.7 to 14.4 seconds to clear 119' while the conflicting southbound through vehicle takes 3.4 seconds to reach the point of conflict:

10.7 to 14.4 minus 3.4 = 7.3 to 11.0 seconds of Green+Yellow+All-Red

No additional time is needed for those cyclists who can accelerate at 3.0 ft/sec^2. 2.0 additional seconds may be needed for slower cyclists. However if the southbound left turn follows the westbound through phase it takes 2.7 seconds less for a slow cyclist to clear the #2 southbound left turn lane than it does to clear the #3 southbound through lane. This emphasizes the need to provide local engineers with discretion to use engineering judgment when setting minimum phase lengths. Also the light traffic in the photo shows that often only standard minimum green time is needed to clear standing queues even on major arterial roadways. **Note the southbound free right turn lane. Another example of why the last conflicting lane should be the last through lane and not the last right turn lane.**



Crossing Wide Arterial Roadways

Example: Hopyard Road at Stoneridge Drive

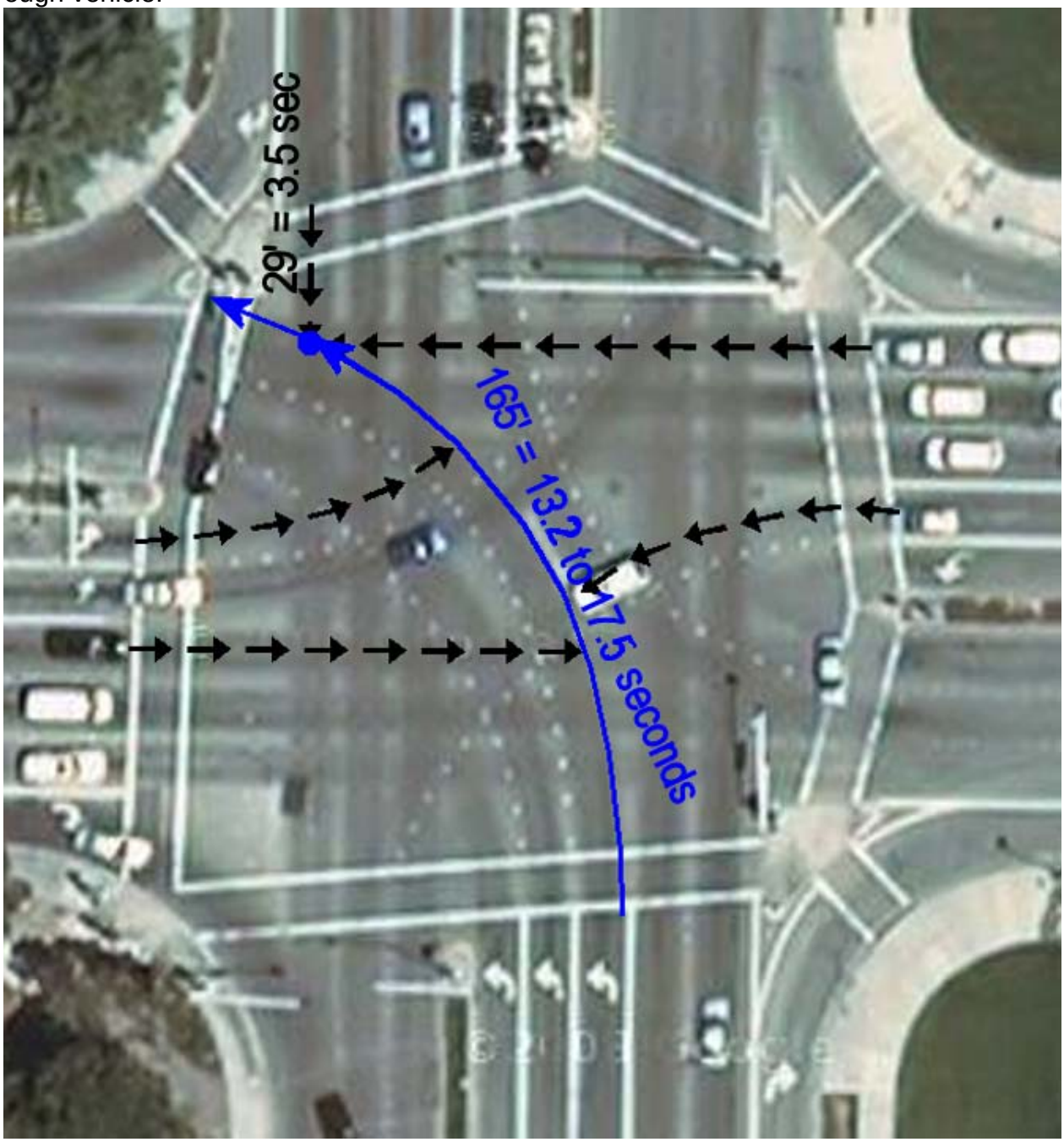
Northbound bicycle left turn path of travel, distance and travel time in blue

Conflicting motor vehicle paths of travel, distance and travel time in black

A bicyclist making a northbound left turn takes 13.2 to 17.5 seconds to clear 165 feet while the conflicting southbound through vehicle takes 3.5 seconds to reach the point of conflict:

13.2 to 17.5 minus 3.5 = 9.7 to 14.0 seconds of Green+Yellow+All-Red

Only slightly more green time, or a supplemental detection zone in the crosswalk would be needed if an acceleration rate of 3.0 ft/sec^2 is assumed and time is allotted for the conflicting through vehicle.



Crossing Wide Arterial Roadways

Example: Hawthorne Boulevard at Sepulveda Boulevard

Westbound bicycle path of travel, distance and travel time in blue

Conflicting motor vehicle paths of travel, distance and travel time in black

A westbound bike takes 11.8 to 15.8 seconds to clear 140' while the conflicting southbound through vehicle takes 3.2 seconds to reach the point of conflict:

11.8 or 15.8 minus 3.2 = 8.6 to 12.6 seconds of Green+Yellow+All-Red

The westbound through phase may be followed by the north and southbound left turn phases. A bicyclist requires 3.0 seconds less time to clear the #2 southbound left turn lane. A minimal amount of additional phase time or supplemental detection may be needed at this location instead of the 6.8 seconds required by Section 4D.105(CA) of the MUTCD.

Crossing Wide Arterial Roadways

Example: Hawthorne Boulevard at Sepulveda Boulevard

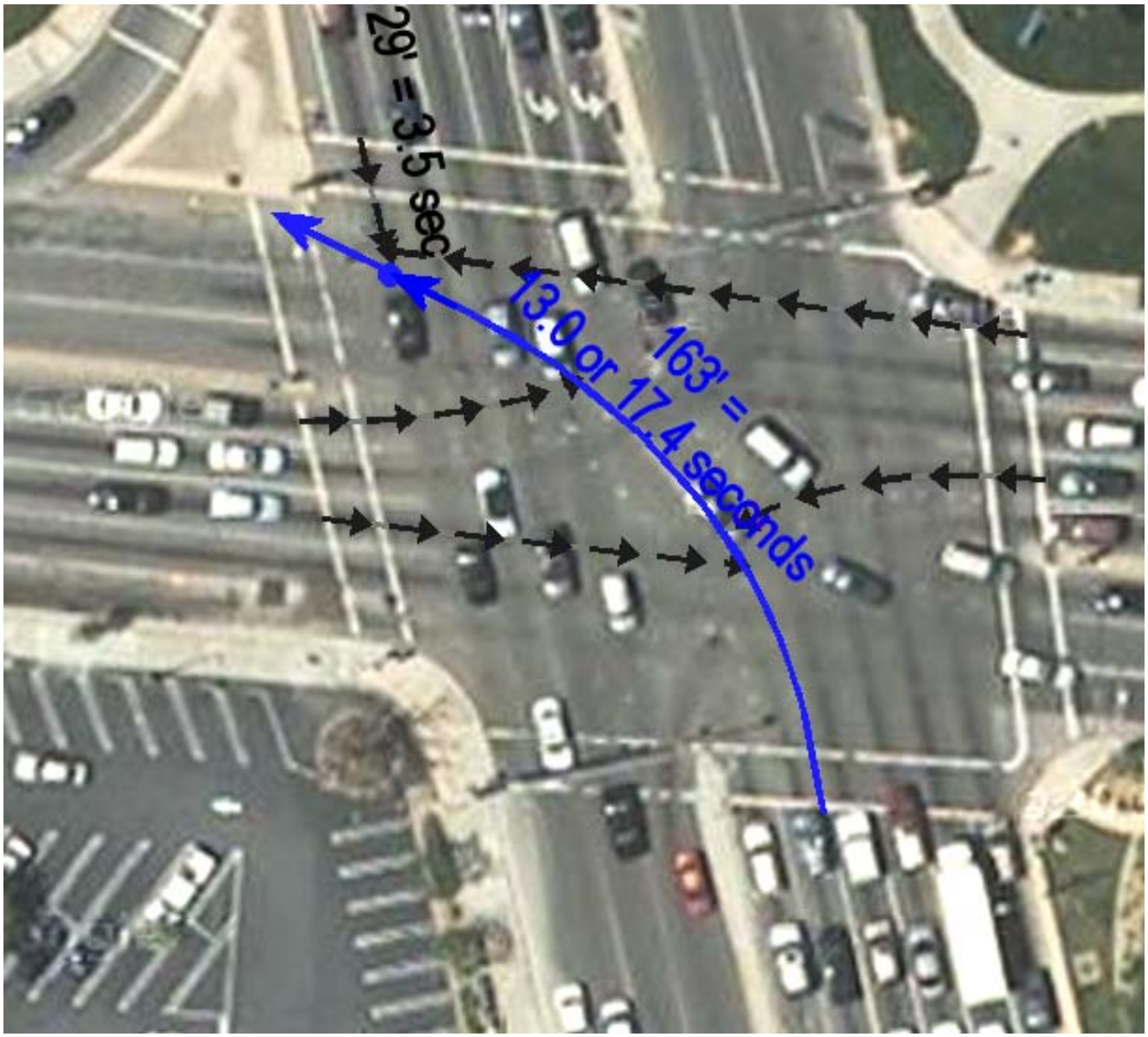
Northbound left turn bicycle path of travel, distance and travel time in blue

Conflicting motor vehicle paths of travel, distance and travel time in black

A bicyclist making a northbound left turn takes 13.0 to 17.4 seconds to clear 163 feet while the conflicting southbound through vehicle takes 3.5 seconds to reach the point of conflict:

13.0 or 17.4 minus 3.5 = 9.5 or 13.9 seconds of Green+Yellow+All-Red

0.5 to 4.9 seconds of additional minimum phase time may be needed, or supplemental detectors may be needed. I grew up in this area and even as a teenager, I would not weave through traffic to access any of these left turn pockets. Future traffic counts may be needed at the time new detection is installed to determine the demand for additional bicycle phase time.



Crossing Wide Arterial Roadways

Example: Thousand Oaks Boulevard at Westlake Boulevard

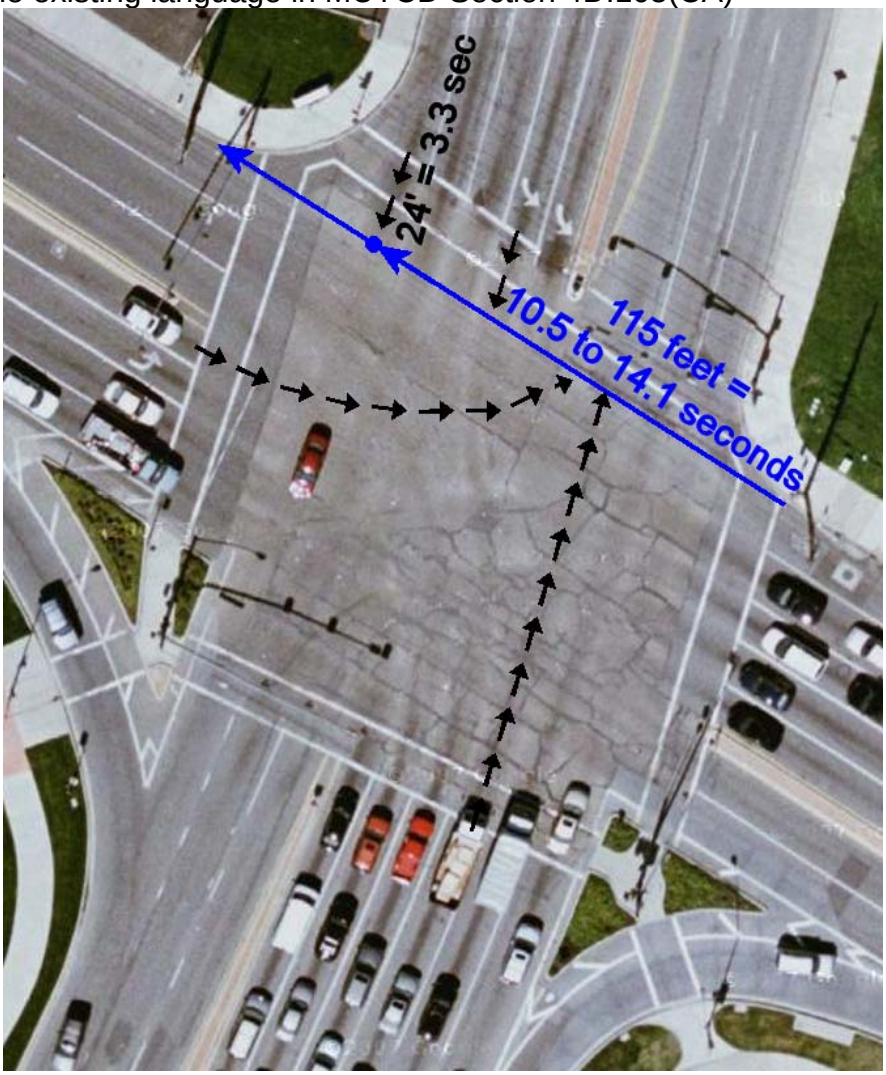
Westbound bicycle path of travel, distance and travel time in blue

Conflicting motor vehicle paths of travel, distance and travel time in black

A westbound bike takes 10.5 to 14.1 seconds to clear 115 feet while the conflicting southbound through vehicle takes 3.3 seconds to reach the point of conflict:

10.5 to 14.1 minus 3.3 = 7.2 to 10.8 seconds of Green+Yellow+All-Red

There is a High School two blocks east of this intersection and a movie theater on the southeast corner, so it is possible that some younger and slower cyclists may travel westbound through this intersection. The westbound phase may need to be increased by 1.8 seconds, or a supplemental detection zones may be needed to detect slower vehicles. The need for additional time may be eliminated if the northbound left turn phase follows the westbound through phase. Providing local engineers with options and discretion at intersections like this one is critical to providing reasonable bicycle phase lengths while also minimizing the significant negative environmental impacts that would result from implementing the existing language in MUTCD Section 4D.105(CA)



Crossing Wide Arterial Roadways

Example: Thousand Oaks Boulevard at Westlake Boulevard

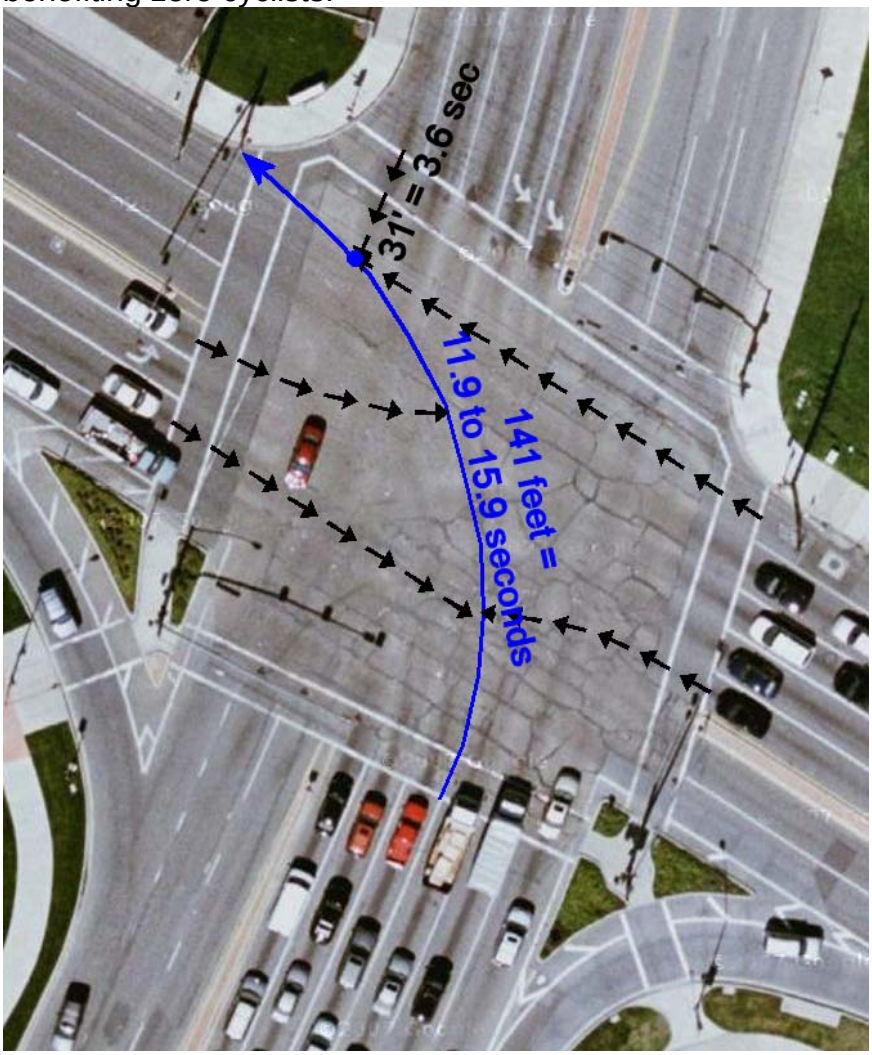
Northbound left turn bicycle path of travel, distance and travel time in blue

Conflicting motor vehicle paths of travel, distance and travel time in black

A bicyclist making a northbound left turn takes 11.9 to 15.9 seconds to clear 141 feet while the conflicting southbound through vehicle takes 3.6 seconds to reach the point of conflict:

11.9 to 15.9 minus 3.6 = 8.3 to 12.3 seconds of Green+Yellow+All-Red

Having working in this city for 17 years, it is my experience that virtually no cyclists with acceleration rates as low as 1.5 ft/sec^2, and with maximum travel speeds of only 10mph would ever attempt to make a northbound left turn from the #3 left turn lane at this intersection which is only one block from the 101 freeway interchange. So there is no reason the MUTCD should recommend that a city increase the left turn phase length from 9.0 second up to 15.9 seconds, 24 hours a day. This intersection is coordinated with signals to the east, west and north and increasing the cycle length here would compound existing left turn storage issues and increase green house gas emissions, fuel use, stops, delays and collisions, while benefiting zero cyclists.



Crossing Wide Arterial Roadways

Example: Harbor Blvd at Katella

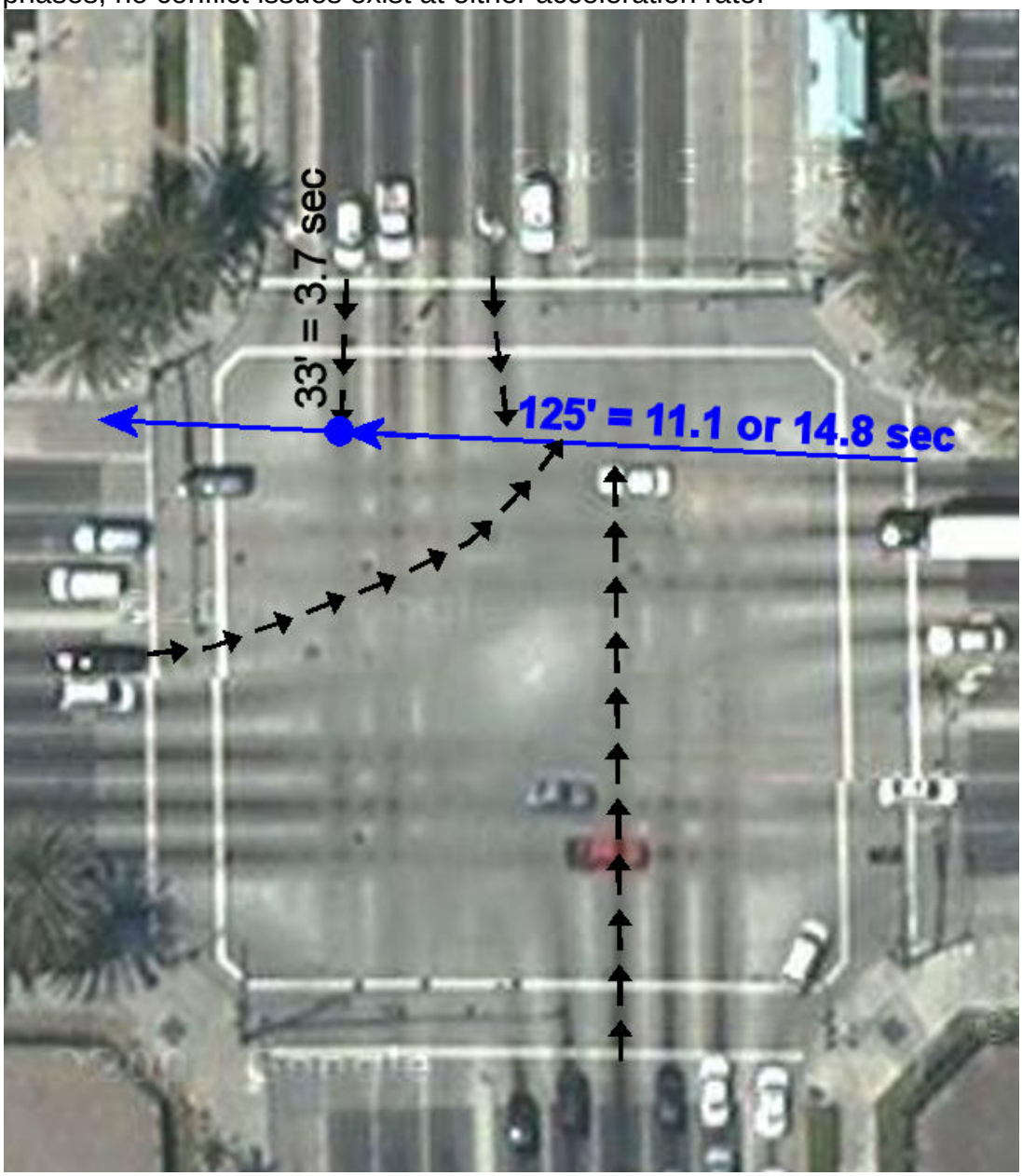
Westbound bicycle path of travel, distance and travel time in blue

Conflicting motor vehicle paths of travel, distance and travel time in black

A westbound bicyclist takes 11.1 to 14.8 seconds to clear 125 feet while the conflicting southbound through vehicle takes 3.7 seconds to reach the point of conflict:

11.1 or 14.8 minus 3.7 = 7.4 or 11.1 seconds of Green+Yellow+All-Red

Note that if the westbound through is usually followed by the northbound and/or southbound left turn phases, no conflict issues exist at either acceleration rate.



Crossing Wide Arterial Roadways

Example: Harbor Blvd at Katella

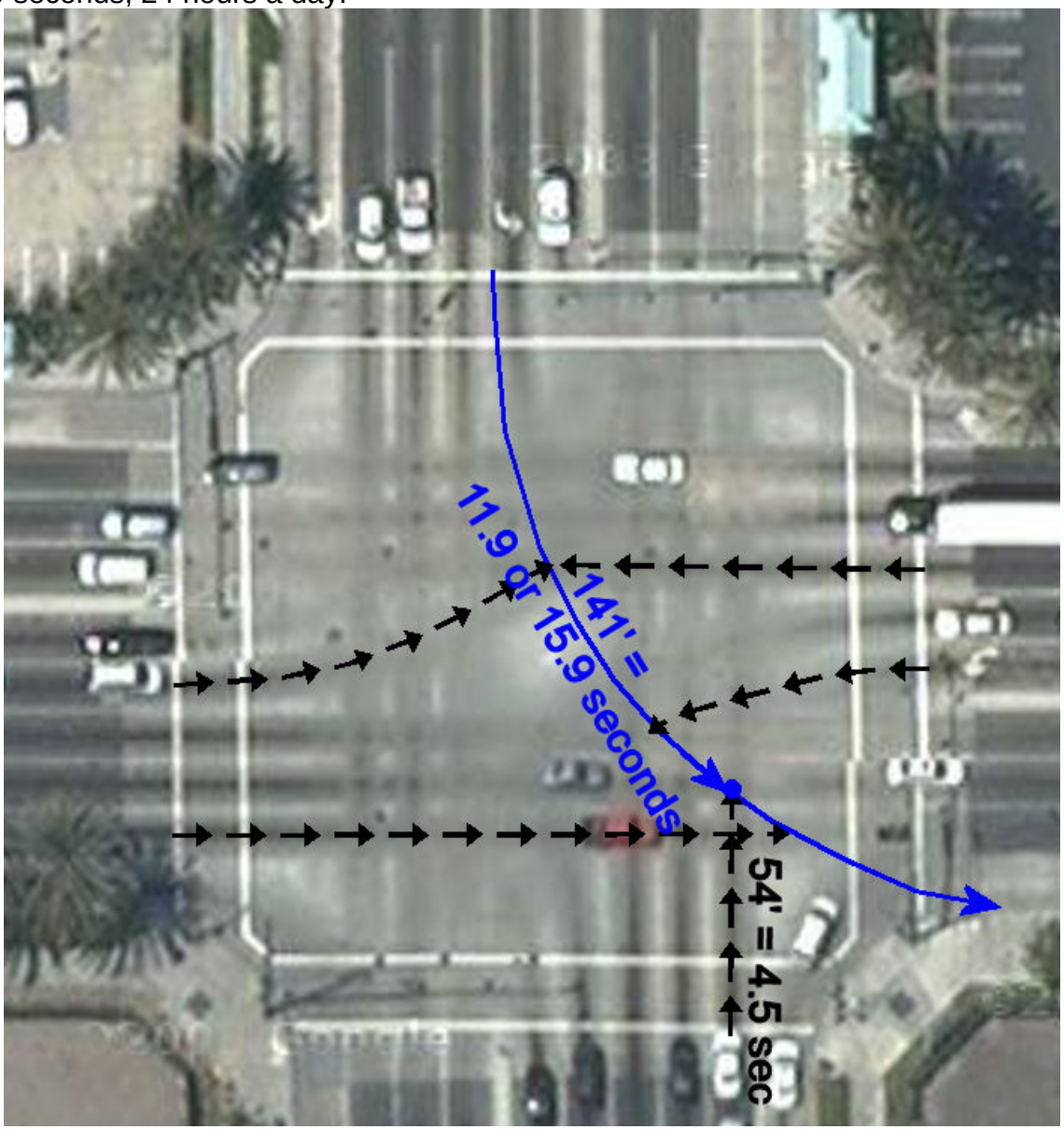
Southbound left turn bicycle path of travel, distance and travel time in blue

Conflicting motor vehicle paths of travel, distance and travel time in black

A bicyclist making a southbound left turn takes 11.9 to 15.9 seconds to clear 141 feet while a conflicting northbound through vehicle takes 4.5 seconds to reach the point of conflict:

11.9 or 15.9 minus 4.5 = 7.4 or 11.5 seconds of Green+Yellow+All-Red

It is my experience that virtually no cyclists with acceleration rates as low as 1.5 ft/sec^2, and with maximum travel speeds of only 10mph would ever attempt to make a southbound left turn from the #2 left turn lane at this type of intersection. So there is no reason the MUTCD should recommend that a city should increase the left turn phase length from 9.0 seconds up to 15.9 seconds, 24 hours a day.



Residential Collector Crossing Wide Arterial

Example: Hopyard Road at Valley Trails

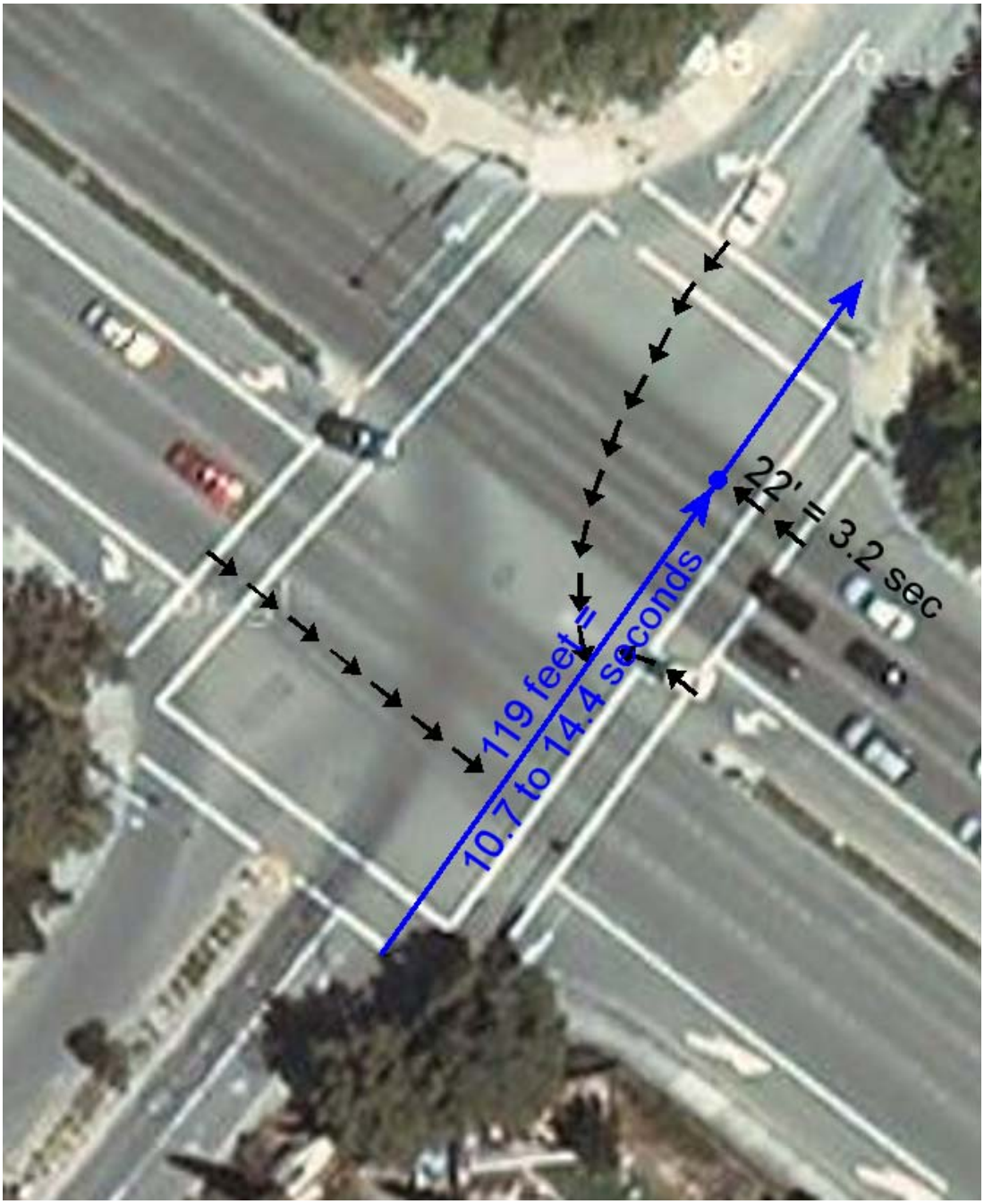
Eastbound bicycle path of travel, distance and travel time in blue.

Conflicting motor vehicle paths of travel, distance and travel time in black

An eastbound bicyclist takes 10.7 to 14.4 seconds to clear 119 feet while the conflicting northbound through vehicle takes 3.2 seconds to reach the point of conflict:

10.7 or 14.4 minus 3.2 = 7.5 or 11.2 seconds of Green+Yellow+All-Red

Note that if the eastbound through is usually followed by the southbound left turn phase, no conflict issues exist at either acceleration rate.



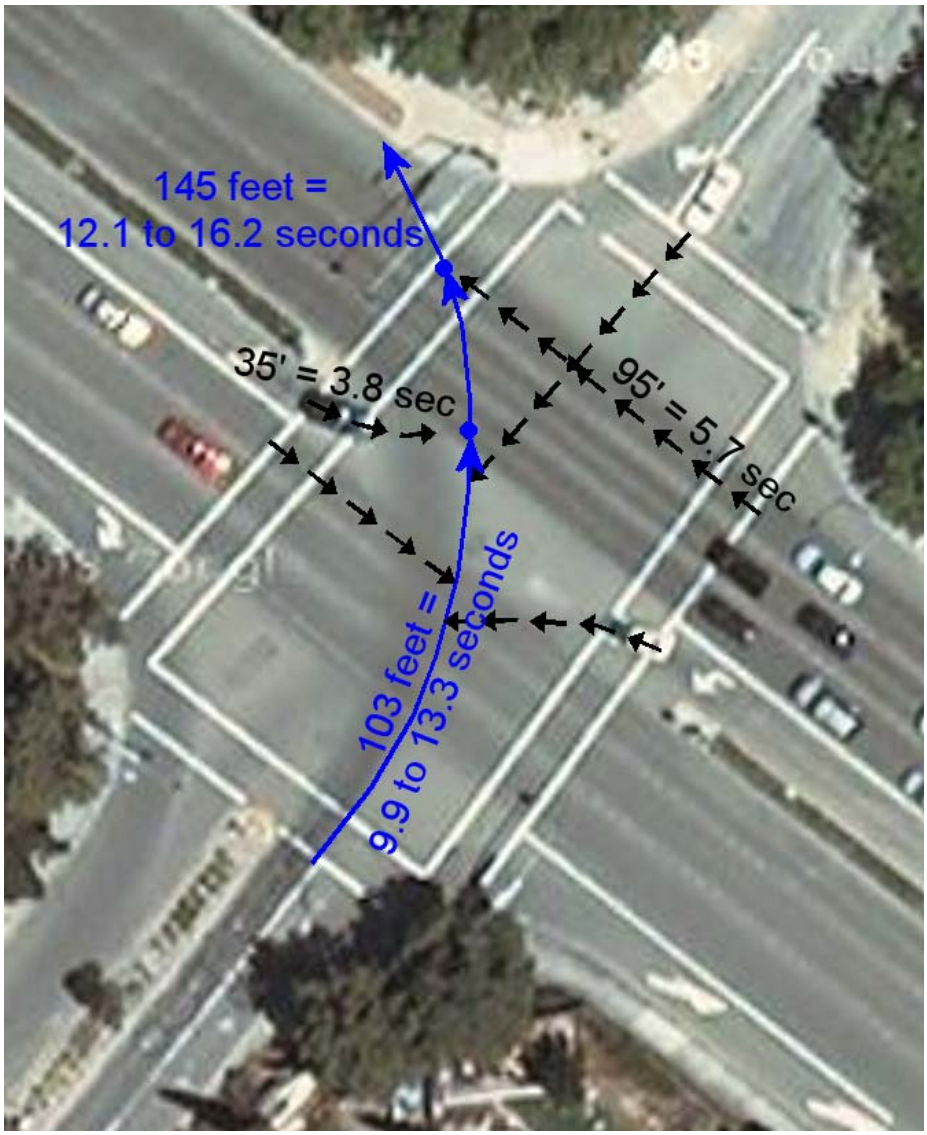
Residential Collector Crossing Wide Arterial

Example: Hopyard Road at Valley Trails

Eastbound left turn bicycle path of travel, distance and travel time in blue

Conflicting motor vehicle paths of travel, distance and travel time in black

A bicyclist making an eastbound left turn takes 12.1 to 16.2 seconds to clear 145 feet while the conflicting northbound through vehicle takes 5.7 seconds to reach the point of conflict:

12.1 or 16.2 minus 5.7 = 6.4 or 10.5 seconds of Green+Yellow+All-Red

In this case, if the eastbound left is usually followed by the southbound left turn phase, some additional time may be needed to clear the southbound left turn lane if slower moving bicyclists routinely make this movement. This is not so much a problem at crossing arterials, but is more likely to occur where narrower residential collectors cross wide arterials. Supplemental detection can also be used to detect slow moving vehicles and eliminate the need for extending the minimum green time for all vehicles. Good visibility of the cyclist during the left turn may make increased green time unnecessary due to existing provisions in the CVC.