TECHNICAL MEMORANDUM

DATE: **May 6, 2021**

TO: **Maurice Goulet, Director of Public Works, Town of Medfield**

FROM: **Chen-Yuan Wang and Chaopeng Hu, MPO Staff**

RE: **Safety and Operations Analyses at Selected Intersections, FFY 2020—North Meadows Road (Route 27) at West Street in Medfield**

This memorandum summarizes the analyses and improvement strategies for the intersection of North Meadows Road (Route 27) at West Street in Medfield. This intersection was selected through a comprehensive review of 30 potential study locations in the region.[1]

The memorandum covers the following sections:

1. Study Background
2. Existing Intersection Conditions
3. Issues and Concerns
4. Crash Data Analysis
5. Existing Traffic Conditions
6. Operations Analysis
7. Proposed Short-Term Improvements
8. Long-Term Improvement Alternatives
9. Recommendations

In addition, the memorandum includes technical appendices that contain supporting data and methods applied in the study.

1 STUDY BACKGROUND

The purpose of the "Safety and Operations Analyses at Selected Intersections" study is to examine safety, operations, and mobility issues at major intersections in the Boston Region Metropolitan Planning Organization (MPO) area's arterial highways where many crashes occur, congestion during peak traffic periods may be heavy, or improvements for bus, bicycle, and pedestrian travel are needed.

[1] Details of the selection process and criteria may be found in the Central Transportation Planning Staff's technical memorandum, "Safety and Operation at Selected Intersections: Federal Fiscal Year 2020," Chen-Yuan Wang, November 7, 2019.

Civil Rights, nondiscrimination, and accessibility information is on the last page.

For more than 10 years, the MPO has been conducting these planning studies with municipalities in the region. The communities find the studies beneficial, as they give them an opportunity to begin looking at the needs of problematic locations at the conceptual level, before they commit funds for design and engineering. Eventually, if the project qualifies for federal funds, the study's documentation will also be useful to the Massachusetts Department of Transportation (MassDOT) and its project-development process.

These studies support the MPO's visions and goals, which include increasing transportation safety, maintaining the transportation system, advancing mobility, and reducing congestion.

2 EXISTING INTERSECTION CONDITIONS

North Meadows Road (Route 27) at West Street is a four-way signalized intersection. It is one of a few signalized intersections in Medfield, located within one mile northwest of the town center. Figure 1 shows the location of the intersection, existing street layouts, and major developments in the study area.

Route 27 is a north-south state highway running from Kingston to Chelmsford. For most of its route, it serves as an intermediate arterial between Interstate 95 and Interstate 495 and is heavily used by commuters in the region. The section of Route 27 north of Route 129 in Medfield is known as North Meadows Road. It consists of two travel lanes, one in each direction (approximately 12 to 14 feet wide) with a double yellow centerline, and a relatively wide (10 feet or greater) shoulder on both sides. There are no sidewalks on either side of the roadway. The speed limit is 45 miles per hour (mph) in both directions approaching the study intersection.[2] The roadway, classified as an urban principal arterial, is under the town's jurisdiction and is a part of the National Highway System (NHS).

West Street is an urban minor arterial owned by the town. The roadway is about one and one-quarter miles long. It connects to Harding Street and Dover Road, which continue east to Dover and west to Millis. It is a two-lane roadway that contains a travel lane approximately 11 to 12 feet wide and a shoulder of two to three feet in each direction. It has no sidewalks, except the north side of the street about 600 to 1,400 feet west of the intersection from Marsh Drive to Gatehouse Drive. The speed limit is 35 mph in both directions in the vicinity of the intersection.

[2] In the northbound approach, the regulated speed limit changes from 25 mph in the downtown area to 40 mph at Dale Street and to 45 mph after passing Grove Street about 1,000 feet from the intersection. In the southbound approach, the speed limit changes from 55 mph in the undeveloped areas north of North Brook to 45 mph about 2,200 feet from the intersection.

BOSTON
REGION
MPO

N

Figure 1
Study Area Map
North Meadows Road at West Street, Medfield

Addressing Safety, Mobility, and Access on Subregional Priority Roadways

At the intersection, all the approaches increase in width but remain a single travel lane shared by all turning movements. North Meadows Road flares to more than 30 feet wide in both approaches, which allows one or two right-turning vehicles to wait at the stop line or to turn right on red. However, there are no lane use pavement markings on these approaches. The flared areas on both approaches are also frequently used by through traffic to go around a left-turning traffic queue. West Street flares just slightly with no space for the storage of additional right-turning vehicle at the stop line. With the stop lines positioned far back (20 to 30 feet) from the intersection and wide turning radii at all corners, the intersection appears to be very large even though it has only one lane on all approaches.

The traffic signal at the intersection operates in a simple two-phase mode: one phase for both approaches of North Meadows Road and one phase for both approaches of West Street, with no pedestrian signal phases. Based on field observations, it operates at a cycle length of 74 seconds that consist of 38 seconds (30-second green time, plus 4-second yellow change interval and 4-second all-red interval) for North Meadows Road approaches and 36 seconds (30-second green time, plus 4-second yellow change and 2-second all-red interval) for West Street approaches.

Standard three-section signals are provided on all approaches of the intersection. Two overhead signals are provided for each of the North Meadows Road approaches. One overhead signal and one post-mounted signal are provided for both approaches of West Street. The post-mounted signals are not well positioned for drivers, as they are low and located far from the intersection center. All the signals at the intersection are not equipped with backplates or retroreflective borders.

There are no crosswalks at the intersection and no sidewalks on either side of all the approaches. There are guardrails present at all corners, except the northeast corner. Under the existing intersection layout, these guardrails are used to prevent the turning vehicles from driving into adjacent ditches or parking lots and to protect the roadside signal and lighting equipment. They also deter people who are walking from crossing the intersection where the traffic conditions can be complicated and compel them to cross at other locations with narrower road width or marked crosswalks with protected pedestrian signals, such as the intersection of North Meadows Road at Dale Street.

There are no dedicated bicycle accommodations on either roadway in the study area. North Meadows Road contains shoulders of approximately 10 feet wide on both sides. Some shoulder sections between Route 109 and Dale Street are marked with white hatch lines to prohibit parking. The hatched shoulders could discourage people who ride bicycles from using the shoulders and compel them to use the travel lanes. Meanwhile, in other unmarked shoulder sections, parked vehicles could occupy the space from time to time, as there are no clear regulations about parking on North Meadows Road. West Street contains narrow shoulders of approximately two to three feet wide, which are not suitable for bicycle travel.

There are no public transit stops and no marked on-street parking spaces in the areas adjacent to the intersection.

The land uses in the vicinity of the intersection include business, industrial, residential, and school. Adjacent to the intersection, there are a number of businesses, including a fun and fitness center for children (My Gym), a landscape design company, a daycare (Medfield Children's Center), an auto body shop, an early education school (The Goddard School of Medfield), and a veterinarian clinic. Further out, the land uses on North Meadows Road include multi-family residents and undeveloped land to the south, and mostly open space to the north. The land uses on West Street include a number of businesses and industrial offices and a nonprofit organization (American Region) to the east, and mostly residential and a hardware store (Do it Best) to the west.

The intersection is located in one of the fastest growing areas in Medfield. The Town currently is in the process of developing a new master plan. The areas adjacent to North Meadows Road have the potential for vibrant mixed-use developments, with the support of essential Complete Streets elements. A key element would be to reconstruct the intersection and improve operations and safety for users of all modes.

3 ISSUES AND CONCERNS

Based on MPO staff's field observations, discussions with the town officers, and analyses of crash data and existing operations, major issues and concerns at the intersection include the following.

- Crash severity
  The intersection is on the list of 2014–16 statewide top 200 crash locations (ranked 121). The severity of crashes at this intersection is a major concern, as nearly half of the crashes caused personal injuries.
- High frequency of red-light running
  Further analysis of crash data indicates that about 30 percent of the crashes were caused by red light violations and almost all of them resulted in injuries.
- High approach travel speeds
  Based on comments from the town and field observations, vehicles

generally are traveling above the speed limit on North Meadows Road (45 mph) and West Street (35 mph).

- Inadequate intersection geometry
  Nearly unchanged from the rural highway layout, the wide single-lane approaches with wide turning radii are not suitable for walking and biking trips. Meanwhile, the current traffic volumes (with high proportion of turning movements) are increasing. Drivers are likely to be confused in the unmarked flared areas near the intersection, which also causes drivers to attempt to maneuver around turning vehicles leading to confusion and crashes at the intersection.

- Insufficient signal displays
  All the approaches of the intersection currently use the basic three-section signals, with no backplates and no retroreflective borders. They appear to be insufficient for drivers to observe from a distance, especially on the westbound approach, where the overhead signal is not aligned with the approach and the post-mounted signal is low and located too far from the intersection.

- Obsolete signal equipment and operations
  The signal control equipment is outdated. Constrained by the existing geometry, the traffic signal operates in a basic two-phase mode, with traffic running concurrently from opposing approaches. Recent intersection turning counts indicate that left-turn lanes with protected or permissive signal phases are needed at this intersection.

- No pedestrian and bicycle accommodations
  There are no crosswalks or pedestrian signals at the intersection. Meanwhile, the signal is not equipped with bicycle detection. Based on the land use and the surrounding developable area, these accommodations are needed at the intersection.

4 CRASH DATA ANALYSIS

Crash data analysis is essential to identify safety and operational problems at an intersection. Analyzing the data on the frequency of crashes, types and patterns of collisions, and the circumstances under which crashes occur, such as the time of day and roadway surface conditions, helps to develop improvement strategies.

4.1 Collision Trends and Crash Statistics

This intersection is ranked 121 of the 2014–16 state top 200 crash locations with a high Equivalent Property Damage Only (EPDO) crash rate.[3] MassDOT conducted a Road Safety Audit (RSA) for this intersection on June 15, 2019.[4] The RSA analysis was based on crash data from 2014 to 2017. To further examine the intersection safety conditions with updated data, MPO staff added the recent two-year crash data (Medfield Police crash reports from January 2018 to November 2019) for this study.

In total, 46 crashes occurred during the six-year period. Table 1 summarizes the severity, collision type, pedestrian or bicycle involvement, time of day, weather, and pavement conditions of the 46 crashes by year and in total.

Nearly 40 percent (17) of total crashes at the intersection caused personal injuries. The most prevalent crash type is the angle collision, 60 percent (28) of all crashes. The second most common type is the rear-end collision, accounting for nearly 25 percent (11) of all crashes. There were a few other types of collisions, such as single-vehicle and sideswipe collisions, which account for approximately 15 percent (7) of all crashes. No crashes at the intersection involved pedestrians or bicyclists. Noticeably, 56 percent (26) occurred during the weekday peak traffic periods (7:00–9:00 AM and 3:30–6:30 PM).

[3] In the state EPDO index, property-damage-only and severity unknown crashes are awarded one point each, fatal crashes and crashes involving injuries are given 21 points each.

[4] RSA is a practice recommended by Federal Highway Administration (FHWA) as the formal safety examination of an existing or future road or intersection by an independent, multidisciplinary team. The purpose of an RSA is to identify safety issues and possible opportunities for safety improvement for all roadway users.

Table 1
Crash Data Summary
Medfield Police Crash Reports, January 2014 –November 2019

Statistics Period	2014	2015	2016	2017	2018	2019	6-Year Total	Annual Avg
Total number of crashes	7	5	10	6	11	7	46	7.7
Severity, Property damage only	3	2	3	4	9	7	28	4.7
Severity, Nonfatal injury	4	3	6	2	2	0	17	2.8
Severity, Fatality	0	0	0	0	0	0	0	0.0
Severity, Not reported/unknown	0	0	1	0	0	0	1	0.2
Collision type, Single Vehicle	0	1	2	0	1	0	4	0.7
Collision type, Rear-end	1	2	1	2	1	4	11	1.8
Collision type, Angle	6	2	6	4	7	3	28	4.7
Collision type, Sideswipe, same direction	0	0	1	0	1	0	2	0.3
Collision type, Sideswipe, opposite direction	0	0	0	0	0	0	0	0.0
Collision type, Head on	0	0	0	0	1	0	1	0.2
Collision type, Rear-to-rear	0	0	0	0	0	0	0	0.0
Collision type, Not reported/unknown	0	0	0	0	0	0	0	0.0
Involved pedestrian(s)	0	0	0	0	0	0	0	0.0
Involved cyclist(s)	0	0	0	0	0	0	0	0.0
Occurred during weekday peak periods*	4	2	6	6	5	3	26	4.3
Wet or icy pavement conditions	0	1	2	0	1	1	5	0.8
Dark conditions (lit or unlit)	0	1	1	3	1	1	7	1.2

* Peak periods are defined as 7:00–10:00 AM and 3:30–6:30 PM.

Avg = Average

4.2 Collision Diagram

Based on police reports, staff constructed a collision diagram (Figure 2) that shows the locations and collision patterns of all the crashes at the intersection in the period of nearly six years (each indexed by chronological order of occurrence, including the 2014–17 crashes identified in the RSA). The information of each crash, including date, time, severity, collision type, weather and road conditions, driver contributing code, and police comments are listed in Appendix A.

4.3 Safety Analysis

The major severe crash type at signalized intersections is a right-angle crash, where one vehicle violates the red signal.[5] The high number of angle crashes at this intersection resulted in a high injury rate.

As shown in the collision diagram (Figure 2), there were 21 right-angle crashes that can be separated into the following patterns:

- seven involving a northbound (North Meadows Road) through vehicle and an eastbound (West Street) through vehicle
- seven involving a southbound (North Meadows Road) through vehicle and an eastbound (West Street) through vehicle
- four involving a southbound through vehicle and a westbound through vehicle
- three involving a northbound through vehicle and a westbound through vehicle

[5] Two other concerns at signalized intersections are crashes involving left turn-opposing flow crashes and pedestrian crashes.

SYMBOLS

- Moving Vehicle
- Backing Vehicle
- Non-Involved Vehicle
- Pedestrian
- Parked Vehicle
- Fixed Object
- Bicycle
- Animal

TYPES OF CRASH

- Head On
- Angle
- Rear End
- Sideswipe
- Out of Control

SEVERITY

- Injury Accident
- Fatal Accident

BOSTON
REGION
MPO

North

Figure 2
Collision Diagram: North Meadows Road at West Street
Medfield Police Reports: January 2014–November 2019

Addressing Safety, Mobility, and Access on Subregional Priority Roadways

These right-angle crashes plus another angle crash involving a westbound left-turn vehicle and an eastbound through vehicle on West Street, 22 crashes in total (accounting for nearly one-half of all the intersection crashes), were identified to be caused by a vehicle running a red light at the intersection. Further analysis indicates that the number of red-light running on the West Street approaches (14 in total, nine eastbound and five westbound) is higher than that on the North Meadows Road approaches (eight in total, six southbound and two northbound), even though the prevailing travel speeds are much higher on the North Meadows Road approaches.

There is no simple or single reason to explain why motorists run red lights at an intersection. It usually involves a number of factors and the compound effects. For this intersection, the high frequency of red-light running may occur because of one of the following reasons:

- Speeding: The RSA noted that vehicles generally are traveling above the speed limit on North Meadows Road and West Street. Under the high-speed situation, motorists may not be able to stop in time for a red light or the clearance interval is inadequate.
- Intersection environment: The geometry of North Meadows Road (Route 27) approaching the intersection is straight and wide. The adjacent open areas may not provide sufficient visual cues for motorists to be aware of their excessive speed and that they are approaching an intersection. Though not as wide, the adjacent areas of West Street are wooded with spotty residences and businesses. Motorists, including a large portion of cross-town travelers, also tend to drive fast on West Street approaching the intersection.
- Signal visibility: The standard three-section signals with no backplates and no retroreflective borders on all approaches at this intersection may not be sufficient for motorists to see them. The two overhead signals on North Meadows Road appear to be small under the wide roadway environment. The post-mounted signal on West Street, low and far away from the intersection center, is especially difficult for motorists to see. The overhead signal on West Street, not positioned in the center with no double-up display, can be hard to see when it blends into the street's overgrown vegetation. Meanwhile, the stop lines of all approaches are located far back from the intersection, which may reduce motorists' visibility of signal changes.
- Signal operation: The high red-light running frequency may also occur because of inappropriate signal timing settings at the intersection. Motorists' decision at the light-changing moment is highly correlated to the duration of the yellow change interval and the approaching speed.

According to The *Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD)*, the duration of the yellow change interval should be approximately three to six seconds, with longer intervals reserved for high-speed approaches.[6] The four-second yellow change interval on the North Meadows Road approaches may not be sufficient under the prevailing speed of 50 mph or higher (see further analysis in Section 6.2).

- Sun glare: The police reports show that a few red-light violators claimed that they were blinded by the sun glare when they were approaching the intersection. As North Meadows Road is oriented in the northwest-southeast direction, motorists are affected by the sun glare in peak traffic periods (the southbound in the morning and the northbound in the evening). The sun glare also affects motorists on West Street in peak traffic periods and in the direction with busier traffic (the eastbound in the morning and the westbound in the evening).

There were six angle crashes that can be categorized as left-turn crashes. They all involved a left turning vehicle and a through vehicle in the opposite direction. These crashes usually occurred at the intersections where left turns are operated in permissive phasing under the heavy opposite traffic. The six crashes at this intersection can be separated as follows:

- two involving a northbound left-turn vehicle and a southbound through vehicle
- two involving a southbound left-turn vehicle and a northbound through vehicle
- two involving a westbound left-turn vehicle and an eastbound through vehicle

The traffic signal at this intersection operates in permissive phasing that allows traffic in the opposite approaches to move concurrently. With no storage lane and no exclusive signal phase, left turns usually have to wait at the intersection for gaps in the opposite traffic stream. Meanwhile, approaching the intersection with no separated lanes, all the movements tend to cluster in the intersection and block each other's views and cause driver confusion, especially during busy traffic conditions.

[6] The *MUTCD* defines the standards used by road managers nationwide to install and maintain traffic control devices on all public streets, highways, bikeways, and private roads open to public travel. The *MUTCD* is published by FHWA. The 2009 *MUTCD* with Revision Numbers 1 and 2 incorporated, dated May 2012, is the most current edition of the official FHWA publication.

Note that the left-turn crashes occurred more frequently on the North Meadows Road approaches and on the West Street westbound approaches. Both approaches of North Meadows Road are wide, which contains a flared area for through vehicles to go around the vehicle(s) waiting to turn left. However, such maneuvers create potential conflicts between the through vehicle and a left turning vehicle in the opposite direction, as the two drivers' view to each other can be blocked by the vehicle waiting to turn left. The West Street westbound approach carries a high left-turn volume during peak traffic periods. The left-turn vehicles tend to be stuck in the intersection, especially in the morning peak hours.

There was only one right-turn angle crash that involved a vehicle turning right on westbound and a vehicle going straight on northbound. The crash did not cause injuries.

There were 11 rear-end crashes, which can be separated into the following approaches:

- five on the northbound approach
- three on the southbound approach
- two on the westbound approach
- one on the eastbound approach

Rear-end crashes at an intersection usually caused by motorists' inattention, distraction, or not keeping sufficient distance (following too closely) to the vehicle in front. At this intersection, they were mainly caused by the sudden stop of a vehicle in front traveling fast or suddenly slowing down by a left turning vehicle. The RSA indicated that vehicles traveling in the northbound approach on North Meadows Road through the intersection are especially prone to speeding. As a result, there are more rear-end crashes occurring on this approach than the other approaches. Two of the rear-end crashes caused injuries and both occurred on the northbound approach.

The last observed collision pattern contains three single vehicle crashes at the intersection, two at the southwest corner, and one at the northeast corner. They mainly were caused by speeding motorists, turning too fast, or driving carelessly.

5 EXISTING TRAFFIC CONDITIONS

To examine the existing traffic conditions, MPO staff requested MassDOT's assistance in collecting intersection turning movement counts (TMC) and roadway approach speeds using Automatic Traffic Recorder (ATR) counts at various locations for this study. The data collection was delayed by a snowstorm in late November 2019 and periodic snowfall in the following months. In March, just as MassDOT scheduled to collect the counts for this study, the state's traffic data collection operations were suspended because of the COVID-19 pandemic.

Fortunately, traffic studies for recently proposed developments in the vicinity of the intersection were available for this study to evaluate the existing traffic conditions. These studies are

- Traffic Impact Assessment for Proposed American Legion Apartments, October 30, 2019 (traffic data collected on October 30, 2018);
- Transportation Impact Assessment for Medfield Green (Meadows) Residential Development, October 2018 (traffic data collected on September 28–29, 2016);
- Traffic Impact Assessment for New Apartment Building (Hillside Village) at 90 North Meadows Road, March 2018; and
- Traffic and Circulation Assessment for Proposed Daycare Facility (Medfield Children's Center), January 2018.

5.1 Daily Traffic Volumes

Based on the ATR counts collected for the Medfield Meadows development traffic study in September 2016 and historical counts collected at the MassDOT continuous count station on Route 27 south of Hospital Road in Medfield (location ID: 39), staff estimated daily traffic volumes on the four roadway sections adjoining the intersection. The estimated volumes represent daily traffic near the intersection under normal conditions (not affected by the pandemic conditions).

- North Meadows Road south of the intersection—approximately 10,500 to 11,000 vehicles per day (vpd), with a split of 49 percent northbound/51 percent southbound
- North Meadows Road north of the intersection—approximately 8,500 to 9,000 vpd, with a split of 50 percent northbound/50 percent southbound
- West Street east of the intersection—approximately 6,000 vpd, with a split of 49 percent eastbound/51 percent westbound
- West Street west of the intersection—approximately 6,000 vpd, with a split of 50 percent eastbound/50 percent westbound

5.2 Turning Movement Volumes

Staff estimated the turning movements at this intersection based on counts from the four traffic studies but pivoting on the two recent studies, the proposed

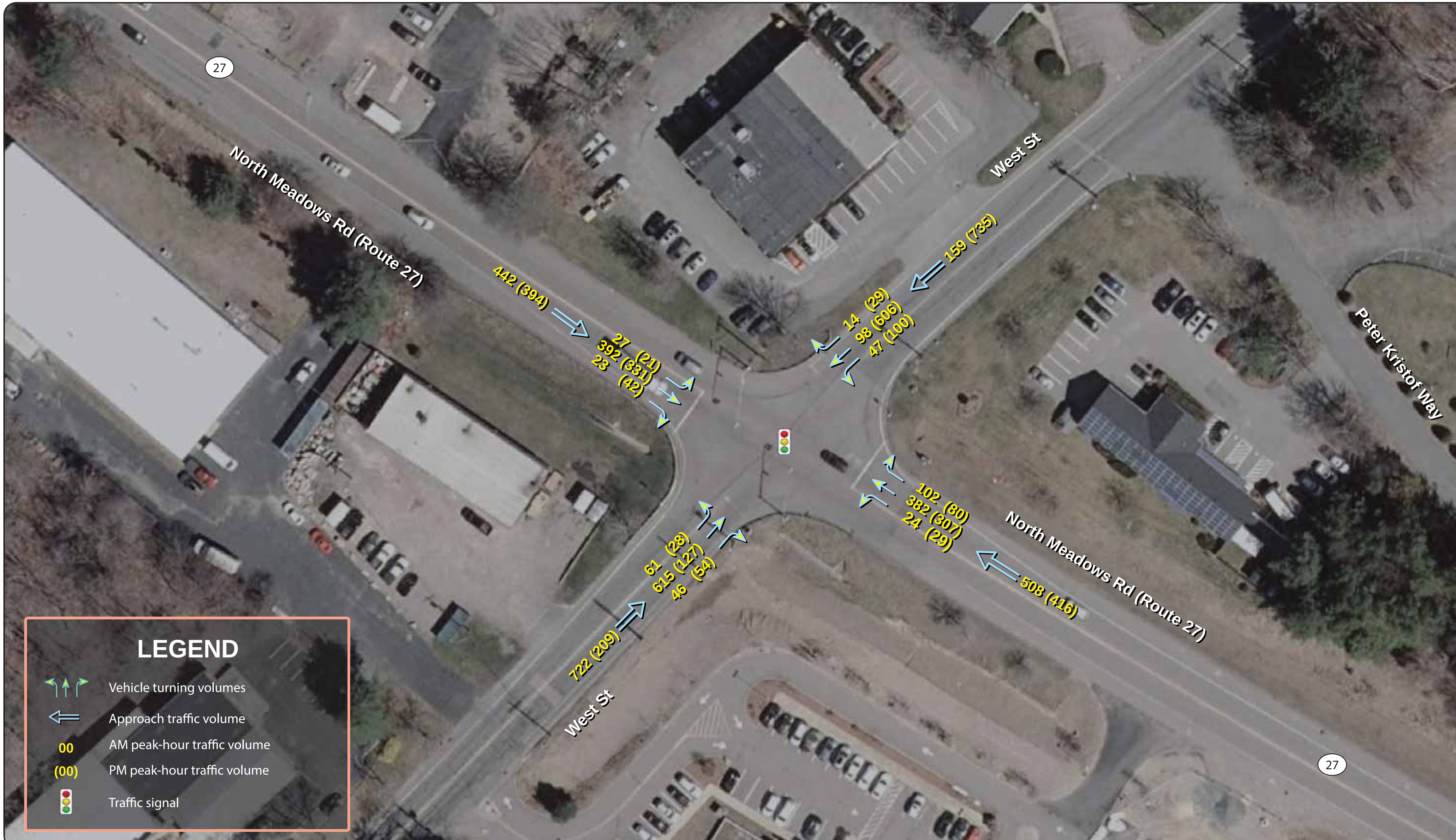
American Legion apartments and the Medfield Meadows residential developments.[7] Figure 3 summarizes the estimated 2020 AM and PM peak-hour traffic volumes by approaches. The estimation represents the optimal conditions in 2020, not the COVID-19 conditions.

The intersection is estimated to carry approximately 1,750 to 1,850 entry vehicles per peak hour during high travel months (September and October) under the normal traffic conditions. In the AM peak hour, the West Street eastbound approach carries a volume much higher than other approaches. In the PM peak hour, the West Street westbound approach carries the highest volume at the intersection. Right-turn volumes are generally low, except the North Meadows Road northbound in the morning, which carries about 100 vehicles per peak hour.

5.3 Intersection Approach Speeds

Traffic studies usually apply the observed or estimated 85th percentile speeds to assess how fast vehicles are approaching an intersection. The 85th percentile speed is the speed at or below which 85 percent of vehicles passing a given point are traveling, and is the principal value used to establish speed controls by the state. It can be regarded as the prevailing vehicle speed on the roadway adjacent to the specific location.

[7] The estimation was based on comparisons of the four data sets by volumes and turning movement percentages and analyses of seasonal factors and growth factors.



BOSTON
REGION
MPO

N

Figure 3
Estimated 2020 Weekday Traffic Volumes
North Meadows Road at West Street, Medfield

Addressing Safety, Mobility, and Access on Subregional Priority Roadways

The above traffic studies provided a few observed 85th percentile speeds at the following locations:

- North Meadows Road just north of the intersection, at the Medfield Children's Center (45 mph speed limit in both directions)—49 mph in the northbound and 50 mph in the southbound (observed on January 3, 2018)
- West Street just east of the intersection, at Peter Kristof Way (35 mph speed limit in both directions)—39 mph in the eastbound and 38 mph in the westbound (observed on October 30, 2018)
- North Meadows Road about a half mile south of the intersection, between Grove Street and Dale Street at the Medfield Children's Center (40 mph speed limit in both directions)—44 mph in the northbound and 41 mph in the southbound (observed on September 28–29, 2016)

These observed 85th percentile speeds may not be suitable to directly use as approach speeds for the intersection, as the first two locations are located too close to the intersection (about 250 to 300 feet) and the third location is too far and under a lower speed limit. Staff therefore applied 7 mph above the posted speeds as the prevailing approach speeds for the intersection's operational analyses based on the Institute of Transportation Engineers (ITE) guideline.[8]

6 INTERSECTION OPERATIONS ANALYSIS

Based on the estimated turning movement volumes, staff conducted the intersection capacity analysis by using the Synchro traffic analysis and simulation program.[9] Staff also reviewed the signal settings of the yellow change and all-red clearance intervals and the issue of pedestrian and bicycle accommodations.

6.1 Intersection Capacity Analysis

In general, the intersection operates at an acceptable level of service (LOS) on all approaches in both the AM and PM peak hours. Field observations indicated that there were no extensive traffic queues during the peak hours, except the eastbound approach in the morning and the westbound approach in the evening.

Table 2 summarizes the estimated LOS, average delay, and volume to capacity ratio (V/C) for all the approaches at the intersection in the AM and PM peak hours. The estimation is based on an observed cycle length of 74 seconds that

---

[8] *Guidelines for Determining Traffic Signal Change and Clearance Intervals: An ITE Proposed Recommended Practice*, Institute of Transportation Engineers, Washington D.C., 2015.

[9] Staff used Synchro Version 10.3, developed and distributed by Trafficware Ltd. It can perform capacity analysis and traffic simulation (when combined with SimTraffic) for an individual intersection or a series of intersections in a roadway network.

consist of 38 seconds (30-second green, plus 4-second yellow, and 4-second all-red) for North Meadows Road approaches and 36 seconds (30-second green, plus 4-second yellow and 2-second all-red) for West Street approaches.

Table 2
Summary of Intersection Capacity Analyses
Estimated 2020 AM and PM Peak-Hour Traffic Conditions

Analysis Period	AM	AM	AM	PM	PM	PM
Approach	**LOS**	**Delay**	**V/C**	**LOS**	**Delay**	**V/C**
North Meadows Road NB	C	29.6	0.82	C	28.6	0.78
North Meadows Road SB	C	28.8	0.79	C	26.3	0.73
West Street EB	D	35.0	0.90	B	12.0	0.29
West Street WB	B	15.2	0.34	D	35.9	0.91
Intersection Average	C	30.0	-	C	29.0	-

Notes:
Approach: NB = Northbound; SB = Southbound; EB = Eastbound; WB = Westbound
All movements share a single lane on all approaches
AM Peak Hour = 8:00–9:00; PM Peak Hour = 5:00–6:00
Delay = Average delay per vehicle (seconds)
LOS = Level of Service. V/C = Volume to capacity ratio.

Appendix B contains the Synchro reports of the AM and PM intersection capacity analyses underestimated existing conditions. Note that these analyses do not include safety concerns and impacts from the shared single-lane operations (analyzed in the section of crash data analysis).

6.2 Yellow Change Interval and Red Clearance Interval

To further examine the issue of red-light running at this intersection, staff conducted a quick analysis of the yellow change and all-red (red) clearance intervals at this intersection. The yellow change and red clearance intervals compose the two parts of the traffic signal change period. The determination of the intervals depend on a number of factors, including the intersection and approaching roadway characteristics, and traffic conditions.

Appendix C summarizes the estimation of yellow change and red clearance intervals for all the approaches at the intersection, based on the guidelines recommended by ITE. It also includes the existing yellow change and red clearance intervals observed in the field for comparison. Appendix D contains details of the ITE method and formula for calculating the two intervals.

The calculation for the yellow change interval provides the minimum interval to allow time for a motorist to see the yellow signal indication and decide whether to stop or to enter the intersection. This time includes the motorist's perception-reaction time, generally one second. It should be sufficient time for motorists that are too close to the intersection to decelerate comfortably to a stop and thus reach the intersection before the right-of-way terminates. The calculation for the red clearance interval allows motorists that enter the intersection before the yellow change interval terminates time to continue through to the far side of the intersection before conflicting traffic enters.

Currently, North Meadows Road approaches operate with a signal change period of eight seconds that consists of four seconds of yellow change interval and four seconds of red clearance interval, and West Street approaches operate with a signal change period of six seconds that consists of four seconds of yellow change interval and two seconds of red clearance interval. The yellow change interval for North Meadows Road approaches is slightly short, compared to the estimated five seconds. The red clearance interval for West Street approaches is slightly short, compared to the estimated 2.5 seconds. In terms of the total signal change periods for both roadway approaches, they are close to the estimated 7.5 seconds for North Meadows Road approaches and 6.5 seconds for West Street approaches.

The signal change setting is critical for traffic safety at an intersection. Note that this is a quick estimation based on some assumptions and approximations, including the estimated 85th percentile speeds. In the short term, a further engineering study should be conducted with radar-measured 85th percentile speeds on all approaches and surveyed intersection geometry, before making adjustments to the existing yellow change and red clearance intervals.

In the long term, the intersection should be redesigned with lower approach speeds, reduced turning radii, and signal vehicle detection to minimize dilemma zones.[10] Under the new intersection design, the intersection would operate at the usual range of yellow change interval (three to four seconds) and red clearance interval (one to two seconds).

6.3 Pedestrian and Bicycle Accommodations

There are insufficient pedestrian and bicycle accommodations at the intersection and its adjacent areas. Both North Meadows Road and West Street have no

[10] The (yellow light) dilemma zone is widely known as an area on the high-speed intersection approach where vehicles neither safely stop before the stop line nor proceed through the intersection during amber interval. Within such an area, a vehicle is more likely to be involved in a right-angle crash or rear-end collision.

sidewalks, except an 800-foot section on the north side of West Street west of the intersection. The intersection has no crosswalks on all approaches.

Both roadways have no dedicated bicycle accommodations. Although North Meadows Road has shoulders of approximately 10 feet wide in both directions approaching the intersection, it has no consistent treatment in accommodating bicycles as parking on the shoulders is not explicitly prohibited and some sections are hatch-marked.

During the recent development of the Medfield town-wide master plan, residents strongly supported more sidewalks and bikes to reduce the dependence on cars and buses and prioritizing walking and biking in the transportation system to enhance the health and wellness of residents. Meanwhile, the intersection was described as a location with major safety and congestion concerns and new developments in the area have generated and will generate more walking trips. Pedestrian and bicycle accommodations should be prioritized in the redesign and reconstruction of the intersection.

7 PROPOSED SHORT-TERM IMPROVEMENTS

Based on the above analyses, MPO staff developed a series of short- and long-term improvements to address safety and operational problems at the intersection. The proposed short-term improvements generally can be implemented within two years at a relatively low cost (usually under $30,000). The proposed long-term improvements are more complicated and cover larger areas, thus requiring intensive planning and design, and significant funding. They are analyzed in the next section. The proposed short-term improvements are summarized below, from the lowest to the highest cost:

- Reinforce speed regulations on the roadways approaching the intersection.[11]
- Restripe the stop lines of all approaches to at least 1.5 feet wide and consider relocating the stop lines on both approaches of North Meadows Road and the eastbound approach of West Street approximately five to 10 feet toward the intersection.

[11] Staff observed police enforcement during the site reconnaissance in March 2020. The police crash reports indicate no injury crashes in 2019 (January to November). In previous years, there were approximately two to six injury crashes each year.

- Install *MUTCD* Signal Ahead warning sign (W3-3) on both approaches of North Meadows Road to increase motorists' awareness and readiness to stop.[12]
- Consider installing solar-powered speed feedback (Your Speed) warning signs in conjunction with the posted speed regulation at suitable locations approaching the intersection.
- Consider and examine the feasibility of reducing the speed limit from 45 MPH to 40 MPH on both approaches of North Meadows Road.[13]
- Examine the feasibility of installing backplates with retroreflective borders on the existing signal heads or new signal heads.[14]
- Consider adjusting the yellow change intervals and red clearance intervals based on a further engineering study and retiming the traffic signal after the study.[15]
- Consider striping all travel lanes from 12 to 11 feet wide approaching the intersection and striping the 10-foot shoulders on North Meadows Road to six-foot bike lanes with a four-foot buffer from traffic.[16]

8 LONG-TERM IMPROVEMENT ALTERNATIVES

The proposed long-term improvements would require intensive planning and design and significant funding. Staff developed a number of long-term improvement alternatives for this intersection and its immediate areas. Based on

[12] The warning sign should be placed at a suitable location of approximately 1,000 to 1,200 feet from the intersection on both approaches.

[13] A suitable 40-mph speed zone on North Meadows Road would be from Grove Street, via the intersection, to the north side of the rail bridge just north of the driveway of Sluggers Academy (approximately 3,000 feet in total length). Note that an engineering study would be required to justify the change, based on "Procedures for Speed Zoning on State and Municipal Roadways" (MassDOT Highway Division, May 2012). The exact location of the new speed zone should be based on this study.

[14] The backplates and retroreflective borders would be effective in increasing the awareness of the signal presence and changes and to reduce sun glare. However, the existing mast arms or foundations may not be strong enough to support the additional weight. Their functions and specifications need to be examined.

[15] The current signal provides the equal amount of green time for both roadways. Although the highest traffic volume usually exists on West Street (eastbound in the morning and westbound in the evening), the setting is considered reasonable as North Meadows Road is a state highway. Using Synchro to examine different signal timing plans, staff found the existing setting is fairly optimized. Under the existing intersection layout, the signal can only be improved by adjusting the yellow change and red clearance intervals and slightly reducing the overall cycle length.

[16] The restriping should be considered when Route 27 is planned for resurfacing or pavement maintenance. Preferably the shoulders on Route 27 can be converted for the bike accommodation from Route 109 all the way to Route 115 in Sherborn.

the goals of maximizing safety and operational benefits for all transportation modes and minimizing land-taking and construction impacts, staff identified three alternatives that are more feasible than others.

Staff also analyzed traffic operations for the alternatives and the base case (no-build scenario) under the projected 2030 traffic conditions. For comparison purposes, the analysis includes a future year no-build scenario that contains only signal retiming with no geometry modifications and no signal system upgrade.

Key elements of the no-build scenario and the three alternatives are summarized as below.

No-Build Scenario

The no-build alternative assumes that the intersection would remain the same as the existing conditions, which include a single lane for all approaches, no crosswalks, no bicycle detection, and no signal system update. The only improvement included is to retime the signal with the estimated yellow change and red clearance intervals (Section 6.2) and a slight reduction of overall cycle length.

Alternative One

Alternative 1 proposes to modify the intersection layout and upgrade the signal system for adding protected left-turn operation, protected pedestrian crossing, and bicycle detection. Figure 4 shows the conceptual plan of the alternative. Key elements of the alternative include

- adding a left-turn exclusive lane on all approaches;
- reducing turning radii at all corners;
- installing crosswalks on all roadways;
- installing six-foot sidewalks on both sides of all approaches with Americans with Disabilities Act (ADA) compliant wheelchair ramps connected to the crosswalk;
- upgrading the signal system to include accessible count-down pedestrian signals, bicycle detection, and new signal indications;[17]

[17] The signal heads should be designed and positioned according to traffic operations and the intersection layout and equipped with backplates and retroreflective borders. Signal lights that are 12 inches in diameter should be used on all approaches.

- installing six-foot bike lanes on North Meadows Road in both directions;[18] and
- making West Street a bike shared road.

Alternative Two

Alternative 2 proposes to modify the intersection layout and upgrade the signal system for adding protected/permissive left-turn operation, protected pedestrian crossing, and bicycle detection. The alternative would require a similar layout to Alternative 1 (see Figure 4 for the conceptual plan).[19] Key elements of the alternative include

- adding a left-turn exclusive lane on all approaches;
- reducing turning radii at all corners;
- installing crosswalks on all approaches;
- installing six-foot sidewalks on both sides of all roadways with ADA compliant wheelchair ramps connected to the crosswalk;
- upgrading the signal system to include accessible count-down pedestrian signals, bicycle detection, and new signal indications;
- installing six-foot bike lanes on North Meadows Road in both directions; and
- making West Street a bike shared road.

Alternative Three

Alternative 3 proposes to convert the intersection into a single-lane modern roundabout. Figure 5 shows the conceptual plan of the alternative. Key elements of the alternative include

- designing and constructing a single-lane modern roundabout with an inscribed circle of at least 130 feet in diameter;
- adding a right-turn exclusive lane on the northbound approach;
- installing six-foot sidewalks on both sides of all roadways;

---

[18] As shown in Figure 4, the bike lanes can be separated from traffic by using a three feet to four feet street buffer. They should be installed in the entire section of Route 27 between Route 119 and West Street and in the section west of West Street as far as the abutting environments and budget allow.

[19] In general, the protected left turn (Alternative 1) would require a longer storage length than the protected/permissive left turn (Alternative 2). Synchro analyses indicate that Alternative 2 would generally require less storage by one to two cars in all approaches than Alternative 1. To keep flexibility between the two left-turn signal operations for future traffic growth and safety considerations, staff thus proposes the same intersection layout based on the required length of Alternative 1.

- installing crosswalks on all approaches;
- installing 10-foot shared-use paths encircling the roundabout with ADA-compliant wheelchair ramps connected to the crosswalk;[20]
- Installing six-foot bike lanes on North Meadows Road in both directions;
- making West Street a bike shared road; and
- installing sharrow makings on West Street and in the circulatory roadway for bicycle travel.

Table 3 summarizes the intersection capacity analyses for the no-build scenario and the three alternatives under the predicted 2030 AM and PM peak-hour traffic conditions.[21] Appendix E contains Synchro intersection capacity analysis reports that detail input volumes, lane configurations, signal timing settings, and analysis results of the various alternatives.

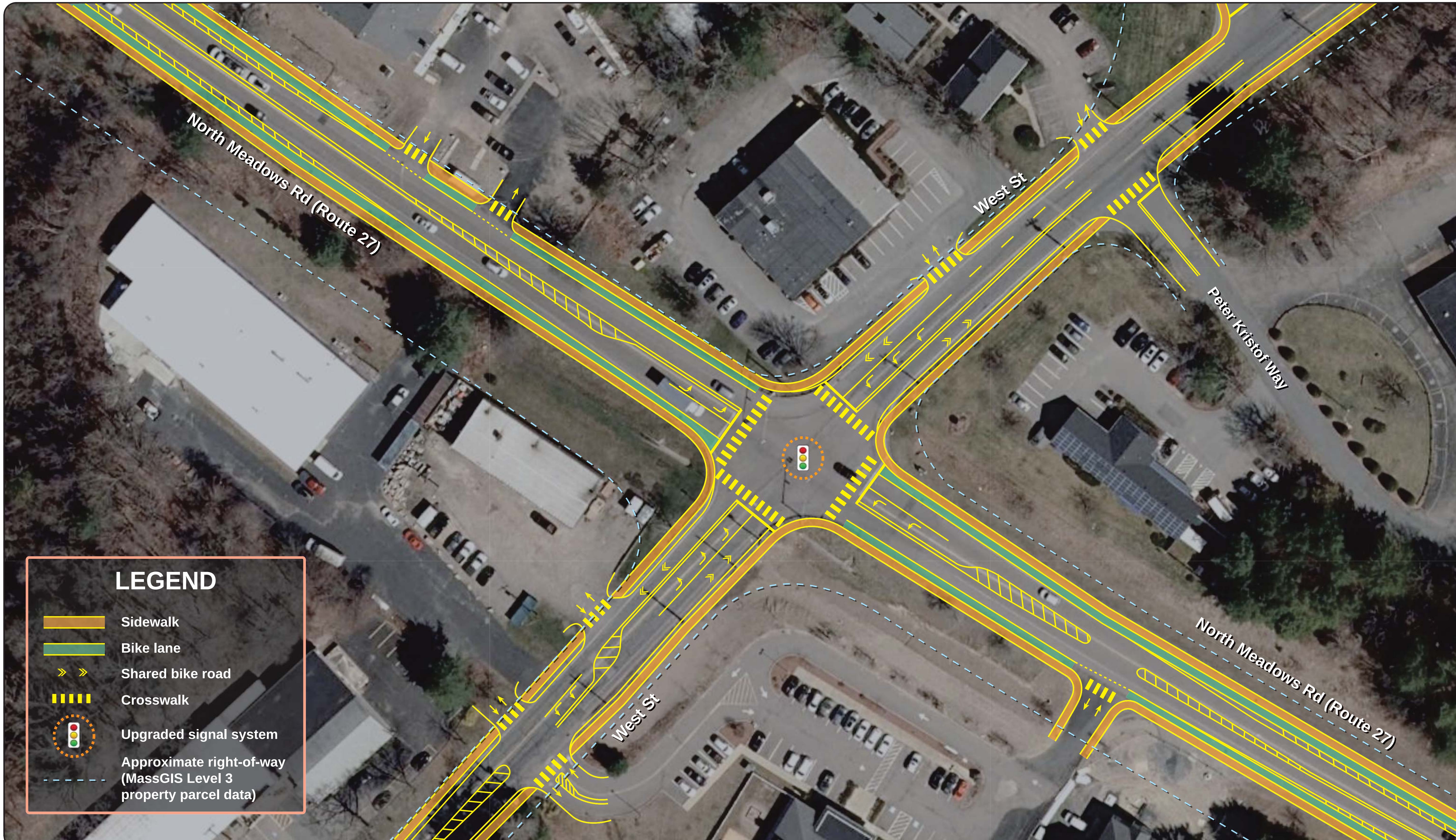
In terms of the overall intersection operation, all three alternatives would operate at acceptable levels of services in both the AM and PM peak hours.[22] In terms of individual approaches, all three alternatives would operate at acceptable levels of services in the AM peak hour, except the left turns on the West Street westbound in Alternative 1 and the entire approach of West Street eastbound in Alternative 3. In the PM peak hour, all approaches in the three alternatives would operate acceptably.

Note that these capacity analyses do not explicitly indicate the safety benefits of the three alternatives. Alternatives 1and 2 would reduce left-turn crashes and right-angle crashes and thus reduce the crash severity and improve safety for users of all modes at the intersection. Alternative 1 would provide more protection for left turns than Alternative 2 but would also increase average delay per vehicle on all approaches. Alternative 3 would slow down all the traffic through the roundabout and would reduce the crash severity most significantly.

[20] According to the MassDOT Guidelines for Planning and Design of Roundabouts (published September 2020), bicyclists are always offered the option of traveling through a roundabout as a vehicle. However, at locations with planned or existing bicycle facilities on the roundabout approaches, bicyclists are provided with additional options for navigating the roundabout, such as continuing biking on a share-use path (10 feet minimal) or walking their bike as a pedestrian on a sidewalk (at constrained locations less than 10 feet wide).

[21] Staff estimated that the intersection would have about six percent traffic growth (about 0.6 percent per year) in the AM peak hour and seven percent traffic growth (about 0.7 percent per year) in the PM peak hour from 2020 to 2030, based on analysis of the historical counts and forecasts from the most recent MPO transportation planning model.

[22] For the intersections in a metropolitan urban area, LOS A, B, and C are considered desirable; LOS D and E are considered acceptable; and LOS F is considered undesirable.

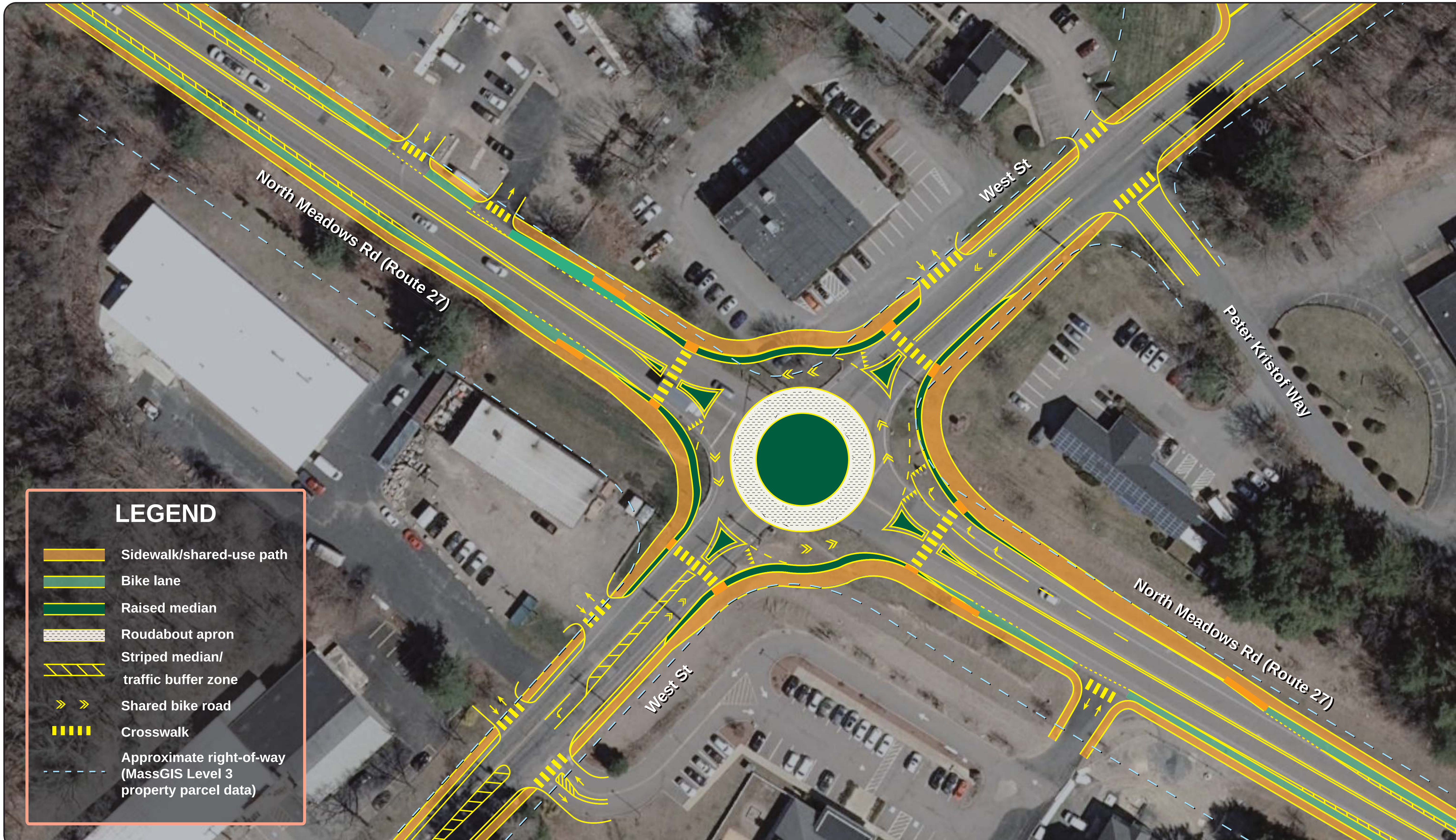


BOSTON REGION MPO

N

Figure 4
Proposed Long-Term Improvement Alternatives 1 and 2
North Meadows Road at West Street, Medfield

Addressing Safety, Mobility, and Access on Subregional Priority Roadways



BOSTON
REGION
MPO

N

Figure 5
Proposed Long-Term Improvement Alternative 3
North Meadows Road at West Street, Medfield

Addressing Safety, Mobility, and Access on Subregional Priority Roadways

Table 3
Intersection Capacity Analysis
No-Build and Long-Term Improvement Alternatives
2030 Projected Traffic Conditions

AM Peak Hour Analysis

Alternative	No-Build Signal Retiming No Geometry/Signal Improvements				Alternative 1 Intersection Reconstruction with Protected Left Turns				Alternative 2 Intersection Reconstruction with Protected/Permissive Left Turns				Alternative 3 Modern Roundabout Conversion Single-Lane Circulation			
Approach	Lane Group	LOS	Delay	V/C	Lane Group	LOS	Delay	V/C	Lane Group	LOS	Delay	V/C	Lane Group	LOS	Delay	V/C
North Meadows Road NB	L/T/R	C	32.4	0.85	L	E	59.2	0.37	L	B	19.2	0.16	L/T	C	20.8	0.71
					T/R	E	66.9	0.98	T/R	D	54.6	0.93	R	A	7.6	0.18
North Meadows Road SB	L/T/R	C	31.0	0.82	L	E	68.4	0.48	L	C	21.1	0.23	L/T/R	A	9.8	0.53
					T/R	D	51.6	0.90	T/R	D	44.6	0.85				
West Street EB	L/T/R	D	46.0	0.96	L	D	48.0	0.41	L	B	14.3	0.12	L/T/R	F	85.3	1.10
					T/R	E	57.8	0.98	T/R	D	58.9	0.98				
West Street WB	L/T/R	B	16.2	0.39	L	F	121.4	0.86	L	C	21.7	0.41	L/T/R	A	7.9	0.28
					T/R	C	23.4	0.22	T/R	B	19.9	0.21				
Intersection Average	-	D	35.5	-	-	E	58.0	-	-	D	48.0	-	-	E	39.9	-

PM Peak Hour Analysis

Alternative	No-Build Signal Retiming No Geometry/Signal Improvements				Alternative 1 Intersection Reconstruction with Protected Left Turns				Alternative 2 Intersection Reconstruction with Protected/Permissive Left Turns				Alternative 3 Modern Roundabout Conversion Single-Lane Circulation			
Approach	Lane Group	LOS	Delay	V/C	Lane Group	LOS	Delay	V/C	Lane Group	LOS	Delay	V/C	Lane Group	LOS	Delay	V/C
North Meadows Road NB	L/T/R	C	31.3	0.83	L	E	57.5	0.37	L	C	26.5	0.23	L/T	A	6.8	0.37
					T/R	D	37.1	0.73	T/R	D	39.8	0.76	R	A	3.8	0.09
North Meadows Road SB	L/T/R	C	27.9	0.77	L	D	54.2	0.28	L	C	25.7	0.18	L/T/R	E	38.5	0.87
					T/R	D	40.5	0.76	T/R	D	43.1	0.79				
West Street EB	L/T/R	B	12.5	0.32	L	E	63.1	0.41	L	B	17.9	0.20	L/T/R	A	8.7	0.33
					T/R	C	27.5	0.35	T/R	C	20.5	0.29				
West Street WB	L/T/R	D	50.8	0.99	L	D	51.2	0.55	L	B	16.6	0.21	L/T/R	E	46.1	0.97
					T/R	D	40.5	0.87	T/R	D	35.2	0.82				
Intersection Average	-	D	35.9	-	-	D	39.8	-	-	C	35.0	-	-	D	29.9	-

Notes:
- Approach: NB = Northbound, SB = Southbound, EB = Eastbound, WB = Westbound
- Turning movement: L = Left turn; T = Through movement; R = Right turn
- LOS = Level of Service
- Delay = Average delay per vehicle (seconds)
- V/C = Volume to capacity ratio

However, Alternatives 1 and 2 can be constructed within the existing roadway layout without any land takings. Alternative 3 would require a much larger footprint and require some land takings on the east side of North Meadows Road. In addition, Alternative 3 would require significant landfill and drainage rearrangements, as the roundabout would take up the ditched areas on the west side of North Meadows Road. All of these should be further investigated at the functional design stage.

9 RECOMMENDATIONS

This study performed a series of safety and operations analyses, identified issues and concerns, and proposed short- and long-term improvements at the intersection. The proposed short-term improvements would enhance safety and operations for the intersection under the existing conditions. With a relatively high benefit/cost ratio, they should be implemented as soon as resources are available from highway maintenance or local Chapter 90 funding.

The proposed long-term improvements, such as reconstructing the intersection by adding necessary turning lanes; installing sidewalks, crosswalks, and bicycle accommodations; and renovating the signal system to include pedestrian signals and bicycle detection, would significantly address the safety and operational problems at the intersection. At this preliminary planning stage, staff recommend Alternatives 1 or 2, considering that Alternative 3 would require land takings and major landfill and drainage rearrangements and thus may have some impacts to the surrounding areas. However, all three proposed alternatives should be included and further investigated at the functional design stage.

The Town of Medfield has jurisdiction of the intersection and roadways in the study area, and is responsible for renovation of the intersection to improve safety, mobility, connectivity, and operations. The Town is currently in the process of developing a new master plan. North Meadows Road and its adjacent areas have the potential to accommodate vibrant mixed-use developments with Complete Streets design. Improving safety and operations at this intersection is one essential component in successfully developing the areas.

This study gives the Town an opportunity to address the needs of the intersection and plan for design and engineering. The next steps would be to select the preferred alternative that is sensitive to the goals and needs of stakeholders and advance the project through the planning process. These steps will depend upon cooperation between MassDOT, the Town, and the MPO to begin the project notification and review process, and complete the project initiation form. After completing the initial steps, the Town and MassDOT can start preliminary design and engineering to place the project in the Transportation Improvement Program.

Project development is a complicated process that takes transportation improvements from concept to construction and is influenced by factors such as financial limitations and agency programmatic commitments (see Appendix F for an overview of this process).

This study supports the MPO's visions and goals, which include increasing transportation safety, maintaining the transportation system, advancing mobility and access, reducing congestion, and expanding the opportunities for walking and bicycling, while making them safer. If implemented, the improvements proposed in this report would modernize the roadway and significantly improve safety and mobility of all users.

cc: Sarah Raposa, Town of Medfield
Joseph Frawley, MassDOT Highway Division District 3

Appendices

The Boston Region Metropolitan Planning Organization (MPO) operates its programs, services, and activities in compliance with federal nondiscrimination laws including Title VI of the Civil Rights Act of 1964 (Title VI), the Civil Rights Restoration Act of 1987, and related statutes and regulations. Title VI prohibits discrimination in federally assisted programs and requires that no person in the United States of America shall, on the grounds of race, color, or national origin (including limited English proficiency), be excluded from participation in, denied the benefits of, or be otherwise subjected to discrimination under any program or activity that receives federal assistance. Related federal nondiscrimination laws administered by the Federal Highway Administration, Federal Transit Administration, or both, prohibit discrimination on the basis of age, sex, and disability. The Boston Region MPO considers these protected populations in its Title VI Programs, consistent with federal interpretation and administration. In addition, the Boston Region MPO provides meaningful access to its programs, services, and activities to individuals with limited English proficiency, in compliance with U.S. Department of Transportation policy and guidance on federal Executive Order 13166.

The Boston Region MPO also complies with the Massachusetts Public Accommodation Law, M.G.L. c 272 sections 92a, 98, 98a, which prohibits making any distinction, discrimination, or restriction in admission to, or treatment in a place of public accommodation based on race, color, religious creed, national origin, sex, sexual orientation, disability, or ancestry. Likewise, the Boston Region MPO complies with the Governor's Executive Order 526, section 4, which requires that all programs, activities, and services provided, performed, licensed, chartered, funded, regulated, or contracted for by the state shall be conducted without unlawful discrimination based on race, color, age, gender, ethnicity, sexual orientation, gender identity or expression, religion, creed, ancestry, national origin, disability, veteran's status (including Vietnam-era veterans), or background.

A complaint form and additional information can be obtained by contacting the MPO or at http://www.bostonmpo.org/mpo_non_discrimination. To request this information in a different language or in an accessible format, please contact

Title VI Specialist
Boston Region MPO
10 Park Plaza, Suite 2150
Boston, MA 02116
civilrights@ctps.org
857.702.3700 (voice)
617.570.9193 (TTY)

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

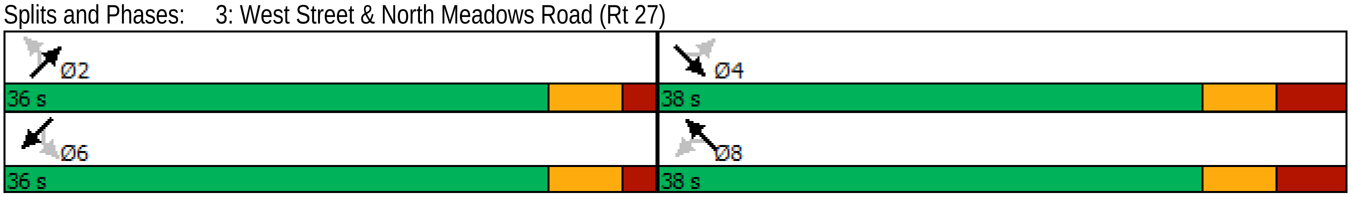
APPENDIX B

Intersection Capacity Analyses
2020 Existing Conditions

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	

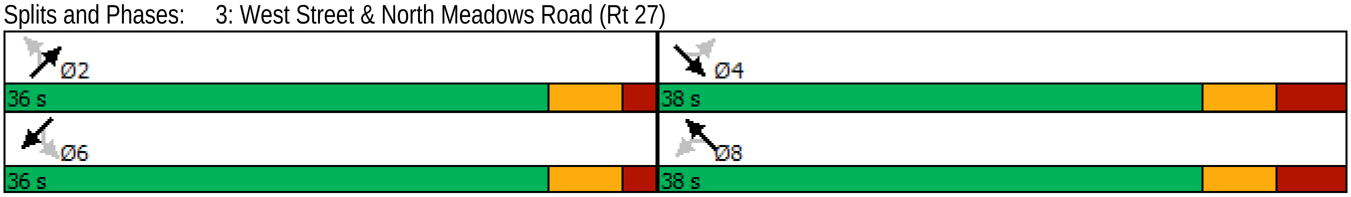
Splits and Phases: 3: West Street & North Meadows Road (Rt 27)



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

A P P E N D I X 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

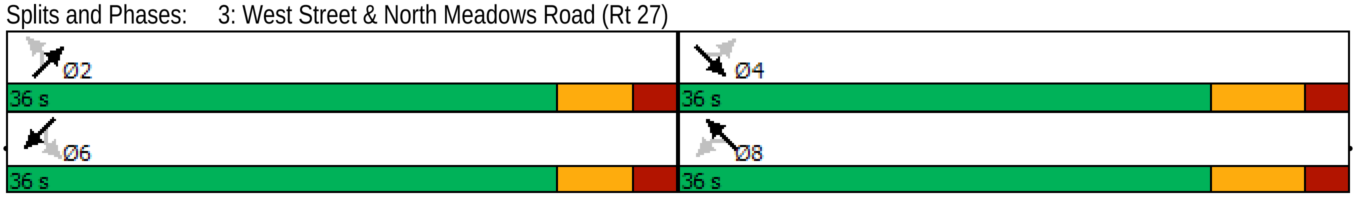
Intersection Capacity Analysis: 2030 AM No-Build (with Signal Retiming)
West Street & North Meadows Road (Rt. 27)

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	

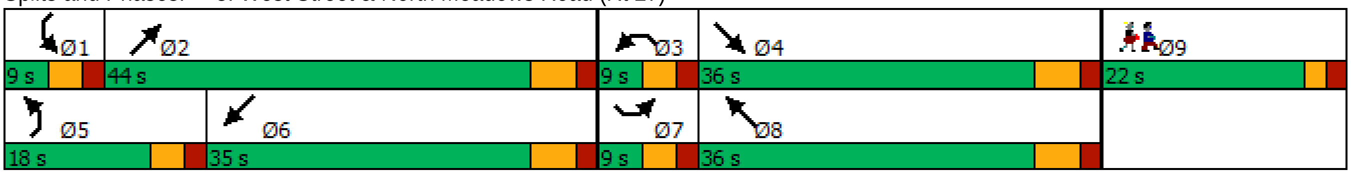
Intersection Summary	
Area Type:	Other

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)



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	

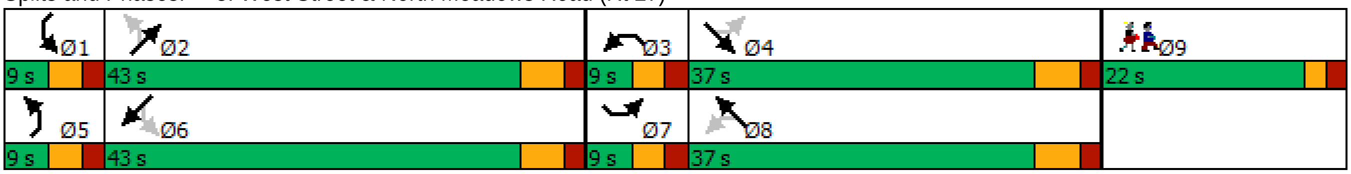
Intersection Summary	
Area Type:	Other

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

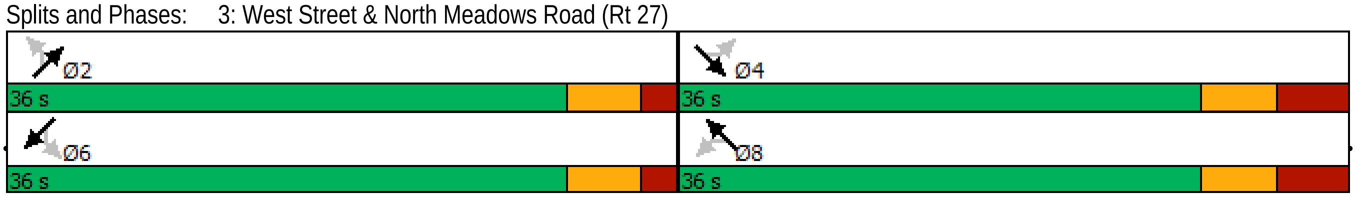
Lane	Left	Left	Right	Left	Left
Designated Moves	LTR	LT	R	LTR	LTR
Assumed Moves	LTR	LT	R	LTR	LTR
RT Channelized					
Lane Util	1.000	0.797	0.203	1.000	1.000
Follow-Up Headway, s	2.609	2.535	2.535	2.609	2.609
Critical Headway, s	4.976	4.544	4.544	4.976	4.976
Entry Flow, veh/h	575	486	124	812	221
Cap Entry 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	

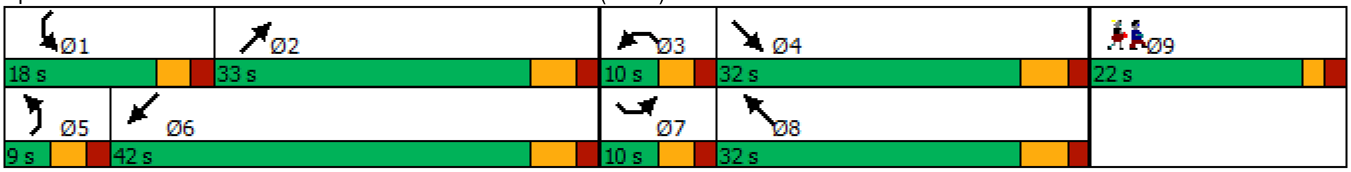
Splits and Phases: 3: West Street & North Meadows Road (Rt 27)



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

Intersection Caacity 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)	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

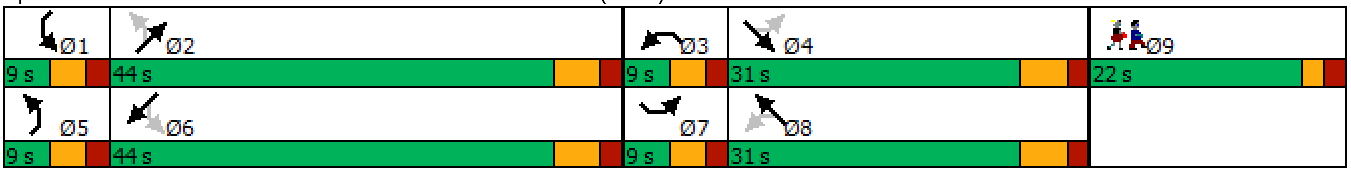
Maximum v/c Ratio: 0.82

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