APPENDIX A

Crash Data Summary
Medfield Police Crash Reports
January 2014–November 2019

Table A-1 Summary of Crash Date
Medfield Police Crash Reports January 2014-November 2019

Crash Diagram Ref #	Crash Date	Crash Day	Time of Day	Peak	Manner of Collision	Light Condition	Weather Condition	Road Surface	Driver Contributing Code	Driver Distracted By	Injury Severity	Comments
#	*mm/dd/year*	*Day*	*hh:mm*	*Type*	*Type*	*Type*	*Type*	*Type*	*Type*	*Type*	*Unknown*	
1	06/17/14	Tuesday	7:57 AM	Yes	Angle	Daylight	Clear	Dry	Disregarded traffic signs, signals, road markings	Unknown	Non-fatal injury	OP2 NB failed to stop at red light struck MV1 WB
2	07/02/14	Wednesday	6:50 PM	No	Angle	Daylight	Clear	Dry	Inattention	Passenger	Non-fatal injury	OP2 EB failed to stop at the red light and struck MV2 NB
3	07/18/14	Friday	4:41 PM	Yes	Angle	Daylight	Clear	Dry	Unknown	Unknown	Non-fatal injury	Both operators state they had a green light
4	07/29/14	Tuesday	1:32 PM	No	Angle	Daylight	Clear	Dry	Failed to yield right of way	External distraction (outside the vehicle)	Non-fatal injury	OP1 attempted to turn left in front of MV2(Motorcycle) forcing MV2 to take evasive action. MV2 struck front end of MV1
5	08/08/14	Friday	4:38 PM	Yes	Angle	Daylight	Clear	Dry	Disregarded traffic signs, signals, road markings	Other activity (searching, eating, personal hygiene, etc.)	No Injury	OP1(WB) stated she ran the red light and struck MV2(NB)
6	09/18/14	Thursday	2:43 PM	No	Angle	Daylight	Clear	Dry	Distracted	Other activity, electronic device(navigation system, DVD player,	No Injury	OP1(WB) ran the red light struck MV2(NB) and tried to flee the scene
7	11/20/14	Thursday	4:08 PM	Yes	Rear-end	Daylight	Clear	Dry	No improper driving	Not distracted	No Injury	MV1 rear ended MV2
8	02/05/15	Thursday	9:53 AM	Yes	Rear-end	Daylight	Snow	Snow	No improper driving	Not distracted	No Injury	MV2 attempted to stop but skidded on snow. MV2 rear ended MV1 (TT)
9	05/07/15	Thursday	6:20 PM	Yes	Angle	Daylight	Clear	Dry	Distracted	Unknown	Non-fatal injury	OP1(SB) ran the red light and struck MV2(WB) causing it to flip over.
10	09/19/15	Saturday	12:15 PM	No	Rear-end	Daylight	Clear	Dry	Distracted	Unknown	Non-fatal injury	OP2 failed to stop and rear ended MV1
11	12/04/15	Friday	9:19 PM	No	Single vehicle crash	Dark - lighted roadway	Clear	Dry	Operating vehicle in erratic, reckless, careless, negligent, or aggressive manner	Unknown	No Injury	OP1 (WB) attempted to turn right onto N. Meadow Road and struck the southbound guardrail
12	12/24/15	Thursday	11:51 AM	No	Angle	Daylight	Clear	Dry	Disregarded traffic signs, signals, road markings	Unknown	Non-fatal injury	OP1(EB) failed to stop for the red light and struck MV2(NB)
13	01/05/16	Tuesday	8:19 AM	Yes	Angle	Daylight	Clear	Dry	Disregarded traffic signs, signals, road markings	Unknown	Non-fatal injury	OP2(SB) failed to stop for the red light and struck MV1(EB)
14	01/21/16	Thursday	4:21 PM	Yes	Angle	Daylight	Clear	Dry	Failed to yield right of way	Not distracted	No Injury	OP1 (NB) attempted to turn left in front of MV2(SB)
15	03/07/16	Monday	12:25 PM	No	Angle	Daylight	Clear	Dry	Failed to yield right of way	Unknown	Non-fatal injury	OP1 (WB) went through a red light and hit MV2(SB) then spun and rolled over onto MV3 (EB)
16	04/23/16	Saturday	10:29 AM	No	Rear-end	Daylight	Rain	Wet	No improper driving	Not distracted	Non-fatal injury	MV1 rear ended MV2 after stopping for the red light
17	05/13/16	Friday	7:34 AM	Yes	Angle	Daylight	Clear	Dry	Unknown	Unknown	No Injury	OP1 (WB) went through a red light and hit MV2(NB)
18	05/21/16	Saturday	8:39 AM	Yes	Angle	Daylight	Clear	Dry	Disregarded traffic signs, signals, road markings	Unknown	Non-fatal injury	OP1 (EB) ran a red light and struck MV2 (NB). MV1 then hit MV3 (WB)
19	06/21/16	Tuesday	8:12 PM	No	Angle	Dusk	Clear	Dry	Glare	Not distracted	Non-fatal injury	OP1 (NB) ran the red light and struck MV2 (EB). Sun Glare was a factor
20	08/01/16	Monday	6:00 PM	Yes	Single vehicle crash	Daylight	Clear	Dry	Operating vehicle in erratic, reckless, careless, negligent, or aggressive manner	Unknown	Unknown	OP1 (TT) (NB) attempted to turn left and struck the traffic signal on the NW corner
21	10/22/16	Saturday	1:26 AM	No	Single vehicle crash	Dark - lighted roadway	Rain	Wet	Unknown	Unknown	Non-fatal injury	MV1 (EB) on West street crashed into a utility pole. No operator found
22	12/23/16	Friday	8:45 AM	Yes	Sideswipe, same direction	Daylight	Clear	Dry	Failure to keep in proper lane or running off road	Unknown	No Injury	OP1 (WB)driving a Tractor Trailer attempted to turn right and OP2 (WB) attempted to pass on the right to turn right. OP2 claimed to be in the right hand turn lane
23	07/22/17	Saturday	3:39 PM	Yes	Rear-end	Daylight	Clear	Dry	Followed too closely	Unknown	No Injury	OP2 (NB) was stopped attempting to turn left onto West St when it was rear ended by OP1
24	11/15/17	Wednesday	7:32 AM	Yes	Angle	Daylight	Clear	Dry	Unknown	Unknown	No Injury	OP2 (NB) was turning left when its trailer was struck by MV1 going through the intersection on yellow
25	11/15/17	Wednesday	6:13 PM	Yes	Angle	Dark - lighted roadway	Clear	Dry	Inattention	Unknown	Non-fatal injury	OP2 (WB) was stopped at the intersection when it went through a red light and struck MV1(SB)
26	11/21/17	Tuesday	6:16 PM	Yes	Rear-end	Dark - lighted roadway	Clear	Dry	Inattention	Unknown	No Injury	MV2 rear ended MV1
27	11/27/17	Monday	5:42 PM	Yes	Angle	Dark - lighted roadway	Clear	Dry	Other improper action	Not distracted	No Injury	OP2 (EB) ran the red light striking MV1(NB). OP2 stated "was being impatient and thought he could make it"
28	11/28/17	Tuesday	5:12 PM	Yes	Angle	Daylight	Clear	Dry	No improper driving	Not distracted	Non-fatal injury	OP3 (NB) was attempting to turn left onto West St when it was struck by MV2(SB). MV1 was struck by MV2
29	01/05/18	Friday	3:46 PM	Yes	Angle	Daylight	Clear	Dry	Inattention	Unknown	No injury	OP1 EB ran red light struck MV2 SB
30	01/07/18	Sunday	7:49 AM	Yes	Angle	Daylight	Clear	Dry	Glare	Unknown	No injury	OP2 SB ran red light struck MV1 WB
31	03/10/18	Saturday	11:33 AM	No	Angle	Daylight	Cloudy	Dry	Distracted	Other activity (searching, eating, personal hygiene, etc.)	No injury	OP1 EB ran red light struck MV2 SB
32	04/05/18	Thursday	12:55 PM	No	Angle	Daylight	Clear	Dry	Failure to keep in proper lan or running off road	Unknown	Non fatal injury	OP1 NB passing stopped vehicle struck MV2 SB turning left
33	05/10/18	Thursday	10:22 AM	No	Rear-end	Daylight	Clear	Dry	Distracted	Other activity (searching, eating, personal hygiene, etc.)	No injury	OP2 SB stopped to turn left. OP1 SB pick up things from floor and rear-end MV2
34	06/29/18	Friday	1:07 PM	No	Angle	Daylight	Clear	Dry	Unknown	Unknown	No injury	OP2 EB ran red light struck MV1 SB
35	07/11/18	Wednesday	9:02 AM	Yes	Angle	Daylight	Clear	Dry	Faild to yield right of way	Unknown	No injury	OP1 WB right turn failed to yield on coming traffic and struck MV2 NB
36	07/26/18	Thursday	4:39 PM	Yes	Sideswipe,same direction	Daylight	Rain	Wet	Inattention	Unknown	No injury	OP1 NB stopped to turn left. OP2 NB clipped the right rear of MV1 NB
37	08/23/18	Thursday	1:58 PM	No	Single vehicle crash	Daylight	Clear	Dry	Unknown	Unknown	No injury	OP1 state road sign was broken and laying down on the pavement. OP1 did not see sign as she drove over sign and cause the accident
38	10/24/18	Wednesday	8:02 AM	Yes	Angle	Daylight	Clear	Dry	Unknown	Unknown	Non fatal injury	MV2 SB struck MV1 EB
39	11/27/18	Tuesday	7:30 PM	No	Head on	Dark - roadway not lighte	Clear	Dry	No improper driving	Unknown	No injury	Dear ran across North Meadows Road and struck by MV2 SB and MV1 NB
40	02/20/19	Wednesday	1:02 PM	No	Angle	Daylight	Clear	Dry	Disregarded traffic signs, signals, road markings	Unknown	No injury	OP1 EB ran red light struck MV2 NB
41	03/02/19	Saturday	7:05 PM	No	Angle	Dark - lighted roadway	Clear	Dry	Fatigued/asleep	Unknown	No injury	MV1 EB struck MV2 SB
42	06/16/19	Sunday	1:23 PM	No	Rear-end	Daylight	Cloudy	Dry	Followed too closely	Unknown	No injury	MV1 WB rear-end MV2 WB
43	07/12/19	Friday	4:43 PM	Yes	Rear-end	Daylight	Rain	Wet	Inattention	Not distracted	No injury	MV2 EB failed to stop and slid due to road conditions and rear-end MV1 EB
44	07/16/19	Tuesday	8:51 AM	Yes	Angle	Daylight	Clear	Dry	Unknown	Unknown	No injury	OP1 EB ran red light struck MV2 WB turning left
45	10/24/19	Thursday	10:38 AM	No	Rear-end	Daylight	Clear	Dry	No improper driving	Not distracted	No injury	MV2 WB rear-end MV1 WB
46	11/01/19	Friday	3:46 PM	Yes	Rear-end	Daylight	Clear	Dry	Followed too closely	Unknown	No injury	MV1 EB rear-end MV2 EB

APPENDIX B

Intersection Capacity Analyses
2020 Existing Conditions

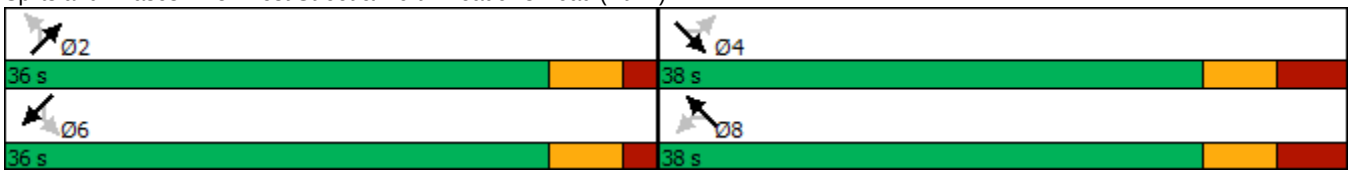
Intersection Capacity Analysis
West Street & North Meadows Road (Rt. 27)

08/03/2020

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Traffic Volume (vph)	27	392	23	24	382	102	61	615	46	47	98	14
Future Volume (vph)	27	392	23	24	382	102	61	615	46	47	98	14
Peak Hour Factor	0.84	0.84	0.84	0.91	0.91	0.91	0.95	0.95	0.95	0.78	0.78	0.78
Heavy Vehicles (%)	7%	3%	0%	0%	3%	4%	0%	1%	0%	0%	4%	0%
Shared Lane Traffic (%)												
Turn Type	Perm	NA		Perm	NA		Perm	NA		Perm	NA	
Protected Phases		4			8			2			6	
Permitted Phases	4			8	8		2			6		
Detector Phase	4	4		8	8		2	2		6	6	
Switch Phase												
Minimum Initial (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	
Minimum Split (s)	18.0	18.0		18.0	18.0		16.0	16.0		16.0	16.0	
Total Split (s)	38.0	38.0		38.0	38.0		36.0	36.0		36.0	36.0	
Total Split (%)	51.4%	51.4%		51.4%	51.4%		48.6%	48.6%		48.6%	48.6%	
Yellow Time (s)	4.0	4.0		4.0	4.0		4.0	4.0		4.0	4.0	
All-Red Time (s)	4.0	4.0		4.0	4.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)		0.0			0.0			0.0			0.0	
Total Lost Time (s)		8.0			8.0			6.0			6.0	
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	Min	Min		Min	Min		None	None		None	None	
Act Effct Green (s)		23.2			23.2			29.8			29.8	
Actuated g/C Ratio		0.35			0.35			0.44			0.44	
v/c Ratio		0.79			0.82			0.90			0.34	
Control Delay		28.8			29.6			35.0			15.2	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		28.8			29.6			35.0			15.2	
LOS		C			C			D			B	
Approach Delay		28.8			29.6			35.0			15.2	
Approach LOS		C			C			D			B	

Intersection Summary	
Cycle Length: 74	
Actuated Cycle Length: 67.1	
Natural Cycle: 65	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.90	
Intersection Signal Delay: 30.0	Intersection LOS: C
Intersection Capacity Utilization 86.1%	ICU Level of Service E
Analysis Period (min) 15	

Splits and Phases: 3: West Street & North Meadows Road (Rt 27)



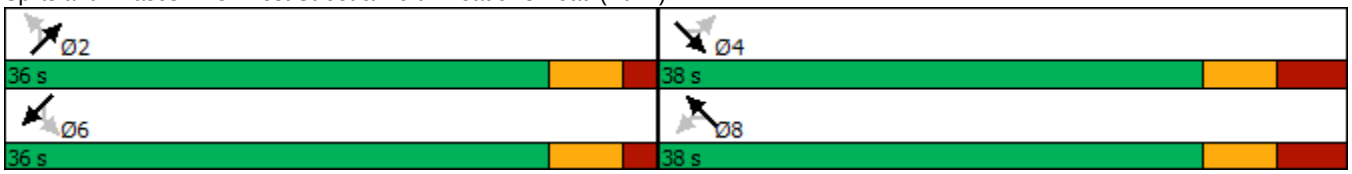
Intersection Capacity Analysis
West Street & North Meadows Road (Rt. 27)

08/03/2020

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Traffic Volume (vph)	21	331	42	29	307	80	28	127	54	100	606	29
Future Volume (vph)	21	331	42	29	307	80	28	127	54	100	606	29
Peak Hour Factor	0.84	0.84	0.84	0.85	0.85	0.85	0.89	0.89	0.89	0.95	0.95	0.95
Heavy Vehicles (%)	5%	1%	0%	3%	1%	0%	0%	1%	3%	1%	1%	0%
Shared Lane Traffic (%)												
Turn Type	Perm	NA		Perm	NA		Perm	NA		Perm	NA	
Protected Phases		4			8			2			6	
Permitted Phases	4			8	8		2			6		
Detector Phase	4	4		8	8		2	2		6	6	
Switch Phase												
Minimum Initial (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	
Minimum Split (s)	18.0	18.0		18.0	18.0		16.0	16.0		16.0	16.0	
Total Split (s)	38.0	38.0		38.0	38.0		36.0	36.0		36.0	36.0	
Total Split (%)	51.4%	51.4%		51.4%	51.4%		48.6%	48.6%		48.6%	48.6%	
Yellow Time (s)	4.0	4.0		4.0	4.0		4.0	4.0		4.0	4.0	
All-Red Time (s)	4.0	4.0		4.0	4.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)		0.0			0.0			0.0			0.0	
Total Lost Time (s)		8.0			8.0			6.0			6.0	
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	Min	Min		Min	Min		None	None		None	None	
Act Effct Green (s)		20.7			20.7			30.3			30.3	
Actuated g/C Ratio		0.32			0.32			0.47			0.47	
v/c Ratio		0.73			0.78			0.29			0.91	
Control Delay		26.3			28.6			12.0			35.9	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		26.3			28.6			12.0			35.9	
LOS		C			C			B			D	
Approach Delay		26.3			28.6			12.0			35.9	
Approach LOS		C			C			B			D	

Intersection Summary	
Cycle Length: 74	
Actuated Cycle Length: 65.1	
Natural Cycle: 65	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.91	
Intersection Signal Delay: 29.0	Intersection LOS: C
Intersection Capacity Utilization 95.1%	ICU Level of Service F
Analysis Period (min) 15	

Splits and Phases: 3: West Street & North Meadows Road (Rt 27)



APPENDIX C

Estimation of Yellow Change and Red Clearance Intervals

Table C-1
Estimation of Yellow Change and Red Clearance Intervals

Estimate for Through and Right-Turn Movements

Approach	Speed Limit	V (mph)	W (ft)	L (ft)	Yellow Interval	All-Red Clearance	Total Period
Route 27 NB	45	52	80	20	4.8	1.0	5.8
Route 27 SB	45	52	80	20	4.8	1.0	5.8
West Street EB	35	42	80	20	4.1	1.0	5.1
West Street WB	35	42	80	20	4.1	1.0	5.1

Estimate for Left-Turn Movements

Approach	Speed Limit	V (mph)	W (ft)	L (ft)	Yellow Interval	All-Red Clearance	Total Period
Route 27 NB	45	40	85	20	3.5	2.6	6.1
Route 27 SB	45	40	85	20	3.5	2.6	6.1
West Street EB	35	30	85	20	2.8	2.6	5.4
West Street WB	35	30	85	20	2.8	2.6	5.4

Estimate for All Movements

Approach	Speed Limit	V (mph)	W (ft)	L (ft)	Yellow Interval	All-Red Clearance	Total Period
Route 27 NB	45	52	80	20	5.0	2.5	7.5
Route 27 SB	45	52	80	20	5.0	2.5	7.5
West Street EB	35	42	80	20	4.0	2.5	6.5
West Street WB	35	42	80	20	4.0	2.5	6.5

Existing Setting (based on field observations)

Approach	Speed Limit	V (mph)	W (ft)	L (ft)	Yellow Interval	All-Red Clearance	Total Period
Route 27 NB	45	NA	80	20	4.0	4.0	8.0
Route 27 SB	45	NA	80	20	4.0	4.0	8.0
West Street EB	35	NA	80	20	4.0	2.0	6.0
West Street WB	35	NA	80	20	4.0	2.0	6.0

Notes
Approach: NB = Northbound, SB = Southbound, EB= Eastbound, WB= Westbound
L = Length of vehicle; set at 20 feet
V = 85th percentile approach speed (mph), mph = miles per hour
W = Intersection width measured from the approaching movement stop line to the far side of the intersection (feet)
Based on the *Institute of Transportation Engineers' Guidelines for Determining Traffic Signal Change and Clearance Intervals*, this study applied the following assumptions. The through movement 85th percentile approach speeds and intersection clearance speeds were estimated by adding 7 mph to the posted speeds, the left-turn 85th percentile approach speeds were estimated by deducting 5 mph from the posted speeds, and the left-turn intersection clearance speeds were assumed to be 20 mph. The motorist perception-reaction time was assumed to be 1.0 second for through and right-turn movements and 0.6 second for left-turn movements. The conflicting movement start-up delay was assumed to be one second. The deceleration rate was assumed 10 feet/second/second. The approach grade was assumed to be zero for all approaches.

APPENDIX D

Guidelines for Timing Yellow and All-Red Intervals
National Cooperative Highway Research Program 731: Appendix A

APPENDIX A

Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections

BACKGROUND

The yellow change interval is the period of time following the green signal indication during which a yellow signal indication is displayed. The red clearance interval is the period of time that follows the yellow signal indication during which a red signal indication is displayed to all conflicting movements at an intersection. The yellow change interval and red clearance interval are collectively referred to as the change interval.

The purpose of the yellow change interval is to warn drivers of an impending change in the right-of-way assignment. The purpose of the red clearance interval is to provide additional time as a safety factor for a driver that legally entered the intersection at the very last instant of the yellow change interval to avoid conflict with traffic releasing from an adjacent opposing intersection approach.

CHANGE INTERVAL CALCULATION

The yellow change and red clearance intervals are calculated using the equations and associated parameters as presented in the following sections.

Yellow Change Interval

The yellow change interval (Y) is calculated using Equation A:

$$Y = t + \frac{1.47V}{2a+64.4g} \qquad \textbf{Equation A}$$

Where:

- t = PRT (s); *set at 1.0 seconds*
- a = deceleration rate (ft/s^2); *set at 10 ft/s^2*
- V = 85th percentile approach speed (mph)
- g = approach grade (percent divided by 100, negative for downgrade)

The value recommended for PRT (t) is 1.0 second and for deceleration rate (a) is 10 ft/s^2. The value for the approach speed (V) is recommended as the 85th percentile speed determined under free-flow conditions. If the 85th percentile approach speed is available, then the yellow change interval is calculated

directly from Equation A. Since the 85th percentile speed is typically not available, it can be assumed as the posted speed limit plus 7 mph, except for left-turn movements (as explained). Table A provides yellow change intervals for through movements based on typical roadway and driver conditions assuming the posted speed limit plus 7 mph for grades in the range of ±4 percent.

Table A. Yellow Change Interval (seconds) by Approach Speed Limit and Grade

Posted Speed Limit (mph)*	Grade (%)				
	-4	-2	0	2	4
25	3.7	3.5	3.4	3.2	3.1
30	4.1	3.9	3.7	3.6	3.4
35	4.5	4.3	4.1	3.9	3.7
40	5.0	4.7	4.5	4.2	4.1
45	5.4	5.1	4.8	4.6	4.4
50	5.8	5.5	5.2	4.9	4.7
55	6.2	5.9	5.6	5.3	5.0

*Yellow change intervals calculated using 85th percentile approach speed estimation of posted speed limit +7 mph

Red Clearance Interval

The red clearance interval (R) is calculated using Equation B:

$$R = \frac{W+L}{1.47V} - 1 \qquad \textbf{Equation B}$$

Where:

W = intersection width measured from the back/upstream edge of the approaching movement stop line to the far side of the intersection as defined by the extension of the curb line or outside edge of the farthest travel lane (ft)

L = length of vehicle (ft); *set at 20 feet*

V = 85th percentile approach speed (mph)

The width of the intersection (W) should be measured from the back/upstream edge of the stop line to the far-side intersection limit as determined by the extension of the curb line or outside edge of the farthest travel lane. A pedestrian crossing equipped with pedestrian signals on a receiving lane should not be considered unless the nearest crossing line is 40 feet or more from the extension of the farthest edge of the farthest conflicting traffic lane. If this condition exists, the intersection width should be measured from the back/upstream edge of the approaching movement stop line to the nearest pedestrian crossing line. The length of the vehicle (L) should be assumed as 20 feet. The same approach speed value used to calculate the yellow change interval should be used to calculate the red clearance interval, except for left-turn movements (as explained). The reduction of 1 second is to account for the start-up delay typically incurred by a driver stopped on a conflicting approach to react to a green signal indication and proceed forward.

The following provisions apply for specifying the duration of a calculated red clearance interval:

- If the calculated red clearance interval is less than or equal to 1.0 seconds, then the minimum implemented duration should be 1.0 seconds.

- If the calculated red clearance interval is greater than 1.0 seconds, then the implemented duration should be as calculated.

For Left-Turn Movements

Yellow change and red clearance intervals for left-turn movements should be calculated using Equations A and B with the following modified parameters:

Yellow Change Interval

V = approach speed (mph); *should be set at the approach speed limit minus 5 mph*

Red Clearance Interval

W = length of the approaching vehicle turning path measured from the back/upstream edge of the approaching movement stop line to the far side of the intersection as defined by the extension of the curb line or outside edge of the farthest travel lane (ft)*

V = approach speed (mph); *should be set at 20 mph regardless of the approach speed limit*

*A pedestrian crossing equipped with pedestrian signals on a receiving lane should not be considered unless the nearest crossing line is 40 feet or more from the extension of the farthest edge of the farthest conflicting traffic lane. If this condition exists, the intersection width should be measured from the back/upstream edge of the approaching movement stop line to the nearest pedestrian crossing line.

When calculating yellow change and red clearance intervals for left-turning vehicles, signal phasing should be considered as follows:

- For protected-only left-turn movements, the yellow and red intervals shall be calculated for each approach and implemented as calculated. The intervals do not have to be the same duration for opposing approaches.
- For permissive-only left-turn movements, the yellow and red intervals shall be calculated for opposing approaches, including the through movements. The implemented intervals shall be the longest of the calculated values (left, through, or combination). The intervals shall be the same duration for the left-turn and through movements on opposing approaches to ensure that termination is concurrent.
- For protected/permissive left-turn movements, the yellow and red intervals shall be calculated and implemented as described above for the respective protected and permissive portions of the phase.

OTHER CONSIDERATIONS

Grade Measurement

If a measurement of approach grade is required, as a general rule, it 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 approach speed limit plus 7 mph.

Unusual Conditions

While the guidelines are based on typical roadway and driver conditions, there may be instances when exceptions are necessary to accommodate unusual conditions. Under these circumstances, the engineer or practitioner may exercise "engineering judgment" to determine that the conditions warrant the use of other calculation or implementation practices than those presented in the guideline. However, under typical roadway and driver conditions, drivers should expect that the duration of the yellow change and red clearance intervals will be calculated according to the recommended kinematic equation and its associated recommended values.

Rounding

Modern digital traffic signal controllers are capable of programming values to one-tenth of a second (0.1 s) for any interval; therefore, the timings for the yellow change and red clearance intervals can be calculated in tenths of a second. Using Equations A and B to calculate the yellow change and red clearance interval durations, the resulting values should be rounded to the nearest 0.1 seconds. Values ending in 0.01 to 0.04 should be rounded down to the nearest tenth of a second whereas values ending in 0.05 to 0.09 should be rounded up to the nearest tenth of a second.

If an existing agency policy rounds change interval values to the nearest half-second (0.5 s), then the following methodology is suggested:

- Values ending in 0.0 to 0.1 should be rounded down to the nearest whole number;
- Values ending in 0.2, 0.3, and 0.4 should be rounded up to the half-second;
- Values ending in 0.6 should rounded down to the half-second; and,
- Values ending in 0.7, 0.8, and 0.9 should be rounded up to the nearest whole number.

APPENDIX E

Intersection Capacity Analyses
No-Build and Proposed Alternatives
2030 Projected Traffic Conditions

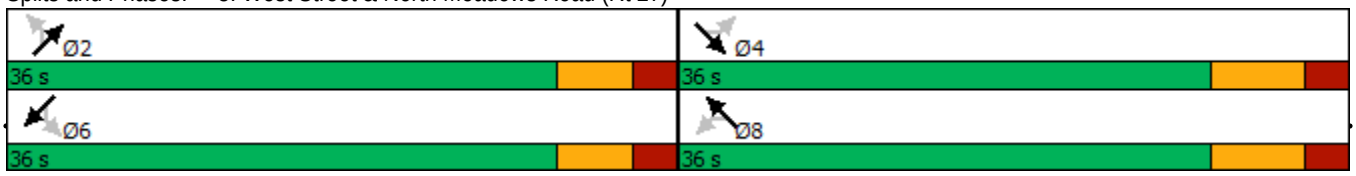
Intersection Capacity Analysis: 2030 AM No-Build (with Signal Retiming)
West Street & North Meadows Road (Rt. 27)

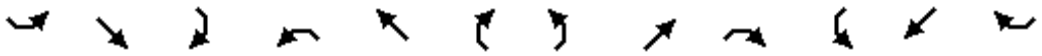
08/02/2020

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Traffic Volume (vph)	27	392	23	24	382	102	61	615	46	47	98	14
Future Volume (vph)	27	392	23	24	382	102	61	615	46	47	98	14
Peak Hour Factor	0.84	0.84	0.84	0.91	0.91	0.91	0.95	0.95	0.95	0.78	0.78	0.78
Growth Factor	106%	106%	106%	106%	106%	106%	106%	106%	106%	106%	106%	106%
Heavy Vehicles (%)	7%	3%	0%	0%	3%	4%	0%	1%	0%	0%	4%	0%
Shared Lane Traffic (%)												
Turn Type	Perm	NA		Perm	NA		Perm	NA		Perm	NA	
Protected Phases		4			8			2			6	
Permitted Phases	4			8	8		2			6		
Detector Phase	4	4		8	8		2	2		6	6	
Switch Phase												
Minimum Initial (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	
Minimum Split (s)	18.0	18.0		18.0	18.0		16.0	16.0		16.0	16.0	
Total Split (s)	36.0	36.0		36.0	36.0		36.0	36.0		36.0	36.0	
Total Split (%)	50.0%	50.0%		50.0%	50.0%		50.0%	50.0%		50.0%	50.0%	
Maximum Green (s)	28.5	28.5		28.5	28.5		29.5	29.5		29.5	29.5	
Yellow Time (s)	5.0	5.0		5.0	5.0		4.0	4.0		4.0	4.0	
All-Red Time (s)	2.5	2.5		2.5	2.5		2.5	2.5		2.5	2.5	
Lost Time Adjust (s)		0.0			0.0			0.0			0.0	
Total Lost Time (s)		7.5			7.5			6.5			6.5	
Lead/Lag												
Lead-Lag Optimize?												
Vehicle Extension (s)	3.0	3.0		3.0	3.0		3.0	3.0		3.0	3.0	
Recall Mode	Min	Min		Min	Min		None	None		None	None	
Act Effct Green (s)		23.8			23.8			29.7			29.7	
Actuated g/C Ratio		0.35			0.35			0.44			0.44	
v/c Ratio		0.82			0.85			0.96			0.39	
Control Delay		31.0			32.4			46.0			16.2	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		31.0			32.4			46.0			16.2	
LOS		C			C			D			B	
Approach Delay		31.0			32.4			46.0			16.2	
Approach LOS		C			C			D			B	

Intersection Summary	
Cycle Length: 72	
Actuated Cycle Length: 67.6	
Natural Cycle: 80	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.96	
Intersection Signal Delay: 35.5	Intersection LOS: D
Intersection Capacity Utilization 90.6%	ICU Level of Service E
Analysis Period (min) 15	

Splits and Phases: 3: West Street & North Meadows Road (Rt 27)





Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Traffic Volume (vph)	27	392	23	24	382	102	61	615	46	47	98	14
Future Volume (vph)	27	392	23	24	382	102	61	615	46	47	98	14
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	12	12	12	12	12	12	11	12	12	11	12	12
Storage Length (ft)	100		0	100		0	100		0	100		0
Storage Lanes	1		0	1		0	1		0	1		0
Taper Length (ft)	25			25			25			25		
Right Turn on Red			Yes			Yes			Yes			Yes
Link Speed (mph)		40			40			35			35	
Link Distance (ft)		1106			855			1207			921	
Travel Time (s)		18.9			14.6			23.5			17.9	
Peak Hour Factor	0.84	0.84	0.84	0.91	0.91	0.91	0.95	0.95	0.95	0.78	0.78	0.78
Growth Factor	106%	106%	106%	106%	106%	106%	106%	106%	106%	106%	106%	106%
Heavy Vehicles (%)	7%	3%	0%	0%	3%	4%	0%	1%	0%	0%	4%	0%
Shared Lane Traffic (%)												
Turn Type	Prot	NA		Prot	NA		Prot	NA		Prot	NA	
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases					8							
Detector Phase	7	4		3	8		5	2		1	6	
Switch Phase												
Minimum Initial (s)	4.0	5.0		4.0	5.0		4.0	5.0		4.0	5.0	
Minimum Split (s)	9.0	18.0		9.0	18.0		9.0	16.0		9.0	16.0	
Total Split (s)	9.0	36.0		9.0	36.0		18.0	44.0		9.0	35.0	
Total Split (%)	7.5%	30.0%		7.5%	30.0%		15.0%	36.7%		7.5%	29.2%	
Maximum Green (s)	4.0	30.0		4.0	30.0		13.0	38.0		4.0	29.0	
Yellow Time (s)	3.0	4.0		3.0	4.0		3.0	4.0		3.0	4.0	
All-Red Time (s)	2.0	2.0		2.0	2.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Lost Time (s)	5.0	6.0		5.0	6.0		5.0	6.0		5.0	6.0	
Lead/Lag	Lead	Lag		Lead	Lag		Lead	Lag		Lead	Lag	
Lead-Lag Optimize?	Yes	Yes		Yes	Yes		Yes	Yes		Yes	Yes	
Vehicle Extension (s)	3.0	3.0		3.0	3.0		3.0	3.0		3.0	3.0	
Recall Mode	None	Min		None	Min		None	None		None	None	
Walk Time (s)												
Flash Dont Walk (s)												
Pedestrian Calls (#/hr)												
Act Effct Green (s)	4.0	30.1		4.0	30.1		9.0	38.1		4.0	35.4	
Actuated g/C Ratio	0.04	0.32		0.04	0.32		0.10	0.40		0.04	0.38	
v/c Ratio	0.48	0.90		0.37	0.98		0.41	0.98		0.86	0.22	
Control Delay	68.4	51.6		59.2	66.9		48.0	57.8		121.4	23.4	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	68.4	51.6		59.2	66.9		48.0	57.8		121.4	23.4	
LOS	E	D		E	E		D	E		F	C	
Approach Delay		52.6			66.5			57.0			52.5	
Approach LOS		D			E			E			D	

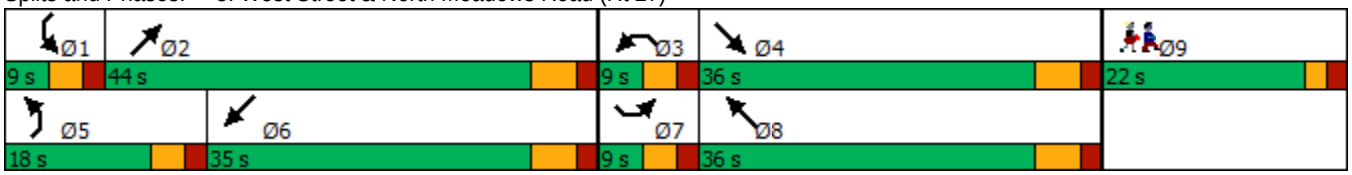
Intersection Summary	
Area Type:	Other

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Ideal Flow (vphpl)	
Lane Width (ft)	
Storage Length (ft)	
Storage Lanes	
Taper Length (ft)	
Right Turn on Red	
Link Speed (mph)	
Link Distance (ft)	
Travel Time (s)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	5.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	18%
Maximum Green (s)	18.0
Yellow Time (s)	2.0
All-Red Time (s)	2.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Vehicle Extension (s)	3.0
Recall Mode	None
Walk Time (s)	7.0
Flash Dont Walk (s)	11.0
Pedestrian Calls (#/hr)	0
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	

Intersection Summary

Cycle Length: 120	
Actuated Cycle Length: 94.4	
Natural Cycle: 150	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.98	
Intersection Signal Delay: 58.0	Intersection LOS: E
Intersection Capacity Utilization 79.3%	ICU Level of Service D
Analysis Period (min) 15	

Splits and Phases: 3: West Street & North Meadows Road (Rt 27)



Intersection Capacity Analysis
West Street & North Meadows Road (Rt. 27)

08/02/2020

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Traffic Volume (vph)	27	392	23	24	382	102	61	615	46	47	98	14
Future Volume (vph)	27	392	23	24	382	102	61	615	46	47	98	14
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	12	12	12	12	12	12	11	12	12	11	12	12
Storage Length (ft)	100		0	100		0	100		0	100		0
Storage Lanes	1		0	1		0	1		0	1		0
Taper Length (ft)	25			25			25			25		
Satd. Flow (prot)	1687	1833	0	1805	1782	0	1745	1864	0	1745	1801	0
Flt Permitted	0.128			0.161			0.660			0.108		
Satd. Flow (perm)	227	1833	0	306	1782	0	1212	1864	0	198	1801	0
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)		2			11			3			6	
Link Speed (mph)		40			40			35			35	
Link Distance (ft)		1106			855			1207			921	
Travel Time (s)		18.9			14.6			23.5			17.9	
Peak Hour Factor	0.84	0.84	0.84	0.91	0.91	0.91	0.95	0.95	0.95	0.78	0.78	0.78
Growth Factor	106%	106%	106%	106%	106%	106%	106%	106%	106%	106%	106%	106%
Heavy Vehicles (%)	7%	3%	0%	0%	3%	4%	0%	1%	0%	0%	4%	0%
Shared Lane Traffic (%)												
Lane Group Flow (vph)	34	524	0	28	564	0	68	737	0	64	152	0
Turn Type	pm+pt	NA		pm+pt	NA		pm+pt	NA		pm+pt	NA	
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases	4			8	8		2			6		
Detector Phase	7	4		3	8		5	2		1	6	
Switch Phase												
Minimum Initial (s)	4.0	5.0		4.0	5.0		4.0	5.0		4.0	5.0	
Minimum Split (s)	9.0	18.0		9.0	18.0		9.0	16.0		9.0	16.0	
Total Split (s)	9.0	37.0		9.0	37.0		9.0	43.0		9.0	43.0	
Total Split (%)	7.5%	30.8%		7.5%	30.8%		7.5%	35.8%		7.5%	35.8%	
Yellow Time (s)	3.0	4.0		3.0	4.0		3.0	4.0		3.0	4.0	
All-Red Time (s)	2.0	2.0		2.0	2.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Lost Time (s)	5.0	6.0		5.0	6.0		5.0	6.0		5.0	6.0	
Lead/Lag	Lead	Lag		Lead	Lag		Lead	Lag		Lead	Lag	
Lead-Lag Optimize?	Yes	Yes		Yes	Yes		Yes	Yes		Yes	Yes	
Recall Mode	None	Min		None	Min		None	None		None	None	
Act Effct Green (s)	34.5	31.2		34.5	31.2		41.3	37.2		41.3	37.2	
Actuated g/C Ratio	0.37	0.34		0.37	0.34		0.45	0.40		0.45	0.40	
v/c Ratio	0.23	0.85		0.16	0.93		0.12	0.98		0.41	0.21	
Control Delay	21.1	44.6		19.2	54.6		14.3	58.9		21.7	19.9	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	21.1	44.6		19.2	54.6		14.3	58.9		21.7	19.9	
LOS	C	D		B	D		B	E		C	B	
Approach Delay		43.1			52.9			55.1			20.5	
Approach LOS		D			D			E			C	

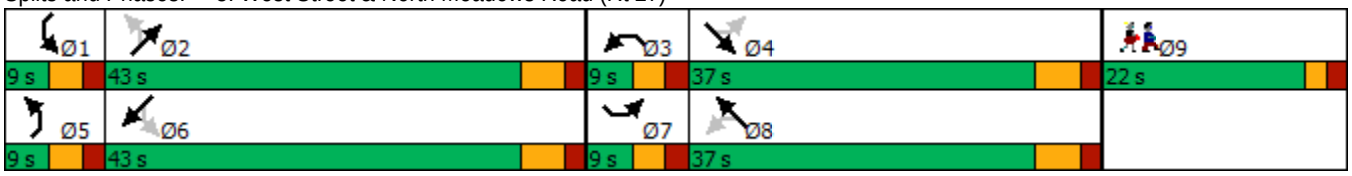
Intersection Summary	
Area Type:	Other

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Ideal Flow (vphpl)	
Lane Width (ft)	
Storage Length (ft)	
Storage Lanes	
Taper Length (ft)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Right Turn on Red	
Satd. Flow (RTOR)	
Link Speed (mph)	
Link Distance (ft)	
Travel Time (s)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	5.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	18%
Yellow Time (s)	2.0
All-Red Time (s)	2.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	

Intersection Summary

Cycle Length: 120	
Actuated Cycle Length: 92.6	
Natural Cycle: 150	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.98	
Intersection Signal Delay: 48.0	Intersection LOS: D
Intersection Capacity Utilization 79.3%	ICU Level of Service D
Analysis Period (min) 15	

Splits and Phases: 3: West Street & North Meadows Road (Rt 27)



Intersection	
Intersection Delay, s/veh	39.9
Intersection LOS	E

Approach	SE	NW	NE	SW
Entry Lanes	1	2	1	1
Conflicting Circle Lanes	1	1	1	1
Adj Approach Flow, veh/h	558	592	805	216
Demand Flow Rate, veh/h	575	610	812	221
Vehicles Circulating, veh/h	230	797	610	554
Vehicles Exiting, veh/h	545	625	195	853
Ped Vol Crossing Leg, #/h	0	0	0	0
Ped Cap Adj	1.000	1.000	1.000	1.000
Approach Delay, s/veh	9.8	18.2	85.3	7.9
Approach LOS	A	C	F	A

Lane	Left	Left	Right	Left	Left
Designated Moves	LTR	LT	R	LTR	LTR
Assumed Moves	LTR	LT	R	LTR	LTR
RT Channelized					
Lane Util	1.000	0.797	0.203	1.000	1.000
Follow-Up Headway, s	2.609	2.535	2.535	2.609	2.609
Critical Headway, s	4.976	4.544	4.544	4.976	4.976
Entry Flow, veh/h	575	486	124	812	221
Cap Entry Lane, veh/h	1091	688	688	741	784
Entry HV Adj Factor	0.971	0.973	0.960	0.992	0.976
Flow Entry, veh/h	558	473	119	805	216
Cap Entry, veh/h	1059	669	660	734	765
V/C Ratio	0.527	0.707	0.180	1.096	0.282
Control Delay, s/veh	9.8	20.8	7.6	85.3	7.9
LOS	A	C	A	F	A
95th %tile Queue, veh	3	6	1	22	1

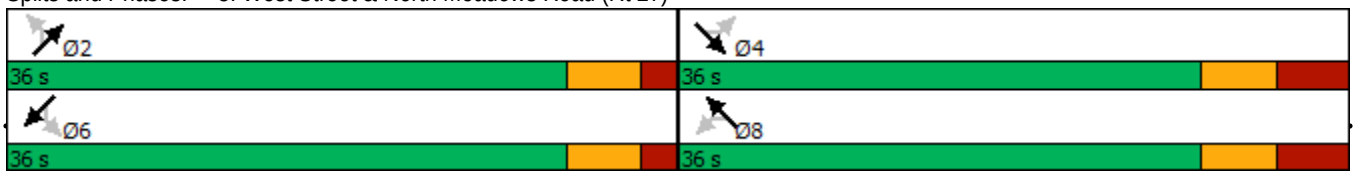
Intersection Capacity Analysis: 2030 PM No-Build (with Signal Retiming)
West Street & North Meadows Road (Rt. 27)

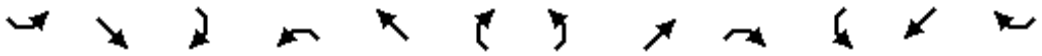
08/02/2020

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Traffic Volume (vph)	21	331	42	29	307	80	28	127	54	100	606	29
Future Volume (vph)	21	331	42	29	307	80	28	127	54	100	606	29
Peak Hour Factor	0.84	0.84	0.84	0.85	0.85	0.85	0.89	0.89	0.89	0.95	0.95	0.95
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	5%	1%	0%	3%	1%	0%	0%	1%	3%	1%	1%	0%
Shared Lane Traffic (%)												
Turn Type	Perm	NA		Perm	NA		Perm	NA		Perm	NA	
Protected Phases		4			8			2			6	
Permitted Phases	4			8	8		2			6		
Detector Phase	4	4		8	8		2	2		6	6	
Switch Phase												
Minimum Initial (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	
Minimum Split (s)	18.0	18.0		18.0	18.0		16.0	16.0		16.0	16.0	
Total Split (s)	36.0	36.0		36.0	36.0		36.0	36.0		36.0	36.0	
Total Split (%)	50.0%	50.0%		50.0%	50.0%		50.0%	50.0%		50.0%	50.0%	
Maximum Green (s)	28.0	28.0		28.0	28.0		30.0	30.0		30.0	30.0	
Yellow Time (s)	4.0	4.0		4.0	4.0		4.0	4.0		4.0	4.0	
All-Red Time (s)	4.0	4.0		4.0	4.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)		0.0			0.0			0.0			0.0	
Total Lost Time (s)		8.0			8.0			6.0			6.0	
Lead/Lag												
Lead-Lag Optimize?												
Vehicle Extension (s)	3.0	3.0		3.0	3.0		3.0	3.0		3.0	3.0	
Recall Mode	Min	Min		Min	Min		None	None		None	None	
Act Effct Green (s)		21.5			21.5			30.2			30.2	
Actuated g/C Ratio		0.33			0.33			0.46			0.46	
v/c Ratio		0.77			0.83			0.32			0.99	
Control Delay		27.9			31.3			12.5			50.8	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		27.9			31.3			12.5			50.8	
LOS		C			C			B			D	
Approach Delay		27.9			31.3			12.5			50.8	
Approach LOS		C			C			B			D	

Intersection Summary	
Cycle Length: 72	
Actuated Cycle Length: 65.8	
Natural Cycle: 80	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.99	
Intersection Signal Delay: 35.9	Intersection LOS: D
Intersection Capacity Utilization 100.9%	ICU Level of Service G
Analysis Period (min) 15	

Splits and Phases: 3: West Street & North Meadows Road (Rt 27)

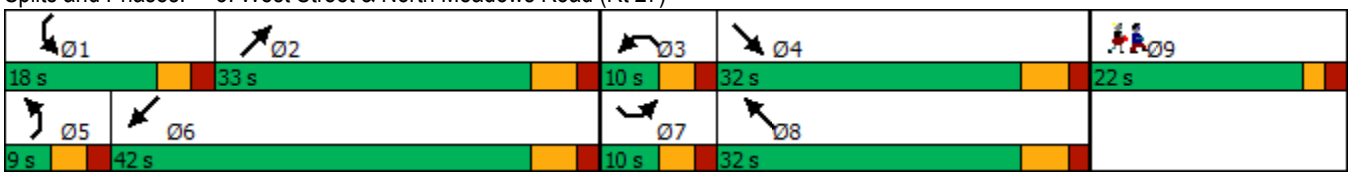




Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Traffic Volume (vph)	21	331	42	29	307	80	28	127	54	100	606	29
Future Volume (vph)	21	331	42	29	307	80	28	127	54	100	606	29
Peak Hour Factor	0.84	0.84	0.84	0.85	0.85	0.85	0.89	0.89	0.89	0.95	0.95	0.95
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	5%	1%	0%	3%	1%	0%	0%	1%	3%	1%	1%	0%
Shared Lane Traffic (%)												
Turn Type	Prot	NA		Prot	NA		Prot	NA		Prot	NA	
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases					8							
Detector Phase	7	4		3	8		5	2		1	6	
Switch Phase												
Minimum Initial (s)	4.0	5.0		4.0	5.0		4.0	5.0		4.0	5.0	
Minimum Split (s)	9.0	11.0		9.0	11.0		9.0	11.0		9.0	16.0	
Total Split (s)	10.0	32.0		10.0	32.0		9.0	33.0		18.0	42.0	
Total Split (%)	8.7%	27.8%		8.7%	27.8%		7.8%	28.7%		15.7%	36.5%	
Maximum Green (s)	5.0	26.0		5.0	26.0		4.0	27.0		13.0	36.0	
Yellow Time (s)	3.0	4.0		3.0	4.0		3.0	4.0		3.0	4.0	
All-Red Time (s)	2.0	2.0		2.0	2.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Lost Time (s)	5.0	6.0		5.0	6.0		5.0	6.0		5.0	6.0	
Lead/Lag	Lead	Lag		Lead	Lag		Lead	Lag		Lead	Lag	
Lead-Lag Optimize?	Yes	Yes		Yes	Yes		Yes	Yes		Yes	Yes	
Vehicle Extension (s)	3.0	3.0		3.0	3.0		3.0	3.0		3.0	3.0	
Recall Mode	None	Min		None	Min		None	None		None	None	
Walk Time (s)												
Flash Dont Walk (s)												
Pedestrian Calls (#/hr)												
Act Effct Green (s)	5.1	26.7		5.1	28.7		4.1	29.2		10.4	37.0	
Actuated g/C Ratio	0.06	0.30		0.06	0.32		0.05	0.33		0.12	0.41	
v/c Ratio	0.28	0.76		0.37	0.73		0.41	0.35		0.55	0.87	
Control Delay	54.2	40.5		57.5	37.1		63.1	27.5		51.2	40.5	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	54.2	40.5		57.5	37.1		63.1	27.5		51.2	40.5	
LOS	D	D		E	D		E	C		D	D	
Approach Delay		41.3			38.6			32.3			42.0	
Approach LOS		D			D			C			D	

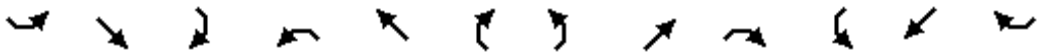
Intersection Summary			
Cycle Length: 115			
Actuated Cycle Length: 89.8			
Natural Cycle: 120			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.87			
Intersection Signal Delay: 39.8		Intersection LOS: D	
Intersection Capacity Utilization 79.3%		ICU Level of Service D	
Analysis Period (min) 15			

Splits and Phases: 3: West Street & North Meadows Road (Rt 27)



Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	5.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	19%
Maximum Green (s)	18.0
Yellow Time (s)	2.0
All-Red Time (s)	2.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Vehicle Extension (s)	3.0
Recall Mode	None
Walk Time (s)	7.0
Flash Dont Walk (s)	11.0
Pedestrian Calls (#/hr)	2
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	

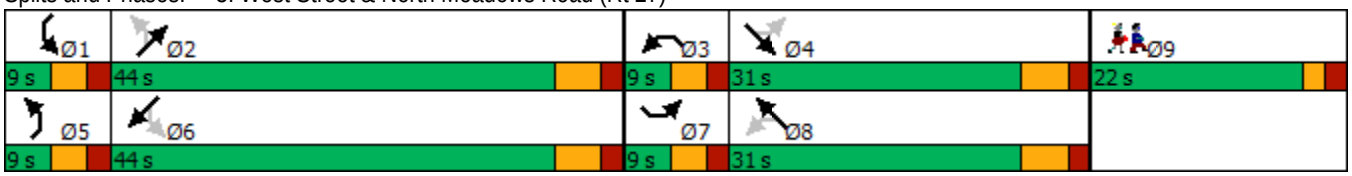
Intersection Summary



Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Traffic Volume (vph)	21	331	42	29	307	80	28	127	54	100	606	29
Future Volume (vph)	21	331	42	29	307	80	28	127	54	100	606	29
Peak Hour Factor	0.84	0.84	0.84	0.85	0.85	0.85	0.89	0.89	0.89	0.95	0.95	0.95
Growth Factor	106%	106%	106%	106%	106%	106%	106%	106%	106%	106%	106%	106%
Heavy Vehicles (%)	5%	1%	0%	3%	1%	0%	0%	1%	3%	1%	1%	0%
Shared Lane Traffic (%)												
Turn Type	pm+pt	NA		pm+pt	NA		pm+pt	NA		pm+pt	NA	
Protected Phases	7	4		3	8		5	2		1	6	
Permitted Phases	4			8	8		2			6		
Detector Phase	7	4		3	8		5	2		1	6	
Switch Phase												
Minimum Initial (s)	4.0	5.0		4.0	5.0		4.0	5.0		4.0	5.0	
Minimum Split (s)	9.0	11.0		9.0	11.0		9.0	11.0		9.0	16.0	
Total Split (s)	9.0	31.0		9.0	31.0		9.0	44.0		9.0	44.0	
Total Split (%)	7.8%	27.0%		7.8%	27.0%		7.8%	38.3%		7.8%	38.3%	
Maximum Green (s)	4.0	25.0		4.0	25.0		4.0	38.0		4.0	38.0	
Yellow Time (s)	3.0	4.0		3.0	4.0		3.0	4.0		3.0	4.0	
All-Red Time (s)	2.0	2.0		2.0	2.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Lost Time (s)	5.0	6.0		5.0	6.0		5.0	6.0		5.0	6.0	
Lead/Lag	Lead	Lag		Lead	Lag		Lead	Lag		Lead	Lag	
Lead-Lag Optimize?	Yes	Yes		Yes	Yes		Yes	Yes		Yes	Yes	
Vehicle Extension (s)	3.0	3.0		3.0	3.0		3.0	3.0		3.0	3.0	
Recall Mode	None	Min		None	Min		None	None		None	None	
Walk Time (s)												
Flash Dont Walk (s)												
Pedestrian Calls (#/hr)												
Act Effct Green (s)	28.9	25.6		29.8	27.4		39.8	34.7		42.2	39.0	
Actuated g/C Ratio	0.32	0.28		0.33	0.30		0.44	0.38		0.47	0.43	
v/c Ratio	0.18	0.79		0.23	0.76		0.20	0.29		0.21	0.82	
Control Delay	25.7	43.1		26.5	39.8		17.9	20.5		16.6	35.2	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	25.7	43.1		26.5	39.8		17.9	20.5		16.6	35.2	
LOS	C	D		C	D		B	C		B	D	
Approach Delay		42.1			38.9			20.1			32.7	
Approach LOS		D			D			C			C	

Intersection Summary			
Cycle Length: 115			
Actuated Cycle Length: 90.2			
Natural Cycle: 120			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.82			
Intersection Signal Delay: 35.0		Intersection LOS: C	
Intersection Capacity Utilization 78.7%		ICU Level of Service D	
Analysis Period (min) 15			

Splits and Phases: 3: West Street & North Meadows Road (Rt 27)



Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	5.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	19%
Maximum Green (s)	18.0
Yellow Time (s)	2.0
All-Red Time (s)	2.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Vehicle Extension (s)	3.0
Recall Mode	None
Walk Time (s)	7.0
Flash Dont Walk (s)	11.0
Pedestrian Calls (#/hr)	5
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	

Intersection Summary

Intersection	
Intersection Delay, s/veh	29.9
Intersection LOS	D

Approach	SE	NW	NE	SW
Entry Lanes	1	2	1	1
Conflicting Circle Lanes	1	1	1	1
Adj Approach Flow, veh/h	503	524	252	829
Demand Flow Rate, veh/h	508	529	256	837
Vehicles Circulating, veh/h	842	217	568	462
Vehicles Exiting, veh/h	457	607	782	284
Ped Vol Crossing Leg, #/h	0	0	0	0
Ped Cap Adj	1.000	1.000	1.000	1.000
Approach Delay, s/veh	38.5	6.2	8.7	46.1
Approach LOS	E	A	A	E

Lane	Left	Left	Right	Left	Left
Designated Moves	LTR	LT	R	LTR	LTR
Assumed Moves	LTR	LT	R	LTR	LTR
RT Channelized					
Lane Util	1.000	0.809	0.191	1.000	1.000
Follow-Up Headway, s	2.609	2.535	2.535	2.609	2.609
Critical Headway, s	4.976	4.544	4.544	4.976	4.976
Entry Flow, veh/h	508	428	101	256	837
Cap Entry Lane, veh/h	585	1166	1166	773	861
Entry HV Adj Factor	0.990	0.989	1.000	0.986	0.991
Flow Entry, veh/h	503	423	101	252	829
Cap Entry, veh/h	579	1152	1166	762	853
V/C Ratio	0.869	0.367	0.087	0.331	0.972
Control Delay, s/veh	38.5	6.8	3.8	8.7	46.1
LOS	E	A	A	A	E
95th %tile Queue, veh	10	2	0	1	16

APPENDIX F

MassDOT Project Development Process

Overview of the Project Development Process

Transportation decision-making is complex and can be influenced by legislative mandates, environmental regulations, financial limitations, agency programmatic commitments, and partnering opportunities. Decision-makers and reviewing agencies, when consulted early and often throughout the project development process, can ensure that all participants understand the potential impact these factors can have on project implementation. Project development is the process that takes a transportation improvement from concept through construction.

The MassDOT Highway Division has developed a comprehensive project development process which is contained in Chapter 2 of the *MassDOT Highway Division's Project Development and Design Guide*. The eight-step process covers a range of activities extending from identification of a project need, through completion of a set of finished contract plans, to construction of the project. The sequence of decisions made through the project development process progressively narrows the project focus and, ultimately, leads to a project that addresses the identified needs. The descriptions provided below are focused on the process for a highway project, but the same basic process will need to be followed for non-highway projects as well.

1. Needs Identification

For each of the locations at which an improvement is to be implemented, MassDOT leads an effort to define the problem, establishes project goals and objectives, and defines the scope of the planning needed for implementation. To that end, it has to complete a Project Need Form (PNF), which states in general terms the deficiencies or needs related to the transportation facility or location. The PNF documents the problems and explains why corrective action is needed. For this study, the information defining the need for the project will be drawn primarily, perhaps exclusively, from the present report. Also, at this point in the process, MassDOT meets with potential participants, such as the Metropolitan Planning Organization (MPO) and community members, to allow for an informal review of the project.

The PNF is reviewed by the MassDOT Highway Division district office whose jurisdiction includes the location of the proposed project. MassDOT also sends the PNF to the MPO, for informational purposes. The outcome of this step determines whether the project requires further planning, whether it is already well supported by prior planning studies, and, therefore, whether it is ready to move forward into the design phase, or whether it should be dismissed from further consideration.

2. Planning

This phase will likely not be required for the implementation of the improvements proposed in this planning study, as this planning report should constitute the outcome of this step. However, in general, the purpose of this implementation step is for the project proponent to identify issues, impacts, and approvals that may need to be obtained, so that the subsequent design and permitting processes are understood.

The level of planning needed will vary widely, based on the complexity of the project. Typical tasks include: define the existing context, confirm project need, establish goals and objectives, initiate public outreach, define the project, collect data, develop and analyze alternatives, make recommendations, and provide documentation. Likely outcomes include consensus on the project definition to enable it to move forward into environmental documentation (if needed) and design, or a recommendation to delay the project or dismiss it from further consideration.

3. Project Initiation

At this point in the process, the proponent, MassDOT Highway Division, fills out a Project Initiation Form (PIF) for each improvement, which is reviewed by its Project Review Committee (PRC) and the MPO. The PRC is composed of the Chief Engineer, each District Highway Director, and representatives of the Project Management, Environmental, Planning, Right-of-Way, Traffic, and Bridge departments, and the MassDOT Federal Aid Program Office (FAPO). The PIF documents the project type and description, summarizes the project planning process, identifies likely funding and project management responsibility, and defines a plan for interagency and public participation. First the PRC reviews and evaluates the proposed project based on the MassDOT's statewide priorities and criteria. If the result is positive, MassDOT Highway Division moves the project forward to the design phase, and to programming review by the MPO. The PRC may provide a Project Management Plan to define roles and responsibilities for subsequent steps. The MPO review includes project evaluation based on the MPO's regional priorities and criteria. The MPO may assign project evaluation criteria score, a Transportation Improvement Program (TIP) year, a tentative project category, and a tentative funding category.

4. Environmental Permitting, Design, and Right-of-Way Process

This step has four distinct but closely integrated elements: public outreach, environmental documentation and permitting (if required), design, and right-of-way acquisition (if required). The outcome of this step is a fully designed and permitted project ready for construction. However, a project does not have to be fully designed in order for the MPO to program it in the TIP. The sections below provide more detailed information on the four elements of this step of the project development process.

Public Outreach

Continued public outreach in the design and environmental process is essential to maintain public support for the project and to seek meaningful input on the design elements. The public outreach is often in the form of required public hearings, but can also include less formal dialogues with those interested in and affected by a proposed project.

Environmental Documentation and Permitting

The project proponent, in coordination with the Environmental Services section of the MassDOT Highway Division, will be responsible for identifying and complying with all applicable federal, state, and local environmental laws and requirements. This includes determining the appropriate project category for both the Massachusetts Environmental Protection Act (MEPA) and the National Environmental Protection Act (NEPA). Environmental documentation and permitting is often completed in conjunction with the **Preliminary Design** phase described below.

Design

There are three major phases of design. The first is **Preliminary Design**, which is also referred to as the 25-percent submission. The major components of this phase include full survey of the project area, preparation of base plans, development of basic geometric layout, development of preliminary cost estimates, and submission of a functional design report. Preliminary Design, although not required to, is often completed in conjunction with the Environmental Documentation and Permitting. The next phase is **Final Design**, which is also referred to as the 75-percent and 100-percent submission. The major components of this phase include preparation of a subsurface exploratory plan (if required), coordination of utility relocations, development of traffic management plans through construction zones, development of final cost estimates, and refinement and finalization of the construction plans. Once Final Design is complete, a full set of **Plans, Specifications, and Estimates (PS&E)** is developed for the project.

Right-of-Way Acquisition
A separate set of Right-of-Way plans are required for any project that requires land acquisition or easements. The plans must identify the existing and proposed layout lines, easements, property lines, names of property owners, and the dimensions and areas of estimated takings and easements.

5. Programming (Identification of Funding)
Programming, which typically begins during the design phase, can actually occur at any time during the process, from planning to design. In this step, which is distinct from project initiation, the proponent requests that the MPO place the project in the region's Transportation Improvement Program (TIP). The proponent requesting the project's listing on the TIP can be the community or it can be one of the MPO member agencies (the Regional Planning Agency, MassDOT, and the Regional Transit Authority). The MPO then considers the project in terms of state and regional needs, evaluation criteria, and compliance with the regional Transportation Plan and decides whether to place it in the draft TIP for public review and then in the final TIP.

6. Procurement
Following project design and programming of a highway project, the MassDOT Highway Division publishes a request for proposals. It then reviews the bids and awards the contract to the qualified bidder with the lowest bid.

7. Construction
After a construction contract is awarded, MassDOT Highway Division and the contractor develop a public participation plan and a management plan for the construction process.

8. Project Assessment
The purpose of this step is to receive constituents' comments on the project development process and the project's design elements. MassDOT Highway Division can apply what is learned in this process to future projects.

Project Development Schematic Timetable

Description	Schedule Influence	Typical Duration
Step I: Problem/Need/Opportunity Identification The proponent completes a Project Need Form (PNF). This form is then reviewed by the MassDOT District office which provides guidance to the proponent on the subsequent steps of the process.	The Project Need Form has been developed so that it can be prepared quickly by the proponent, including any supporting data that is readily available. The District office shall return comments to the proponent within one month of PNF submission.	1 to 3 months
Step II: Planning Project planning can range from agreement that the problem should be addressed through a clear solution to a detailed analysis of alternatives and their impacts.	For some projects, no planning beyond preparation of the Project Need Form is required. Some projects require a planning study centered on specific project issues associated with the proposed solution or a narrow family of alternatives. More complex projects will likely require a detailed alternatives analysis.	Project Planning Report: 3 to 24+ months
Step III: Project Initiation The proponent prepares and submits a Project Initiation Form (PIF) and a Transportation Evaluation Criteria (TEC) form in this step. The PIF and TEC are informally reviewed by the Metropolitan Planning Organization (MPO) and MassDOT District office, and formally reviewed by the PRC.	The PIF includes refinement of the preliminary information contained in the PNF. Additional information summarizing the results of the planning process, such as the Project Planning Report, are included with the PIF and TEC. The schedule is determined by PRC staff review (dependent on project complexity) and meeting schedule.	1 to 4 months
Step IV: Design, Environmental, and Right of Way The proponent completes the project design. Concurrently, the proponent completes necessary environmental permitting analyses and files applications for permits. Any right of way needed for the project is identified and the acquisition process begins.	The schedule for this step is dependent upon the size of the project and the complexity of the design, permitting, and right-of-way issues. Design review by the MassDOT district and appropriate sections is completed in this step.	3 to 48+ months
Step V: Programming The MPO considers the project in terms of its regional priorities and determines whether or not to include the project in the draft Regional Transportation Improvement Program (TIP) which is then made available for public comment. The TIP includes a project description and funding source.	The schedule for this step is subject to each MPO's programming cycle and meeting schedule. It is also possible that the MPO will not include a project in its Draft TIP based on its review and approval procedures.	3 to 12+ months
Step VI: Procurement The project is advertised for construction and a contract awarded.	Administration of competing projects can influence the advertising schedule.	1 to 12 months
Step VII: Construction The construction process is initiated including public notification and any anticipated public involvement. Construction continues to project completion.	The duration for this step is entirely dependent upon project complexity and phasing.	3 to 60+ months
Step VIII: Project Assessment The construction period is complete and project elements and processes are evaluated on a voluntary basis.	The duration for this step is dependent upon the proponent's approach to this step and any follow-up required.	1 month

Source: MassDOT Highway Division Project Development and Design Guide