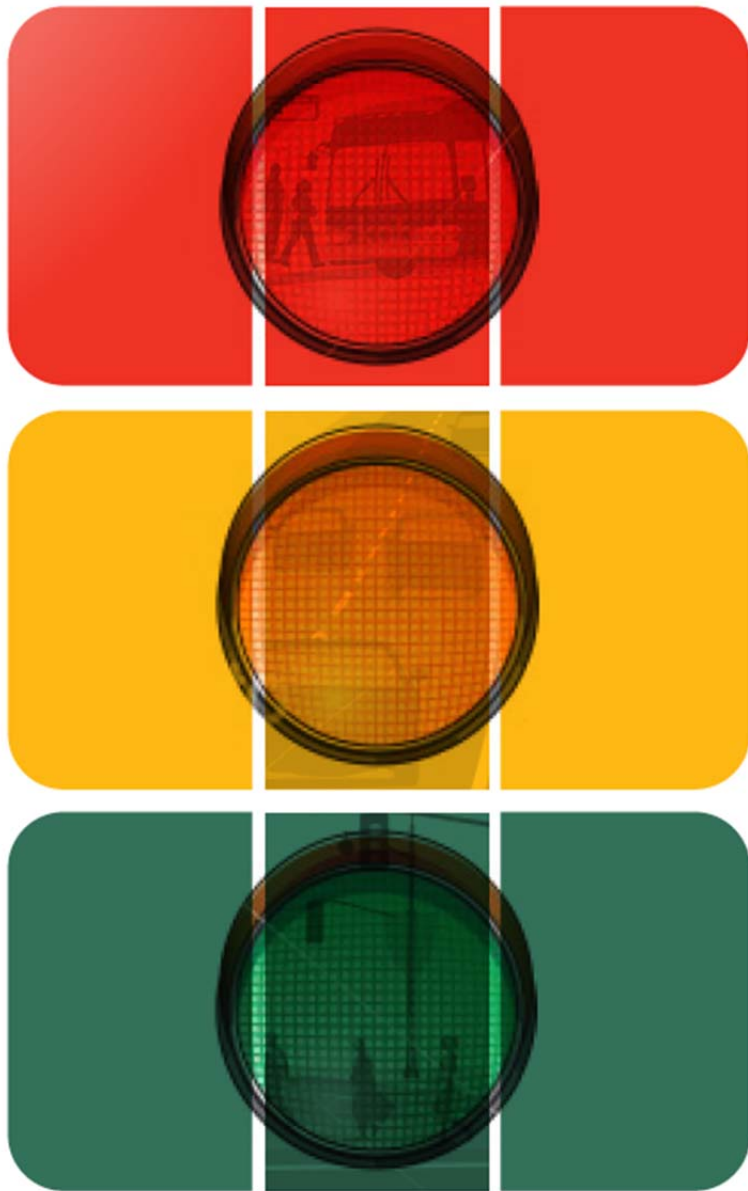


Guidelines for Traffic Signal Timing in Utah

2017



A. GUIDELINE INFORMATION

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B. TABLE OF APPROVAL / ACCEPTANCE

Responsibility	Name	Role
Developed By:	Utah Department of Transportation – Signal Operations; Salt Lake City; Salt Lake County; Orem City; Provo City; St George City; Sandy City	Document Originator
Reviewed By:	Traffic management technical subcommittees in SLC, Utah County, Davis/Weber, and Dixie	Quality Control
Approved By:	UDOT Traffic Policy Committee, 7/31/17	Approve for use at UDOT

C. REVISION GRID

Revision Number	Date	Updated By	Purpose of Revision
0.4	August 2, 2017	Mark Taylor Matt Luker	Incorporated comments from Traffic Policy Committee, release for UDOT's use.
1.1	September 6, 2017	Mark Taylor	Incorporated comments from Sandy City and Salt Lake County.

I. INTRODUCTION

This guideline was developed as part of the continuing effort to provide guidance for consistency in operating traffic signals within the State of Utah. This guideline is not intended to establish policy within UDOT or any agency in Utah, but to only provide guidance for consistency in operating traffic signals. This guideline supersedes all previous guidelines on signal timing. However, this guideline is in no way intended to conflict with the Utah Manual on Uniform Traffic Control Devices (Utah MUTCD). Should any conflict arise, the current edition of the Utah MUTCD shall prevail.

Also, the intent of this guideline is to give employees guidance in traffic signal operations for mostly safety-related parameters. This guideline will briefly discuss some of the practices for intersection operations. The following documents are references for these guidelines:

- Signal Timing Manual – Institute of Transportation Engineers (2009).
- Signal Timing Manual 2nd Edition – NCHRP Report 812 (2015).
- NCHRP Report 731 – Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections (2012).
- An ITE Proposed Recommended Practice – Guidelines for Determining Traffic Signal Change and Clearance Intervals (2015).
- Traffic Engineering Handbook 7th Edition – Institute of Transportation Engineers (2016).
- Guideline for the Development of Bicycle Facilities 4th Edition, AASHTO (2012).
- Utah Manual on Uniform Traffic Control Devices for Streets and Highways (Utah MUTCD), December 2011.

II. PROCESS AND SCHEDULE FOR CHANGES TO TIMING PARAMETERS

Process and Schedule for Updating the Walk, Pedestrian Clearance, Yellow Change, and Red Clearance Intervals

Changes to signal timing parameters (walk, pedestrian clearance, minimum green, yellow and red clearance) also may require changes to traffic signal coordination cycle lengths, splits, and offsets. As a result, it is recommended to update the new signal timing parameters as new coordination plans are installed, and/or during the timing routine maintenance process. For consistency reasons, it may be appropriate to update all intersections (state, county, and city) in a regional area at approximately the same time. We anticipate it may take up to 5 years to update all intersections statewide with the recommended timing parameters in this guideline.

III. VEHICLE CHANGE AND CLEARANCE INTERVALS

Vehicle change and clearance intervals consist of both the yellow change and red clearance intervals.

YELLOW CHANGE INTERVAL

The yellow change interval warns users that there is about to be a change in right-of-way assignment at the intersection. The MUTCD states that the yellow change interval should last approximately 3 to 6 seconds, with longer intervals being used on higher speed approaches (Section 4D.26).

Equation 1:
$$Y = t + \frac{1.47v}{2a + 64.4g}$$
 (Through and left movements)

Where:

Y = yellow change interval (s)

t = perception-reaction time to the onset of yellow indication (1.0 s)

v =

- For through movements: 85th percentile approach speed (mph) or posted speed limit + 7 mph, whichever is higher (see discussion below)
- For left turn movements: Approach speed limit minus 5 mph

a = deceleration rate in response to the onset of a yellow indication (10 ft/s²)

g = grade, with uphill positive and downhill negative (percent grade/100)

Guidelines in obtaining or estimating 85th percentile approach speed:

Through movements

- If 85th percentile speed is known [Automated Traffic Signal Performance Measures (ATSPM) or another source] and is higher than the posted speed limit, use this information.
 - If using ATSPM approach speed, evaluate the 85th percentile and the posted speed limit +7 mph over several days during the off-peak time periods. Compare this speed with other intersections on the same corridor with similar traffic characteristics so a speed is used that is consistent and appropriate along the corridor. Use the highest of the 85th percentile or posted speed limit + 7 mph.
- If 85th percentile speed is not known, use the posted speed limit + 7 mph.

Left turns

- Use the approach speed limit minus 5 mph.

Measuring Grade

- A grade measurement should be taken at the distance corresponding to the upper boundary of the dilemma zone (i.e., approximately 5.0 seconds upstream of the stop line) based on the speed being used for the yellow calculation.
- Measure grade for all approaches with speeds of 25 mph or greater.
- Measurements can be made using a level in the field, or obtained from plan sets.

Rounding and Minimum/Maximum Values

- When computing the yellow change interval, round up to the nearest tenth of a second.
- The minimum yellow will be 3.0 seconds for all movements.
- The maximum yellow to use is 6.0 seconds. If the computed yellow is more than 6 seconds, increase the red clearance interval with the excess.

Table 1: Yellow - Through Movement - Posted Speed Limit (MPH)

Yellow Change Interval (seconds) - Through Movements													
Posted Speed Limit (MPH)*	Grade of Approach (%)												
	Downhill						Level	Uphill					
	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6
25	4.0	3.9	3.7	3.7	3.6	3.5	3.4	3.3	3.3	3.2	3.1	3.1	3.0
30	4.4	4.3	4.2	4.1	4.0	3.9	3.8	3.7	3.6	3.5	3.5	3.4	3.3
35	4.9	4.7	4.6	4.5	4.3	4.2	4.1	4.0	4.0	3.9	3.8	3.7	3.6
40	5.3	5.2	5.0	4.9	4.7	4.6	4.5	4.4	4.3	4.2	4.1	4.0	3.9
45	5.8	5.6	5.4	5.3	5.1	5.0	4.9	4.8	4.6	4.5	4.4	4.3	4.3
50	6.2	6.0	5.9	5.7	5.5	5.4	5.2	5.1	5.0	4.9	4.8	4.7	4.6
55	6.7	6.5	6.3	6.1	5.9	5.8	5.6	5.5	5.3	5.2	5.1	5.0	4.9
60	7.2	6.9	6.7	6.5	6.3	6.1	6.0	5.8	5.7	5.5	5.4	5.3	5.2
65	7.6	7.4	7.1	6.9	6.7	6.5	6.3	6.2	6.0	5.9	5.7	5.6	5.5

*Posted Speed Limit: Yellow change interval calculated using posted speed limit plus 7 mph

Red cells: Use maximum value of 6.0 seconds for yellow change interval and add excess to red clearance interval.

Table 2: Yellow - Through Movement - 85th Percentile Approach Speed (MPH)

Yellow Change Interval (seconds) - Through Movements													
85th Percentile Approach Speed (MPH)	Grade of Approach (%)												
	Downhill						Level	Uphill					
	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6
25	3.3	3.2	3.2	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
30	3.8	3.7	3.6	3.5	3.4	3.3	3.3	3.2	3.1	3.1	3.0	3.0	3.0
35	4.2	4.1	4.0	3.9	3.8	3.7	3.6	3.5	3.5	3.4	3.3	3.3	3.2
40	4.7	4.6	4.4	4.3	4.2	4.1	4.0	3.9	3.8	3.7	3.7	3.6	3.5
45	5.1	5.0	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.1	4.0	3.9	3.8
50	5.6	5.4	5.3	5.1	5.0	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.1
55	6.1	5.9	5.7	5.5	5.4	5.2	5.1	5.0	4.8	4.7	4.6	4.5	4.4
60	6.5	6.3	6.1	5.9	5.8	5.6	5.5	5.3	5.2	5.1	5.0	4.8	4.7
65	7.0	6.7	6.5	6.3	6.2	6.0	5.8	5.7	5.5	5.4	5.3	5.2	5.1

Red cells: Use maximum value of 6.0 seconds for yellow change interval and add excess to red clearance interval.

Table 3: Yellow - Left Turn Movement - Posted Speed Limit (MPH)

Yellow Change Interval (seconds) - Left Turn Movements													
Posted Speed Limit (MPH)*	Grade of Approach (%)												
	Downhill						Level	Uphill					
	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6
25	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
30	3.3	3.2	3.2	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
35	3.8	3.7	3.6	3.5	3.4	3.3	3.3	3.2	3.1	3.1	3.0	3.0	3.0
40	4.2	4.1	4.0	3.9	3.8	3.7	3.6	3.5	3.5	3.4	3.3	3.3	3.2
45	4.7	4.6	4.4	4.3	4.2	4.1	4.0	3.9	3.8	3.7	3.7	3.6	3.5
50	5.1	5.0	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.1	4.0	3.9	3.8
55	5.6	5.4	5.3	5.1	5.0	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.1
60	6.1	5.9	5.7	5.5	5.4	5.2	5.1	5.0	4.8	4.7	4.6	4.5	4.4
65	6.5	6.3	6.1	5.9	5.8	5.6	5.5	5.3	5.2	5.1	5.0	4.8	4.7

*Posted Speed Limit: Yellow change interval calculated using posted speed limit minus 5 mph

Red cells: Use maximum value of 6.0 seconds for yellow change interval and add excess to red clearance interval.

RED CLEARANCE INTERVAL

The red clearance interval is an interval following the yellow change interval during which the phase has a red signal display before the display of green of the next phase. The purpose of this interval is to allow time for vehicles that entered the intersection during the yellow change interval to reach an appropriate location prior to the next phase.

Utah's vehicle code has a permissive vehicle law that states:

"The operator of a vehicle facing a steady circular yellow or yellow arrow signal is warned that the allowable movement related to a green signal is being terminated" (Utah Code 41-6a-305).

Vehicular traffic in Utah (and most other states) can legally enter the intersection during any portion of the yellow change interval (Utah Code 41-6a-305). As a result, it is necessary that a red clearance interval is programmed for each phase. Equation 2 (Through Movements) & Equation 3 (Left Turn Movements) calculate the red clearance intervals that should follow each yellow interval. A 1.0-second conflicting movement start up intersection entry delay factor is subtracted from the calculated red clearance interval as long as the result is not less than 1.5 seconds.

$$\text{Equation 2: } R = \frac{w + L}{1.47v} - 1 \text{ (Through Movements)}$$

$$\text{Equation 3: } R = \frac{w}{1.47v} - 1 \text{ (Left Turn Movements)}$$

Where:

R = red clearance interval (s)

w = width of intersection (ft)

L = length of vehicle (20 ft)

v = speed (mph)

- o Through Movements – minimum of the posted speed limit or 85th percentile speed.
- o Left Turn Movements (including permissive lefts) – Use 20 mph for normal left turns; wide left turns (e.g. SPUIs) should use 30 mph

Guidelines for measuring the width of the intersection:

- For through movements, intersection width is the total distance from the back/upstream edge of the stop line to the curb-line extension, or outside edge of the travel lane, of farthest conflicting movement along the vehicle's travel path (See Figure 1).
- For left turns, use the length of the vehicle turning path measured from the back/upstream edge of the approaching movement stop line to the center of the furthest traveled lane on the far side of the intersection. If there are multiple lanes, measure the path for each lane and use the longest distance (See Figure 1).
- If the nearest pedestrian crosswalk is 40 feet or more from the extension of the farthest edge of the farthest conflicting travel lane, then the intersection width should be measured from the back/upstream edge of the approaching movement stop line to the nearest pedestrian crossing line for both through and left turn movements.
- The approach speed used for the through phases is the minimum of the 85th percentile or posted speed limit.
- The approach speed used for left turns should be set at 20 mph except at unusual intersections such as SPUIs where turning speeds are higher. SPUIs and other wide left turns should use 30 mph.
- For through phases with permissive left turn movements (including permissive-only, 5-section, and Flashing Yellow Arrow displays), red clearance is calculated by measuring both the permissive left movement and the through movement. The highest of the two calculations (left or through) is used for the red clearance of the through phase.

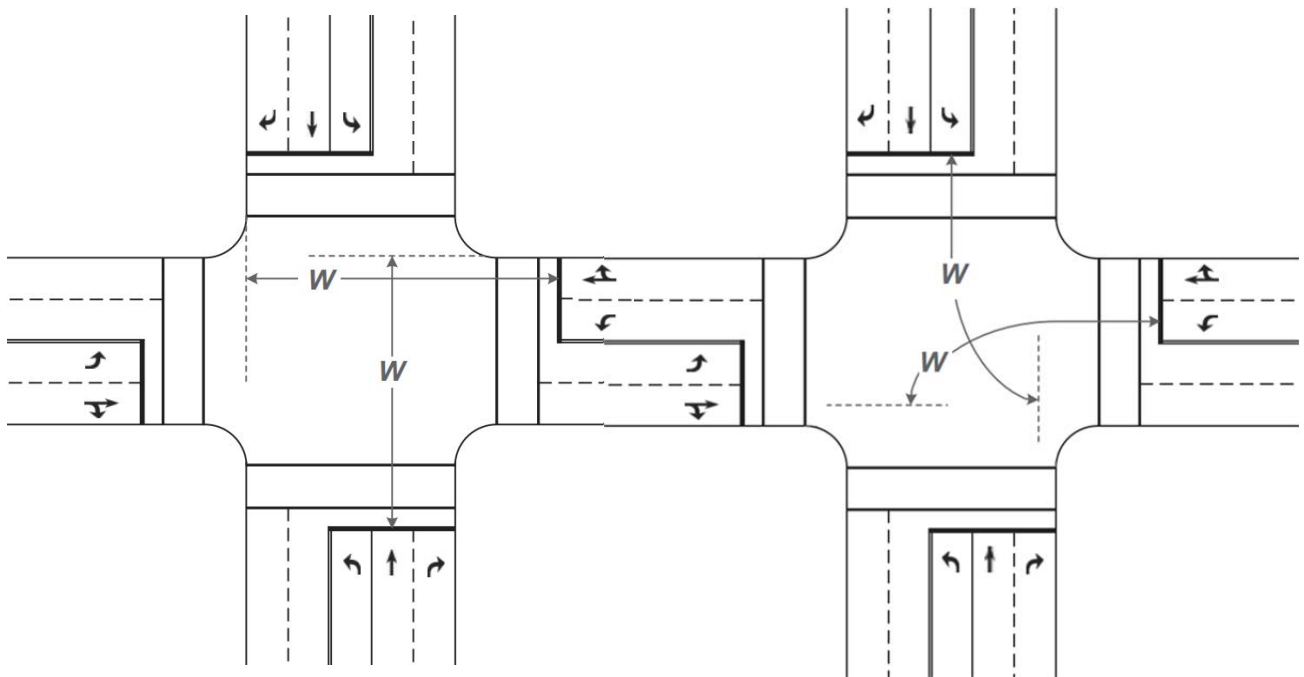


Figure 1: Diagram of Intersection Width for Through and Left Movements

Rounding and Minimum/Maximum Values

- When computing the red clearance interval, round up to the nearest tenth of a second.
- If the calculated yellow clearance time is more than 6.0 seconds, increase the red clearance interval with the excess.
- The minimum red clearance interval will be 1.5 seconds for all movements. Red clearance intervals less than 1.5 seconds require approval from the Traffic Signal Operations Engineer.
- Except when clearing a one-lane, two-way facility or when clearing an exceptionally wide intersection, a red clearance interval should have a duration not exceeding 6 seconds.

Table 4: Red Clearance (s) - Through Movements (50 ft to 120 ft) - Posted Speed Limit (MPH)

Red Clearance (seconds) - Through Movements (50 ft to 120 ft)															
Posted Speed Limit (mph)	Intersection Width (feet)														
	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120
20	1.5	1.6	1.8	1.9	2.1	2.3	2.5	2.6	2.8	3.0	3.1	3.3	3.5	3.6	3.8
25	1.5	1.5	1.5	1.5	1.5	1.6	1.8	1.9	2.0	2.2	2.3	2.5	2.6	2.7	2.9
30	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.7	1.8	1.9	2.0	2.1	2.2
35	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.7	1.8
40	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
45	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
50	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
55	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
60	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
65	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5

Equation includes: vehicle length of 20 feet and 1 s perception reaction time.

Table 5: Red Clearance (s) - Through Movements (125 ft to 200 ft) - Posted Speed Limit (MPH)

Red Clearance (seconds) - Through Movements (125 ft to 200 ft)																
Posted Speed Limit (mph)	Intersection Width (feet)															
	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200
20	4.0	4.2	4.3	4.5	4.7	4.8	5.0	5.2	5.3	5.5	5.7	5.9	6.0	6.0	6.0	6.0
25	3.0	3.1	3.3	3.4	3.5	3.7	3.8	3.9	4.1	4.2	4.4	4.5	4.6	4.8	4.9	5.0
30	2.3	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.4	3.5	3.6	3.7	3.8	3.9	4.0
35	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3
40	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.5	2.6	2.7	2.8
45	1.5	1.5	1.5	1.5	1.5	1.6	1.7	1.8	1.8	1.9	2.0	2.1	2.1	2.2	2.3	2.4
50	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.6	1.7	1.8	1.8	1.9	2.0	2.0
55	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.6	1.7	1.8
60	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
65	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Equation includes: vehicle length of 20 feet and 1 s perception reaction time.																

Table 6: Red Clearance (s) - Left Turn Movements (50 ft to 120 ft) - Constant Speed Value

Red Clearance (seconds) - Left Turn Movements (50 ft to 120 ft)															
Constant Value (mph)	Intersection Width (feet)														
	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120
20	1.5	1.5	1.5	1.5	1.5	1.6	1.8	1.9	2.1	2.3	2.5	2.6	2.8	3.0	3.1
30 (e.g. SPUIs)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.7	1.8
Equation includes: no vehicle length and a 1 s perception reaction time.															

Table 7: Red Clearance (s) - Left Turn Movements (125 ft to 200 ft) - Constant Speed Value

Red Clearance (seconds) - Left Turn Movements (125 ft to 200 ft)																		
Constant Value (mph)	Intersection Width (feet)																	
	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200		
20	3.3	3.5	3.6	3.8	4.0	4.2	4.3	4.5	4.7	4.8	5.0	5.2	5.3	5.5	5.7	5.9		
30 (e.g. SPUIs)	1.9	2.0	2.1	2.2	2.3	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.4	3.5	3.6		
Equation includes: no vehicle length and a 1 s perception reaction time.																		

The equation for red clearance for left turns (Equation 3) used in this guideline deviates slightly from other guidelines as recommended in NCHRP Report 731 titled “Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections,” published 2012, and in ITE’s proposed recommended practice “Guidelines for Determining Traffic Signal Change and Clearance Intervals,” published January 2015. Appendix B includes justification for deviation.

IV. PEDESTRIAN CONTROL FEATURES

The following pedestrian-related items are covered in this portion of the guideline, including:

- Minimum pedestrian walk intervals for pedestrian signal phasing,
- Recommended pedestrian walking speeds, and
- Guidelines for pedestrian clearance intervals.

The MUTCD states in Section 1A.01:

“The purpose of traffic control devices, as well as the principles for their use, is to promote highway safety and efficiency by providing for the orderly movement of all road users on streets, highways, bikeways, and private roads open to public travel throughout the Nation.”

Pedestrian timings often dictate the splits and cycle length at signalized intersections. In order to reduce vehicle, bicycle and pedestrian delay, preserve infrastructure, reduce air pollution, and improve safety for pedestrians (by minimizing jay walking occurrences) and bicyclists (running red lights), engineering judgment may recommend the use of minimum pedestrian timings.

WALK INTERVAL

The walk interval is intended for pedestrians to start their crossing. It is an indication providing initial right-of-way to pedestrians during a pedestrian phase and prior to the pedestrian clearance interval. The walk interval should provide pedestrians adequate time to perceive the WALK indication and depart the

curb before the pedestrian clearance interval begins. It should be long enough to allow a pedestrian that has pushed the pedestrian push button to enter the crosswalk.

The Utah MUTCD states:

“The walk interval shall be at least 4 seconds in length so that pedestrians will have adequate opportunity to leave the curb or shoulder before the pedestrian clearance time begins.”

The Utah MUTCD further states:

“Where pedestrian volumes or characteristics require a longer walk interval, values longer than 4 seconds should be used.”

Guidelines for Walk Interval

- Walk interval shall never be below 4.0 seconds.
- 7 seconds should be the “default” value. However, at many locations side-street values will be lower to minimize disruption to mainline.
- Locations with frequent large groups of pedestrians should generally not be less than 7 seconds and may need to be higher, especially during special events.
- Walk times may be different by time-of-day if needed for efficiency or peak pedestrian volumes. But keep in mind the complexity this causes in controller programming.

PEDESTRIAN WALKING SPEED

The Utah MUTCD states,

“...the pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder at the end of the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 4 feet per second to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait.”

Walking speed should be:

- 4.0 feet per second for normal circumstances.
- 3.5 feet per second for school crossings or areas where there are heavy concentrations of elderly persons or children.
- 3.0 feet per second or lower for special cases (engineering judgment).

PEDESTRIAN CLEARANCE INTERVAL

The pedestrian clearance interval follows the walk interval. When the pedestrian clearance interval begins, pedestrians should either complete their crossing if already in the intersection or refrain from entering the intersection until the next pedestrian walk interval is displayed.

$$\text{Equation 4: } PC = \frac{w}{pws} - (Y + R)$$

Where:

PC = pedestrian clearance interval duration (s)

w = crossing distance (ft)

pws = pedestrian walking speed (ft/s)

Y = yellow change interval (s)

R = red clearance interval (s)

- The minimum pedestrian clearance interval should be 7 seconds.
- The crossing distance should be measured in the center of the crosswalk and extending curb to curb.
- The pedestrian clearance interval should be rounded up to the nearest second.
- The pedestrian clearance interval should not change by time-of-day or for special events, since this confuses the countdown pedestrian heads. If extra crossing time is needed, add to the “walk” time. The only exception to this is where “pedestrian scramble” is used because the distance to cross the street changes. A “pedestrian scramble”, also known as a “Barnes Dance” temporarily stops all vehicular traffic, thereby allowing pedestrians to cross an intersection in every direction, including diagonally, at the same time.
- Typically, the “flashing don’t walk” (FDW) ends at the beginning of yellow. However, some controllers allow the FDW to time through the yellow so more time can be displayed on the countdown for pedestrians. If the FDW extends into the yellow, please ensure the following:
 - Following the pedestrian change interval, a buffer interval consisting of a steady upraised hand (symbolizing don’t walk) signal indication shall be displayed for at least 3 seconds prior to the release of any conflicting vehicular movement.
 - The buffer interval (at least 3 seconds) shall not begin later than the beginning of the red clearance interval.
 - The difference in seconds from the beginning of yellow to the end of the FDW needs to be added to the Pedestrian Clearance equation 4.

V. MINIMUM VEHICLE GREEN

The minimum green parameter represents the least amount of time that a green signal indication will be displayed for a movement. Minimum green is used to allow drivers to react to the start of the green interval and meet driver expectancy.

Guidelines for Minimum Green

- Never below 4 seconds except for “dummy” phases. A dummy phase is defined as a phase that does not have an output, but is still used in the controller software to achieve a certain operation. Minimum green intervals less than 4 seconds require approval from the Engineer.
- Generally 5 seconds for minor movements with stop line detection, however this can be reduced to 4 seconds if needed for signal coordination.
- Generally 10 seconds for major movements with stop line detection. May be higher to satisfy driver expectation, especially on higher speed approaches, but consider whether dilemma zone detection can provide the same driver expectation without the late-night impacts to other movements.
- Generally 15-20 seconds for approaches on recall with no stop line detection. May be higher in locations with no detection at all or where detection is located farther than 100 feet from the stop line. Use engineering judgement.
- If there is a crosswalk or frequent pedestrians without pedestrian signals, minimum green should be set long enough for a pedestrian to cross the street.
- If there is an exclusive bike phase or a detection technology in use that differentiates bicycles from vehicles, program Bike Minimum Green for the phase based on the equation below from

the AASHTO Guide for the Development of Bicycles Facilities 2012 Fourth Edition. With a bike-only detector present this does not replace the minimum green setting.

$$\text{Equation 5: } BMG = PRT + \frac{V}{2a} + \frac{W+L}{V} - Y - R$$

Where:

BMG = Bike Minimum Green (s)

PRT = perception reaction time (1.0 s)

V = attained bicycle crossing speed (14.7 ft/s = 10 mph)

a = bicycle acceleration (1.5 ft/s²)

W = intersection width (ft, measured as for cars)

L = bicycle length (6 ft)

Yellow change interval (s)

Red clearance interval (s)

Thus for typical values:

$$\text{Equation 6: } BMG = 5.9 + \frac{W+6}{14.7} - Y - R$$

Round up to nearest whole second.

- At intersections with significant bicycle volumes and stop line detection which detects bicycles but does not differentiate from cars, consider increasing vehicle Minimum Green using the bike minimum green equation to account for cyclists. Particular consideration should be made at wide intersections, those with irregular geometry, and those where there is no other way (such as a pedestrian crossing) for cyclists to get across the intersection. Without a dedicated bike detector, Bike Minimum Green needs to be programmed in vehicle Minimum Green.

VI. VEHICLE EXTENSION / PASSAGE

The passage time (also called vehicle extension) is used to extend the green interval based on the detector status once the phase is green. This parameter extends the green interval for each vehicle actuation up to the maximum green. If the passage time is too short, the green may end prematurely, before the vehicular movement has been adequately served. If the passage interval is too long, there will be delays to other movements caused by unnecessary extension of a phase, resulting in delay to the other movements at the intersection.

Passage time should be based on the detection zone length and approach speed.

$$\text{Equation 7: } PT = MAH - \frac{L_v + L_d}{1.47V_a}$$

Where:

PT = passage time (s)

MAH = maximum Allowable Headway (s)

V_a = average approach speed (mph)

L_v = length of vehicle (typically 20 ft, use engineering judgment)

L_d = length of detection zone (ft)

- MAH = Use 3 seconds for most locations; may be increased based on grade and presence of heavy trucks. Increase by 0.1 for each 1% of upgrade; increase by 1.0 if there are a large percentage of heavy vehicles.
- V_a = Use engineering judgement to determine this value. Use ATSPMs to find average approach speed if available. The Signal Timing Manual 1st edition suggests using 88% of 85th Percentile speed if average is not directly available. The 85th Percentile speed (if not known) can be estimated by taking the posted speed and adding 7 mph (see chart below).

Table 8 calculates values of passage time for various posted speeds and detection zone lengths. However, it is recommended to use the *“Interactive Form” from the “UDOT Detection Form”* spreadsheet that considers other factors (e.g., advance detection, location of detectors, 85th percentile approach speed), in obtaining the appropriate vehicle extension/phase passage time to use for each phase.

Table 8: Phase Passage/Vehicle Extension Time Based on Detector Length and Posted Speed Limit

Phase Passage/Vehicle Extension Time Based on Detector Length and Posted Speed Limit														
Length of Detector, ft	Thru Phases with Stop Line Presence Detection												Queue Clearance Zone in Advance with Max Speed Filter = 35mph	Left Turn Phases
	Posted Speed Limit, mph													
	15	20	25	30	35	40	45	50	55	60	65	70		
0	2.3	2.4	2.5	2.6	2.6	2.7	2.7	2.7	2.8	2.8	2.8	2.8	3.0	2.3
5	2.1	2.3	2.4	2.5	2.5	2.6	2.6	2.7	2.7	2.7	2.7	2.7	2.9	2.1
10	1.9	2.1	2.3	2.4	2.4	2.5	2.6	2.6	2.6	2.7	2.7	2.7	2.8	2.0
15	1.8	2.0	2.2	2.3	2.4	2.4	2.5	2.5	2.6	2.6	2.6	2.6	2.7	1.8
20	1.6	1.9	2.0	2.2	2.3	2.3	2.4	2.5	2.5	2.5	2.6	2.6	2.6	1.6
25	1.4	1.7	1.9	2.1	2.2	2.3	2.3	2.4	2.4	2.5	2.5	2.5	2.5	1.5
30	1.2	1.6	1.8	2.0	2.1	2.2	2.3	2.3	2.4	2.4	2.5	2.5	2.4	1.3
35	1.1	1.4	1.7	1.8	2.0	2.1	2.2	2.3	2.3	2.4	2.4	2.4	2.3	1.1
40	0.9	1.3	1.5	1.7	1.9	2.0	2.1	2.2	2.3	2.3	2.4	2.4	2.2	1.0
45	0.7	1.1	1.4	1.6	1.8	1.9	2.0	2.1	2.2	2.2	2.3	2.3	2.1	0.8
50	0.5	1.0	1.3	1.5	1.7	1.8	2.0	2.0	2.1	2.2	2.2	2.3	2.0	0.6
55	0.4	0.8	1.2	1.4	1.6	1.8	1.9	2.0	2.1	2.1	2.2	2.2	1.9	0.4
60	0.2	0.7	1.1	1.3	1.5	1.7	1.8	1.9	2.0	2.1	2.1	2.2	1.8	0.3
65	0.0	0.6	0.9	1.2	1.4	1.6	1.7	1.8	1.9	2.0	2.1	2.1	1.7	0.1
70		0.4	0.8	1.1	1.3	1.5	1.7	1.8	1.9	2.0	2.0	2.1	1.6	
75		0.3	0.7	1.0	1.2	1.4	1.6	1.7	1.8	1.9	2.0	2.0	1.5	
80		0.1	0.6	0.9	1.2	1.4	1.5	1.6	1.8	1.8	1.9	2.0	1.4	
85			0.5	0.8	1.1	1.3	1.4	1.6	1.7	1.8	1.9	1.9	1.3	
90			0.3	0.7	1.0	1.2	1.4	1.5	1.6	1.7	1.8	1.9	1.2	
95			0.2	0.6	0.9	1.1	1.3	1.4	1.6	1.7	1.8	1.8	1.1	
100			0.1	0.5	0.8	1.0	1.2	1.4	1.5	1.6	1.7	1.8	1.1	
105				0.4	0.7	0.9	1.1	1.3	1.4	1.6	1.7	1.7	1.0	
110				0.3	0.6	0.9	1.1	1.2	1.4	1.5	1.6	1.7	0.9	
115				0.2	0.5	0.8	1.0	1.2	1.3	1.4	1.5	1.6	0.8	
120				0.1	0.4	0.7	0.9	1.1	1.3	1.4	1.5	1.6	0.7	
125					0.3	0.6	0.8	1.0	1.2	1.3	1.4	1.5	0.6	
130					0.2	0.5	0.8	1.0	1.1	1.3	1.4	1.5	0.5	
135					0.1	0.4	0.7	0.9	1.1	1.2	1.3	1.4	0.4	
140					0.0	0.4	0.6	0.8	1.0	1.1	1.3	1.4	0.3	
145						0.3	0.5	0.8	0.9	1.1	1.2	1.3	0.2	
150						0.2	0.5	0.7	0.9	1.0	1.2	1.3	0.1	
155						0.1	0.4	0.6	0.8	1.0	1.1	1.2		
Results in the blank area are 0.0 or less Use of a shorter detector is recommended														

Results in the blank area are 0.0 or less
Use of a shorter detector is recommended

Assumptions in this table:

- 1) Vehicle length = 20ft (used only for stop line presence detection)
- 2) Average Speed for Thru Movements = $0.88 * (\text{Posted Speed} + 7)$
Note: Average Speed is used only for stop line presence detection.
For Queue Clearance zone, max speed of 35mph is used directly
- 3) Maximum Allowable Headway for All Movements = 3s
- 4) Average Speed for Left Turn Movements = 20mph

If any of these assumptions are not valid, do not use this table - use equation or UDOT Detection Worksheet

VII. MAXIMUM GREEN

The maximum green parameter represents the maximum amount of time that a green signal indication can be displayed in the presence of conflicting demand. Maximum green is used to limit the delay to any other movement at the intersection and to keep the cycle length to a maximum amount. It also guards against long green times due to continuous demand or broken detectors. A maximum green that is too long may result in wasted time at the intersection. If its value is too short, then the phase capacity may be inadequate for the traffic demand, and some vehicles will remain unserved at the end of the green interval.

Guidelines for Maximum Green

- Where possible, use ATSPMs to help determine maximum green.
- Maximum green should be set to handle traffic during the hours when the signal is normally set free, not necessarily to handle traffic during peak hours when the signal may be expected to run coordination.
- Maximum green should be set higher for higher speed roadways where dilemma zone detection is present so the phase gaps out more/maxes out less.
- If ATSPMs provide little guidance on where to set maximum green, some general ballpark guidance (from the Signal Timing Manual 2nd edition section 6.1.4.2) is below:
 - o Through Phase Major Arterial with dilemma zone detection (> 40 mph): 50s to 70s
 - o Through Phase Major Arterial (<= 40 mph): 40 s to 60 s
 - o Through Minor Arterial: 30 s to 50 s
 - o Through Collector, Local, or Driveway: 20 s to 40 s
 - o Left Turn: 15 s to 30 s

VIII. RECALLS

MINIMUM RECALL

The minimum recall parameter causes the controller to place a call for vehicle service on the phase. The phase is timed at least for its minimum green regardless of whether there is demand on the movement.

SOFT RECALL

The soft recall parameter causes the controller to place a call for vehicle service on the phase in the absence of a serviceable conflicting call. The most typical application for soft recall is for the major-road through movement phases (usually phases 2&6). The use of soft recall ensures that the major-road through phases will dwell in green when demand for the conflicting phases is absent, but allows conflicting phases to time beyond their maximum when there is no demand on the major road.

MAXIMUM RECALL

The maximum recall parameter causes the controller to place a continuous call for vehicle service on the phase. It results in the presentation of the green indication for its maximum duration every cycle as defined by the maximum green parameter (or coordination split) for the phase.

- Recalls are not required to be on the main street through phases (e.g. phase 2 and 6) at all intersections.
- Minimum or maximum recalls are required on any approach that does not have stop line detection.
- Consider using locking memory or soft recalls where appropriate in place of minimum recalls.

- It's usually a good idea to have the major street on soft recall where minor streets are present.

LOCKING MEMORY

Controller memory (locking memory) modes refer to the controller's ability to "remember" (i.e., retain) a detector actuation. One of two modes can be used: non-locking or locking. It dictates whether an actuation received during the red interval (and optionally, the yellow interval) is retained until the assigned phase is served by the controller. All actuations received during the green interval are treated as non-locking by the controller. The non-locking mode is the default mode.

All channels should be placed on non-locking memory except in the following situations:

- Detector(s) are poorly placed in reference to the stop line.
- The detector(s) are not functioning properly.
- The stop line is not clearly visible.
- The geometry of the intersection requires vehicles to pull up ahead of the stop line due to sight restrictions.

If locking memory is used, it should only lock on red.

Non-locking memory is the preferred method (except in Central Business Districts where fixed time operations are present). All channels placed on locking memory should be explained in either the signal cabinet or central system logbook. Locking memory (if used) should be a short-term fix. Steps should be taken to repair detection, paint the stop line, or add additional detection so the intersection detection (if present) can operate in the non-locking memory mode.

IX. MISCELLANEOUS CONTROLLER PARAMETERS (SIMULTANEOUS GAP-OUT, YELLOW TRAP, FLASHING OPERATION)

SIMULTANEOUS GAP-OUT

Simultaneous gap-out requires all current green phases to concurrently "gap-out" prior to crossing the barrier. Simultaneous gap-out should only be used when there is dilemma zone detection.

PREVENTION OF YELLOW TRAP

The "yellow trap" is a condition where a left-turning driver interprets the onset of a steady yellow ball indication and incorrectly assumes oncoming through traffic sees the same steady yellow ball indication. This can be problematic if the left-turning user attempts to "sneak" through the intersection on yellow when oncoming traffic still sees a green indication.

Another potentially problematic situation is the "perceived yellow trap" that sometimes occurs with FYA indications. This can be problematic if the driver of the left-turning vehicle observes the adjacent through signal head indication turn to a steady yellow ball indication and incorrectly assumes that oncoming through traffic also sees a steady yellow indication. Drivers of left-turning vehicles should not rely on signal indications for adjacent through lanes. The FYA signal indication in the left turn lane is logically tied to the opposing through green indications and will remain a flashing yellow arrow until the start of yellow for the opposing through movement.

These “yellow trap” and “perceived yellow trap” situations are problematic as the left-turning user may assume the need to clear the intersection and turn in front of an opposing through user assuming that they are stopping whereas they may still have a green indication.

Due to the various combinations of traffic signal phasing configurations and various methods to take in defeating the “yellow trap” situations, please see that it is addressed appropriately. Appendix C shows the various signal phasing combinations and signal head types that require yellow trap to be defeated by using various levels of yellow trap protection in the signal controller.

ADVANCE WARNING SIGNAL (AWS) SYSTEMS

Dynamic advance warning signals consist of sign and warning lights that are placed upstream of the intersection. The purpose of an AWS system is to warn drivers of, and provide information on, the impending signal change at an approaching intersection. The desired results include a reduction in red-light-running and a safer speed distribution, with the ultimate goal of improved safety at the intersection. Warranting for AWS systems is done through Central Traffic & Safety’s standard warranting process. Design for the AWS systems is found in UDOT’s “Signalized Intersection Design Guidelines” found at: <https://www.udot.utah.gov/main/uconowner.gf?n=13679121470326565>. It is important when configuring and timing AWS to avoid yellow trap.

Table 9: AWS - Considerations to Avoid Yellow Trap

Advance Warning System Design - Important considerations to avoid yellow trap					
Combination	AWS on Approach 1?	AWS on Approach 2?	Left Turn Type Approach 1	Left Turn Type Approach 2	
					Requirements for an intersection with these parameters:
1	Yes	Yes	B	B	Ideally, lead flash time for both approaches should be the same. Consequently, AWS and detection placement should be the same for both approaches. However, if necessary (e.g., because of grade) each AWS can be placed and programmed individually. The result will be a longer red clearance on the approach with the shorter lead flash time.
2	Yes	Yes	A	A	Lead flash time <u>MUST</u> be the same for both approaches or yellow trap will result. Consequently, AWS and detection placement should be the same for both approaches.
3	Yes	No	B	B	Ideally, Approach 2 will have a "dummy" lead flash time equal to that of Approach 1, to avoid wasted dwell-red time in one direction at the intersection. Consequently, detection for Approach 2 should be placed the same distance back from the stop line as that for Approach 1, even though Approach 2 has no AWS. If detection cannot be placed at this distance, the "dummy" lead flash time for Approach 2 can be reduced or left out, and there will be a longer red clearance time for that approach.
4	Yes	No	A	A	Approach 2 MUST have a "dummy" lead flash time equal to that on Approach 1, to avoid a yellow trap. Detection for Approach 2 MUST be placed the same distance from the stop line as that for Approach 1, or detected gaps will be past the stop line before signal actually changes.
5	Yes	Yes	B	A	Generally the same as combination 2 above. Lead flash times may be different if absolutely necessary, provided that the lead flash time for Approach 2 is at least as long as that for Approach 1. Otherwise a yellow trap will result.
6	Yes	No	B	A	Generally the same as combination 4 above. Lead flash times may be different if absolutely necessary, provided that the "dummy" lead flash time for Approach 2 is at least as long as the lead flash time for Approach 1. Otherwise a yellow trap will result.
7	Yes	No	A	B	Generally the same as combination 3 above. "Dummy" lead flash time for Approach 2 must not be longer than lead flash time for Approach 1 or yellow trap will result. (A longer "dummy" time would serve no useful purpose, anyway.)
Left Turn Type "A" means that the approach has one of the following left-turn treatments susceptible to yellow trap: - Permissive-only with Type I head - Protected/Permissive with Type V head Left Turn Type "B" means that the approach has one of the following left-turn treatments not susceptible to yellow trap: - Protected-only (i.e., Type III heads) - Protected/Permissive with Flashing Yellow Arrow (i.e., Type VI) - Permissive-only but using Flashing Yellow Arrow (i.e., 3-section without green arrow) - Approach is one-way, with no opposing traffic lanes - Left turns are prohibited or physically impossible					

Programming AWS at an intersection requires many user inputs (e.g. posted speed limit, distance between stop line and AWS, detection setup and coverage, phase passage time, etc.) and several calculations from AWS research. Please use the “UDOT AWS Timing Worksheet” in setting timing parameters for AWS.

FLASHING OPERATION

Most intersections should be wired to flash red-red as opposed to yellow-red for emergency flash. Yellow-red flashing operations are appropriate for HAWKS (to differentiate from the normal red-flash operation during ped clearance) and at other intersections where the side street vehicle phase is non-existent or at other locations using engineering judgement.

It is also discouraged to use programmed flashing mode operations at night. However, flashing during inload/outload for special events is sometimes appropriate.

Please follow the guidance in MUTCD section 4D.31 for transitioning out of flashing mode. For red-red flashing mode, the steady red clearance interval provided during the change from red-red flashing mode to steady (stop-and-go) mode should have a duration of 6 seconds.

X. RAILROAD PREEMPTION

Preemption of a traffic signal at or near a highway-rail at-grade crossing occurs when traffic signal operations are modified

1. to clear roadway users from a railroad track before a train arrives at a crossing,
2. to prevent roadway users from being directed onto an occupied crossing, and/or
3. to provide for orderly movement of traffic while a crossing is occupied by a train.

UDOT has a manual titled, “Preempting Traffic Signals near Railroad Crossings in Utah” and a “Utah Railroad Preemption Form” worksheet that should be used in setting up or configuring railroad preemption at traffic signals.

Any changes or modifications to the railroad preemption settings should be discussed with the Engineer. Please be aware that adjusting some timing parameters may affect preemption timing. Prior to making any adjustments, the Engineer should confirm that the change does not affect preemption timing. The timing parameters that may affect preemption timings include:

- Pedestrian clearance interval – This includes changes to the pedestrian clearance interval.
- Yellow change interval – This includes increasing or decreasing the yellow change interval.
- Red clearance interval – This includes increasing or decreasing the red clearance time.
- Guaranteed minimum time – The guaranteed minimum times will override preemption timing if the values violate the programmed guaranteed times.
- Railroad preemption menu – This includes all changes within the railroad preemption menu.

Railroad preemption uses preempt plans 1 and 2 in the signal cabinets and signal controllers. Railroad preemption should not shorten the yellow or red clearance for any vehicle phase.

XI. EMERGENCY VEHICLE PREEMPTION

Preemption of a traffic signal for emergency vehicles should follow the policies & guidance of the owning signal agency. A convention UDOT follows for emergency vehicle preemption is:

- Preempt Plan 3: Emergency Vehicle Phase 1 & 6, else phase 6 if phase 1 doesn't exist – wired to Preempt A.
- Preempt Plan 4: Emergency Vehicle Phases 2 & 5, else phase 2 if phase 5 doesn't exist – wired to Preempt B.
- Preempt Plan 5: Emergency Vehicle Phases 3 & 8, else phase 8 if phase 3 doesn't exist – wired to Preempt C.
- Preempt Plan 6: Emergency Vehicle Phases 4 & 7, else phase 4 if phase 7 doesn't exist – wired to Preempt D.

Salt Lake County uses a different convention that calls for Preempt Plan 3 to call 2&5, Plan 4 to call 6 & 1, plan 5 to call 4 & 7, and plan 6 to call 8 & 3.

Emergency vehicle preemption should not shorten the yellow, red clearance or pedestrian clearance for any vehicle and pedestrian phase. The pedestrian “walk” may be preempted to zero. When permissive left turns are present, ensure that the controller doesn't create a “yellow trap”.

XII. DETECTION

Detection is a device used to count and/or determine the presence of a motorized vehicle, bicycle, or pedestrian. Stop line detection is detection located at the stop line that is generally used to call the phase, discharge the queue, and collect data for ATSPMs. Setback or advance detection is located upstream of the stop line and is used for dilemma zone detection, queue clearance (in the absence of stop line detection), and ATSPMs. Detection of all varieties are in use in Utah, including but not limited to radar, magnetometers, inductive loops, video detection, and push buttons. Installing, setting up, and programming detection requires the consideration of many variables that are dependent on the detection type and brand, intersection and roadway geometry, location and placement of the detectors, available view and range of the detectors, phasing and timing, ATSPMs, and objectives/purposes desired. The “UDOT Detection Form” (located on the TOC share drive at: S:\TMD 8384 Traffic Signal Operations\Policies and Procedures\UDOT Detection Form) should be used when setting up detection for calling and extending a phase and programming the vehicle extension/passage time.

Some general guidance for setting up detection:

- It is suggested to use the “UDOT Detection Form” to ensure the correct vehicle extension/passage time is used, that the proper amount of detection is used and that the dilemma zone is adequately covered and that detector settings are properly used and configured. Many of the guidelines below are taken from the current version of this form. Note that as the form is updated these guidelines may change slightly.
- Detection is generally not needed to call and extend the through phase in the right turn lanes unless the right turn is the critical movement for the approach.
- At intersections with Flashing Yellow Arrows (FYA), configure the detection to call and extend the opposing through phase for the permissive movement.
- With protected/permissive phasing, the queue zone for the protected portion should be located about 3 car lengths (50 feet) away from the stop line with approximately a 3-second delay to prevent the protected phase from coming on with vehicles rolling over the detection zone. Normally, the queue detector is approximately 15 feet long.
- For normal detection operations, longer detection zones reduce the vehicle extension/passage time that is required and therefore reduce overall vehicle delay. If using Wavetronix Matrix, the

following zone lengths for calling/extending the phase seem to work well and results in a passage time of 1 second or less:

- o For through movements, use 65-70 feet
- o For turning movements, use 50 feet

Queue clearance detection zone instructions for Wavetronix Advance:

- If the approach has stop line detection:
 - o Do not include a queue clearance zone if using Wavetronix Advance.
 - o Set stop line detector channel(s) in controller to Type “P – Passage Type Queue/Stop Bar.”
 - o Set detector channel “passage” time equal to phase “vehicle extension” time.
- If the approach does not have stop line detection:
 - o Include a queue clearance zone in the Wavetronix Advance detector; make it as close to the stop line as possible while still reliably detecting vehicles. Length should be approximately 65-70 feet.
 - o Queue clearance zone should have max speed filter set, typically to 35 mph, but no Estimated Time of Arrival (ETA) filter.

Dilemma Zone Detection Zone instructions (Wavetronix Advance or Extended Range):

- For “Legacy” Wavetronix Advance (not Extended Range):
 - o Use “Simple” or “Normal” mode
 - o Use Legacy Advance Min ETA/Legacy Advance Max ETA thresholds from the UDOT Detection Form.
 - o “Range” should be as large as possible within the limits of radar coverage.
- For Wavetronix Advance Extended Range:
 - o Use “Priority” mode. Set “Discovery Range” to the point beyond which trucks but not cars are detected.
 - o Use TRUCKS Min ETA/TRUCKS Max ETA from the “UDOT Detection Form” as the ETA thresholds in Level 1.
 - o Use CARS Min ETA/CARS Max ETA from the “UDOT Detection Form” as the ETA thresholds in Level 2.
 - o “Range” should be as large as possible within limits of radar coverage for both Level 1 and Level 2.
- Speed Filters:
 - o For Dilemma Zone zones, speed filters are not needed but may be useful to filter out slower-moving vehicles, such as those preparing to make turns. A typical speed filter that has been used successfully is 30-100 mph.
 - o If there are a lot of heavy trucks, severe weather, and/or a lack of stop line detection or approach speeds are often less than 35 mph, consider setting lower speed filter to a smaller value, or disabling the speed filter altogether.

XIII. Appendix A (Links to Guidelines and Documents)

- Signal Timing Manual – Institute of Transportation Engineers (2009): http://www.signaltiming.com/The_Signal_Timing_Manual_08082008.pdf
- Signal Timing Manual Second Edition - NCRHP Report 812 (2015): http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_812.pdf
- An ITE Proposed Recommended Practice – Guidelines for Determining Traffic Signal Change and Clearance Intervals: http://redlightrobber.com/red/links_pdf/Guidelines-for-Determining-Traffic-Signal-Change-and-Clearance-Intervals-110RP040Er2.pdf
- Preempting Traffic Signals near Railroad Crossings in Utah – A UDOT Manual. Located at: <http://www.udot.utah.gov/main/uconowner.gf?n=29256830125849243>
- Utah Railroad Preemption Form. Found at: <https://www.udot.utah.gov/main/f?p=100:pg:0:::1:T,V:4812>,
- “Interactive Form” from the “UDOT Detection Form”: Located at: S:\TMD 8384 Traffic Signal Operations\Policies and Procedures\UDOT Detection Form
- “UDOT AWS Timing Worksheet”: Located at: S:\TMD 8384 Traffic Signal Operations\Policies and Procedures\Advance Warning Systems
- Utah Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways (FHWA’s MUTCD 2009 Edition as amended for use in Utah) – December 2011 <https://www.udot.utah.gov/main/uconowner.gf?n=12281504735606387>
- Automated Traffic Signal Performance Measures – Utah. <http://udottraffic.utah.gov/ATSPM>.

XIV. Appendix B (Red Clearance Justification)

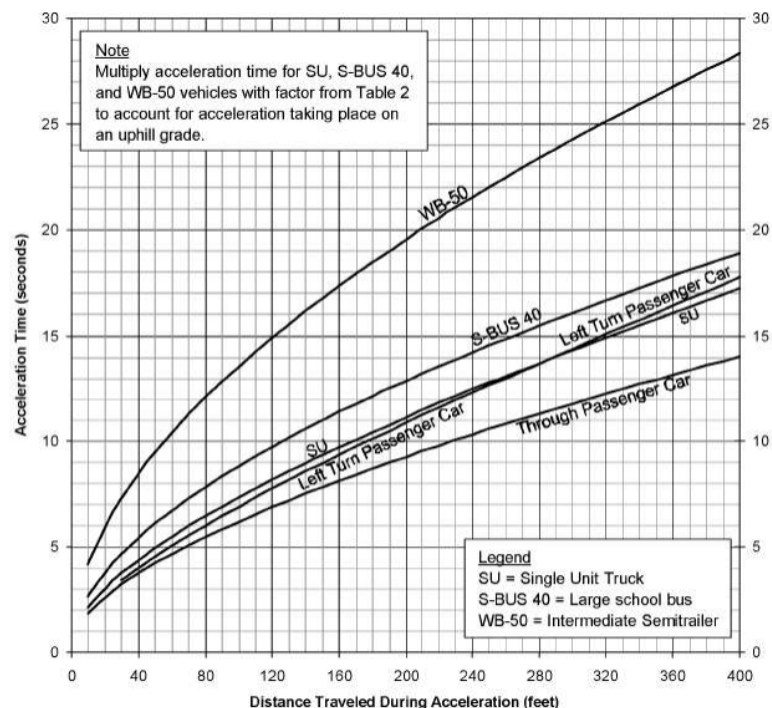
Justification for Deviation from National Guidelines

Red Clearance for Left Turns

The equation for red clearance used in this guideline deviates slightly from other guidelines as recommended in NCHRP Report 731 titled “Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections,” published 2012, and in ITE’s proposed recommended practice “Guidelines for Determining Traffic Signal Change and Clearance Intervals” published January 2015. The two deviations in red clearance calculations for left turns omit the length of a vehicle from the numerator (assumed to be 20 feet) and allow the intersection width to be measured to the center of the farthest conflicting traveled lane as opposed to the outside edge of the farthest travel lane. These changes are made for the following reasons:

1. The duration of the red clearance interval can be set to provide full or partial clearance. (Traffic Engineering Handbook, ITE, Seventh Edition, 2016).
2. Longer red clearance intervals reduce effective green time.
3. A comprehensive study of long-term effects by the Minnesota Department of Transportation indicated short-term reductions in crash rates were achieved (approximately one year after the implementation), but long-term reductions were not observed, which implies that increased red clearance intervals may not have a safety benefit. (Souleyrette, R.R., M.M. O’Brien, T. McDonald, H. Preston, and R. Storm. Effectiveness of All-Red Clearance Interval on Intersection Crashes. Report MN/RC-2004-26, Minnesota Department of Transportation, 2004.)
4. A study by Purdue showed that the delay caused by the all-red clearance interval negated the safety benefits of implementing the all-red clearance interval. (Souleyrette, R.R., M.M. O’Brien, T. McDonald, H. Preston, and R. Storm. Effectiveness of All-Red Clearance Interval on Intersection Crashes. Report MN/RC-2004-26, Minnesota Department of Transportation, 2004.)

5. The revised red clearance calculations are still higher than the existing calculations that have been in operation in Utah for over a decade.
6. Utah Code Title 41, Chapter 6a Part 3 Section 305 states that “the operator of a vehicle facing a circular green signal, including an operator turning right or left...shall yield the right-of-way to other vehicles and to pedestrians lawfully within the intersection or an adjacent crosswalk at the time the signal is exhibited....” Similar language exists for drivers facing a green arrow.
7. There is a delay for vehicles to cross the stop line at the start of green. Turning vehicles are traveling at low speed (less than 20 mph). When the next green light in the cycle sequence occurs, traffic at the stop usually accelerates from a stop (thus low speed also) if a conflict was to occur.
8. Graph – Acceleration time over a fixed distance on a level surface (<http://library.ite.org/pub/e1dc9f7d-2354-d714-5141-8b7105e48649>), Figure 2. This shows that approximately 2 seconds of acceleration time is lost within a short distance for a vehicle at rest to accelerate and potentially hit a car still in the intersection. The figure is based on slower-than-average vehicles – which are a worst case scenario for track clearance but best case for intersection conflicts.

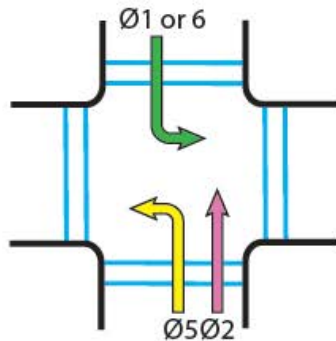


Red Clearance for Through Movements

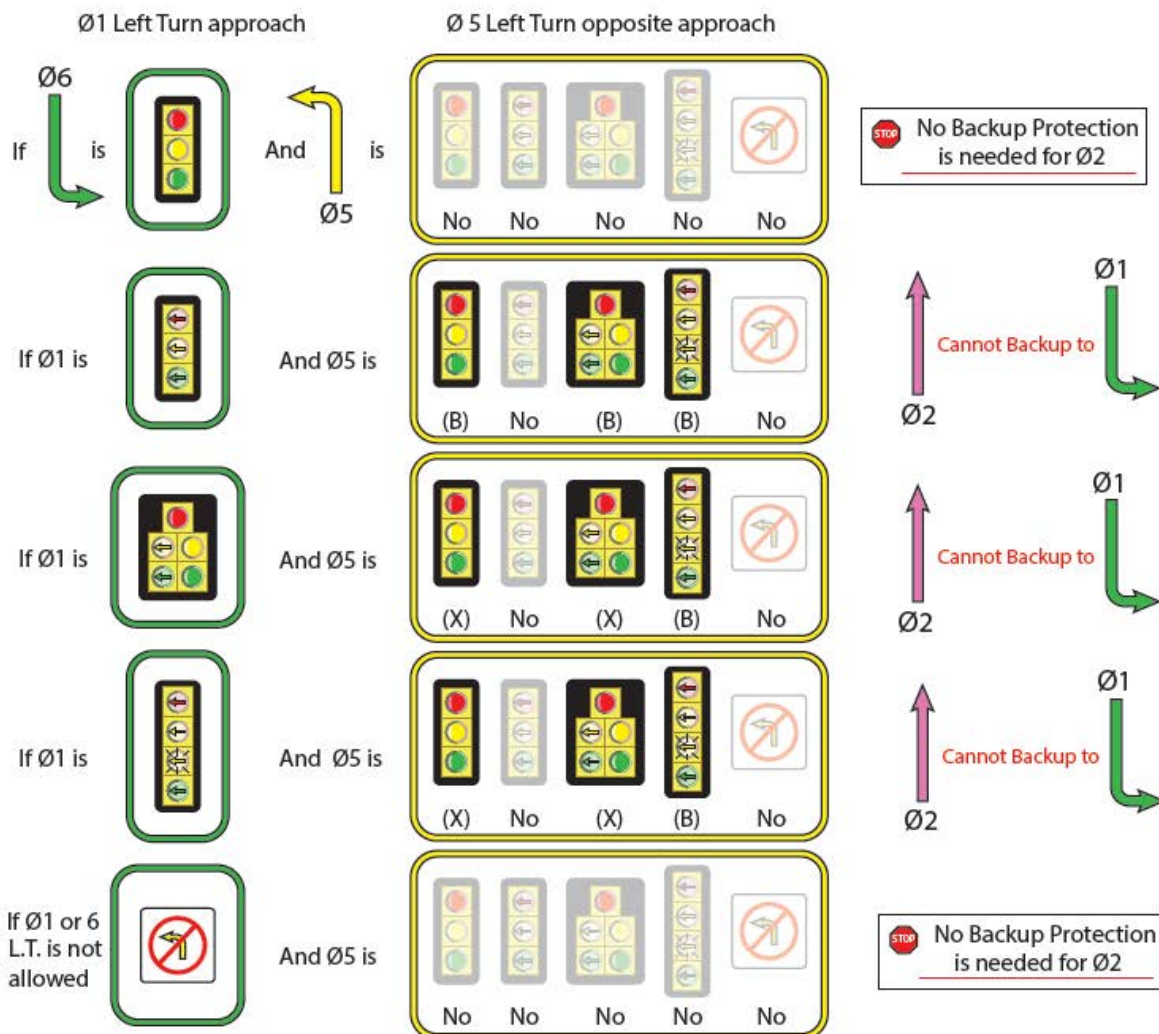
Instead of using the 85th percentile speed for this calculation as recommended in some of the research, for added safety reasons we are using the lowest of the 85th percentile or posted speed limit. In most cases, the posted speed limit will be the lower speed to use. This is more of a conservative approach, considers more the other modes of transportation and will result in a slightly higher red clearance being used.

XV. Appendix C (Prevention of Yellow Trap)

Back-up protect using Ø's 1,2, and 5,6



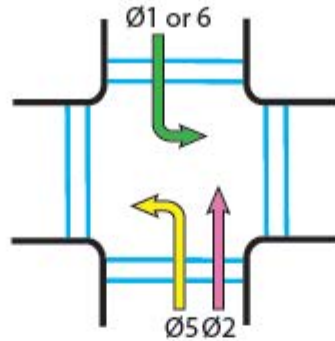
(You must analyze each approach separately NB,SB,EB,WB)



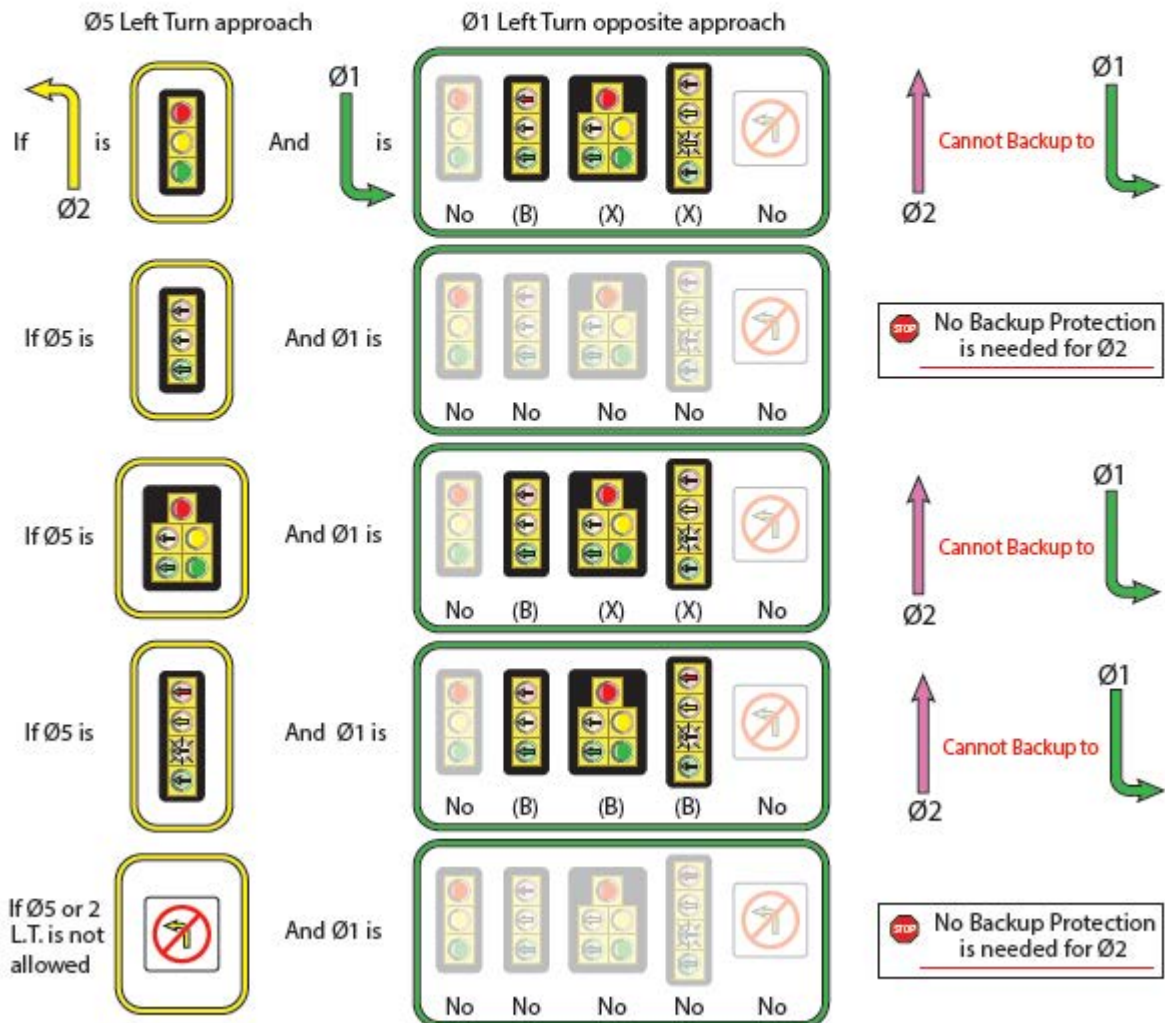
Note: For protected opposing right turns, check the ring structure and overlaps.

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Back-up protect using Ø's 1,2, and 5,6



(You must analyze each approach separately NB,SB,EB,WB)



Note: For protected opposing right turns, check the ring structure and overlaps.

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