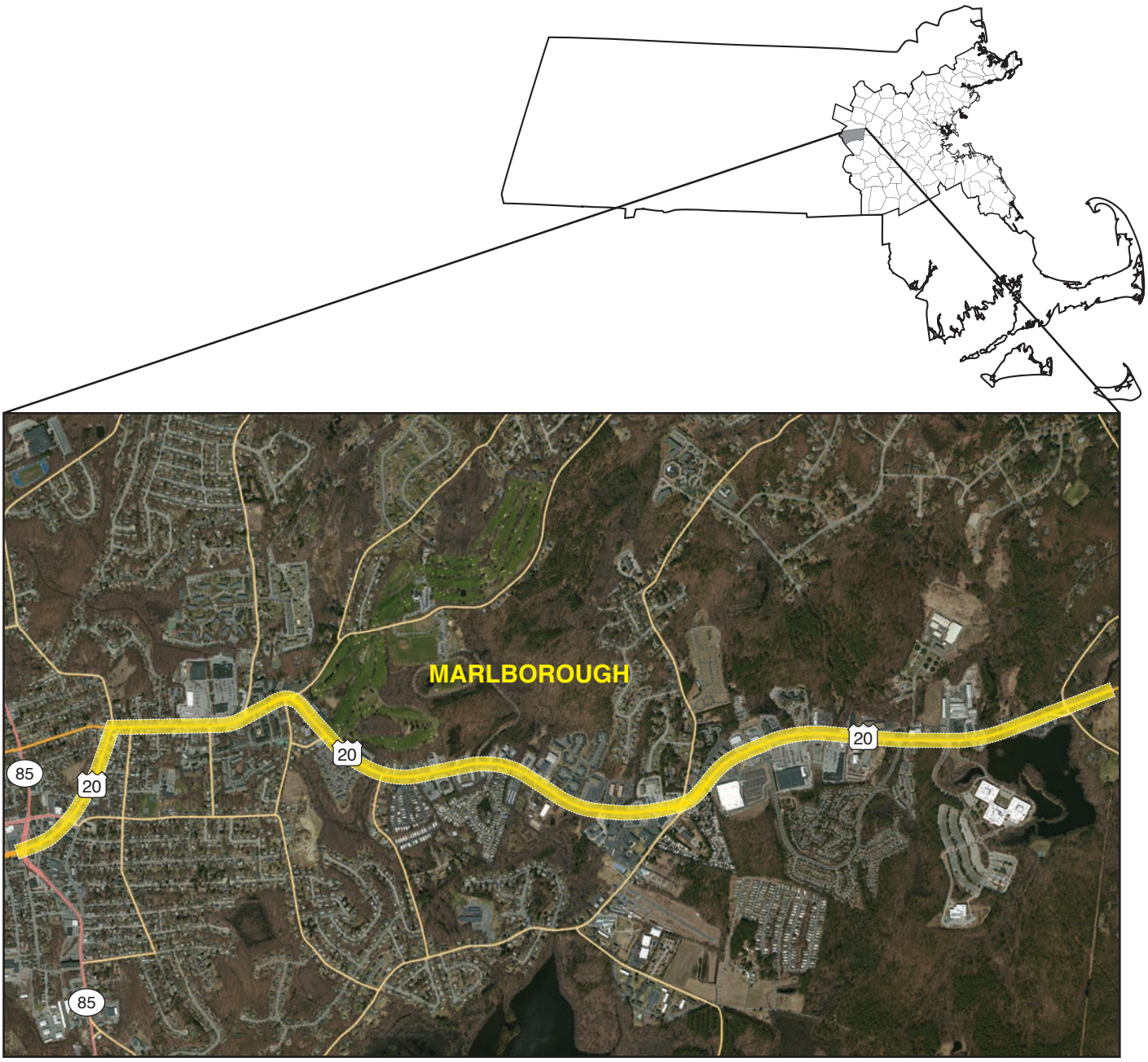
Route 20 East Corridor Study in Marlborough



To request additional copies of this document or copies in an accessible format, contact:

Central Transportation Planning Staff
State Transportation Building
Ten Park Plaza, Suite 2150
Boston, Massachusetts 02116

(857) 702-3700
(617) 570-9192 (fax)
(617) 570-9193 (TTY)

ctps@ctps.org
www.bostonmpo.org

Route 20 East Corridor Study in Marlborough

Project Manager
Chen-Yuan Wang

Project Principal
Mark Abbott

Data Analysts
Chen-Yuan Wang
Ben Gomes

Graphics
Kenneth Dumas
Kim DeLauri

Cover Design
Jane Gillis

The preparation of this document was supported by the Federal Highway Administration through MHD 3C PL contracts #89787 and #84080.

Central Transportation Planning Staff
Directed by the Boston Region Metropolitan Planning Organization. The MPO is composed of state and regional agencies and authorities, and local governments.

February 2017

Abstract

The Route 20 East Corridor in Marlborough was approved for study by the Boston Region Metropolitan Planning Organization (MPO), through a comprehensive selection process that reviewed 24 potential corridors in the region. The study corridor is about 3.6 miles from Marlborough city center to the Sudbury town line. It contains several high-crash locations that need to be improved for the safety and mobility of users of all transportation modes. Major portions of the corridor have strong potential for design and implementation towards a Complete Streets roadway.

MPO staff, working with City of Marlborough and the Massachusetts Department of Transportation (MassDOT), collected crash and transportation data, conducted safety and operational analyses, and developed short- and long-term improvements for the entire corridor and at specific locations. This report documents the analyses and proposed improvements; it provides background information about the study, summarizes recommended improvements, and discusses steps toward implementation. The report also includes technical appendices that contain the data and methods used in the study.

Major recommended improvements for the corridor and expected benefits include:

- A three-lane roadway reconfiguration (Boston Post Road East Section) would slow traffic, provide separate bicycle accommodations, and reduce pedestrian crossing distances and risks.
- Sidewalk and bicycle lane installations would enhance pedestrian and cyclist accommodations and safety, and improve traffic operations.
- The proposed improvements at intersections would improve safety and mobility for all users.
- The proposed signal coordination of the intersections on East Main Street would improve mobility, access, and safety for all users.

This study offers a vision for the corridor's future development and confirms its potential for transforming into a pedestrian- and cyclist-friendly roadway while maintaining its regional travel capacity. It will require significant effort and collaboration on the part of all stakeholders, including the City of Marlborough, residents and owners of adjacent developments, and MassDOT to achieve this vision.

TABLE OF CONTENTS PAGE

TABLES PAGE

FIGURES PAGE

APPENDIXES BEGINNING ON PAGE 62

Chapter 1—Introduction

1.1 STUDY BACKGROUND

During the MPO's outreach for developing the Unified Planning Work Program (UPWP) and the Long-Range Transportation Plan (LRTP), Metropolitan Area Planning Council (MAPC) subregional groups and other entities submit comments and identify transportation problems that concern them. These issues are related to bicycle, pedestrian, and freight accommodation, bottlenecks, safety, or lack of safe or convenient access for abutters along roadway corridors. They can affect not only mobility and safety on a roadway and its side streets, but also quality of life, including economic development and air quality.

To address these concerns, the Priority Corridors study (which included Route 20 in Marlborough) was included in the UPWP for federal fiscal year (FFY) 2016[1] and a work program was approved on October 15, 2015. The purpose of this study was to identify roadway segments in the MPO region that are of concern to subregional groups but that have not been identified in the LRTP regional needs assessment.[2]

1.2 STUDY OBJECTIVES

The Route 20 East Corridor Study in Marlborough emphasizes issues identified by the relevant subregional groups, along with recommendations to address them. In addition to topics about mobility, safety, and access, it includes bicycle and pedestrian transportation, transit feasibility, and other subjects raised by subregional groups.

The objectives of the study were to:

- Identify the safety, mobility, access, and other transportation-related problems in the corridor
- Develop and evaluate potential multimodal transportation solutions to the problems, including pedestrian, bicycle, truck, and transit modes

1.3 SELECTION PROCEDURE

The Route 20 East corridor in Marlborough was selected through a comprehensive process. First, MPO staff identified potential study locations using various sources: soliciting suggestions during the outreach process for the FFY

[1] Unified Planning Work Program, Federal Fiscal Year 2016, endorsed by the Boston Region Metropolitan Planning Organization on July 30, 2015.

[2] A work scope for "Priority Corridors for LRTP Needs Assessment—FFY 2016," was submitted simultaneously to the Boston Region MPO.

2016 UPWP; reviewing meeting records from the UPWP outreach process for the past five years; and appraising potential locations from the monitored roadways in the MPO's Congestion Management Process (CMP).

MPO staff identified 24 roadway corridors in the MPO region as potential study locations. Staff assembled detailed data about the identified roadways and evaluated them according to five selection criteria[3], which are, the location:

- ***Safety Conditions***: Has a high crash rate for its functional class, or contains areas with a large number of crashes or significant number of pedestrian-bicycle collisions
- ***Multimodal Significance****:* Supports transit, bicycle, or pedestrian activity, or accommodates large numbers of heavy vehicles (trucks/busses)
- ***Subregional Priority****:* Carries a significant proportion of subregional vehicle, bicycle, or pedestrian traffic and is essential for the subregion's economic, cultural, or recreational development
- ***Implementation Potential****:* Was proposed or endorsed by the roadway administrative agency/agencies and has strong support from its stakeholders
- ***Regional Equity***: Is situated in a subregion that has not been selected for the Priority Corridors study in the past two years

The Route 20 East corridor in Marlborough contains several high-crash locations that need to be improved for the safety and mobility of users of all modes. Major portions of the corridor have strong potential for design and implementation toward a Complete Streets[4] roadway. The study site has strong support from all stakeholders, including the City of Marlborough and MassDOT.

1.4 STUDY AREA AND DATA COLLECTION

The Route 20 East corridor is about 3.6 miles long and consists of Granger Boulevard (from South Bolton Street (Route 85) to Main Street), East Main Street (from Main Street to Concord Road), and Boston Post Road East (from Concord Road to the Sudbury town border). All segments of the corridor are under the jurisdiction of MassDOT Highway Division District 3, except the segment of

[3] Details of the criteria and rating system may be found in the CTPS technical memorandum "Selection of Study Location: FFY 2016 Addressing Safety, Mobility, and Access on Subregional Priority Roadways," February 17, 2016.

[4] According to Smart Growth America, a "complete street" is a street for everyone. Complete streets are designed and operated to enable safe access for all users, including pedestrians, bicyclists, motorists and transit riders of all ages and abilities. They make it easy to cross the street, walk to shops, and bicycle to work.

Granger Boulevard and East Main Street from Main Street to Lincoln Street, which are owned by the City of Marlborough.

Based on MPO staff requests, MassDOT collected extensive traffic volumes, spot speed data, and intersection turning-movement counts (including pedestrian and bicycle movements and the percentages of heavy vehicles) for this study. The data were collected in spring 2016, between April 6 and April 10. Staff also collected various data from the city and MassDOT, including recent transportation and land-use studies, information about adjacent developments, and multiple-year police crash reports.

1.5 STUDY ADVISORY MEETINGS

During the course of the study, MPO staff worked closely with the city and MassDOT (see Appendix A for a list of study advisory members). Two advisory meetings were held to guide and support the study.

In the first meeting (April 13, 2016), MPO staff introduced the study, received input about the corridor's issues and concerns, and coordinated data collection. In the second meeting (October 21, 2016), MPO staff reviewed the findings and proposed improvements with study advisory members. After the meetings, staff continued to receive comments and revised the proposals accordingly.

Chapter 2—Existing Conditions and Issues

2.1 CORRIDOR LOCATION

United States Route 20 is a cross-country highway. In Massachusetts, its easternmost section of 153 miles runs from the New York state border to Route 2 at Kenmore Square in Boston, generally paralleling Interstate 90 (I-90, also known as the Massachusetts Turnpike). It is a major roadway between Worcester and Boston that connects three Interstate Highways (I-495, I-95, and I-90) and directly serves cities, towns and local business areas that the Massachusetts Turnpike bypasses.

Parts of US Route 20, mainly in Worcester and Middlesex Counties, were an alignment of the Boston Post Road, a colonial roadway designated in 1673 for carrying mail between New York City and Boston.[5] Marlborough, as a major town on the roadway, became a prosperous industrial city in the late 19th century and became a home for companies serving the high-technology industry in the late 20th century. The newly developed office and industrial parks and commercial areas are generally located in the corridors of Route 20 and I-290 adjacent to I-495.

Route 20, running east-west through the city, can be regarded as one of Marlborough's most significant roadways, in addition to I-495, I-290, and Route 85. Because of its long stretch, it is locally referred as Route 20 East and Route 20 West, with the city center as its pivot point. The selected study corridor comprises the eastern section from Route 85 (South Bolton Street) east to the Sudbury town line (Figure 1, Study Area Map). It is about 3.6 miles long and includes Granger Boulevard, East Main Street, and Boston Post Road East.

All segments of the corridor are classified as an urban principal arterial. As shown in Figure 1, the corridor connects other major roadways in the city, including another principal arterial (Lincoln Street), two minor arterials (South Bolton Street and Main Street), and several major collectors (Main Street, Stevens Street, Curtis Avenue, Hosmer Street, Concord Road, Farm Road, Wilson Street, Wayside Inn Road, and Hager Street).

2.2 TRANSIT SERVICE

MetroWest Regional Transit Authority (MWRTA) provides bus service in the MetroWest subregion covering the area from Solomon Pond Mall in Marlborough to Woodland Station in Newton. MWRTA Route 7C serves the area in

[5] S.H. Holbrook, *The Old Post Road: The story of Boston Post Road*, McGraw-Hill, 1962.

Marlborough from Solomon Pond Mall to Wayside Inn Store/Hager Street, running mostly along Route 20.

Figure 2 shows that MWTRA Route 7C covers the entire study corridor with five major stops: Post Road Shopping Center, Farm Road, Wilson Road, Target, and Wayside Inn Store. In addition to the major stops, MWTRA uses a flag-down system that allows buses to stop anywhere along their routes to pick up passengers, where it is safe to do so.

Route 7C provides eight round trips daily (four in the morning and four in the afternoon) by turning around at Hager Street. The frequency appears to be sufficient, with no overcrowding conditions.

2.3 PEDESTRIAN AND BICYCLE FACILITIES

In addition to transit service, Figure 2 also shows the existing pedestrian and bicycle facilities in the corridor. In general, continuous sidewalks exist on both sides of Grange Boulevard and East Main Street, and discontinuous sidewalks exist mostly on the south side of Boston Post Road. No separate bicycle lanes exist in the entire corridor. Wider roadway shoulders of four-to-six feet exist only in the middle section of Boston Post Road between Concord Road and Farm Road and in the easternmost segment between Raytheon Driveway and Sudbury town line. The next section details the existing conditions of pedestrian and bicycle facilities in different segments of the corridor.

2.4 ROADWAY CONDITIONS AND ADJACENT LAND USES

The roadway conditions and adjacent land uses of the corridor vary considerably in different segments. Based on the different land use characteristics, the corridor may be divided into the five segments described below.

2.4.1 Route 20 from Route 85 to Lincoln Street

This segment is about one-half mile long, including the intersections of Route 20 at Route 85 and at Lincoln Street. Located near the city center, both sides of the segment are thickly settled by single- and multiple-family houses, along with a number of stores and restaurants. The roadway has two different configurations: four travel lanes (two in each direction) on Granger Boulevard and two travel lanes (one in each direction) on East Main Street. Sidewalks, generally about five feet wide, exist on both sides of the entire segment. However, utility poles on East Main Street frequently interrupt the sidewalks. No separate bicycle lanes exist in the segment. Roadway shoulders are narrow (about one foot wide) on Granger Boulevard, and somewhat wider (about two-to-four feet wide) on East Main Street.

There are three signalized intersections in this segment: Route 20 at Route 85 (South Bolton Street), Route 20 at Main Street, and Route 20 at Lincoln Street/Stevens Street. The Lincoln Street/Stevens Street intersection is generally congested during the weekday AM and PM and Saturday noon peak hours.

2.4.2 Route 20 from Lincoln Street to Concord Road

This segment is about one-half mile long and includes the Concord Road intersection. It is the busiest segment in the entire study corridor. It is a four-lane roadway with five-foot sidewalks on both sides and almost no shoulders (less than one foot wide). Except for the section from Lincoln Street to Walnut Street/Clinton Street that is settled by single- and multiple-family houses, the adjacent land uses of this roadway segment are mainly businesses, including local and franchised stores and shops, such as CVS Pharmacy, Dunkin' Donuts, Bank of America, and Midas, In addition, a large-scale shopping center, Post Road Plaza, is located on the north side of Route 20 just across from Curtis Avenue. Major businesses in the plaza include Price Chopper, Marshalls, Ocean State Job Lot, Savers Community Donation Center, and AutoZone.

There are two signalized intersections in this segment: Route 20 at Curtis Avenue/Post Road Plaza Driveway and Route 20 at Hosmer Street. The intersection of Route 20 at Concord Road is currently unsignalized. The stop-controlled Concord Road approach is usually congested during weekday AM and PM and Saturday noon peak hours. No crosswalks exist at the intersection.

2.4.3 Route 20 from Concord Road to Farm Road

This segment is about 1.3 miles long and includes the Farm Road intersection. It is a two-lane roadway (one lane in each direction) with inconsistent sidewalks and shoulders. Sidewalks exist on the south side of the segment from Concord Road to Phelps Street and on both sides near the Farm Road intersection. No sidewalks exist in the rest of the segment. Roadway shoulders are generally two feet wide, except the section from Phelps Street to slightly east of Village Drive, which has four- to six-foot shoulders on both sides.

The entire segment is zoned for business. There are continuous strip malls, driveway-access shopping centers, and individual roadside businesses on both sides of the roadway, with medium- and large-scale housing developments scattered in between. Consequently, there is intensive vehicle-turning activity on this two-lane roadway, causing traffic congestion, and potential crashes between turning and through vehicles.

The traffic signal at the middle of the segment operates only when fire engines exit or enter the adjacent fire station. Route 20 at Farm Road is a fully functional signalized intersection, with pedestrian crosswalks and signals. No crosswalks exist at other locations in the segment.

2.4.4 Route 20 from Farm Road to Raytheon Driveway

This segment is about 0.8 miles long and includes the Raytheon Driveway intersection. It is a four-lane roadway (two lanes in each direction) with five-foot sidewalks on both sides, except the north side of the section from Old Boston Post Road to Raytheon Driveway. No separate bicycle lanes exist and shoulders are generally narrow (two feet or less).

This segment is a business district. In addition to roadside businesses, strip malls and apartment buildings are also on the roadway. A conglomerate of stores and shops, including Target and Home Depot, occupy the south side of a major section of this segment. Although traffic from the Target and Home Depot mainly uses the signalized Dicenzo Boulevard intersection, the roadway still has considerable turning vehicles between Dicenzo Boulevard and Raytheon Driveway. As a four-lane roadway with moderate traffic volumes, vehicle travel speeds in this segment generally are higher than in other segments.

There are two signalized intersections in this segment: Route 20 at Dicenzo Boulevard/Pomphrey Drive and Route 20 at Raytheon Driveway/Wayside Office Driveway. Crosswalks and pedestrian signals exist at the Dicenzo Boulevard intersection, but not at the Raytheon Driveway intersection. No crosswalks exist at other locations in the segment.

2.4.5 Route 20 from Raytheon Driveway to Sudbury Town Line

This segment is about one-half mile long, and surrounded by woods, adjacent to Hager Pond, and less developed than other segments in the corridor. In addition to a few office buildings and houses located near the Raytheon intersection, the roadside plaza that contains the historical Wayside Country Store is the only major development in the segment.

The roadway reduces to two lanes, one in each direction. Sidewalks exist only on the south side for a short section between Raytheon Driveway and Hager Pond. No sidewalks exist in the rest of the segment. Roadway shoulders exist on both sides. They generally are two feet wide in the section west of Hager Pond and four-to-six feet wide in the rest of the segment.

The intersection of Route 20 at Wayside Inn Road/Hager Street is signalized. The signal equipment is outdated and the signal indications are difficult to observe from both approaches of Route 20 (because of the intersection's vertical curve location and wooded surroundings). The jug-handle slip ramp that provides eastbound left turns from Route 20 to Wayside Inn Road could confuse drivers. No crosswalks exist at the intersection or any other locations in the segment.

2.5 ISSUES AND CONCERNS

In the first study advisory meeting, representatives from the city and MassDOT shared their views about the corridor, which are summarized below.

- High crash rate in corridor
- Large number of crashes at the Curtis Avenue, Hosmer Street, and Concord Road intersections
- High travel speeds in most sections of the corridor
- Limited pedestrian access across Route 20
- Insufficient and substandard sidewalks
- Lack of bicycle accommodations
- Traffic congestion during PM and Saturday peak hours at major intersections
- Frequent driveways and curb cuts causing traffic congestion and potential crashes

The advisory members also discussed concerns about specific locations in the corridor, where analyses identified safety and operational problems, which along with the proposed improvements, are summarized by location in Chapter 5.

Chapter 3—Roadway Operations Analysis

3.1 DAILY TRAFFIC VOLUMES

The most fundamental data for analyzing traffic intensity and patterns in a roadway corridor are daily traffic volumes. MassDOT collected traffic volumes at ten locations: seven in the corridor and three on adjacent streets.

Figure 3 shows daily traffic volumes at the ten locations based on Automatic Traffic Recorder (ATR) counts collected in the weekday period of April 6 (Wednesday) to 8 (Friday), 2016. The numbers in the graphic represent average daily directional volumes. The two tables in the graphic further summarize the data by count locations, directional split, combined volume of both directions, and adjusted annual average daily traffic (AADT).

The April counts show that traffic in most segments of the corridor is generally split evenly, by approximately 50 percent in each direction, except in the westernmost and easternmost segments. The segment of Route 20 between Main Street and Lincoln Street (Location 1) carried more daily traffic in the eastbound direction (54 percent) than the westbound direction (46 percent). The segment of Route 20 east of Wayside Inn Road/Hager Street also carried more daily traffic in the eastbound direction (53 percent) than did the westbound direction (47percent).

The counts also show that the western section of Route 20 (East Main Street) carried daily traffic in two different magnitudes: 1) about 14,000 vehicles in the segment between Main Street and Lincoln Street (Location 1); and 2) more than 28,000 vehicles in the segment between Lincoln Street and Concord Road (Location 2), which is the busiest section of the corridor. The middle and eastern sections (Boston Post Road East) carried approximately 19,000 to 22,000 vehicles per day.

Traffic volume in April is somewhat higher than the annual average. Adjusted by the seasonal factors, AADT data estimate that the busiest section of East Main Street between Lincoln Street and Concord Road carries about 26,500 vehicles and most sections of the corridor (Boston Post Road East) carry about 18,000 to 21,000 vehicles on an average day.

3.2 INTERSECTION TRAFFIC, PEDESTRIAN, AND BICYCLE VOLUMES

In addition to daily traffic counts, MassDOT collected turning movement counts at major intersections in the study corridor, including vehicle movements (by vehicle types), bicycle movements, and pedestrian crossings. They were collected during

the morning peak period (7:00–9:00 AM) and the evening peak period (4:00–6:00 PM) on Thursday April 7, 2016, and during the midday peak period (12:00 PM–2:00 PM) on Saturday April 9, 2016. Staff then identified the peak hour in each of the peak periods for various traffic operational analyses.

Figure 4 shows the weekday peak-hour traffic and pedestrian volumes at major intersections in the corridor. Entry volumes at these intersections vary from 1,300 vehicles per hour at the intersection of Route 20 at Main Street to nearly 2,700 vehicles per peak hour at the intersection of Route 20 at Curtis Avenue/Post Road Plaza Driveway. They are generally somewhat higher in the evening than in the morning. Locations in the corridor with noticeably high entry volumes include the intersections of Route 20 at South Bolton Street, Lincoln Street, Curtis Avenue, Hosmer Street, Concord Road, Farm Road, and Dicenzo Boulevard.

In terms of pedestrian volumes, the intersections on East Main Street carried about five-to-ten pedestrians per peak hour, except the Main Street intersection that carried about 10-to-15 pedestrians per peak hour. The intersections on Boston Post Road East carried about five-or-less pedestrians per peak hour. Only two-or-less bicycles per peak hour were observed at all the count locations. Note that pedestrians and cyclists generally are less active in April when the weather is still cold, especially cyclists. The corridor's pedestrian and bicycle volumes presumably would be higher in the months from May to October.

Figure 5 shows the Saturday peak-hour traffic and pedestrian volumes at selected intersections in the business districts of the corridor. Most of the selected intersections carried about five-to-ten percent more traffic during the Saturday peak-hour than in the weekday PM peak hour, except the intersections of Route 20 at Lincoln Street and at Farm Road (which had no obvious difference between the two time periods). Most of the selected intersections also carried slightly higher pedestrian and bicycle volumes in the Saturday peak-hour than in the weekday PM peak hour.

It is essential to examine the amount of heavy-vehicle traffic in a study corridor, as an unusually high percentage of heavy vehicles (trucks and buses) may seriously affect roadway operations. The weekday turning movement counts by vehicle type indicate that, on average, most intersections in the study corridor carried about three-to-five percent of heavy-vehicle traffic in the AM peak hour and about one-to-two percent of heavy-vehicle traffic in the PM peak hour. The heavy-vehicle percentage of the Saturday peak hour is similar to that of the PM peak hour at all the selected intersections. These percentages are considered normal and would not seriously affect roadway operations.

3.3 INTERSECTION CAPACITY ANALYSES

Based on the turning movement counts, MPO staff constructed peak-hour traffic models for the entire corridor and conducted capacity analyses for major intersections by using the Synchro traffic analysis and simulation program.[6] The model set consists of weekday AM, weekday PM, and Saturday midday peak-hour models, with scenarios under existing conditions or various proposed improvement alternatives.

Figure 6 shows weekday AM and PM peak-hour capacity analyses for major intersections in the corridor, under existing conditions. The graphic includes a table of intersection level-of-service (LOS) criteria based on average intersection control delay defined by the Highway Capacity Manual (HCM).[7] LOS is a qualitative measure used to relate the quality of traffic service. The HCM defines LOS—using a qualitative scale from A to F—for signalized and unsignalized intersections as a function of the average vehicle control delay. For the intersections in a metropolitan urban area, LOS C or better is considered desirable; LOS E or better is considered acceptable; and LOS F is considered undesirable.

Overall, all the signalized intersections generally operate at LOS C or better in both peak AM and PM hours, except the intersection of Route 20 at Farm Road/Wilson Street. The Farm Road intersection is evaluated to operate at LOS D, with an average delay of 37 seconds in the AM peak hour and 43 seconds in the PM peak hour. Details of the analyses for major intersections in the Synchro 2016 AM and PM models are included in Appendices B and C.

Although all the intersections are evaluated as desirable or acceptable individually, field observations (and the synchro queue estimations) indicate that the closely located intersections at Curtis Avenue, Hosmer Street, and Concord at times could have traffic queues on its Route 20 approaches extending near the upstream intersections.

At the unsignalized intersection of Route 20 at Concord Road, the southbound approach is estimated to operate at LOS F with average delay more than two minutes in the AM and PM peak hours. Staff conducted a preliminary analysis of

[6] Synchro Version 9.0 was used for the analyses. This software is 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.

[7] HCM 2010, Transportation Research Board of the National Academies, Washington D. C.

the need for a traffic signal at the intersection.[8] The analysis found that a traffic signal is justified at the intersection, as Warrant 1 (Eight-Hour Vehicular Volume), Warrant 2 (Four-Hour Vehicular Volume), and Warrant 7 (Crash Experience) are satisfied based on the April counts and recent crash data. Appendix D contains details of the preliminary analysis.

Figure 7 shows Saturday midday peak-hour capacity analyses at selected intersections in the corridor, under existing conditions. The Lincoln Street, Hosmer Street, and Dicenzo Boulevard intersections operate at LOS C with an average delay of about half a minute per vehicle and the Curtis Avenue and Farm Road intersections operate at LOS D with an average delay of about 40 seconds per vehicle. Because of shopping activities at Post Road Plaza, the Curtis Avenue intersection is more congested than are others, with a slight increase in delays on all approaches in the Saturday peak hour compared to the weekday PM peak hour.

The unsignalized intersection of Route 20 at Concord Road is also somewhat more congested on Saturday than in the weekday peak hour, with increased delays on the southbound approach. On Saturdays, Concord Road carries not only shopping trips but also recreational trips to Ghiloni Recreation Area and Marlborough State Forest. Details of the analyses for major intersections in the Synchro 2016 Saturday model are included in Appendix E.

3.4 ROADWAY TRAVEL SPEEDS

The area's residents are concerned about the high travel speeds in the corridor (mainly on Boston Post Road East). In order to understand these fast driving patterns, MPO staff requested MassDOT to help collect spot speeds during the period when automatic traffic counts were being conducted during April 6-to-8, 2016.

Figure 8 shows the existing speed regulations and estimated 85th percentile at selected locations in the corridor, based on spot speed counts collected from automatic traffic recorders. The 85th percentile 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.

Currently, regulated travel speeds in the corridor are:

- Granger Boulevard from Route 85 to Main Street: 30 miles per hour eastbound and 25 mph westbound

[8] Chapter 4C Traffic Control Signal Needs Studies, *Manual on Uniform Traffic Control Devices*, 2009 Edition with Revisions 1 and 2, Federal Highway Administration, US Department of Transportation, May 2012.

- East Main Street from Main Street to the east of Stevens Street: 30 mph eastbound and 25 mph westbound
- East Main Street from the east of Lincoln Street to the west of Concord Road: 30 mph eastbound and 35 mph westbound
- East Main Street from the east of Lincoln Street to the west of Concord Road: 30 mph eastbound and 35 mph westbound
- East Main Street/Boston Post Road near Concord Road: 30 mph eastbound and 25 mph westbound
- Boston Post Road from the east of Concord Road to the east of Village Drive: 30 mph eastbound and 40 mph westbound
- Boston Post Road from the east of Village Drive to the Sudbury town line: 40 mph both eastbound and westbound

The estimated 85th percentile speeds at the four selected locations on Boston post Road East generally are below or slightly above their regulated speeds, except the location at the middle point of both ends of Dicenzo Boulevard. The estimated 85th percentile speeds at this location (four-lane roadway with several adjacent businesses) are about three-to-five mph higher than the regulated speeds in both directions.

MassDOT procedures for establishing speed regulations require that at speed observation locations, the established safe speed shall not be more than seven mph below the 85th percentile speed, and not higher than the 95th percentile speed.[9]

The westbound 85th percentile speed at the location just west of Village Drive is about nine mph lower than the regulated 40 mph. The entire section of Boston Post Road East between Concord Road and Farm Road is a two-lane roadway with a number of horizontal and vertical curves, with continuous commercial and residential developments. The section may be more suitable to be regulated at 30 mph in both directions.[10] Many segments in the corridor (mainly on Granger Boulevard and East Main Street) contain different directional speed regulations. In the long term, these and their suitable speed regulations should be examined with further engineering studies.

[9] *Procedures for Speed Zoning on State and Municipal Roadways*, MassDOT Highway Division, May 2012.

[10] It would require a further engineering study to support the modification. To establish or modify speed controls, MassDOT requires speed data collected by using radar gun or laser gun at critical locations not to exceed 0.25 miles, in addition to vehicle trial runs in the study area.

Chapter 4—Crash Data Analysis

4.1 CRASH LOCATIONS AND CRASH CLUSTERS

Crash data are an essential source for identifying safety and operational problems in a study area. Analyzing crash locations, collision types, time-of-day, roadway conditions, and other factors also help to develop improvement strategies. For this study, staff collected two datasets:

- 2009–13 MassDOT Registry of Motor Vehicles (RMV) Division Crash Data
- Recent five-year (January 2011 to December 2015) crash reports from Marlborough Police Department (MPD)

Staff used the MassDOT data to examine crash locations and crash rates and the police crash reports to construct collision diagrams to analyze safety and operational problems at the major intersections and in different segments of the corridor.

Figure 9 shows the crash locations and crash clusters in the corridor, based on the MassDOT data. The five-year data show that crashes occurred at different locations of the corridor almost continuously (without a significant roadway gap between crashes) and some locations had a large number of crashes clustered together.

Based on 2011–13 MassDOT Crash Cluster Data, the figure shows four noticeable crash clusters.[11] The most significant cluster is at the Route 20 segment between Curtis Avenue and Hosmer Street (including the Curtis Avenue intersection), where 184 crashes occurred in the three-year period. It is ranked as the seven in the 2011–13 statewide top 200 crash locations, with an estimated 220 Equivalent Property Damage Only (EPDO) crashes.[12]

However, based on staff's review of the MPD crash reports, its ranking might have been overestimated, as a large number of crashes appear to have occurred in the parking areas of Post Road Plaza and not on Route 20. Staff identified 137 crashes in the same segment from the MPD 2011–13 data and further found that

[11] Using a 25-meter (82-foot) radius from each crash locations, a crash cluster is identified by two or more crashes overlapping one another.

[12] MassDOT uses approximated EPDO crashes to rank the statewide top 200 locations. In the estimation, fatal crashes are weighted by 10, injury crashes are weighted by 5, and property damage only and unknown crashes are not weighted.

85 of them (more than 60 percent) actually occurred in the large and poorly defined parking areas of Post Road Plaza.[13]

The other three crash cluster locations are MassDOT Highway Safety Improvement Program (HSIP) eligible locations, which means that they are ranked in the top-five percent of the Boston Region MPO crash locations, based on 2011–13 MassDOT Crash Cluster Data. The three locations are:

- Route 20 between Concord Road and Peters Avenue: 43 EPDO crashes
- Route 20 near the Lincoln Street Intersection: 42 EPDO crashes
- Route 20 between Victoria Lane and Village Drive: 42 EPDO crashes

In addition, a large number of crash clusters are identified in the corridor from the MassDOT 2011–13 data, which indicate the intensity and proximity of the crashes in the entire corridor.

4.2 CRASH RATES

Staff estimated that the entire 3.6-mile corridor has a crash rate of 7.30 crashes per million vehicle miles traveled (MVMT), based on the 2009–13 MassDOT data and an average of the recently collected traffic counts. This crash rate is much higher than the statewide average for urban principal arterials (3.49 crashes per MVMT, updated January 2016 based on 2013 crash data).

As mentioned in Chapter 2, the corridor contains segments with different roadway layouts and land uses. Staff estimated the corridor crash rates by five segments, each with similar layouts and land use characteristics:

- Route 20 from Route 85 to Lincoln Street (including both the Route 85 and Lincoln intersections): 8.09 crashes per MVMT
- Route 20 from Lincoln Street to Concord Road (including the Concord Road intersection): 12.05 crashes per MVMT
- Route 20 from Concord Road to Farm Road (including the Farm Road intersection): 6.99 crashes per MVMT
- Route 20 from Farm Road to Raytheon Driveway (including the Raytheon Driveway intersection): 4.69 crashes per MVMT
- Route 20 from Raytheon Driveway to Sudbury town line: 4.04 crashes per MVMT

[13] As the crash locations usually are coded by street names or the nearest intersection, the parking-lot crash can only be identified from crash reports that contain detailed descriptions of how and where crashes occurred.

These all are higher than the state average crate rate. The segment of Route 20 in the busy business district on East Main Street has a crash rate of more than three times the statewide average. See Appendix F for the corridor and segment crash rate worksheets.

Staff also estimated the crash rates at major intersections of the corridor, based on the 2011–15 MPD data and the intersection traffic counts, which are summarized below.

- Route 20 at Route 85: 1.33 crashes per million entering vehicles (MEV)
- Route 20 at Main Street: 0.75 crashes per MEV
- Route 20 at Lincoln Street: 0.87 crashes per MEV
- Route 20 at Curtis Avenue: 1.39 crashes per MEV
- Route 20 at Hosmer Street: 0.91 crashes per MEV
- Route 20 at Concord Road: 1.17 crashes per MEV
- Route 20 at Farm Road: 1.03 crashes per MEV
- Route 20 at Dicenzo Boulevard: 0.54 crashes per MEV
- Route 20 at Raytheon Driveway: 0.29 crashes per MEV
- Route 20 at Wayside Inn Road: 0.84 crashes per MEV

The average crash rate for signalized intersections in MassDOT District 3 is 0.90 crashes per MEV (updated February 2016 based on 2015 crash data). Three signalized intersections, Route 20 at Route 85, Route 20 at Curtis Avenue, and Route 20 at Farm Road, all have a higher-than-average crash rate. Two intersections, Route 20 at Lincoln Street and Route 20 at Hosmer Street, have a crash rate about the same as the average.

The average rate for unsignalized intersections in MassDOT District 3 is 0.65 crashes per MEV. The crash rate at the Concord Road intersection is nearly twice that of the District 3 average. Appendix G contains worksheets for all the intersection crash rates.

4.3 PEDESTRIAN AND BICYCLE CRASHES

Figure 9 shows the pedestrian and bicycle crashes in the corridor, based on 2009–13 MassDOT Crash Data.[14] In addition, staff used the 2011–15 MPD crash reports to identify more of these crash locations. In total, 12 pedestrian crashes

[14] In this study, the term “pedestrian crashes” refers to those that involve at least one vehicle and one pedestrian; “bicycle crashes” refers to crashes that involve at least one vehicle and one bicycle. No crashes between at least one bicycle and one pedestrian were identified in the available data.

and nine bicycle crashes occurred in the corridor in the seven-year period. The locations, dates, times, and noticeable conditions of these crashes are summarized below.

- Route 20 at Route 85: two pedestrian crashes (1/4/2012, 5:33 PM and 5/12/2015, 4:38 PM), both on Route 20 west of the intersection and involving a crossing pedestrian and an eastbound vehicle
- Route 20 at Main Street: one pedestrian crash (7/29/2010, 4:11 PM), exact location not clear (could have been one of the adjacent parking lots); one bicycle crash (5/12/2015, 4:38 PM) at the crosswalk on the Main Street southbound approach
- Route 20 at Lincoln Street: one bicycle crash (10/17/2010, 4:22 PM) at the Route 20 eastbound approach
- Route 20 between Lincoln Street and Curtis Avenue: one pedestrian crash (9/12/2009, 3:50 PM, rain) involving a Route 20 westbound vehicle
- Route 20 at Curtis Avenue: three pedestrian crashes (9/28/2010, 5:39 PM; 4/30/2013, 9:07 PM; 11/14/2013, 8:48 PM), the first crash location not identifiable, the second occurring north of the intersection, and the last occurring in the shopping plaza parking lot; three bicycle crashes (5/20/2014, 4:21 PM; 7/28/2015, 7:25 PM; 8/13/2015, 8:08 PM), all on the crosswalks of the intersection
- Route 20 at Hosmer Street: one pedestrian crash (9/30/2014, 5:53 PM, rain conditions) at the Route 20 eastbound approach
- Route 20 at Farm Road: three pedestrian crashes (12/31/2010, 5:59 PM; 1/27/2011, 4:14 PM; 10/21/2011, 2:48 PM), the first crash involving a westbound vehicle but exact location not identifiable, the second occurring at the crosswalk on the westbound approach, the last occurring in the nearby Walgreens parking lot
- Route 20 between Dicenzo Boulevard and Raytheon Driveway: one pedestrian crash (8/3/2013, 1:23 PM) involving a Route 20 westbound vehicle and exact location not clear; one bicycle crash (8/8/2014, 11:59 AM) involving a bicycle traveling east on the north-side sidewalk and a vehicle leaving the parking lot of an adjacent business
- Route 20 at Wayside Inn Road: two bicycle crashes (1/8/2010, 12:24 PM; 9/7/2015, 10:01 AM), the first crash's exact location not clear, the second occurring at the intersection and involving a bicycle crossing Route 20 and an eastbound vehicle

Residents in the areas adjacent to Route 20 (Boston Post Road East) are concerned about potential vehicle crashes in winter, when snow is piled on sidewalks or roadway shoulders and pedestrians are forced to walk in the road. The pedestrian crashes collected in this study did not clearly indicate any such incidents.

4.4 COLLISION DIAGRAMS AND CRASH STATISTICS

To investigate safety and operational problems further, MPO staff constructed collision diagrams for the entire corridor by major intersections and in-between roadway segments, based on recent five-year crash reports provided by Marlborough Police Department. The crash reports, containing descriptions of how and where those crashes occurred, are useful in constructing the collision diagram.

Appendix H presents the collision diagrams for different locations in the corridor. It also contains a series of tables summarizing the crash data used for the different locations. The summary statistics include crash severity (property damage only, non-fatal injury, fatality, unknown), collision type (single-vehicle, rear-end, angle, sideswipe, head-on, rear-to-rear, unknown), pedestrian or bicycle involvement, time of day, pavement conditions, and light conditions.

The collision diagrams are useful in identifying safety and operational problems at major intersections or roadway segments in the corridor. The identified problems are included in the issues and concerns portion for proposed improvements in the next chapter.

Chapter 5—Proposed Improvements

Based on the above analyses, MPO staff developed a series of short- and long-term improvements to address safety and operational problems. Short-term improvements generally are implementable within two years at relatively low cost. Long-term improvements are more complicated and cover larger areas, which would require intensive planning, design, and funding. As the corridor covers an extensive length of roadways with different land use characteristics, we describe the proposed improvements in the five segments below.

5.1 ROUTE 20 FROM ROUTE 85 TO LINCOLN STREET

Table 1 lists the proposed short- and long-term improvements for the segment of Route 20 from Route 85 (South Bolton Street) to Lincoln Street, along with the area's issues and concerns; they are arranged according to general roadway section, and by specific location, from west to east.

Major issues and concerns in the segment include:

- Four-lane low-volume section (Granger Boulevard) allowing high-speed traffic in residential area
- Wide-turning radii at street corners on Granger Boulevard, creating long pedestrian crossing distance and allowing high-speed turning traffic
- Two-lane section (East Main Street) in mixed residential/commercial area, with limited right-of-way for expansion
- Sidewalks on East Main Street frequently narrowed by utility poles
- Lack of bicycle accommodations
- Large number of crashes (59 in five years) at the Route 85 intersection, with large proportion of left-turn crashes
- Large intersection layout and long crossing distance with insufficient pedestrian signal time at the Main Street intersection
- Pavement rutting and cracking

Proposed short-term improvements in the segment include:

- Consider restriping Granger Boulevard to two-lane traffic operation (one lane each direction) with a center median/left-turn lane and six-foot shoulders for bicycle accommodation on both sides
- Maintain East Main Street two-lane traffic operation with four-foot shoulders for bicycle accommodation

- Increase signal visibility (by installing signal backplates with retroreflective borders)
- Continue monitoring left-turn crash conditions and consider limiting left-turn operations to only protected phases at the Route 85 intersection
- Increase the exclusive pedestrian signal time from 21 to 31 seconds at the Main Street intersection
- Consider changing the eastbound (Granger Boulevard) approach to a left-turn-only lane and a through/right-turn shared lane[15]

Proposed long-term improvements in the segment include (Figure 10):

- Reconstruct Granger Boulevard to two-lane traffic operation (one lane each direction) with a center median/left-turn lane and six-foot shoulders for bicycle accommodation on both sides
- Reduce turning radii at street corners on Granger Boulevard
- Relocate utility poles or widen sidewalks on East Main Street, within available right-of-way
- Add a southbound left-turn lane, by removing part of the existing traffic median, at the Route 85 intersection, and retime traffic signal
- Reconstruct the Main Street intersection with a smaller layout by extending the north-side sidewalk on East Main Street, channelizing the Brown Street approach for right turns only and replacing the traffic signal with a stop control, adding a crosswalk on the East Main Street westbound approach, and relocating the southbound crosswalk
- Upgrade the entire signal system with mast arms, new signal indications, and count-down and accessible pedestrian signals at the Main Street intersection
- Patch/repave/seal the rutting and cracking pavements

5.2 ROUTE 20 FROM LINCOLN STREET TO CONCORD ROAD

Table 2 lists the proposed short- and long-term improvements for the segment of Route 20 from Lincoln Street to Concord Road. Major issues and concerns in the segment include:

- Four-lane high-volume section in highly developed residential/commercial area

[15] The city applied the change in September 2016. Staff compared the change with the previous layout (a left-turn/through shared lane and a right-turn only lane) and found that it would maintain at the same level of service for the approach, with marginal increase of delay for its through movements and right turns. However, it would potentially reduce conflicts between its left turns and through movements from both Route 20 approaches.

- High crash rates in sections between intersections, especially in the section between Curtis Avenue and Hosmer Street (one of the State's 2011–13 top-200 crash clusters)
- Large number of crashes at major intersections (at Curtis Avenue, Hosmer Street, and Concord Road)
- Two pedestrian and four bicycle crashes in the segment in the past five years
- Insufficient pedestrian crossing facilities at the Curtis Avenue and at Concord Road intersections
- Large number of crashes caused by vehicles turning to and from the businesses on the south side
- Large number of crashes occurring in the parking areas of Post Road Shopping Center (128 in the past five years)
- Traffic congestion at major intersections during PM and Saturday peak hours
- Lack of bicycle accommodations

Proposed short-term improvements in the segment include:

- Increase signal visibility (by installing signal backplates with retroreflective borders)
- Increase the pedestrian signal time (concurrent with southbound traffic) from 16 to 21 seconds and retime the signal at the Curtis Avenue/Post Road Plaza intersection
- Install MUTCD Turning Vehicles Yield to Pedestrians (R10-15) signs on both approaches of Route 20 at the Curtis Avenue/Post Road Plaza intersection
- Consider designating the outside lanes of the roadway segment as a share bicycle/vehicle lane
- Consider installing lane-designation sign on the eastbound approach of the Concord Road intersection

Proposed long-term improvements in the segment include (Figures 11 and 12):

- Maintain the existing four-lane configuration (two lanes in each direction), as the segment carries daily traffic of more than 26,000 vehicles
- Consider installing sharrows (shared-road markings) on the rightmost lane in both directions to accommodate bicycles[16]

[16] Separated bicycle accommodations would require at least 5-foot shoulders, which are not applicable under the adjacent developments and existing right-of-way constraints.

- Consider reconstructing the section between Hosmer Street and Concord Road by providing a two-lane traffic operation in the westbound direction
- Modify the Curtis Avenue intersection and upgrade its traffic signal system with pedestrian signal indications for all crosswalks[17]
- Reconstruct the Hosmer Street intersection and upgrade its traffic signal system
- Reconstruct and signalize the Concord Road intersection, with crosswalks and pedestrian signals
- Coordinate traffic signals of the three adjacent intersections at Curtis Avenue, Hosmer Street, and Concord Road
- Consider providing a section of two-way left-turn lane between Curtis Avenue and Hosmer Street, for vehicles to access the adjacent Dunkin' Donuts and Digital Federal Credit Union[18]
- Consider improving access management and control during prospective business redevelopments on the south side
- Consider redesigning the parking and traffic circulation system in Post Road Shopping Center

5.3 ROUTE 20 FROM CONCORD ROAD TO FARM ROAD

Table 3 lists the proposed short- and long-term improvements for the segment of Route 20 from Concord Road to Farm Road. Major issues and concerns in the segment include:

- Two-lane roadway (one lane in each direction) in mixed residential/commercial area, with extensive traffic entering and exiting from adjacent developments
- Very high corridor crash rate
- Large number of crashes at the Farm Road intersection
- Noticeable number of crashes at the westbound lane-drop location near the Burger King restaurant
- Unsafe pedestrian crossings on Route 20
- Traffic congestion during PM peak hours
- Discontinuous sidewalks

[17] The intersection's pedestrian signal operation, concurrent or exclusive, should be studied and evaluated further, at the design stage. Either operation can operate under the proposed signal coordination. Figure 11 shows the intersection layout under the concurrent pedestrian signal operation with three crosswalks. If the exclusive phasing is chosen at the design stage, a crosswalk should also be installed on the Route 20 westbound approach.

[18] It also requires an opening to connect the parking lots of the two adjacent businesses.

- Lack of bicycle accommodations
- Horizontal and vertical curves with overgrown vegetation

Proposed short-term improvements in the segment include:

- Consider changing the existing 40-mph zone to 35 mph (which would require a further engineering study)
- At the lane-drop location, replace the existing Road Narrow (W5-1) with Land Ends (W4-2) warning sign to clearly inform the outside-lane travelers to slow down and yield
- Retime signal at the Farm Road intersection
- Trim overgrown vegetation in both directions

Proposed long-term improvements in the segment include (Figures 12, 13, 14, and 15):

- Widen the roadway to a three-lane cross-section: two travel lanes (one in each direction) and a center median/left-turn lane, with six-foot bicycle lanes (also as roadway shoulders for emergency stopping) on both sides. The center medians may be raised or flush (paint-striped or concrete-stamped).[19]
- Install continuous five-foot sidewalks on both sides of the roadway.
- Consolidate driveways/curb cuts wherever applicable.
- Further study and evaluate the intersection at Marlborough Fire Station #3 with an emergency hybrid beacon that can serve both emergency vehicles and pedestrian crossings.

5.4 ROUTE 20 FROM FARM ROAD TO RAYTHEON DRIVEWAY

Table 4 lists the proposed short- and long-term improvements for the segment of Route 20 from Farm Road to Raytheon Driveway. Major issues and concerns in the segment include:

- Four-lane roadway (two lanes in each direction) in mostly commercial/office area
- High corridor crash rate
- Noticeable number of crashes in the segment between the two ends of Dicenzo Boulevard

[19] At the design stage, the form of the center medians should be further examined. Raised medians are safer and more comfortable as pedestrian crossing medians than are flush medians. MassDOT District 3 has concerns about snow removal difficulties (and damages) that raised medians may cause.

- Traffic congestion at the Dicenzo Boulevard/Pomphrey Drive intersection during PM and Saturday peak hours
- Discontinuous sidewalks on the north side
- Lack of bicycle accommodations

Proposed short-term improvements in the segment include:

- Consider restriping the four travel lanes between Farm Road and Dicenzo Boulevard with a reduced width of 11 feet in order to include a five-foot shoulder for bicycle accommodation in both directions
- Consider restriping the section east of Dicenzo Boulevard from four to three lanes: two travel lanes (one in each direction) and a center median/left-turn lane, with six-foot shoulders on both sides for bicycle accommodation
- Retime the traffic signal at major intersections

Proposed long-term improvements in the segment include (Figures 16, 17, and 18):

- Reconstruct the section east of Dicenzo Boulevard to three lanes: two travel lanes and a center median/left-turn lane, with six-foot bicycle lanes on both sides
- Install continuous five-foot sidewalks on the north side from Dicenzo Boulevard to Raytheon Driveway
- Change the speed limit of the entire section from the existing 40 mph to 35 mph after the roadway reconfiguration
- Consolidate driveways/curb cuts wherever applicable

5.5 ROUTE 20 FROM RAYTHEON DRIVEWAY TO SUDBURY TOWN LINE

Table 5 lists the proposed short- and long-term improvements for the segment of Route 20 from Raytheon Driveway to Sudbury town line. Major issues and concerns in the segment include:

- Two-lane roadway (one lane in each direction) in wooded/water area, allowing high travel speeds with unsafe access to the few roadside commercial and office developments
- Noticeable number of crashes in the segment adjacent to the Wayside Inn Store commercial development
- High proportion of crashes (30 percent) involving personal injuries at the Wayside Inn Road intersection, possibly because of high travel speeds on Route 20

- No sidewalks on both sides of the roadway
- Lack of bicycle accommodations
- Pavement rutting and cracking

Proposed short-term improvements in the segment include:

- Consider increasing the size of signal lens/heads and installing signal backplates with retroreflective borders at the Wayside Inn Road intersection (requiring further examination of the existing mast arms' capacity)
- Consider increasing the all-red time from one to two seconds (total clearance time six seconds) for the Route 20 signal phase
- Install MUTCD Traffic Signal Ahead (W3-3) warning sign about 500 feet before the intersection on the Route 20 westbound approach
- Patch/repave/seal the rutting and cracking pavements

Proposed long-term improvements in the segment include (Figures 18 and 19):

- Reconstruct the entire section to three lanes: two travel lanes (one in each direction) and a center median/left-turn lane, with six-foot bicycle lanes on both sides (Figure 19)
- Consider the wetland impact of the roadway adjacent to Hager Pond, where a two-lane configuration may be feasible only with five-foot shoulders on both sides for bicycle accommodation (Figure 18)
- Install continuous five-foot sidewalks on both sides of the roadway
- Change the speed limit of the entire section from the existing 40 mph to 35 mph after the roadway reconfiguration
- Reconstruct the Wayside Inn Road intersection with an exclusive left-turn lane on both approaches of Route 20
- Modify the jug-handle slip ramp to be right-turn only
- Install new traffic signal system with pedestrian signals and crosswalks on all approaches of the Wayside Inn Road intersection

5.6 PROPOSED LONG-TERM IMPROVEMENTS UNDER PROJECTED FUTURE-YEAR (2040) TRAFFIC CONDITIONS

The most significant long-term improvement recommendation in the corridor, except in the section from Post Road Plaza to Concord Road, is changing to a three-lane roadway reconfiguration from the existing two- or four-lane roadways. The configuration would consist of two travel lanes (one in each direction) plus a

center lane as traffic median, or for left turns, and bicycle lanes and sidewalks on both sides.

Such three-lane reconfigurations have been applied in a number of US cities with positive results toward improving safety for all modes of travel. The proposed three-lane segments are suitable for such reconfiguration, as recent counts indicate that they generally carry average daily traffic of 20,000 vehicles or fewer.[20]

Similar to the base-year models, staff constructed future-year 2040 traffic models for the entire corridor based on the roadway layouts with the proposed long-term improvements. Staff conducted future-year traffic analyses based on traffic growth projections from the transportation-planning model recently developed for the MPO's Long-Range Transportation Plan.[21] The analyses indicate that the proposed long-term improvements would operate adequately under the future-year traffic conditions.

Figures 20 and 21 show the intersection capacity of major intersections in the corridor under the projected 2040 traffic conditions for the weekday peak hours and Saturday midday peak hour. With the proposed long-term improvements, all intersections would operate at a desirable LOS C or better during the weekday and Saturday peak hours, except the Lincoln Street intersection (acceptable LOS D in the weekday AM peak hour) and the Farm Road intersection (acceptable LOS D in the weekday AM and Saturday midday peak hours). Synchro capacity analysis reports of the major intersections for the future-year weekday AM, weekday PM, and Saturday midday peak hour conditions are included in Appendices I, J, and K.

[20] *Road Diet Information Guide*, Federal Highway Administration, November 2014.

[21] The transportation-planning model predicts that the study area would have moderate traffic growth from 2016 to 2040. Staff applied seven percent (0.25 percent annually) traffic growth to the 2040 weekday AM peak-hour model and eight percent (0.3 percent annually) traffic growth to the 2040 weekday PM and Saturday midday peak-hour models.

Chapter 6—Summary and Recommendations

This study performed a series of safety and operations analyses, identified safety and operational problems, and proposed a number of short- and long-term improvements to address identified problems in the study corridor.

The recommended key short-term improvements include:

- Increase pedestrian signal timing at applicable intersections
- Install traffic signal backplates with reflective borders at applicable intersections
- Install warning and regulatory signs at applicable locations in the corridor
- Repaint faded crosswalk and pavement markings at applicable intersections
- Trim overgrown vegetation at applicable locations

These improvements could enhance safety for all users and improve traffic operations moderately. With a high benefit/cost ratio, these short-term improvements should be implemented as soon as the resources are available from highway maintenance or local Chapter 90 funding.

The conceptual plans and suggested long-term improvements together create a vision that would accommodate all users and would improve their safety, mobility, and access in the corridor significantly. Major recommended long-term improvements for the corridor and expected benefits include:

- Three-lane roadway reconfiguration of the Boston Post Road East section would slow traffic, provide separate bicycle accommodations, and reduce pedestrian crossing distances and risks.
- Sidewalk and bicycle lane installations would enhance pedestrian and cyclist accommodations and safety, and improve traffic operations.
- The proposed improvements at intersections would improve safety and mobility for all users.
- The proposed signal coordination of the intersections on East Main Street would improve mobility, access, and safety for all users.

At this preliminary planning stage, staff estimate reconstruction of the entire corridor with the proposed long-term improvements would cost approximately

$19,000,000 to $22,000,000.[22] The approximate costs of the five different segments in the corridor are:

- Route 20 from Route 85 to Lincoln Street: $3,000,000 to $3,500,000
- Route 20 from Lincoln Street to Concord Road: $4,500,000 to $5,000,000
- Route 20 from Concord Road to Farm Road: $7,0500,000 to $8,000,000
- Route 20 from Farm Road to Raytheon Driveway: $1,500,000 to $2,000,000
- Route 20 from Raytheon Driveway to Sudbury town line: $3,000,000 to $3,500,000

The five segments also could be considered as different stages of sequential implementation, as they are listed in this study. Implementing the proposed long-term improvements would require sufficient resources. Depending on the available and potential resources, the City of Marlborough could reprioritize the implementation stages by rearranging, combining, or dividing the segments (if necessary).[23]

This study provides a vision for the corridor's long-term development, and confirms that the corridor has great potential to operate safely and efficiently for all users and various transportation modes. It will require significant effort and collaboration on the part of all stakeholders, including the city, residents and owners of adjacent developments, MassDOT, MWRTA to achieve the vision.

The implementation process must ensure that all parties concur about how the recommendations should be realized in a resourceful and fiscally responsible manner. The city needs to work with MassDOT District 3 to initiate the project, obtain favorable review from MassDOT's Project Review Committee, and identify potential funding resources through MassDOT and the Boston Region MPO.

Appendix L details the actions that are required in the various steps of MassDOT's project development process, including a schematic timetable. Information about the project development process also may be found on MassDOT's website, at www.massdot.state.ma.us/planning/Main/PlanningProcess/ProjectDevelopmentProcess.aspx and at www.massdot.state.ma.us/Portals/8/docs/designGuide/CH_2_a.pdf.

[22] This cost was estimated by using general expenses of similar projects. The estimate contains only design and construction costs, not right-of-way, utility relocation, or other contingency costs, and is based on 2016 dollars.

[23] The city currently is designing and implementing the proposed improvements in the East Main Street section of the first segment, with funding from the 2015 MassWorks Infrastructure Program.

The section of Route 20 east of Concord Road in Marlborough is scheduled for a resurfacing project to begin in two years,[24] which is an opportunity to improve pedestrian and bicycle accommodations based on the MassDOT Healthy Transportation Policy Directive.

The proposed long-term improvement—widening Route 20 between Concord Road and Farm Road (Section 3 of this report) from two to three lanes—likely would not be applicable in the resurfacing project. However, if the roadway surface is available,[25] staff recommend the following improvements for consideration:

- Add a left-turn lane to Peters Avenue
- Add a left-turn lane to Phelps Street
- Add a left-turn lane to Victoria Lane
- Add a left-turn lane to Village Drive[26]
- Add a two-way left-turn lane between Victoria Lane and Village Drive, or provide a left-turn pocket to the Dunkin' Donuts and the Shell gas station
- Add a two-way left-turn lane between Marlboro Shopping Square and the adjacent Burger King restaurant

[24] MassDOT Highway Division District 3 Project 608467, currently under planning and design, is programed in the 2019 Boston Region MPO Transportation Improvement Program.

[25] Staff identified these locations based on a review of the collision diagrams in the roadway section. These locations all have a large number of crashes, many of them caused by vehicles turning into a side street or adjacent businesses.

[26] These left-turn lanes should have a minimum 50-foot storage length.

Table 1
Proposed Improvements: Route 20 from Route 85 to Lincoln Street

Location	Issues/Concerns	Short-Term Improvements	Long-Term Improvements
The section in general	• Four-lane low-volume section (Granger Boulevard) allowing high-speed traffic in residential area • Wide-turning radii at street corners on Granger Boulevard, creating long pedestrian crossing distance and allowing high-speed turning traffic • Two-lane section (East Main Street) in mixed residential/commercial area, with limited right-of-way for expansion • Sidewalks on East Main Street frequently narrowed by utility poles • Lack of bicycle accommodations • Pavement rutting and cracking	• Increase signal visibility (by installing signal backplates with retroreflective borders) • Readjust signal timing at major intersections • Consider restriping Granger Boulevard to two-lane traffic operation (one lane each direction) with a center median/left-turn lane and 5.5-foot wide shoulders for bicycle accommodation on both sides • Maintain East Main Street two-lane traffic operation with four-foot shoulders for bicycle accommodation	• Reconstruct Granger Boulevard to two-lane traffic operation (one lane each direction) with a center median/left-turn lane and 5.5-foot wide shoulders for bicycle accommodation on both sides • Reduce turning radii at street corners on Granger Boulevard • Relocate utility poles or widen sidewalks on East Main Street, within available right-of-way • Add a southbound left-turn lane at the Route 85 intersection • Reconstruct the Main Street intersection and upgrade its signal system • Patch/repave/seal the rutting and cracking pavements
Route 20 (Granger Boulevard) at Route 85 (South Bolton Street)	• Large number of crashes (59 in the past-five years) • Nearly half (28) of the total crashes were left-turn crashes • Two pedestrian crashes on the Route 20 eastbound approach • Eastbound/westbound drivers facing sun glares during AM and PM peak hours	• Consider readjusting signal timing (by reducing cycle length from 116 seconds to 90 seconds) and continue monitoring traffic conditions (including the Route 85/Main Street intersection) • Consider changing all left-turn operations, except southbound approach, from Protected/Permissive to Protected only, if large number of left-turn crashes prevail • Install signal backplates with retroreflective borders (requiring further examination of existing mast arms' capacity) • Install MUTCD Cross Only at Crosswalks (R9-2) on the sidewalks on both sides of the eastbound approach	• Add a left-turn lane (125-foot storage length) on southbound approach by removing part of the existing traffic median • Increase pedestrian staging areas at the northeast and southeast corners of the intersection
Route 20 (Granger Boulevard/East Main Street) at Main Street/Brown Street	• Large intersection layout (difficult for drivers to view all other approaches) • Long pedestrian crossing distance (about 85 feet) on the Route 20 eastbound approach • No crosswalk on the Route 20 westbound approach where frequent pedestrian crossings were observed • Outdated traffic signal equipment • Poor visibility of signal indications • Confusing signage on Brown Street	• Readjust the exclusive pedestrian signal time from 21 to 31 seconds • Replace existing No Left-Turn and No U-Turn signs with a Right-Turn Only (MUTCD R3-5) sign on Brown Street • Install signal backplates with retroreflective borders (requiring further examination of the overhead wire's capacity) • Consider changing the Granger Boulevard approach to a left-turn-only lane and a through/right-turn-only lane	• Reconstruct intersection with a smaller layout (while maintaining all existing lanes) by extending north-side sidewalk on East Main Street, channelizing the Brown Street approach for right turns only and replacing the traffic signal to a stop control; adding a crosswalk on the East Main Street westbound approach; and relocating the southbound crosswalk • Increase pedestrian staging areas at all corners of intersection • Upgrade entire signal system with mast arms, new signal indications, and count-down/ accessible pedestrian signals
Route 20 (East Main Street) at Lincoln Street/Stevens Street	• Offset northbound and southbound approaches with constrained surroundings • Large number of crashes (35 in past five years) • Nearly one-third of the total crashes (16) occurring on congested westbound approach • Faded pavement markings, especially on the northbound (Route 20 eastbound) approach	• Add yellow retroreflective border on signal backplates • Propose no traffic signal operation changes; already maximized under current intersection layout • Stripe faded Right Turn Only pavement markings on outside of the northbound approach • Consider prohibiting right turns on red on the northbound (Route 20 eastbound) approach, as it would potentially reduce right-turn crashes and would increase delays only slightly	• Consider reconstructing the intersection by realigning the northbound/southbound approaches

Table 2
Proposed Improvements: Route 20 from Lincoln Street and Concord Road

Location	Issues/Concerns	Short-Term Improvements	Long-Term Improvements
The section in general	• Four-lane high-volume section in highly developed residential/commercial area • High crash rates in sections between intersections, especially in between Curtis Avenue and Hosmer Street (one of the State's 2011–13 top-200 crash clusters) • Two pedestrian and four bicycle crashes in the segment in past five years • Traffic congestion at major intersections during PM and Saturday peak hours • High crash rates at major intersections • Large number of crashes caused by vehicles to and from the businesses on the south side • Large number of crashes occurring in the parking lot of Post Road Shopping Center (128 in past five years) • Lack of bicycle accommodations • Pavement rutting and cracking	• Re-time traffic signals at Curtis Avenue intersection • Increase signal visibility (by adding retroreflective borders on existing backplates) • Consider designating outside lanes as shared bicycle/vehicle lanes in both directions • Restripe faded pavement markings at major intersections	• Maintain existing four-lane configuration with no major changes because of high daily traffic volume • Consider installing sharrows (shared-lane markings) and signage to accommodate bicycles • Consider reconstructing section between Hosmer Street and Concord Road under a two-lane operation in the westbound direction • Modify Curtis Avenue intersection and upgrade its traffic signal system with pedestrian signals • Reconstruct Hosmer Street intersection and upgrade its traffic signal system • Reconstruct and signalize Concord Road intersection • Coordinate traffic signals of the three intersections • Consider providing a section of two-way left-turn lane for vehicles to access the adjacent Dunkin' Donuts and Digital Federal Credit Union • Consider improving access management and control during prospective business redevelopments on the south side • Consider redesigning the parking and traffic circulation system in Post Road Shopping Center • Patch/repave/seal rutting and cracking pavements
Route 20 (East Main Street) at Curtis Avenue/Post Road Plaza Driveway	• Large number of crashes (55 in past five years) • Insufficient signal time for pedestrians to cross about 50 feet on Route 20 (about 16 seconds, concurrent with the southbound traffic signal) • No signal indications for pedestrians to cross Curtis Avenue or the shopping center driveway, although crosswalks existing • Three bicycle crashes, all on crosswalks	• Readjust the concurrent pedestrian signal time from 16 to 21 seconds • Add retroreflective borders to signal backplates • Install MUTCD Turning Vehicles Yield to Pedestrians (R10-15) signs on both approaches of Route 20	• Modify the intersection by slightly extending the northwest corner and reconstruct all the crosswalk ramps with ADA standards • Further examine exclusive versus concurrent pedestrian signal phasing at the design stage • Upgrade the traffic signal system with pedestrian signal indications all crosswalks • Coordinate this traffic signal (as the master intersection) with the signals at Hosmer Street and at Concord Road
Route 20 (East Main Street) at Hosmer Street	• Large number of crashes (40 in past five years) • Relatively long distance (about 65 feet) for pedestrians to cross Route 20, but with sufficient exclusive pedestrian signal time (about 30 seconds) • Traffic congestion during peak hours	• Add retroreflective borders to signal backplates • Install MUTCD Turning Vehicles Yield to Pedestrians (R10-15) signs on the Route 20 westbound approach	• Reconstruct intersection by channelizing the southbound right turns with a pedestrian refuge island, relocating the Route 20 crosswalk, extending northwest corner, and moving Route 20 eastbound/west stop lines closer to each other • With the new configuration, change the pedestrian signal phase from exclusive to concurrent • Upgrade traffic signal system • Coordinate this traffic signal with those at Curtis Avenue and Concord Road.
Route 20 (East Main Street) at Concord Road	• Large number of crashes (51 in the past five years) • Traffic congestion during peak hours with extensive vehicle delays on the Concord Road approach (currently under a stop control) • Sudden drop of travel lanes and sudden start of the left-turn only lane on Route 20 eastbound approach causing intensive lane-change activities and potentially crashes • Tight intersection confined by Route 20 center median • Sight distance problems due to its horizontal-curve location	• Consider installing lane-designation sign on the eastbound approach about 100 feet ahead of the start of the left-turn lane. • Consider cutting back the Route 20 westbound median for about 10 to 15 feet. • Add reflective paint or markers to the face of median curbs	• Reconstruct Route 20 to a consistent four-lane roadway (two lanes on each approach) • Extend Left-Turn-Only pavement marking once the roadway is reconfigured • Reconstruct and signalize the intersection and install crosswalks on the eastbound and southbound approaches with pedestrian signal indications • Coordinate this traffic signal with those at Curtis Avenue and Hosmer Street

Table 3
Proposed Improvements: Route 20 from Concord Road to Farm Road

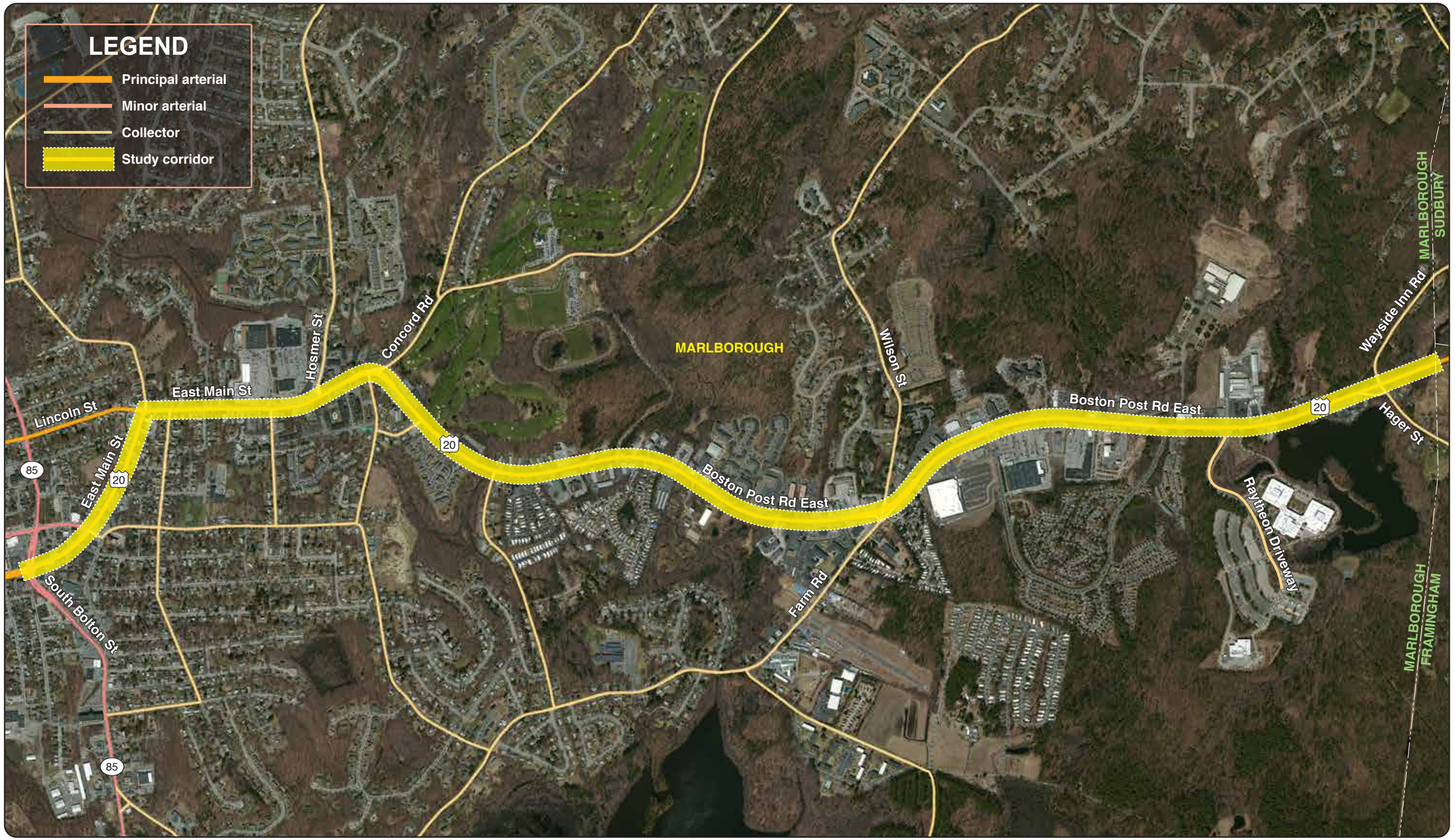
Location	Issues/Concerns	Short-Term Improvements	Long-Term Improvements
The section in general	• Two-lane roadway (one lane in each direction) in mixed residential/commercial area, with extensive traffic entering and exiting from adjacent developments • Very high corridor crash rate • Noticeable number of crashes at westbound lane-drop location near Burger King restaurant • Unsafe pedestrian crossings on Route 20 • Traffic congestion during PM peak hours • Discontinuous sidewalks • Lack of bicycle accommodations • Horizontal and vertical curves with overgrown vegetation • Pavement rutting and cracking	• Consider changing existing 40-mph zone to 35 mph (requiring further engineering study) • At the lane-drop location, replace the existing Road Narrow (W5-1) with Land Ends (W4-2) warning sign to inform outside-lane travelers clearly to slow down and yield • Re-time signal at Farm Road intersection • Trim overgrown vegetation in both directions	• Widen roadway to three-lane: two travel lanes (one in each direction) and a center median/left-turn lane, with six-foot bicycle lanes (also as roadway shoulders for emergency stopping) on both sides; center medians may be raised or flush (paint-striped or concrete-stamped) • Install continuous five-foot sidewalks on both sides of roadway • Consolidate driveways/curb cuts wherever applicable • Further study and evaluate intersection at Marlborough Fire Station #3 with an emergency hybrid beacon that can serve both emergency vehicles and pedestrian crossings • Patch/repave/seal rutting and cracking pavements
Route 20 (Boston Post Road East) at Farm Road	• Dense commercial developments with multiple curb cuts near the intersection • Large number of crashes (48 in the past five years) and a quarter of the crashes (12) involving vehicles entering or exiting from adjacent commercial developments • Traffic congestion during peak hours • Confusing lane-designation pavement markings on the northbound (Farm Road) approach	• Consider readjust signal cycle length from 160 to 120 seconds, including existing 25-second exclusive pedestrian signal phase • Add retroreflective borders to signal backplates • Correct lane-designation pavement markings (outside lane for right-turn only and inside lane for through and left-turn movements) on Farm Road and enhance the stop line before crosswalk at the right-turn approach • Consider restriping the median on Route 20 Westbound to provide access to and from Mustang Avenue and the stores in southeast quadrant of the intersection	• Consider relocating northbound right-turn signals closer to Farm Road just behind crosswalk

Table 4
Proposed Improvements: Route 20 from Farm Road to Raytheon Driveway

Location	Issues/Concerns	Short-Term Improvements	Long-Term Improvements
The section in general	• Four-lane roadway (two lanes in each direction) in mostly commercial/office area • High corridor crash rate • Noticeable number of crashes in segment between the two ends of Dicenzo Boulevard • Traffic congestion at the Dicenzo Boulevard/Pomphrey Drive intersection during PM and Saturday peak hours • Discontinuous sidewalks on the north side • Lack of bicycle accommodations • Pavement rutting and cracking	• Consider restriping the four travel lanes between Farm Road and Dicenzo Boulevard with a reduced width of 11 feet to include a five-foot shoulder for bicycle accommodation in both directions • Consider restriping the section east of Dicenzo Boulevard from four- to three-lanes: two travel lanes (one in each direction) and a center median/left-turn lane, with six-foot shoulders on both sides for bicycle accommodation • Re-time traffic signals at major intersections	• Reconstruct the section east of Dicenzo Boulevard to three-lane: two travel lanes and a center median/left-turn lane, with six-foot bicycle lanes on both sides • Install continuous five-foot sidewalks on the north side from Dicenzo Boulevard to Raytheon Driveway • Change speed limit of entire section from the existing 40 mph to 35 mph after the roadway reconfiguration • Consolidate driveways/curb cuts wherever applicable • Patch/repave/seal the rutting and cracking pavements
Route 20 (Boston Post Road East) at Dicenzo Boulevard/Pomphrey Drive	• Traffic congestion during PM and Saturday peak hours • Large intersection layout (difficult for drivers to view all other approaches) • Noticeable side-swipe crash pattern in the double left-turn lanes from Dicenzo Boulevard to Route 20	• Consider readjusting signal cycle length from 149 to 115 seconds, including the existing 27-second exclusive pedestrian signal phase • Add retroreflective borders to signal backplates • Install pavement dash guide lines (skip lines) to delineate the double left-turn lanes from Dicenzo Boulevard to Route 20	• Consider slightly reducing intersection layout by extending the southwest corner and moving the eastbound stop line and crosswalk about 10 feet closer to the intersection; this should be further examined with the required vehicle turning radius to Dicenzo Boulevard
Route 20 (Boston Post Road East) at Raytheon Driveway/Wayside Office Driveway	• Some drivers use westbound left-turn only lane as a through lane to cross the intersection, potentially causing crashes and increasing delays for eastbound traffic • Southbound signal phase not skipped (even no vehicles present), possibly because if damaged loop detectors (observed in June 2016)	• Restripe and extend westbound left-turn-only pavement markings, with periodical enforcements • Check and repair southbound loop detectors • Re-time signal with 90-second cycles under a shortened southbound split-phase (from 24 to 10 seconds) • Install signal backplates with retroreflective borders (requiring further examination of the overhead wires' capacity)	• Reconstruct intersection according to the proposed corridor three-lane roadway reconfiguration: maintain existing eastbound right-turn-only lane; reduce eastbound through lanes from two to one; designate center lane as left-turn only in both directions; intersection would operate acceptably during peak hours under projected 2040 traffic conditions • Install crosswalks on all approaches, except eastbound • Upgrade signal system with new mast arms and pedestrian signals

Table 5
Proposed Improvements: Route 20 from Raytheon Driveway to Sudbury Town Line

Location	Issues/Concerns	Short-Term Improvements	Long-Term Improvements
The section in general	• Two-lane roadway (one lane in each direction) in wooded/water area with scattered commercial/office developments and a few houses • Noticeable number of crashes in segment adjacent to the Wayside Inn Store commercial development • No sidewalks on both sides of the roadway • Lack of bicycle accommodations • Pavement rutting and cracking	• Re-time traffic signal at the Wayside Inn Road intersection • Increase traffic signal awareness and visibility at Wayside Inn Road intersection by improving signage improvements	• Reconstruct entire section to three-lanes: two travel lanes (one in each direction) and a center median/left-turn lane, with six-foot bicycle lanes on both sides • Consider the wetland impact of roadway adjacent to Hager Pond, where a two-lane configuration may be feasible with five-foot shoulders on both sides for bicycle accommodation • Install continuous five-foot sidewalks on both sides of roadway • Change speed limit of entire section from the existing 40 mph to 35 mph after the roadway reconfiguration • Reconstruct the Wayside Inn Road intersection • Patch/repave/seal the rutting and cracking pavements
Route 20 (Boston Post Road East) at Wayside Inn Road/Hager Street	• Poor visibility of signal indications from either direction of Route 20 • Drivers likely unware or unfamiliar with eastbound left-turn operation via a jug-handle slip ramp • Without an exclusive lane, westbound left turns sometimes block through movements, potentially causing rear-end crashes • High proportion of crashes (30 percent) involving personal injuries, possibly because of high travel speeds at the intersection • Sight distance problems because of vertical-curve location	• Consider increasing size of signal lens/heads and installing signal backplates with retroreflective borders (requires further examination of the existing mast arms' capacity) • Consider increasing the all-red time from one to two seconds (total clearance time six seconds) for the Route 20 signal phase • Install MUTCD Traffic Signal Ahead (W3-3) warning sign about 600-to-800 feet before the intersection on Route 20 westbound approach	• Reconstruct intersection with an exclusive left-turn lane on both approaches of Route 20 • Modify the jug-handle slip ramp to be right-turn only • Install crosswalks on all approaches • Install new traffic signal system with countdown/ accessible pedestrian signals

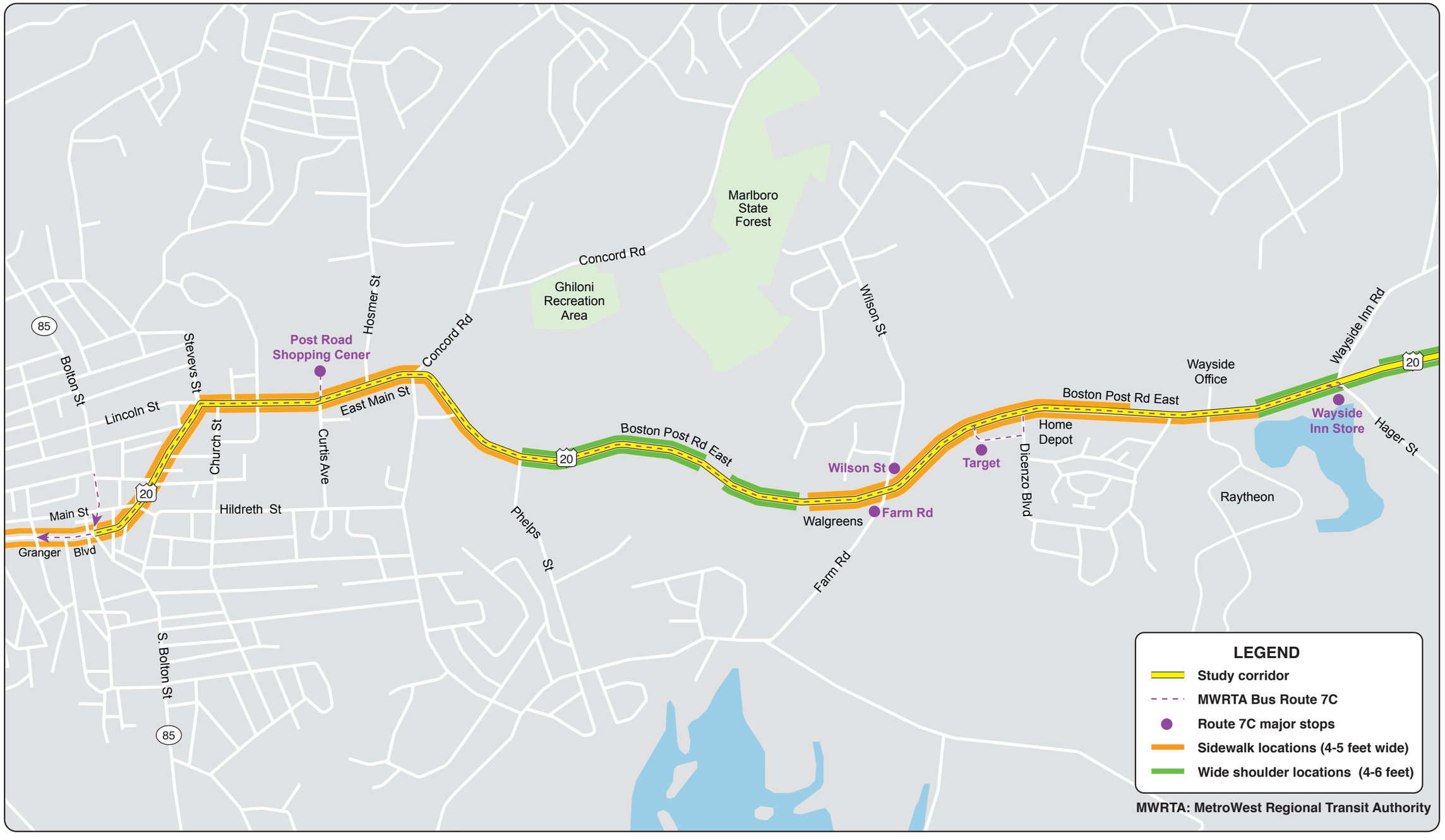


BOSTON
REGION
MPO

N

Figure 1
Study Area Map
Route 20 East Corridor in Marlborough

Addressing Safety, Mobility, and Access on Subregional Priority Roadways



BOSTON
REGION
MPO

N

Figure 2
Transit Service and Pedestrian and Bicycle Facilities
Route 20 East Corridor in Marlborough

Addressing Safety,
Mobility, and Access on
Subregional Priority Roadways

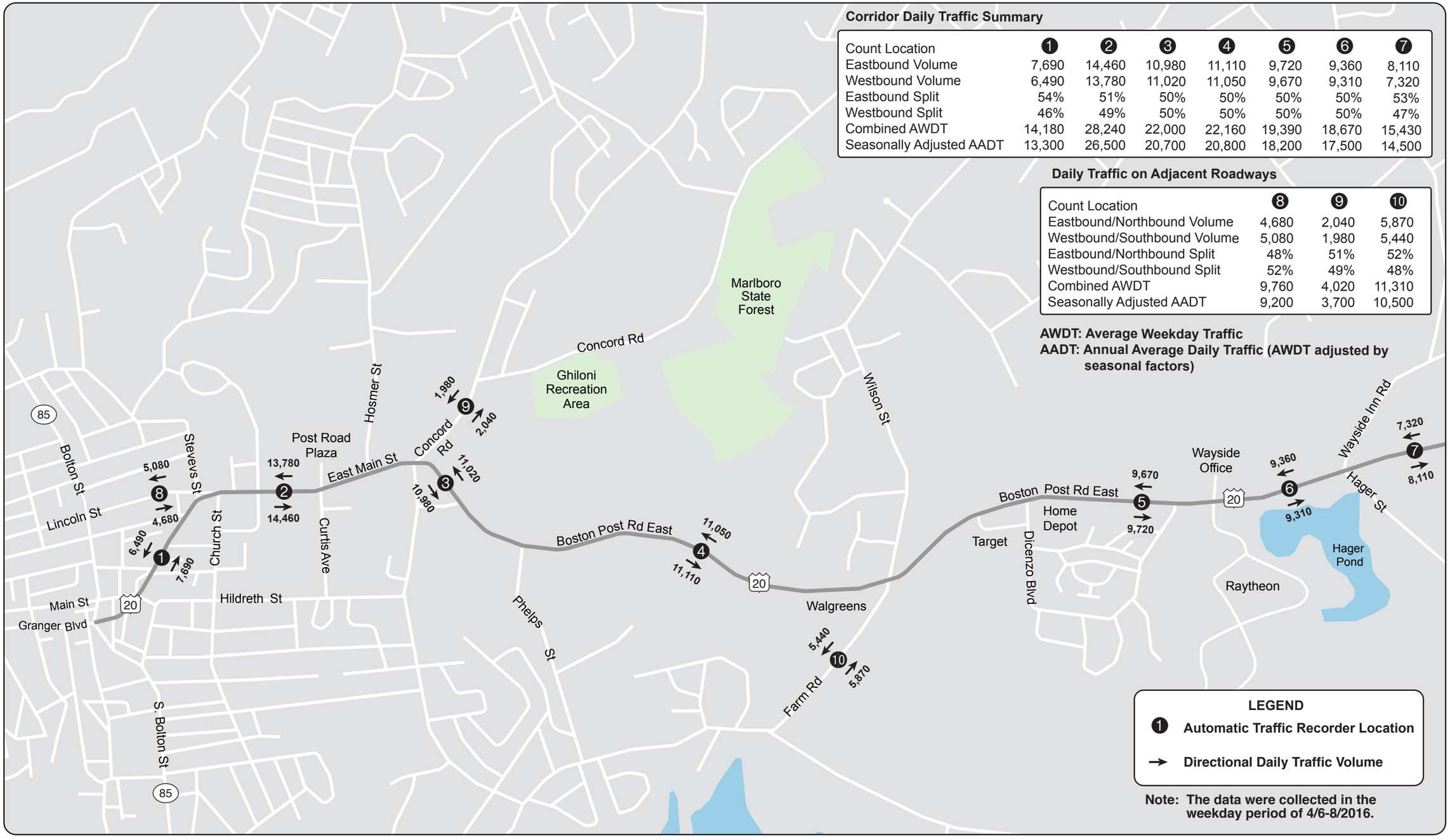
Corridor Daily Traffic Summary

Count Location	1	2	3	4	5	6	7
Eastbound Volume	7,690	14,460	10,980	11,110	9,720	9,360	8,110
Westbound Volume	6,490	13,780	11,020	11,050	9,670	9,310	7,320
Eastbound Split	54%	51%	50%	50%	50%	50%	53%
Westbound Split	46%	49%	50%	50%	50%	50%	47%
Combined AWDT	14,180	28,240	22,000	22,160	19,390	18,670	15,430
Seasonally Adjusted AADT	13,300	26,500	20,700	20,800	18,200	17,500	14,500

Daily Traffic on Adjacent Roadways

Count Location	8	9	10
Eastbound/Northbound Volume	4,680	2,040	5,870
Westbound/Southbound Volume	5,080	1,980	5,440
Eastbound/Northbound Split	48%	51%	52%
Westbound/Southbound Split	52%	49%	48%
Combined AWDT	9,760	4,020	11,310
Seasonally Adjusted AADT	9,200	3,700	10,500

AWDT: Average Weekday Traffic
AADT: Annual Average Daily Traffic (AWDT adjusted by seasonal factors)

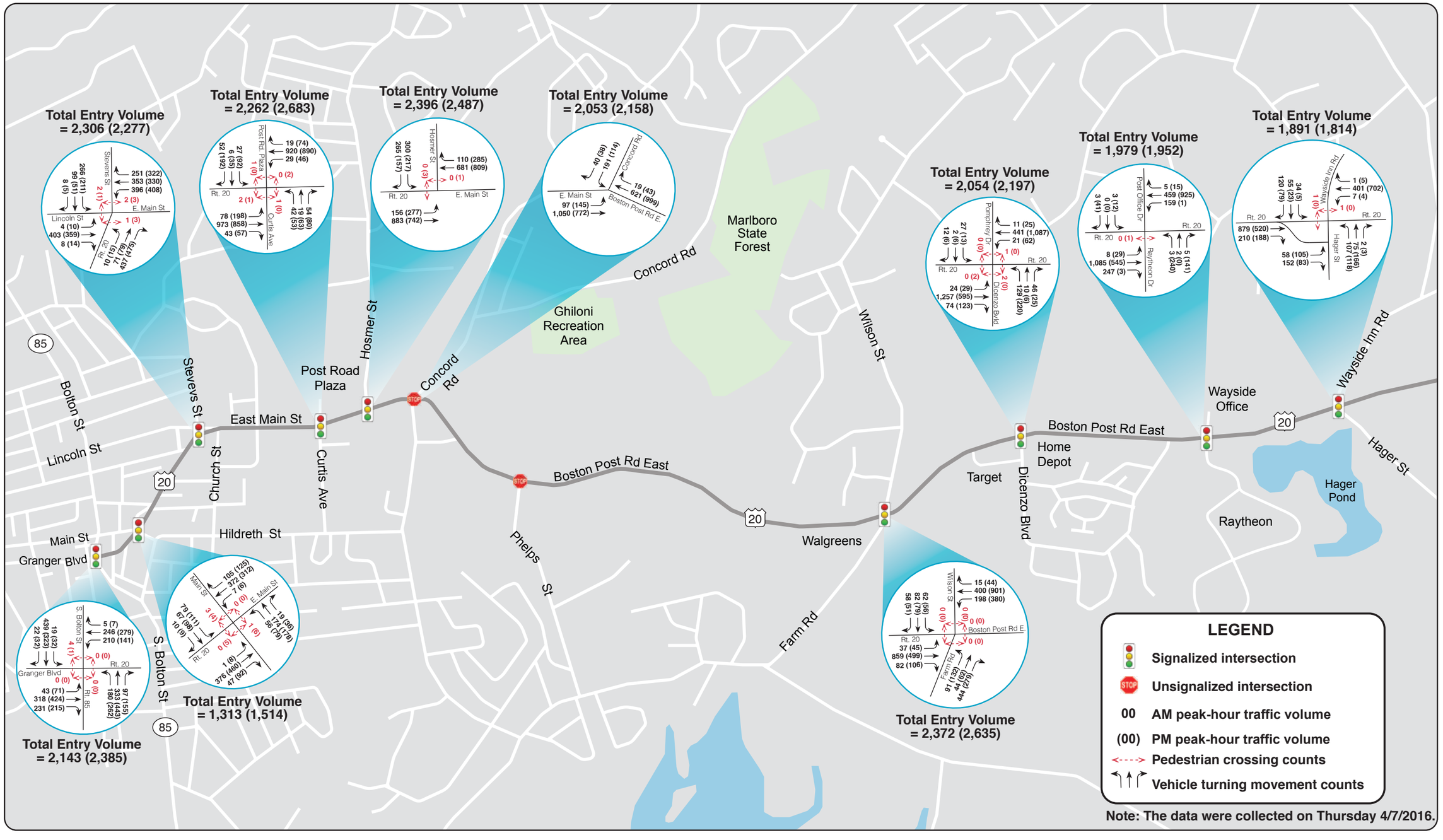


Note: The data were collected in the weekday period of 4/6-8/2016.

BOSTON REGION MPO

Figure 3
Daily Traffic Volumes
Route 20 East Corridor in Marlborough

Addressing Safety, Mobility, and Access on Subregional Priority Roadways

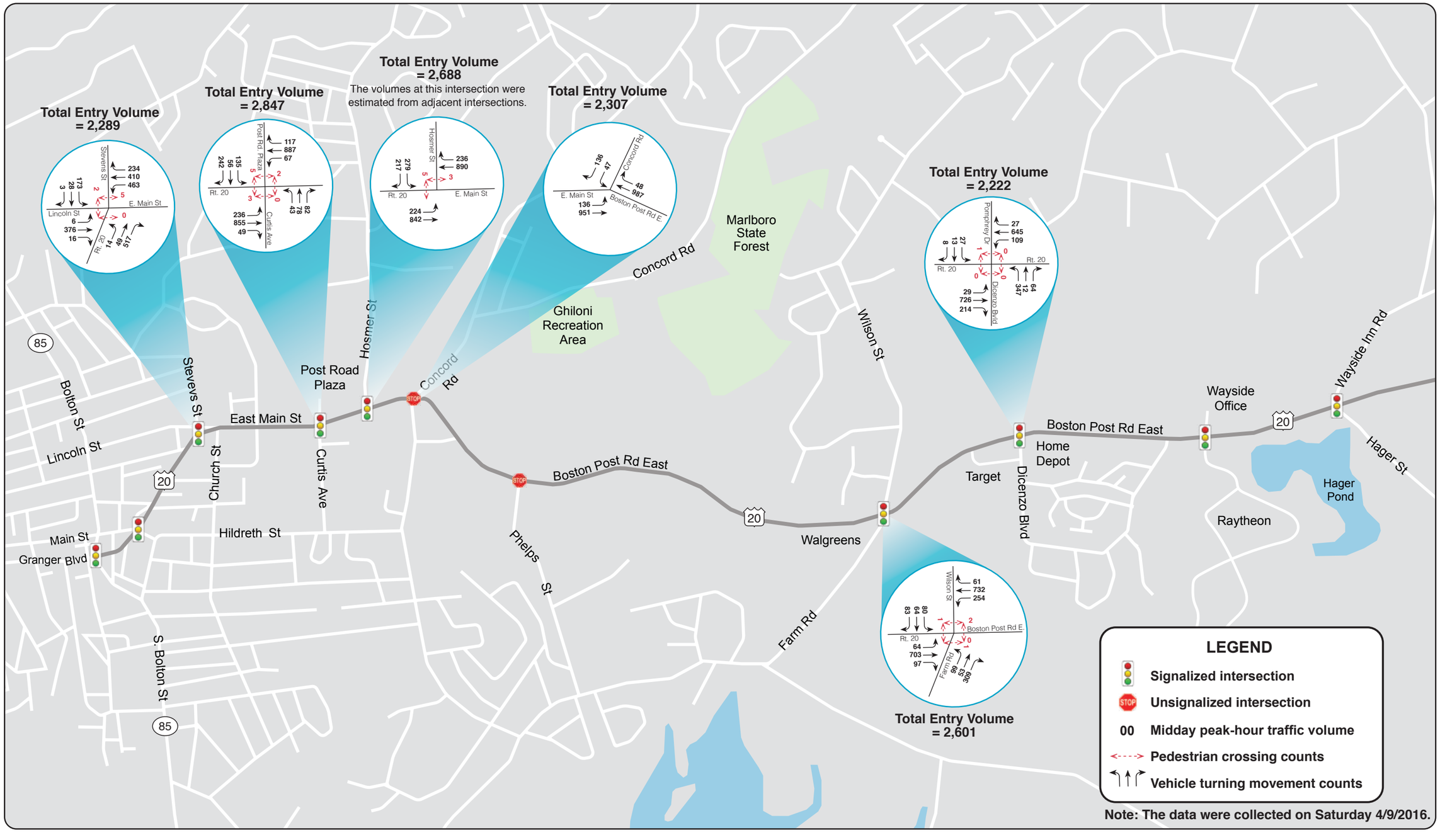


Note: The data were collected on Thursday 4/7/2016.

BOSTON REGION MPO

Figure 4
Weekday Peak-Hour Traffic and Pedestrian Volumes at Major Intersections
Route 20 East Corridor in Marlborough

Addressing Safety, Mobility, and Access on Subregional Priority Roadways



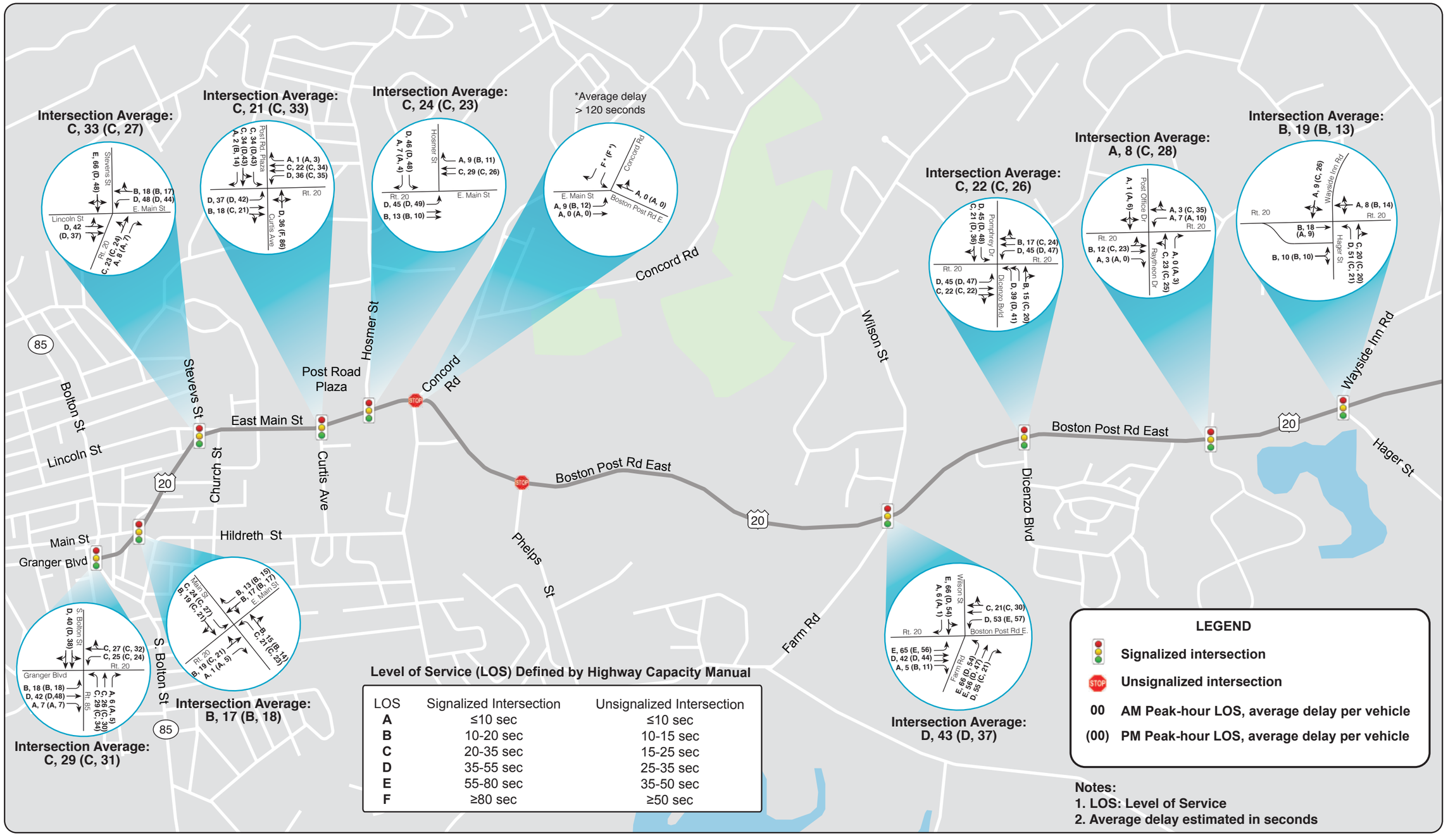
Note: The data were collected on Saturday 4/9/2016.

BOSTON REGION MPO

N

Figure 5
Saturday Peak-Hour Traffic and Pedestrian Volumes at Selected Intersections
Route 20 East Corridor in Marlborough

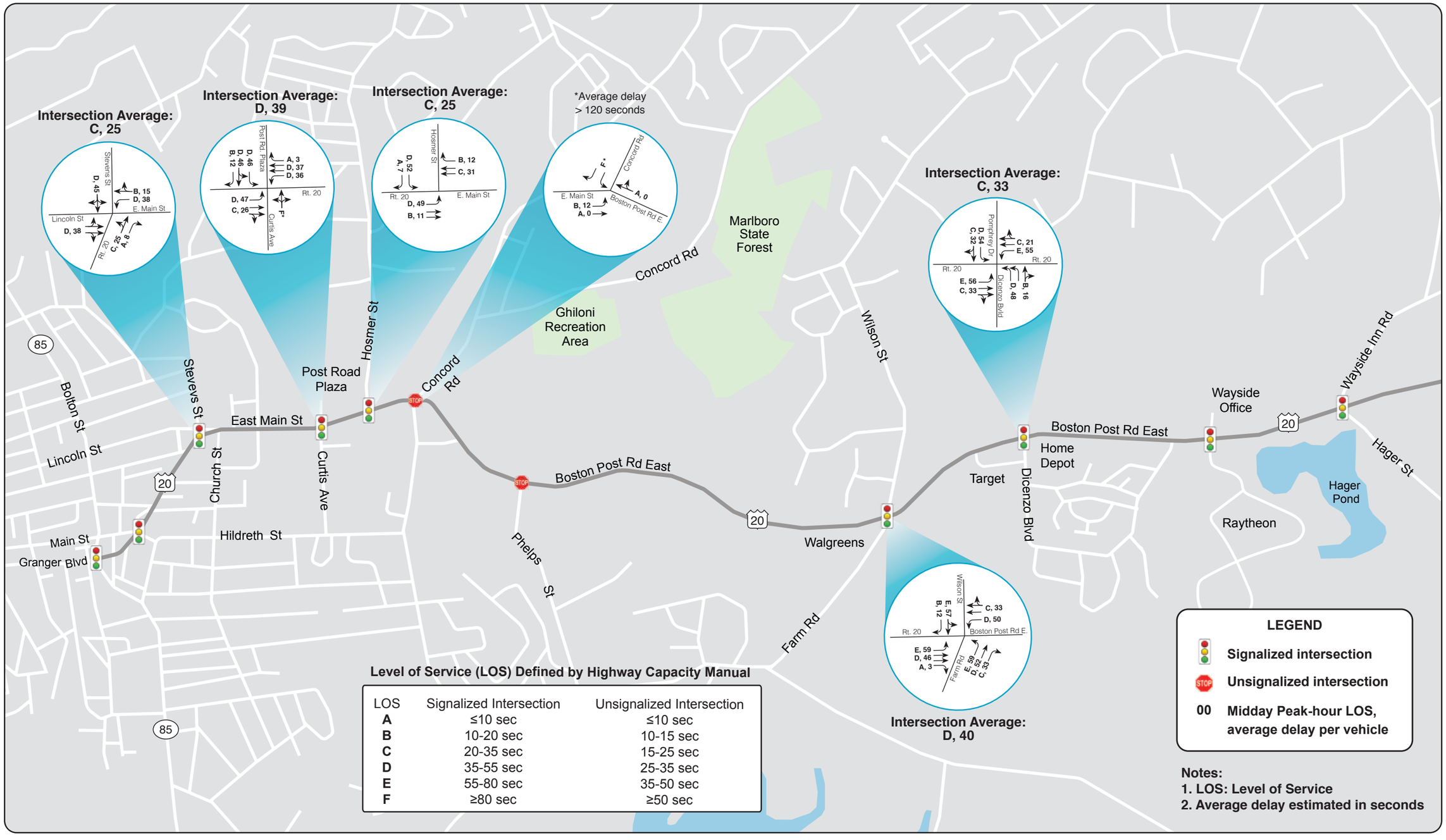
Addressing Safety, Mobility, and Access on Subregional Priority Roadways



BOSTON REGION MPO

Figure 6
Weekday Intersection Capacity Analyses
Route 20 East Corridor in Marlborough

Addressing Safety, Mobility, and Access on Subregional Priority Roadways



Level of Service (LOS) Defined by Highway Capacity Manual

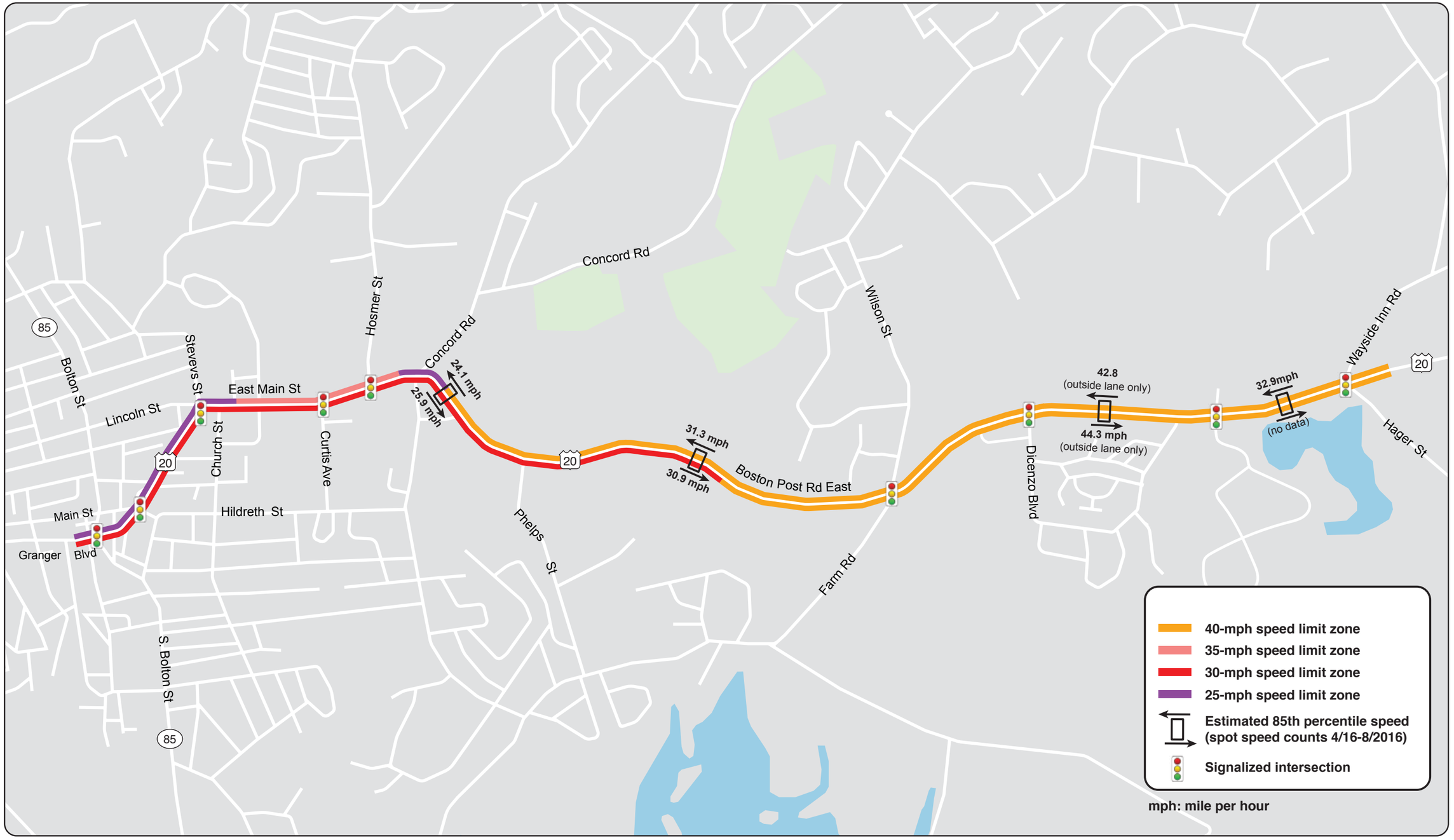
LOS	Signalized Intersection	Unsignalized Intersection
A	≤10 sec	≤10 sec
B	10-20 sec	10-15 sec
C	20-35 sec	15-25 sec
D	35-55 sec	25-35 sec
E	55-80 sec	35-50 sec
F	≥80 sec	≥50 sec

BOSTON REGION MPO

N

Figure 7
Saturday Intersection Capacity Analyses
Route 20 East Corridor in Marlborough

Addressing Safety, Mobility, and Access on Subregional Priority Roadways

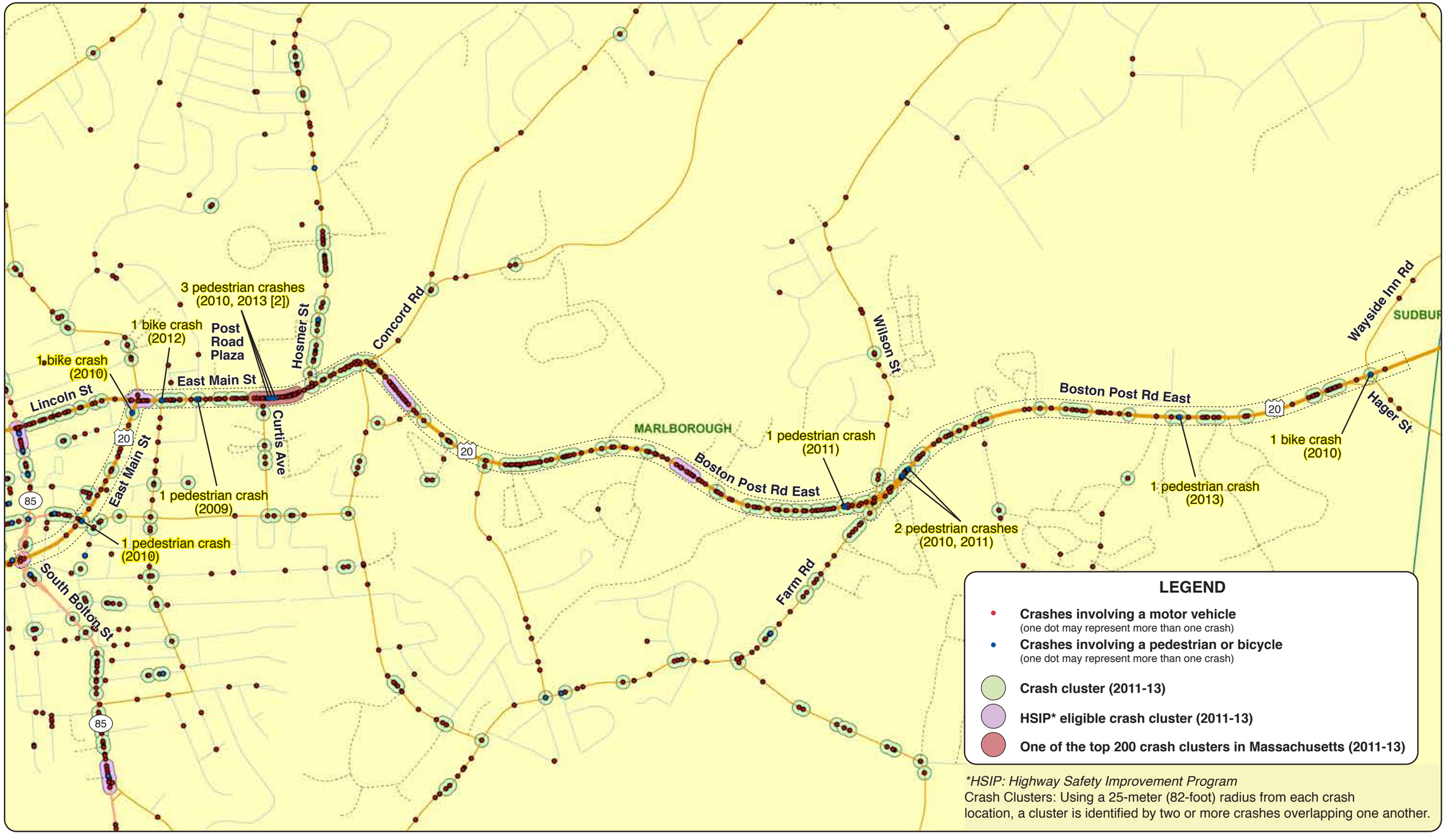


BOSTON
REGION
MPO

N

Figure 8
Speed Regulations and Estimated 85th Percentile Speeds
Route 20 East Corridor in Marlborough

Addressing Safety,
Mobility, and Access on
Subregional Priority Roadways

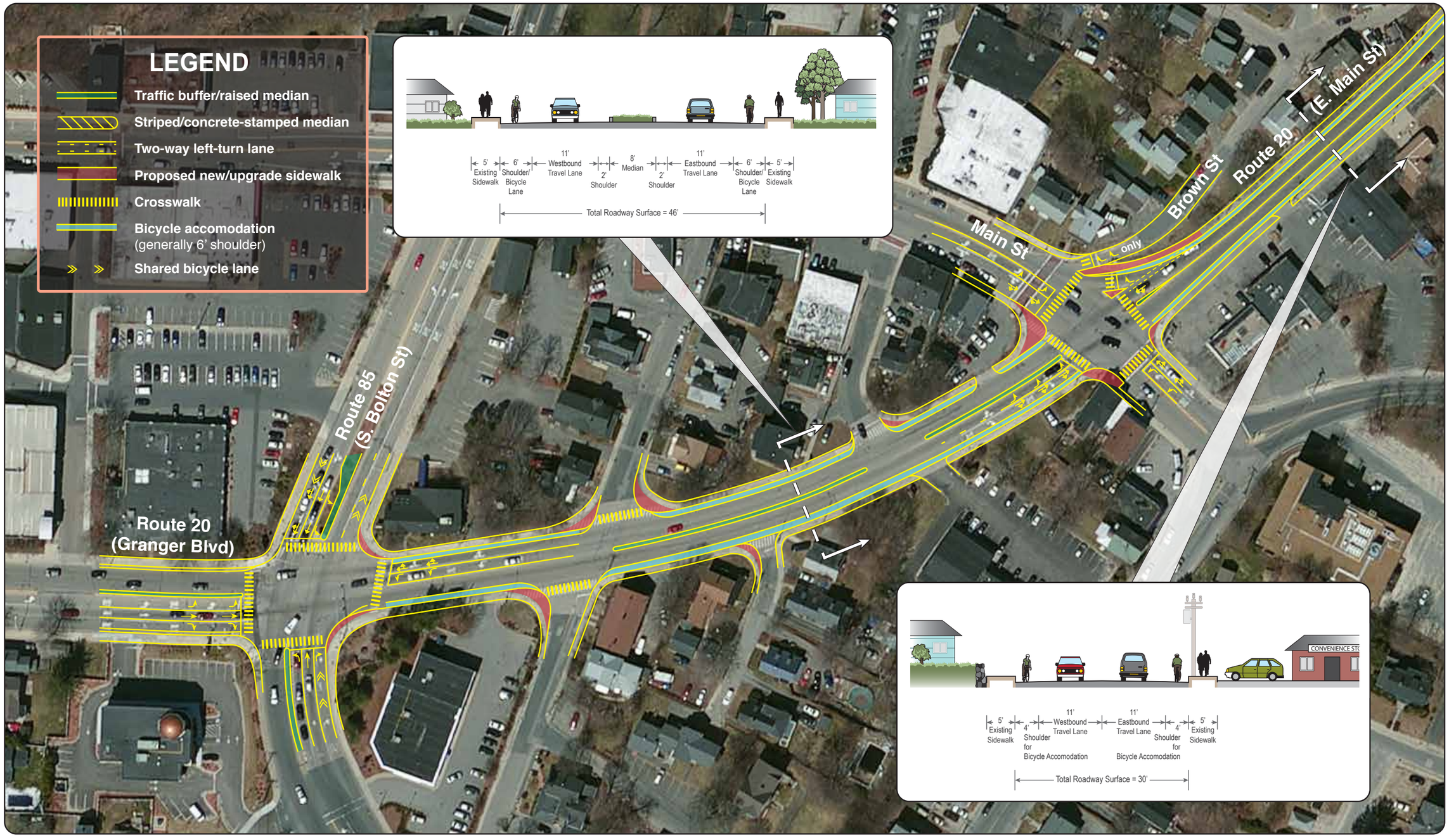


BOSTON
REGION
MPO

N

Figure 9
Crash Locations (MassDOT Crash Data 2009-13)
Route 20 East Corridor in Marlborough

Addressing Safety, Mobility, and Access on Subregional Priority Roadways



BOSTON REGION MPO

Figure 10
Proposed Long-Term improvement Conceptual Plan: Route 20 between Route 85 and Lincoln Street
Route 20 East Corridor in Marlborough

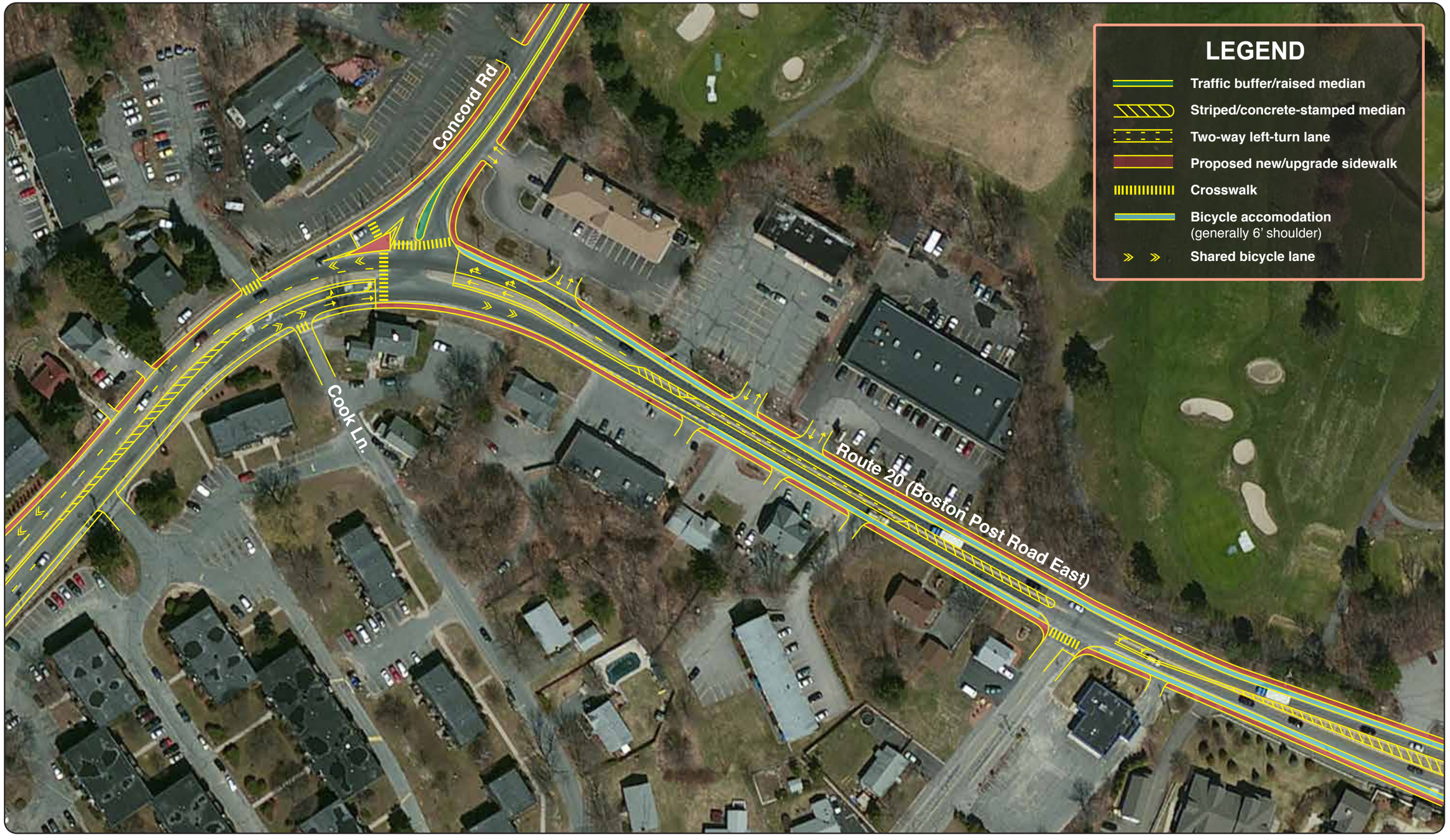
Addressing Safety, Mobility, and Access on Subregional Priority Roadways

BOSTON
REGION
MPO

N

Figure 11
Proposed Long-Term improvement Conceptual Plan: Route 20 between Curtis Avenue and Hosmer Street
Route 20 East Corridor in Marlborough

Addressing Safety,
Mobility, and Access on
Subregional Priority Roadways



BOSTON
REGION
MPO

N

Figure 12
Proposed Long-Term improvement Conceptual Plan: Route 20 in the Vicinity of Concord Road Intersection
Route 20 East Corridor in Marlborough

Addressing Safety,
Mobility, and Access on
Subregional Priority Roadways

BOSTON
REGION
MPO

Figure 13
Proposed Long-Term improvement Conceptual Plan: Route 20 Between Concord Road and Farm Road (1)
Route 20 East Corridor in Marlborough

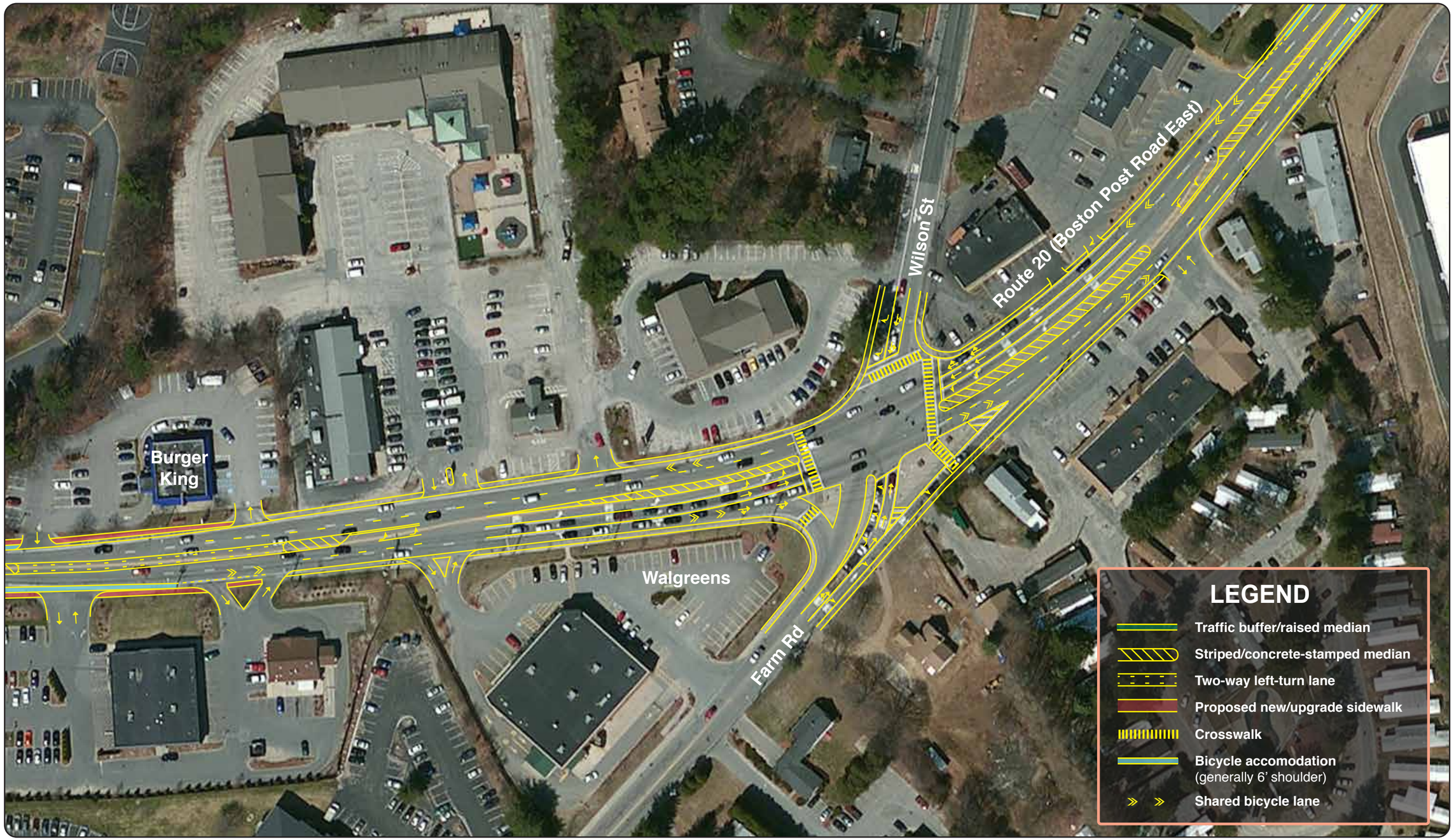
Addressing Safety, Mobility, and Access on Subregional Priority Roadways

BOSTON REGION MPO

N

Figure 14
Proposed Long-Term improvement Conceptual Plan: Route 20 Between Concord Road and Farm Road (2)
Route 20 East Corridor in Marlborough

Addressing Safety, Mobility, and Access on Subregional Priority Roadways

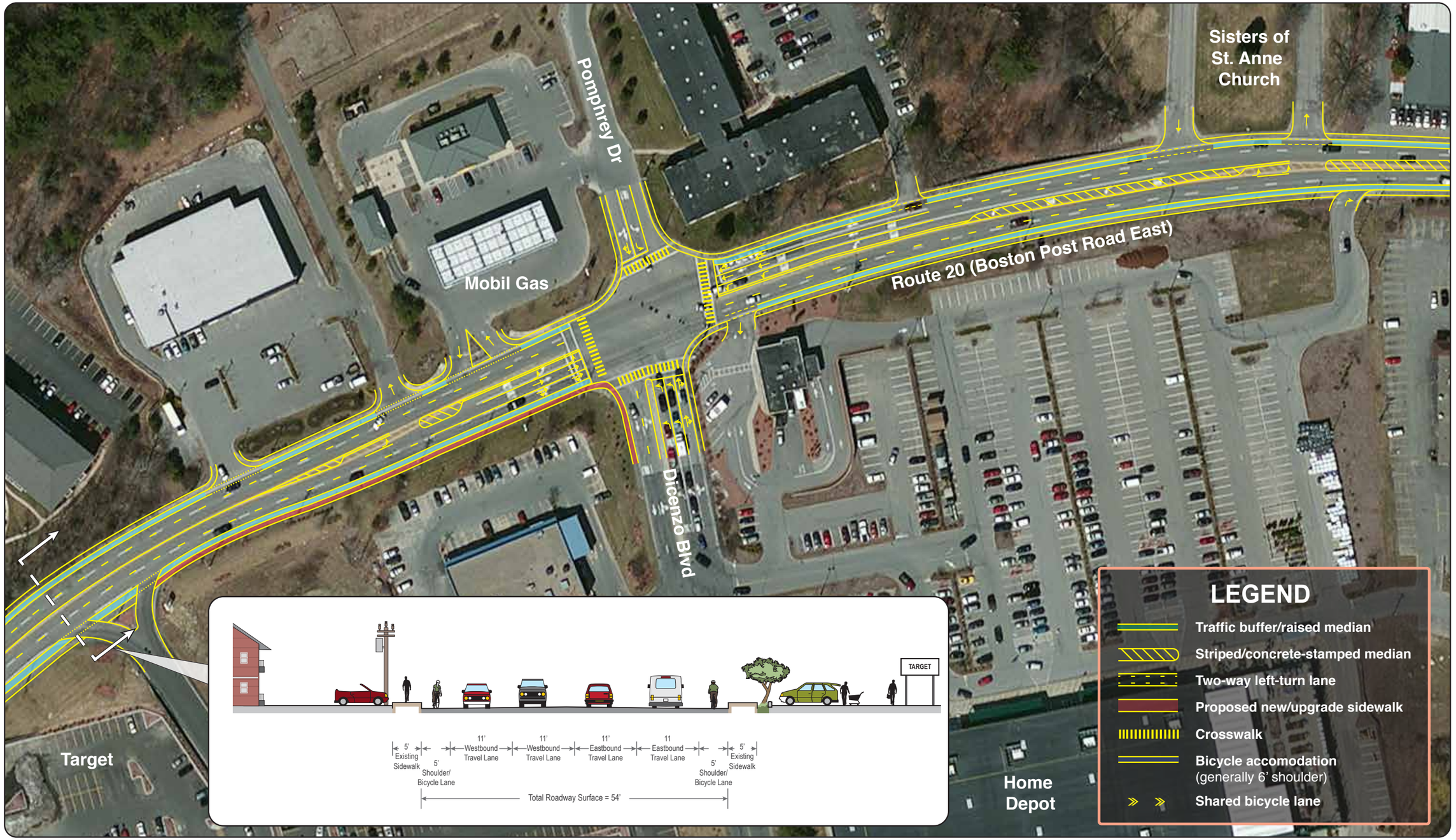


BOSTON
REGION
MPO

N

Figure 15
Proposed Long-Term improvement Conceptual Plan: Route 20 in the Vicinity of Farm Road Intersection
Route 20 East Corridor in Marlborough

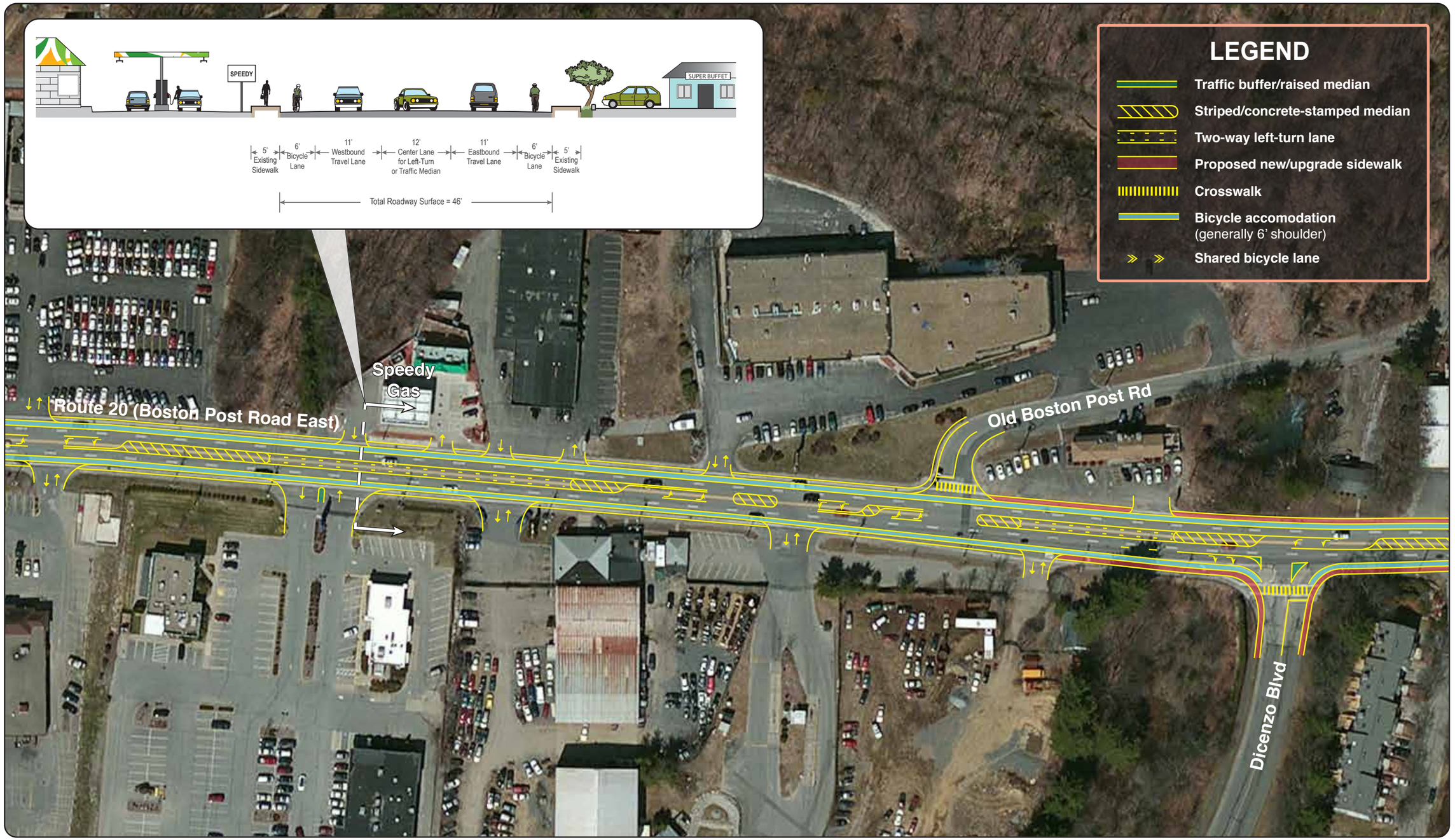
Addressing Safety, Mobility, and Access on Subregional Priority Roadways



BOSTON REGION MPO

Figure 16
Proposed Long-Term improvement Conceptual Plan: Route 20 Between Farm Road and Dicenzo Boulevard Route 20 East Corridor in Marlborough

Addressing Safety, Mobility, and Access on Subregional Priority Roadways

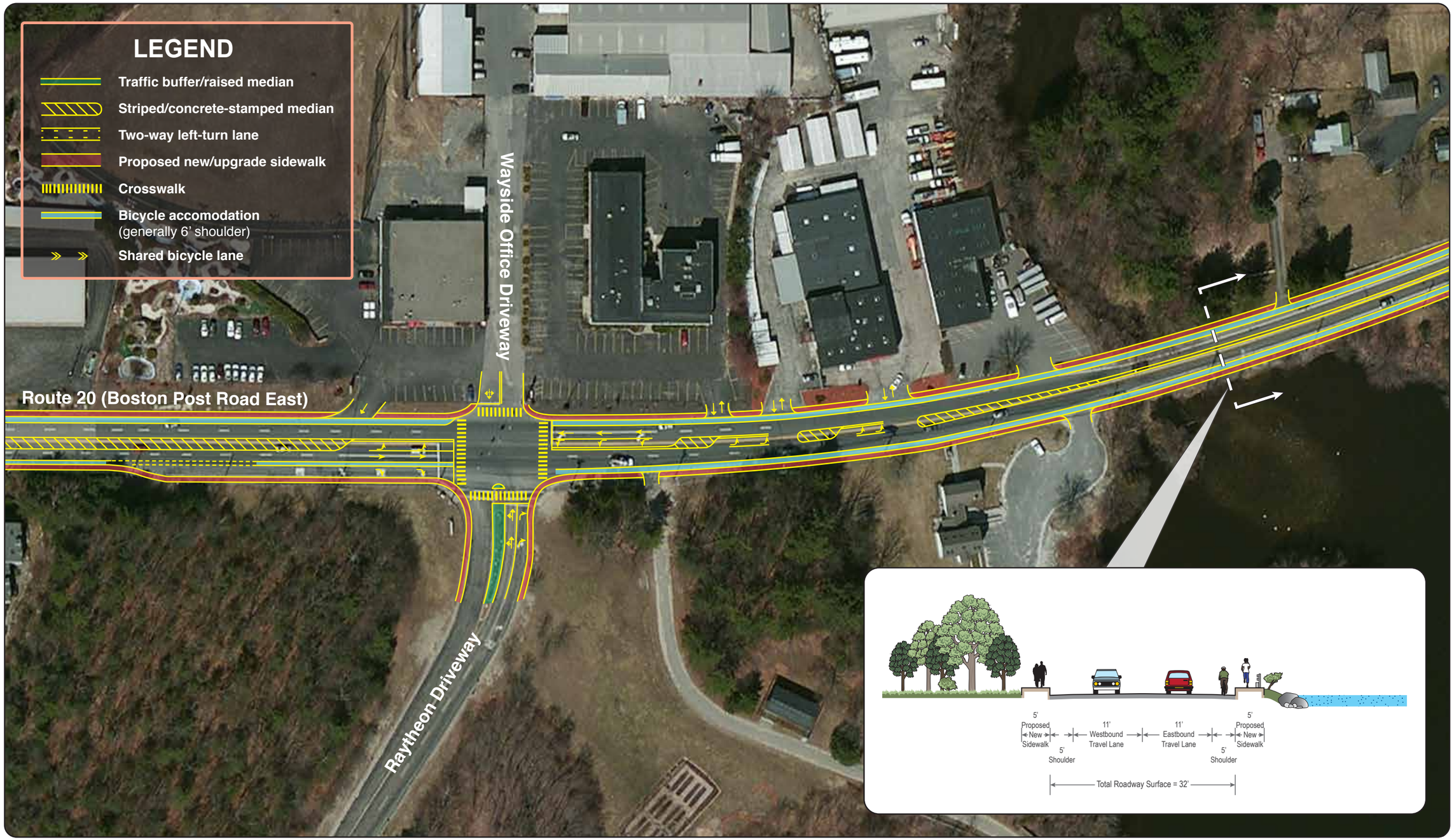


BOSTON REGION MPO

N

Figure 17
Proposed Long-Term improvement Conceptual Plan: Route 20 Between Dicenzo Boulevard and Raytheon Driveway
Route 20 East Corridor in Marlborough

Addressing Safety, Mobility, and Access on Subregional Priority Roadways



BOSTON REGION MPO

N

Figure 18
Proposed Long-Term improvement Conceptual Plan: Route 20 in the Vicinity of Raytheon Driveway
Route 20 East Corridor in Marlborough

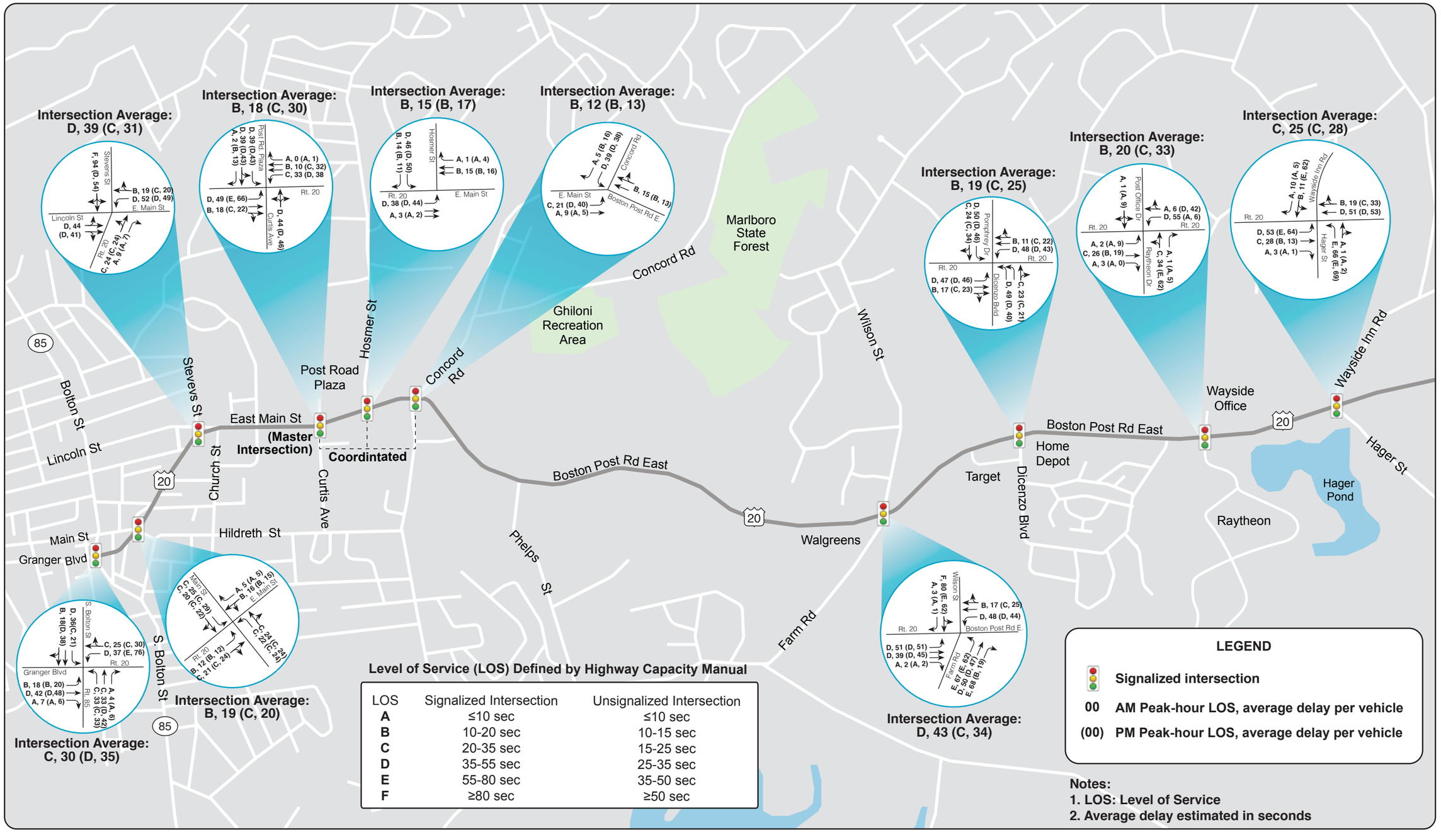
Addressing Safety, Mobility, and Access on Subregional Priority Roadways

BOSTON REGION MPO

N

Figure 19
Proposed Long-Term improvement Conceptual Plan: Route 20 in the Vicinity of Wayside Inn Road/Hager Street Intersection
Route 20 East Corridor in Marlborough

Addressing Safety, Mobility, and Access on Subregional Priority Roadways

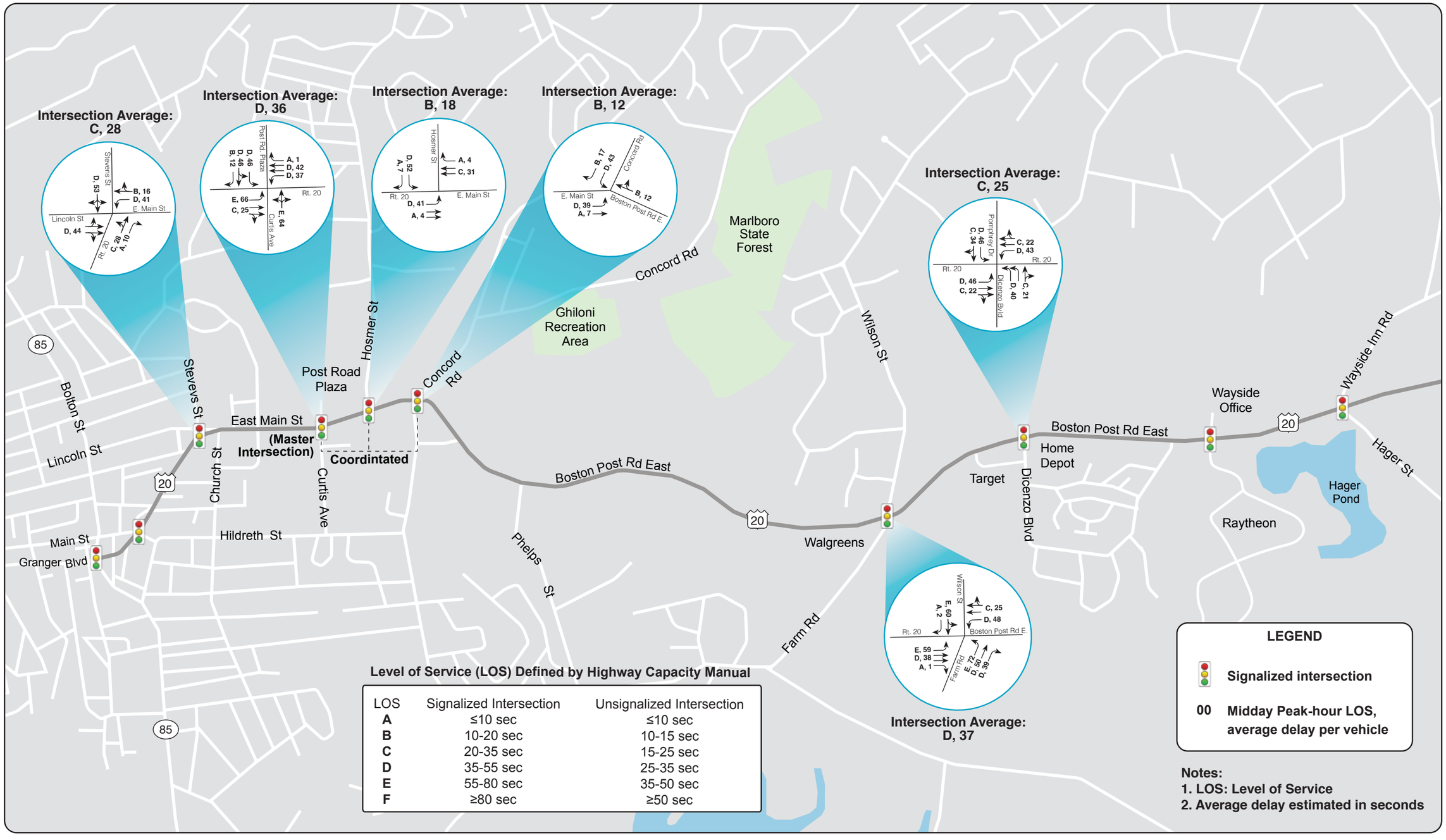


BOSTON REGION MPO

N

Figure 20
2040 Weekday Intersection Capacity Analyses (with Proposed Long-Term Improvements)
Route 20 East Corridor in Marlborough

Addressing Safety, Mobility, and Access on Subregional Priority Roadways



BOSTON REGION MPO

N

Figure 21
2040 Saturday Intersection Capacity Analyses (with Proposed Long-Term Improvements)
Route 20 East Corridor in Marlborough

Addressing Safety, Mobility, and Access on Subregional Priority Roadways

Appendixes

Appendix A. Participants in Study Advisory Meetings, April 13–October 21, 2016

Appendix B. Intersection Capacity Analyses, Weekday AM Peak Hour, 2016 Existing Conditions

Appendix C. Intersection Capacity Analyses, Weekday AM Peak Hour, 2016 Existing Conditions

Appendix D. Preliminary Traffic-Signal Warrants Analysis, Route 20 at Concord Road, Marlborough

Appendix E. Intersection Capacity Analyses, Saturday Midday Peak Hour, 2016 Existing Conditions

Appendix F. Corridor and Segment Crash-Rate Worksheets

Appendix G. Intersection Crash-Rate Worksheets

Appendix H. Collision Diagrams and Crash Statistics—Major intersections in the Corridor

Appendix I. Intersection Capacity Analyses, Weekday AM Peak Hour—Projected 2040 Traffic Conditions with Proposed improvements

Appendix J. Intersection Capacity Analyses, Weekday PM Peak Hour—Projected 2040 Traffic Conditions with Proposed improvements

Appendix K. Intersection Capacity Analyses, Summer Saturday Midday Peak Hour—Projected 2040 Traffic Conditions with Proposed improvements

Appendix L. MassDOT Project Development Process

APPENDIX A

Participants of Study Advisory Meetings
April 13 October 21, 201

Participants of Study Advisory Meetings

Route 20 East Corridor in Marlborough

April 13, 2016

October 21, 2016

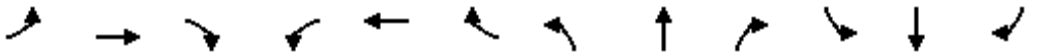
Name	Affiliation	Email
Dave Doucette	City Councilor, Marlborough	DPDOUCETTE@ME.COM
Meredith Harris	Executive Director, Marlborough Economic Development Corporation	MHarris@marlboroughedc.com
Tim Cummings	Former Executive Director, Marlborough Economic Development Corporation (attended April meeting)	
John Ghiloni	DPW Commissioner, Marlborough	jghiloni@marlborough-ma.gov
Thomas DiPersio	City Engineer, DPW Marlborough	tdipersio@marlborough-ma.gov
Timothy Collins	Ass. City Engineer, DPW Marlborough	tcollins@marlborough-ma.gov
Michael Clark	MassDOT Office Transportation Planning	michael.clark@state.ma.us
Joe Frawley	Mass DOT Highway Division District 3	joseph.frawley@state.ma.us
Erin Kinahan	Mass DOT Highway Division District 3	erin.kinahan@state.ma.us
Lori Shattuck	Mass DOT Highway Division District 3	lori.shattuck@DOT.state.ma.us
Mark Abbott	CTPS/Boston Region MPO	mabbott@ctps.org
Chen-Yuan Wang	CTPS/Boston Region MPO	cwang@ctps.org

APPENDIX B

Intersection Capacity Analyses
Weekday AM Peak Hour
2016 Existing Conditions

Intersection Capacity Analysis
Route 20 at Route 85, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	43	318	231	210	246	5	180	333	97	19	439	22
Future Volume (vph)	43	318	231	210	246	5	180	333	97	19	439	22
Satd. Flow (prot)	1646	1733	1473	1678	1761	0	1631	1717	1459	0	3355	0
Flt Permitted	0.590			0.281			0.244				0.929	
Satd. Flow (perm)	1022	1733	1473	496	1761	0	419	1717	1459	0	3123	0
Satd. Flow (RTOR)			254		1				107		4	
Confl. Peds. (#/hr)							1					1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.93	0.93	0.93
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	6%	6%	6%	4%	4%	4%	7%	7%	7%	3%	3%	3%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	47	349	254	231	275	0	198	366	107	0	516	0
Turn Type	pm+pt	NA	Perm	pm+pt	NA		pm+pt	NA	Perm	Perm	NA	
Protected Phases	5	2		1	6		3	8			4	
Permitted Phases	2		2	6			8		8	4		
Total Split (s)	15.0	31.0	31.0	15.0	31.0		15.0	44.0	44.0	29.0	29.0	
Total Lost Time (s)	3.0	5.0	5.0	3.0	5.0		3.0	5.0	5.0		5.0	
Act Effct Green (s)	32.9	23.6	23.6	40.8	33.0		36.0	33.9	33.9		19.5	
Actuated g/C Ratio	0.38	0.27	0.27	0.47	0.38		0.41	0.39	0.39		0.22	
v/c Ratio	0.11	0.74	0.43	0.58	0.41		0.60	0.55	0.17		0.73	
Control Delay	17.5	42.3	6.9	24.9	27.4		28.7	26.4	5.5		39.8	
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	
Total Delay	17.5	42.3	6.9	24.9	27.4		28.7	26.4	5.5		39.8	
LOS	B	D	A	C	C		C	C	A		D	
Approach Delay		26.7			26.3			23.8			39.8	
Approach LOS		C			C			C			D	
Queue Length 50th (ft)	13	165	0	69	111		67	146	0		134	
Queue Length 95th (ft)	49	#426	68	#222	279		#191	335	39		#258	
Internal Link Dist (ft)		424			226			511			208	
Turn Bay Length (ft)	350						220					
Base Capacity (vph)	536	534	630	400	666		345	794	732		892	
Starvation Cap Reductn	0	0	0	0	0		0	0	0		0	
Spillback Cap Reductn	0	0	0	0	0		0	0	0		0	
Storage Cap Reductn	0	0	0	0	0		0	0	0		0	
Reduced v/c Ratio	0.09	0.65	0.40	0.58	0.41		0.57	0.46	0.15		0.58	

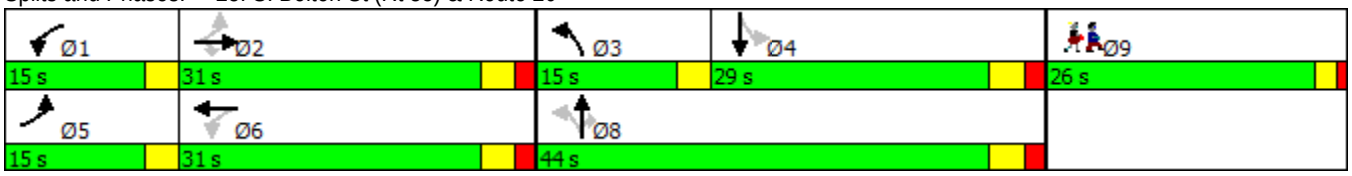
Intersection Summary			
Cycle Length: 116			
Actuated Cycle Length: 87.1			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.74			
Intersection Signal Delay: 28.6		Intersection LOS: C	
Intersection Capacity Utilization 75.1%		ICU Level of Service D	
Analysis Period (min) 15			

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	26.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 25: S. Bolton St (Rt 85) & Route 20



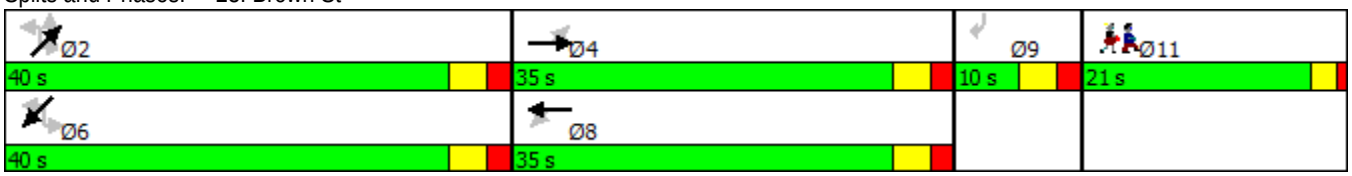
Intersection Capacity Analysis
Route 20 at Main Street, Marlborough

11/7/2016

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR2	SBR2	NEL2	NET	NER	SWL	SWT
Lane Configurations												
Traffic Volume (vph)	78	67	10	56	174	19	2	8	376	47	7	372
Future Volume (vph)	78	67	10	56	174	19	2	8	376	47	7	372
Satd. Flow (prot)	1678	1724	0	1711	1768	0	1589	0	1699	1446	0	1747
Flt Permitted	0.599			0.694					0.989			0.990
Satd. Flow (perm)	1050	1724	0	1242	1768	0	1589	0	1682	1406	0	1732
Satd. Flow (RTOR)		7			103		683			103		
Confl. Peds. (#/hr)	6		4	4		6				5	5	
Confl. Bikes (#/hr)												
Peak Hour Factor	0.80	0.80	0.80	0.92	0.92	0.92	0.92	0.80	0.80	0.80	0.88	0.88
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	4%	4%	4%	2%	2%	2%	0%	8%	8%	8%	5%	5%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%				0%			0%
Shared Lane Traffic (%)												
Lane Group Flow (vph)	98	97	0	61	210	0	2	0	480	59	0	431
Turn Type	Perm	NA		Perm	NA		Perm	Perm	NA	Perm	Perm	NA
Protected Phases		4			8				2			6
Permitted Phases	4	4		8	8		9	2		2	6	
Total Split (s)	35.0	35.0		35.0	35.0		10.0	40.0	40.0	40.0	40.0	40.0
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0		5.0	5.0		5.0
Act Effct Green (s)	12.7	12.7		12.7	12.7		6.0		22.0	22.0		22.0
Actuated g/C Ratio	0.26	0.26		0.26	0.26		0.12		0.44	0.44		0.44
v/c Ratio	0.37	0.22		0.19	0.40		0.00		0.64	0.09		0.56
Control Delay	24.3	19.3		21.1	13.5		0.0		19.0	1.3		16.8
Queue Delay	0.0	0.0		0.0	0.0		0.0		0.0	0.0		0.0
Total Delay	24.3	19.3		21.1	13.5		0.0		19.0	1.3		16.8
LOS	C	B		C	B		A		B	A		B
Approach Delay		21.8			15.2				17.1			16.0
Approach LOS		C			B				B			B
Queue Length 50th (ft)	18	16		11	19		0		71	0		61
Queue Length 95th (ft)	88	78		66	120		0		327	2		325
Internal Link Dist (ft)		297			75				453			794
Turn Bay Length (ft)	150											
Base Capacity (vph)	745	1226		882	1285		791		1333	1136		1373
Starvation Cap Reductn	0	0		0	0		0		0	0		0
Spillback Cap Reductn	0	0		0	0		0		0	0		0
Storage Cap Reductn	0	0		0	0		0		0	0		0
Reduced v/c Ratio	0.13	0.08		0.07	0.16		0.00		0.36	0.05		0.31

Intersection Summary			
Cycle Length: 106			
Actuated Cycle Length: 49.6			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.64			
Intersection Signal Delay: 16.9		Intersection LOS: B	
Intersection Capacity Utilization 58.6%		ICU Level of Service B	
Analysis Period (min) 15			

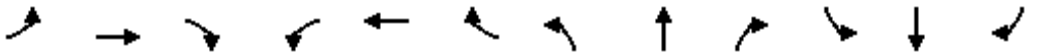
Splits and Phases: 23: Brown St



Lane Group	SWR	Ø11
Lane Configurations		
Traffic Volume (vph)	105	
Future Volume (vph)	105	
Satd. Flow (prot)	1487	
Flt Permitted		
Satd. Flow (perm)	1444	
Satd. Flow (RTOR)		
Confl. Peds. (#/hr)	6	
Confl. Bikes (#/hr)		
Peak Hour Factor	0.88	
Growth Factor	100%	
Heavy Vehicles (%)	5%	
Bus Blockages (#/hr)	0	
Parking (#/hr)		
Mid-Block Traffic (%)		
Shared Lane Traffic (%)		
Lane Group Flow (vph)	119	
Turn Type	Perm	
Protected Phases		11
Permitted Phases	6	
Total Split (s)	40.0	21.0
Total Lost Time (s)	5.0	
Act Effct Green (s)	22.0	
Actuated g/C Ratio	0.44	
v/c Ratio	0.19	
Control Delay	13.0	
Queue Delay	0.0	
Total Delay	13.0	
LOS	B	
Approach Delay		
Approach LOS		
Queue Length 50th (ft)	14	
Queue Length 95th (ft)	91	
Internal Link Dist (ft)		
Turn Bay Length (ft)	100	
Base Capacity (vph)	1145	
Starvation Cap Reductn	0	
Spillback Cap Reductn	0	
Storage Cap Reductn	0	
Reduced v/c Ratio	0.10	

Intersection Capacity Analysis
Route 20 at Lincoln Street, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	4	403	8	396	353	251	10	71	437	266	99	8
Future Volume (vph)	4	403	8	396	353	251	10	71	437	266	99	8
Satd. Flow (prot)	0	3445	0	1711	1689	0	0	1790	1531	0	1751	0
Flt Permitted		0.948		0.950				0.938			0.721	
Satd. Flow (perm)	0	3266	0	1711	1689	0	0	1689	1531	0	1307	0
Satd. Flow (RTOR)		2			64				68		1	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.92	0.92	0.92	0.93	0.93	0.93	0.75	0.75	0.75	0.84	0.84	0.84
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	2%	2%	2%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	451	0	426	650	0	0	108	583	0	445	0
Turn Type	Perm	NA		Prot	NA		Perm	NA	pm+ov	Perm	NA	
Protected Phases		2		1	6			4	1		8	
Permitted Phases	2						4		4	8		
Total Split (s)	25.0	25.0		35.0	60.0		35.0	35.0	35.0	35.0	35.0	
Total Lost Time (s)		5.0		5.0	5.0			5.0	5.0		5.0	
Act Effct Green (s)		15.8		24.8	45.7			30.3	60.2		30.3	
Actuated g/C Ratio		0.18		0.29	0.53			0.35	0.70		0.35	
v/c Ratio		0.75		0.87	0.70			0.18	0.53		0.97	
Control Delay		42.2		48.3	17.8			23.0	7.9		66.0	
Queue Delay		0.0		0.0	0.0			0.0	0.0		0.0	
Total Delay		42.2		48.3	17.8			23.0	7.9		66.0	
LOS		D		D	B			C	A		E	
Approach Delay		42.2			29.9			10.3			66.0	
Approach LOS		D			C			B			E	
Queue Length 50th (ft)		126		219	221			43	115		~254	
Queue Length 95th (ft)		184		#382	339			73	151		#443	
Internal Link Dist (ft)		289			228			617			398	
Turn Bay Length (ft)									150			
Base Capacity (vph)		768		602	1113			595	1184		461	
Starvation Cap Reductn		0		0	0			0	0		0	
Spillback Cap Reductn		0		0	0			0	0		0	
Storage Cap Reductn		0		0	0			0	0		0	
Reduced v/c Ratio		0.59		0.71	0.58			0.18	0.49		0.97	

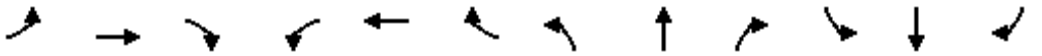
Intersection Summary			
Cycle Length: 95			
Actuated Cycle Length: 86.1			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.97			
Intersection Signal Delay: 32.9		Intersection LOS: C	
Intersection Capacity Utilization 85.0%		ICU Level of Service E	
Analysis Period (min) 15			

~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 21:

Intersection Capacity Analysis
Route 20 at Curtis Avenue, Marlborough

11/7/2016

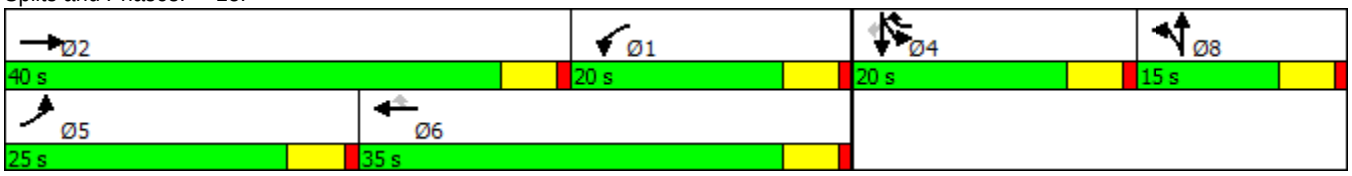


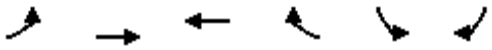
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	78	973	43	29	920	19	42	19	54	27	6	52
Future Volume (vph)	78	973	43	29	920	19	42	19	54	27	6	52
Satd. Flow (prot)	1662	3304	0	1678	3355	1501	0	1639	0	1535	1564	1446
Flt Permitted	0.950			0.950				0.982		0.950	0.968	
Satd. Flow (perm)	1662	3304	0	1678	3355	1501	0	1639	0	1535	1564	1446
Satd. Flow (RTOR)		5				80		38				195
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.89	0.89	0.89	0.98	0.98	0.98	0.82	0.82	0.82	0.71	0.71	0.71
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	5%	5%	5%	4%	4%	4%	3%	3%	3%	8%	8%	8%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)										40%		
Lane Group Flow (vph)	88	1141	0	30	939	19	0	140	0	23	23	73
Turn Type	Prot	NA		Prot	NA	pm+ov	Split	NA		Split	NA	Perm
Protected Phases	5	2		1	6	4	8	8		4	4	
Permitted Phases						6						4
Total Split (s)	25.0	40.0		20.0	35.0	20.0	15.0	15.0		20.0	20.0	20.0
Total Lost Time (s)	5.0	5.0		5.0	5.0	5.0		5.0		5.0	5.0	5.0
Act Effct Green (s)	9.4	37.2		7.2	30.3	43.1		9.0		7.6	7.6	7.6
Actuated g/C Ratio	0.13	0.53		0.10	0.43	0.61		0.13		0.11	0.11	0.11
v/c Ratio	0.40	0.66		0.18	0.65	0.02		0.58		0.14	0.14	0.22
Control Delay	36.9	18.0		36.3	22.4	0.1		35.9		34.3	34.2	1.6
Queue Delay	0.0	0.0		0.0	0.0	0.0		0.0		0.0	0.0	0.0
Total Delay	36.9	18.0		36.3	22.4	0.1		35.9		34.3	34.2	1.6
LOS	D	B		D	C	A		D		C	C	A
Approach Delay		19.3			22.4			35.9			14.2	
Approach LOS		B			C			D			B	
Queue Length 50th (ft)	37	158		13	187	0		42		10	10	0
Queue Length 95th (ft)	88	#392		42	325	0		101		27	27	0
Internal Link Dist (ft)		686			186			446			263	
Turn Bay Length (ft)	360			175		175				75		125
Base Capacity (vph)	488	1765		369	1538	1084		273		338	344	470
Starvation Cap Reductn	0	0		0	0	0		0		0	0	0
Spillback Cap Reductn	0	0		0	0	0		0		0	0	0
Storage Cap Reductn	0	0		0	0	0		0		0	0	0
Reduced v/c Ratio	0.18	0.65		0.08	0.61	0.02		0.51		0.07	0.07	0.16

Intersection Summary			
Cycle Length: 95			
Actuated Cycle Length: 70.8			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.66			
Intersection Signal Delay: 21.2		Intersection LOS: C	
Intersection Capacity Utilization 59.1%		ICU Level of Service B	
Analysis Period (min) 15			

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 18:



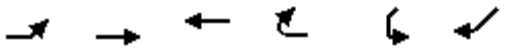


Lane Group	EBL	EBT	WBT	WBR	SBL	SBR	Ø9
Lane Configurations							
Traffic Volume (vph)	156	883	681	110	300	265	
Future Volume (vph)	156	883	681	110	300	265	
Satd. Flow (prot)	1662	3323	3355	1501	1694	1516	
Flt Permitted	0.950				0.950		
Satd. Flow (perm)	1662	3323	3355	1501	1694	1516	
Satd. Flow (RTOR)				91		177	
Confl. Peds. (#/hr)							
Confl. Bikes (#/hr)							
Peak Hour Factor	0.88	0.88	0.92	0.92	0.90	0.90	
Growth Factor	100%	100%	100%	100%	100%	100%	
Heavy Vehicles (%)	5%	5%	4%	4%	3%	3%	
Bus Blockages (#/hr)	0	0	0	0	0	0	
Parking (#/hr)							
Mid-Block Traffic (%)		0%	0%		0%		
Shared Lane Traffic (%)							
Lane Group Flow (vph)	177	1003	740	120	333	294	
Turn Type	Prot	NA	NA	Perm	Prot	pm+ov	
Protected Phases	5	2	6		7	5	9
Permitted Phases				6		7	
Total Split (s)	25.0	75.0	50.0	50.0	25.0	25.0	30.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	
Act Effct Green (s)	14.5	46.2	26.4	26.4	21.4	40.7	
Actuated g/C Ratio	0.18	0.56	0.32	0.32	0.26	0.50	
v/c Ratio	0.60	0.54	0.69	0.22	0.76	0.35	
Control Delay	44.7	13.2	28.9	9.4	44.5	6.7	
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	
Total Delay	44.7	13.2	28.9	9.4	44.5	6.7	
LOS	D	B	C	A	D	A	
Approach Delay		17.9	26.2		26.8		
Approach LOS		B	C		C		
Queue Length 50th (ft)	74	126	149	9	137	25	
Queue Length 95th (ft)	#220	335	343	61	#544	92	
Internal Link Dist (ft)		235	318		492		
Turn Bay Length (ft)	300			150		100	
Base Capacity (vph)	433	2903	1969	918	441	952	
Starvation Cap Reductn	0	149	0	0	0	0	
Spillback Cap Reductn	0	0	0	0	0	0	
Storage Cap Reductn	0	0	0	0	0	0	
Reduced v/c Ratio	0.41	0.36	0.38	0.13	0.76	0.31	

Intersection Summary			
Cycle Length: 130			
Actuated Cycle Length: 82.2			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.76			
Intersection Signal Delay: 22.7		Intersection LOS: C	
Intersection Capacity Utilization 56.6%		ICU Level of Service B	
Analysis Period (min) 15			

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 14:



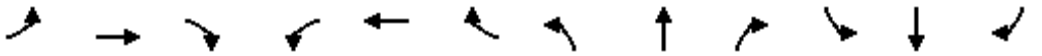
Movement	EBL	EBT	WBT	WBR	SWL	SWR
Lane Configurations						
Traffic Volume (veh/h)	97	1050	621	19	40	191
Future Volume (Veh/h)	97	1050	621	19	40	191
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	105	1141	675	21	43	208
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						2
Median type		None	None			
Median storage veh)						
Upstream signal (ft)		773				
pX, platoon unblocked					0.66	
vC, conflicting volume	696				2026	675
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	696				2291	675
tC, single (s)	4.1				6.4	6.2
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	88				0	54
cM capacity (veh/h)	891				25	452

Direction, Lane #	EB 1	EB 2	WB 1	WB 2	SW 1
Volume Total	105	1141	675	21	251
Volume Left	105	0	0	0	43
Volume Right	0	0	0	21	208
cSH	891	1700	1700	1700	122
Volume to Capacity	0.12	0.67	0.40	0.01	2.05
Queue Length 95th (ft)	10	0	0	0	516
Control Delay (s)	9.6	0.0	0.0	0.0	559.7
Lane LOS	A				F
Approach Delay (s)	0.8		0.0		559.7
Approach LOS					F

Intersection Summary			
Average Delay	64.5		
Intersection Capacity Utilization	65.3%	ICU Level of Service	C
Analysis Period (min)	15		

Intersection Capacity Analysis
Route 20 at Farm Road, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	37	859	82	198	400	15	91	44	444	62	82	58
Future Volume (vph)	37	859	82	198	400	15	91	44	444	62	82	58
Satd. Flow (prot)	1736	3471	1553	1703	3389	0	1752	1845	1568	0	1824	1583
Flt Permitted	0.950			0.950			0.950				0.979	
Satd. Flow (perm)	1736	3471	1553	1703	3389	0	1752	1845	1568	0	1824	1583
Satd. Flow (RTOR)			102		2							102
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.96	0.96	0.96	0.94	0.94	0.94	0.91	0.91	0.91	0.78	0.78	0.78
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	4%	4%	4%	6%	6%	6%	3%	3%	3%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	39	895	85	211	442	0	100	48	488	0	184	74
Turn Type	Prot	NA	Perm	Prot	NA		Split	NA	pm+ov	Split	NA	Perm
Protected Phases	5	2		1	6		8	8	1	4	4	
Permitted Phases			2						8			4
Total Split (s)	30.0	45.0	45.0	30.0	45.0		30.0	30.0	30.0	30.0	30.0	30.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0		5.0	5.0	5.0		5.0	5.0
Act Effct Green (s)	8.4	40.8	40.8	25.5	63.0		12.4	12.4	42.2		17.1	17.1
Actuated g/C Ratio	0.07	0.34	0.34	0.21	0.52		0.10	0.10	0.35		0.14	0.14
v/c Ratio	0.32	0.76	0.14	0.58	0.25		0.55	0.25	0.89		0.71	0.24
Control Delay	64.9	42.1	5.4	53.1	20.8		65.5	56.0	54.5		66.3	5.6
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0
Total Delay	64.9	42.1	5.4	53.1	20.8		65.5	56.0	54.5		66.3	5.6
LOS	E	D	A	D	C		E	E	D		E	A
Approach Delay		39.9			31.2			56.3			48.9	
Approach LOS		D			C			E			D	
Queue Length 50th (ft)	28	298	0	139	94		71	33	324		129	0
Queue Length 95th (ft)	79	#627	31	#324	227		159	88	#730		223	8
Internal Link Dist (ft)		394			534			205			111	
Turn Bay Length (ft)	350		50				75		150			
Base Capacity (vph)	368	1179	594	361	1780		371	391	551		387	416
Starvation Cap Reductn	0	0	0	0	0		0	0	0		0	0
Spillback Cap Reductn	0	0	0	0	0		0	0	0		0	0
Storage Cap Reductn	0	0	0	0	0		0	0	0		0	0
Reduced v/c Ratio	0.11	0.76	0.14	0.58	0.25		0.27	0.12	0.89		0.48	0.18

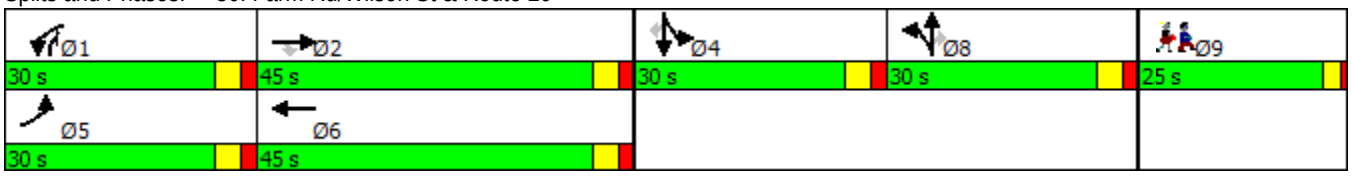
Intersection Summary		
Cycle Length: 160		
Actuated Cycle Length: 120		
Control Type: Actuated-Uncoordinated		
Maximum v/c Ratio: 0.89		
Intersection Signal Delay: 42.7	Intersection LOS: D	
Intersection Capacity Utilization 71.5%	ICU Level of Service C	
Analysis Period (min) 15		

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	25.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

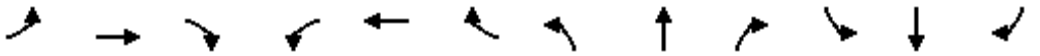
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 30: Farm Rd/Wilson St & Route 20



Intersection Capacity Analysis
Route 20 at Dicenzo Boulevard/Pomphrey Drive, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	24	1257	74	21	441	11	129	10	46	12	2	27
Future Volume (vph)	24	1257	74	21	441	11	129	10	46	12	2	27
Satd. Flow (prot)	1694	3361	0	1662	3310	0	3113	1479	0	1574	1425	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1694	3361	0	1662	3310	0	3113	1479	0	1574	1425	0
Satd. Flow (RTOR)		4			2			57			40	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.83	0.83	0.83	0.81	0.81	0.81	0.68	0.68	0.68
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	3%	3%	3%	5%	5%	5%	5%	5%	5%	7%	7%	7%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	25	1372	0	25	544	0	159	69	0	18	43	0
Turn Type	Prot	NA		Prot	NA		Split	NA		Split	NA	
Protected Phases	5	2		1	6		8	8		4	4	
Permitted Phases												
Total Split (s)	30.0	45.0		30.0	45.0		30.0	30.0		17.0	17.0	
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	
Act Effct Green (s)	7.3	44.8		7.3	44.8		10.0	10.0		7.1	7.1	
Actuated g/C Ratio	0.09	0.56		0.09	0.56		0.12	0.12		0.09	0.09	
v/c Ratio	0.16	0.73		0.17	0.29		0.41	0.29		0.13	0.27	
Control Delay	44.5	22.1		44.6	15.4		39.4	18.6		45.2	20.9	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	44.5	22.1		44.6	15.4		39.4	18.6		45.2	20.9	
LOS	D	C		D	B		D	B		D	C	
Approach Delay		22.5			16.7			33.1			28.0	
Approach LOS		C			B			C			C	
Queue Length 50th (ft)	10	211		10	58		33	5		7	1	
Queue Length 95th (ft)	48	#832		44	208		85	43		28	22	
Internal Link Dist (ft)		536			775			209			131	
Turn Bay Length (ft)	120			400								
Base Capacity (vph)	563	1881		552	1852		1034	529		251	261	
Starvation Cap Reductn	0	0		0	0		0	0		0	0	
Spillback Cap Reductn	0	0		0	0		0	0		0	0	
Storage Cap Reductn	0	0		0	0		0	0		0	0	
Reduced v/c Ratio	0.04	0.73		0.05	0.29		0.15	0.13		0.07	0.16	

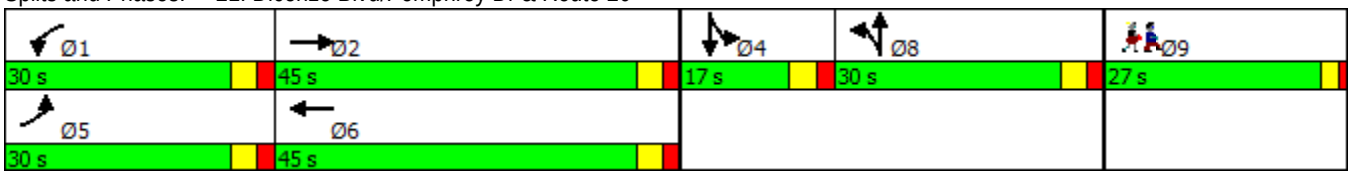
Intersection Summary			
Cycle Length: 149			
Actuated Cycle Length: 80.1			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.73			
Intersection Signal Delay: 22.2		Intersection LOS: C	
Intersection Capacity Utilization 55.8%		ICU Level of Service B	
Analysis Period (min) 15			

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	27.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

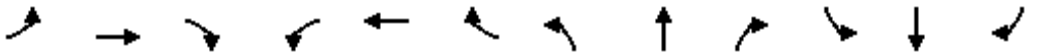
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 21: Dicenzo Blvd/Pomphrey Dr & Route 20



Intersection Capacity Analysis
Route 20 at Raytheon Driveway, Marlborough

11/7/2016

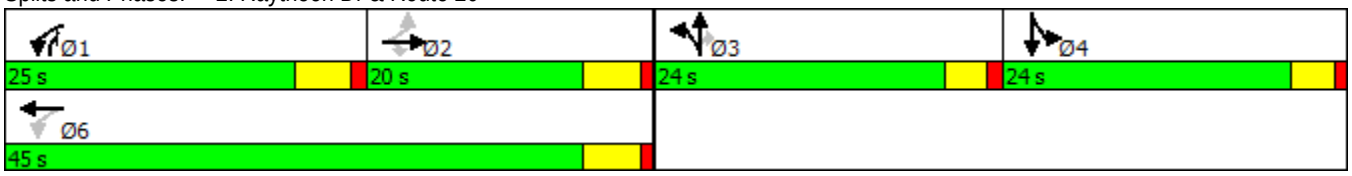


Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	8	1085	247	159	459	5	3	2	5	3	0	3
Future Volume (vph)	8	1085	247	159	459	5	3	2	5	3	0	3
Satd. Flow (prot)	0	3355	1553	1662	1806	0	0	1537	1346	0	1152	0
Flt Permitted		0.951		0.155				0.971			0.976	
Satd. Flow (perm)	0	3191	1553	271	1806	0	0	1537	1346	0	1152	0
Satd. Flow (RTOR)			255		1				70		129	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.83	0.83	0.83	0.50	0.50	0.50	0.50	0.50	0.50
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	4%	4%	4%	5%	5%	5%	20%	20%	20%	50%	50%	50%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	1127	255	192	559	0	0	10	10	0	12	0
Turn Type	Perm	NA	Perm	pm+pt	NA		Split	NA	pm+ov	Split	NA	
Protected Phases		2		1	6		3	3	1	4	4	
Permitted Phases	2		2	6					3			
Total Split (s)	20.0	20.0	20.0	25.0	45.0		24.0	24.0	25.0	24.0	24.0	
Total Lost Time (s)		5.0	5.0	5.0	5.0			4.0	5.0		4.0	
Act Effct Green (s)		28.9	28.9	41.0	45.3			6.3	7.8		6.1	
Actuated g/C Ratio		0.59	0.59	0.83	0.92			0.13	0.16		0.12	
v/c Ratio		0.60	0.25	0.46	0.34			0.05	0.04		0.05	
Control Delay		12.2	2.6	7.1	3.1			23.0	0.2		0.3	
Queue Delay		0.0	0.0	0.0	0.0			0.0	0.0		0.0	
Total Delay		12.2	2.6	7.1	3.1			23.0	0.2		0.3	
LOS		B	A	A	A			C	A		A	
Approach Delay		10.4			4.1			11.6			0.3	
Approach LOS		B			A			B			A	
Queue Length 50th (ft)		63	0	0	0			2	0		0	
Queue Length 95th (ft)		#365	41	57	159			9	0		0	
Internal Link Dist (ft)		655			163			102			237	
Turn Bay Length (ft)			300									
Base Capacity (vph)		1874	1017	804	1664			640	624		554	
Starvation Cap Reductn		0	0	0	0			0	0		0	
Spillback Cap Reductn		0	0	0	0			0	0		0	
Storage Cap Reductn		0	0	0	0			0	0		0	
Reduced v/c Ratio		0.60	0.25	0.24	0.34			0.02	0.02		0.02	

Intersection Summary			
Cycle Length: 93			
Actuated Cycle Length: 49.2			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.60			
Intersection Signal Delay: 8.2		Intersection LOS: A	
Intersection Capacity Utilization 71.4%		ICU Level of Service C	
Analysis Period (min) 15			

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 2: Raytheon Dr & Route 20



Intersection Capacity Analysis
Route 20 at Wayside Inn Road/Hager Street, Marlborough

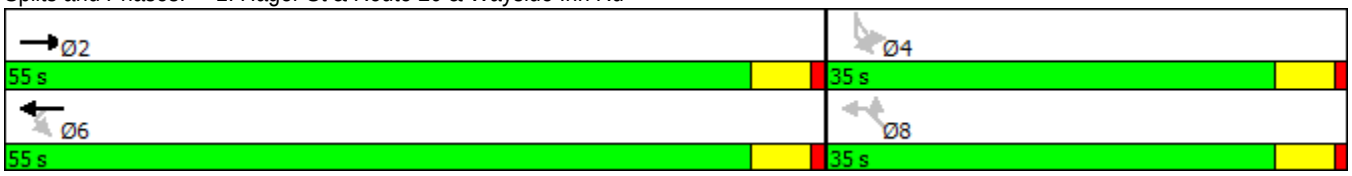
11/7/2016

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	SBL2	SBL	SBR	NWL	NWR	NWR2
Lane Configurations												
Traffic Volume (vph)	0	879	0	7	401	1	34	55	120	107	75	2
Future Volume (vph)	0	879	0	7	401	1	34	55	120	107	75	2
Satd. Flow (prot)	0	1827	0	0	1791	0	0	1665	0	1736	1553	0
Flt Permitted					0.986			0.932		0.456		
Satd. Flow (perm)	0	1827	0	0	1767	0	0	1585	0	833	1553	0
Satd. Flow (RTOR)								81			24	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.91	0.91	0.91	0.84	0.84	0.84	0.83	0.83	0.83	0.88	0.88	0.88
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	4%	4%	4%	6%	6%	6%	3%	3%	3%	4%	4%	4%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%		0%		
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	966	0	0	486	0	0	252	0	122	87	0
Turn Type		NA		Perm	NA		Perm	Perm		Perm	Perm	
Protected Phases		2			6							
Permitted Phases				6			4	4		8	8	
Total Split (s)		55.0		55.0	55.0		35.0	35.0		35.0	35.0	
Total Lost Time (s)		5.0			5.0			5.0		5.0	5.0	
Act Effct Green (s)		42.2			42.2			13.3		13.3	13.3	
Actuated g/C Ratio		0.64			0.64			0.20		0.20	0.20	
v/c Ratio		0.83			0.43			0.66		0.73	0.26	
Control Delay		18.2			8.0			26.0		51.4	20.3	
Queue Delay		0.0			0.0			0.0		0.0	0.0	
Total Delay		18.2			8.0			26.0		51.4	20.3	
LOS		B			A			C		D	C	
Approach Delay		18.2			8.0			26.0		38.4		
Approach LOS		B			A			C		D		
Queue Length 50th (ft)		249			82			65		48	22	
Queue Length 95th (ft)		#672			169			127		107	59	
Internal Link Dist (ft)		190			594			403		33		
Turn Bay Length (ft)												
Base Capacity (vph)		1413			1367			795		395	750	
Starvation Cap Reductn		0			0			0		0	0	
Spillback Cap Reductn		0			0			0		0	0	
Storage Cap Reductn		0			0			0		0	0	
Reduced v/c Ratio		0.68			0.36			0.32		0.31	0.12	

Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 66	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.83	
Intersection Signal Delay: 18.8	Intersection LOS: B
Intersection Capacity Utilization 77.0%	ICU Level of Service D
Analysis Period (min) 15	

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 1: Hager St & Route 20 & Wayside Inn Rd

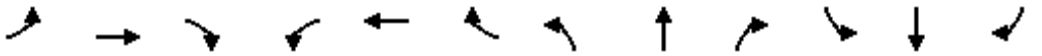


APPENDIX C

Intersection Capacity Analyses
Weekday PM Peak Hour
2016 Existing Conditions

Intersection Capacity Analysis
Route 20 @ Route 85, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	71	424	215	141	279	7	262	443	155	32	323	32
Future Volume (vph)	71	424	215	141	279	7	262	443	155	32	323	32
Satd. Flow (prot)	1728	1818	1546	1694	1776	0	1728	1818	1546	0	3359	0
Flt Permitted	0.471			0.167			0.299				0.872	
Satd. Flow (perm)	857	1818	1546	298	1776	0	544	1818	1546	0	2941	0
Satd. Flow (RTOR)			223		1				172		7	
Confl. Peds. (#/hr)							1					1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.93	0.93	0.93	0.91	0.91	0.91	0.90	0.90	0.90	0.85	0.85	0.85
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	3%	3%	3%	1%	1%	1%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	76	456	231	155	315	0	291	492	172	0	456	0
Turn Type	pm+pt	NA	Perm	pm+pt	NA		pm+pt	NA	Perm	Perm	NA	
Protected Phases	5	2		1	6		3	8			4	
Permitted Phases	2		2	6			8		8	4		
Total Split (s)	15.0	31.0	31.0	15.0	31.0		15.0	44.0	44.0	29.0	29.0	
Total Lost Time (s)	3.0	5.0	5.0	3.0	5.0		3.0	5.0	5.0		5.0	
Act Effct Green (s)	36.6	26.6	26.6	40.9	30.6		37.6	35.6	35.6		20.2	
Actuated g/C Ratio	0.41	0.30	0.30	0.46	0.34		0.42	0.40	0.40		0.23	
v/c Ratio	0.18	0.84	0.38	0.53	0.52		0.74	0.68	0.24		0.68	
Control Delay	18.1	47.8	7.1	24.0	31.7		34.4	29.8	4.6		38.2	
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	
Total Delay	18.1	47.8	7.1	24.0	31.7		34.4	29.8	4.6		38.2	
LOS	B	D	A	C	C		C	C	A		D	
Approach Delay		32.5			29.1			26.7			38.2	
Approach LOS		C			C			C			D	
Queue Length 50th (ft)	21	223	3	44	133		100	203	0		112	
Queue Length 95th (ft)	71	#596	70	132	#357		#335	#499	48		211	
Internal Link Dist (ft)		587			226			511			208	
Turn Bay Length (ft)	350						220					
Base Capacity (vph)	507	540	616	328	608		391	810	784		811	
Starvation Cap Reductn	0	0	0	0	0		0	0	0		0	
Spillback Cap Reductn	0	0	0	0	0		0	0	0		0	
Storage Cap Reductn	0	0	0	0	0		0	0	0		0	
Reduced v/c Ratio	0.15	0.84	0.38	0.47	0.52		0.74	0.61	0.22		0.56	

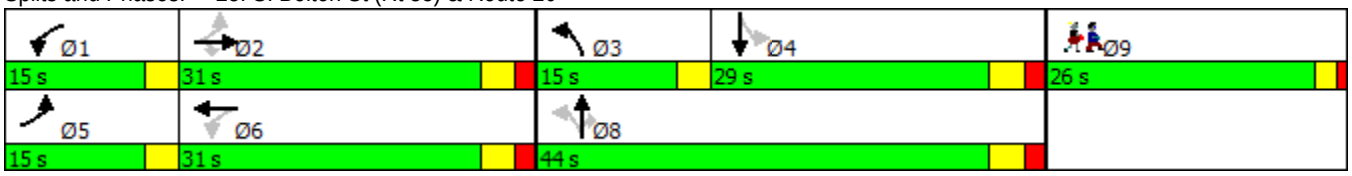
Intersection Summary	
Cycle Length: 116	
Actuated Cycle Length: 89.4	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.84	
Intersection Signal Delay: 30.8	Intersection LOS: C
Intersection Capacity Utilization 80.2%	ICU Level of Service D
Analysis Period (min) 15	

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	26.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 25: S. Bolton St (Rt 85) & Route 20



Intersection Capacity Analysis
Route 20 @ Main Street, Marlborough

11/7/2016

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR2	SBR2	NEL2	NET	NER	SWL	SWT
Lane Configurations												
Traffic Volume (vph)	111	98	9	79	178	36	2	8	460	92	6	312
Future Volume (vph)	111	98	9	79	178	36	2	8	460	92	6	312
Satd. Flow (prot)	1728	1791	0	1728	1764	0	1589	0	1817	1546	0	1799
Flt Permitted	0.556			0.682					0.992			0.990
Satd. Flow (perm)	1004	1791	0	1233	1764	0	1589	0	1804	1503	0	1783
Satd. Flow (RTOR)		4			103		655			103		
Confl. Peds. (#/hr)	6		4	4		6				5	5	
Confl. Bikes (#/hr)												
Peak Hour Factor	0.92	0.92	0.92	0.94	0.94	0.94	0.92	0.91	0.91	0.91	0.85	0.85
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	0%	1%	1%	1%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%				0%			0%
Shared Lane Traffic (%)												
Lane Group Flow (vph)	121	117	0	84	227	0	2	0	514	101	0	374
Turn Type	Perm	NA		Perm	NA		Perm	Perm	NA	Perm	Perm	NA
Protected Phases		4			8				2			6
Permitted Phases	4			8			9	2		2	6	
Total Split (s)	35.0	35.0		35.0	35.0		10.0	40.0	40.0	40.0	40.0	40.0
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0		5.0	5.0		5.0
Act Effct Green (s)	15.6	15.6		15.6	15.6		6.1		24.9	24.9		24.9
Actuated g/C Ratio	0.28	0.28		0.28	0.28		0.11		0.44	0.44		0.44
v/c Ratio	0.43	0.23		0.24	0.40		0.00		0.64	0.14		0.47
Control Delay	27.0	20.7		22.6	14.3		0.0		20.6	4.8		17.1
Queue Delay	0.0	0.0		0.0	0.0		0.0		0.0	0.0		0.0
Total Delay	27.0	20.7		22.6	14.3		0.0		20.6	4.8		17.1
LOS	C	C		C	B		A		C	A		B
Approach Delay		23.9			16.5				18.0			16.5
Approach LOS		C			B				B			B
Queue Length 50th (ft)	24	21		15	23		0		84	0		55
Queue Length 95th (ft)	125	107		86	134		0		#501	35		288
Internal Link Dist (ft)		301			90				453			794
Turn Bay Length (ft)	150											
Base Capacity (vph)	650	1162		799	1179		756		1304	1115		1288
Starvation Cap Reductn	0	0		0	0		0		0	0		0
Spillback Cap Reductn	0	0		0	0		0		0	0		0
Storage Cap Reductn	0	0		0	0		0		0	0		0
Reduced v/c Ratio	0.19	0.10		0.11	0.19		0.00		0.39	0.09		0.29

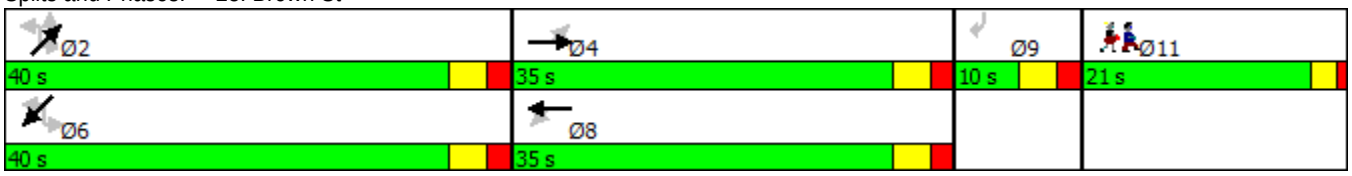
Intersection Summary	
Cycle Length: 106	
Actuated Cycle Length: 56	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.64	
Intersection Signal Delay: 18.1	Intersection LOS: B
Intersection Capacity Utilization 65.5%	ICU Level of Service C
Analysis Period (min) 15	

Lane Group	SWR	Ø11
Lane Configurations		
Traffic Volume (vph)	125	
Future Volume (vph)	125	
Satd. Flow (prot)	1531	
Flt Permitted		
Satd. Flow (perm)	1486	
Satd. Flow (RTOR)		
Confl. Peds. (#/hr)	6	
Confl. Bikes (#/hr)		
Peak Hour Factor	0.85	
Growth Factor	100%	
Heavy Vehicles (%)	2%	
Bus Blockages (#/hr)	0	
Parking (#/hr)		
Mid-Block Traffic (%)		
Shared Lane Traffic (%)		
Lane Group Flow (vph)	147	
Turn Type	Perm	
Protected Phases		11
Permitted Phases	6	
Total Split (s)	40.0	21.0
Total Lost Time (s)	5.0	
Act Effct Green (s)	24.9	
Actuated g/C Ratio	0.44	
v/c Ratio	0.22	
Control Delay	15.2	
Queue Delay	0.0	
Total Delay	15.2	
LOS	B	
Approach Delay		
Approach LOS		
Queue Length 50th (ft)	19	
Queue Length 95th (ft)	117	
Internal Link Dist (ft)		
Turn Bay Length (ft)	100	
Base Capacity (vph)	1074	
Starvation Cap Reductn	0	
Spillback Cap Reductn	0	
Storage Cap Reductn	0	
Reduced v/c Ratio	0.14	

Intersection Summary

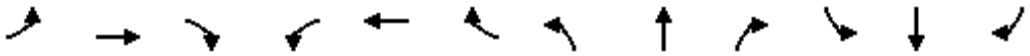
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 23: Brown St



Intersection Capacity Analysis
Route 20 @ Lincoln Street, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	10	359	14	408	330	322	15	77	475	211	51	5
Future Volume (vph)	10	359	14	408	330	322	15	77	475	211	51	5
Satd. Flow (prot)	0	3431	0	1711	1667	0	0	1786	1531	0	1746	0
Flt Permitted		0.926		0.950				0.924			0.702	
Satd. Flow (perm)	0	3180	0	1711	1667	0	0	1664	1531	0	1274	0
Satd. Flow (RTOR)		4			88				101		1	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.95	0.95	0.95	0.91	0.91	0.91	0.88	0.88	0.88	0.82	0.82	0.82
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	2%	2%	2%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	404	0	448	717	0	0	105	540	0	325	0
Turn Type	Perm	NA		Prot	NA		Perm	NA	pm+ov	Perm	NA	
Protected Phases		2		1	6			4	1		8	
Permitted Phases	2						4		4	8		
Total Split (s)	25.0	25.0		35.0	60.0		35.0	35.0	35.0	35.0	35.0	
Total Lost Time (s)		5.0		5.0	5.0			5.0	5.0		5.0	
Act Effct Green (s)		15.0		24.5	44.8			24.0	53.8		24.0	
Actuated g/C Ratio		0.19		0.31	0.56			0.30	0.68		0.30	
v/c Ratio		0.67		0.85	0.73			0.21	0.50		0.84	
Control Delay		37.4		43.5	17.0			23.6	6.8		47.9	
Queue Delay		0.0		0.0	0.0			0.0	0.0		0.0	
Total Delay		37.4		43.5	17.0			23.6	6.8		47.9	
LOS		D		D	B			C	A		D	
Approach Delay		37.4			27.2			9.5			47.9	
Approach LOS		D			C			A			D	
Queue Length 50th (ft)		107		219	235			41	85		158	
Queue Length 95th (ft)		165		#412	398			85	167		#272	
Internal Link Dist (ft)		289			228			617			398	
Turn Bay Length (ft)									150			
Base Capacity (vph)		843		678	1226			659	1196		505	
Starvation Cap Reductn		0		0	0			0	0		0	
Spillback Cap Reductn		0		0	0			0	0		0	
Storage Cap Reductn		0		0	0			0	0		0	
Reduced v/c Ratio		0.48		0.66	0.58			0.16	0.45		0.64	

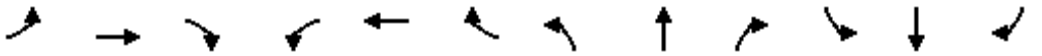
Intersection Summary			
Cycle Length: 95			
Actuated Cycle Length: 79.3			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.85			
Intersection Signal Delay: 27.0		Intersection LOS: C	
Intersection Capacity Utilization 81.6%		ICU Level of Service D	
Analysis Period (min) 15			

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 21:

Intersection Capacity Analysis
Route 20 @ Curtis Avenue, Marlborough

11/7/2016

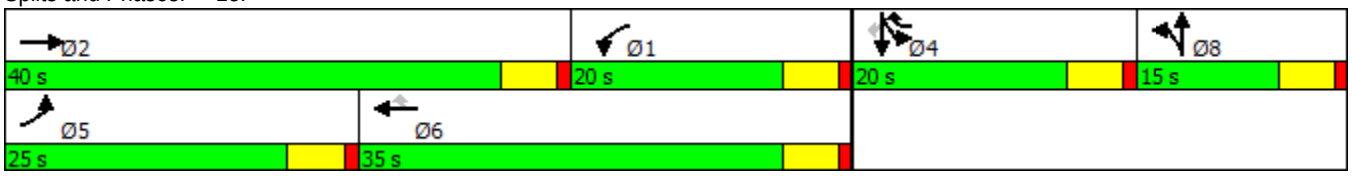


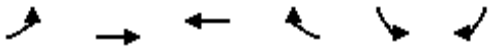
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	198	858	57	46	890	74	53	63	80	92	35	192
Future Volume (vph)	198	858	57	46	890	74	53	63	80	92	35	192
Satd. Flow (prot)	1728	3424	0	1728	3455	1546	0	1696	0	1625	1673	1546
Flt Permitted	0.950			0.950				0.987		0.950	0.978	
Satd. Flow (perm)	1728	3424	0	1728	3455	1546	0	1696	0	1625	1673	1546
Satd. Flow (RTOR)		8				82		29				204
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.90	0.90	0.90	0.85	0.85	0.85	0.94	0.94	0.94
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)										32%		
Lane Group Flow (vph)	204	944	0	51	989	82	0	230	0	67	68	204
Turn Type	Prot	NA		Prot	NA	pm+ov	Split	NA		Split	NA	Perm
Protected Phases	5	2		1	6	4	8	8		4	4	
Permitted Phases						6						4
Total Split (s)	25.0	40.0		20.0	35.0	20.0	15.0	15.0		20.0	20.0	20.0
Total Lost Time (s)	5.0	5.0		5.0	5.0	5.0		5.0		5.0	5.0	5.0
Act Effct Green (s)	14.5	36.1		10.9	27.3	40.7		10.2		8.4	8.4	8.4
Actuated g/C Ratio	0.18	0.45		0.14	0.34	0.50		0.13		0.10	0.10	0.10
v/c Ratio	0.66	0.61		0.22	0.85	0.10		0.97		0.40	0.39	0.59
Control Delay	42.4	21.4		34.8	33.8	3.1		85.7		43.1	42.8	13.5
Queue Delay	0.0	0.0		0.0	0.0	0.0		0.0		0.0	0.0	0.0
Total Delay	42.4	21.4		34.8	33.8	3.1		85.7		43.1	42.8	13.5
LOS	D	C		C	C	A		F		D	D	B
Approach Delay		25.1			31.6			85.7			25.2	
Approach LOS		C			C			F			C	
Queue Length 50th (ft)	99	222		22	236	0		106		34	35	0
Queue Length 95th (ft)	179	318		60	#405	22		#262		80	81	62
Internal Link Dist (ft)		686			186			446			263	
Turn Bay Length (ft)	360			175		175				75		125
Base Capacity (vph)	435	1592		327	1305	946		238		307	316	457
Starvation Cap Reductn	0	0		0	0	0		0		0	0	0
Spillback Cap Reductn	0	0		0	0	0		0		0	0	0
Storage Cap Reductn	0	0		0	0	0		0		0	0	0
Reduced v/c Ratio	0.47	0.59		0.16	0.76	0.09		0.97		0.22	0.22	0.45

Intersection Summary			
Cycle Length: 95			
Actuated Cycle Length: 80.6			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.97			
Intersection Signal Delay: 32.6		Intersection LOS: C	
Intersection Capacity Utilization 65.9%		ICU Level of Service C	
Analysis Period (min) 15			

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 18:





Lane Group	EBL	EBT	WBT	WBR	SBL	SBR	Ø9
Lane Configurations							
Traffic Volume (vph)	277	742	809	285	217	157	
Future Volume (vph)	277	742	809	285	217	157	
Satd. Flow (prot)	1728	3455	3455	1546	1711	1531	
Flt Permitted	0.950				0.950		
Satd. Flow (perm)	1728	3455	3455	1546	1711	1531	
Satd. Flow (RTOR)				198		145	
Confl. Peds. (#/hr)							
Confl. Bikes (#/hr)							
Peak Hour Factor	0.96	0.96	0.93	0.93	0.94	0.94	
Growth Factor	100%	100%	100%	100%	100%	100%	
Heavy Vehicles (%)	1%	1%	1%	1%	2%	2%	
Bus Blockages (#/hr)	0	0	0	0	0	0	
Parking (#/hr)							
Mid-Block Traffic (%)		0%	0%		0%		
Shared Lane Traffic (%)							
Lane Group Flow (vph)	289	773	870	306	231	167	
Turn Type	Prot	NA	NA	Perm	Prot	pm+ov	
Protected Phases	5	2	6		7	5	9
Permitted Phases				6		7	
Total Split (s)	25.0	75.0	50.0	50.0	25.0	25.0	30.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	
Act Effct Green (s)	20.9	58.2	32.1	32.1	18.4	43.8	
Actuated g/C Ratio	0.23	0.64	0.35	0.35	0.20	0.48	
v/c Ratio	0.73	0.35	0.72	0.46	0.67	0.21	
Control Delay	48.5	9.8	30.4	11.4	47.5	4.2	
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	
Total Delay	48.5	9.8	30.4	11.4	47.5	4.2	
LOS	D	A	C	B	D	A	
Approach Delay		20.3	25.5		29.4		
Approach LOS		C	C		C		
Queue Length 50th (ft)	147	87	208	40	113	6	
Queue Length 95th (ft)	#454	245	413	148	#342	39	
Internal Link Dist (ft)		257	297		486		
Turn Bay Length (ft)	300			150		100	
Base Capacity (vph)	395	2765	1780	892	391	810	
Starvation Cap Reductn	0	0	0	0	0	0	
Spillback Cap Reductn	0	0	0	0	0	0	
Storage Cap Reductn	0	0	0	0	0	0	
Reduced v/c Ratio	0.73	0.28	0.49	0.34	0.59	0.21	

Intersection Summary			
Cycle Length: 130			
Actuated Cycle Length: 91.2			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.73			
Intersection Signal Delay: 24.0		Intersection LOS: C	
Intersection Capacity Utilization 62.2%		ICU Level of Service B	
Analysis Period (min) 15			

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 14:

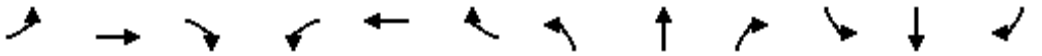
Movement	EBL	EBT	WBT	WBR	SWL	SWR
Lane Configurations						
Traffic Volume (veh/h)	145	772	999	43	38	114
Future Volume (Veh/h)	145	772	999	43	38	114
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.98	0.98	0.95	0.95	0.81	0.81
Hourly flow rate (vph)	148	788	1052	45	47	141
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						2
Median type		None	None			
Median storage veh)						
Upstream signal (ft)		752				
pX, platoon unblocked					0.84	
vC, conflicting volume	1097				2136	1052
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	1097				2259	1052
tC, single (s)	4.1				6.4	6.2
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	77				0	49
cM capacity (veh/h)	640				29	275

Direction, Lane #	EB 1	EB 2	WB 1	WB 2	SW 1
Volume Total	148	788	1052	45	188
Volume Left	148	0	0	0	47
Volume Right	0	0	0	45	141
cSH	640	1700	1700	1700	95
Volume to Capacity	0.23	0.46	0.62	0.03	1.99
Queue Length 95th (ft)	22	0	0	0	402
Control Delay (s)	12.3	0.0	0.0	0.0	554.0
Lane LOS	B				F
Approach Delay (s)	1.9		0.0		554.0
Approach LOS					F

Intersection Summary			
Average Delay	47.7		
Intersection Capacity Utilization	73.9%	ICU Level of Service	D
Analysis Period (min)	15		

Intersection Capacity Analysis
Route 20 at Farm Road, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	45	499	106	380	901	44	124	59	259	56	79	51
Future Volume (vph)	45	499	106	380	901	44	124	59	259	56	79	51
Satd. Flow (prot)	1770	3539	1583	1787	3549	0	1787	1881	1599	0	1844	1599
Flt Permitted	0.950			0.950			0.950				0.980	
Satd. Flow (perm)	1770	3539	1583	1787	3549	0	1787	1881	1599	0	1844	1599
Satd. Flow (RTOR)			102		3							102
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96	0.90	0.90	0.90	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	2%	2%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	47	520	110	396	985	0	138	66	288	0	142	54
Turn Type	Prot	NA	Perm	Prot	NA		Split	NA	pm+ov	Split	NA	Perm
Protected Phases	5	2		1	6		8	8	1	4	4	
Permitted Phases			2						8			4
Total Split (s)	30.0	45.0	45.0	30.0	45.0		30.0	30.0	30.0	30.0	30.0	30.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0		5.0	5.0	5.0		5.0	5.0
Act Effct Green (s)	8.6	23.0	23.0	26.3	43.7		13.8	13.8	44.7		13.8	13.8
Actuated g/C Ratio	0.08	0.23	0.23	0.26	0.43		0.14	0.14	0.44		0.14	0.14
v/c Ratio	0.31	0.65	0.25	0.86	0.64		0.57	0.26	0.41		0.57	0.18
Control Delay	56.1	41.4	10.8	57.3	29.5		54.3	46.7	21.1		54.1	1.3
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0
Total Delay	56.1	41.4	10.8	57.3	29.5		54.3	46.7	21.1		54.1	1.3
LOS	E	D	B	E	C		D	D	C		D	A
Approach Delay		37.5			37.5			33.8			39.5	
Approach LOS		D			D			C			D	
Queue Length 50th (ft)	27	145	4	223	239		78	36	110		80	0
Queue Length 95th (ft)	88	308	59	#708	#601		199	106	229		203	0
Internal Link Dist (ft)		394			534			205			111	
Turn Bay Length (ft)	350		50				75		150			
Base Capacity (vph)	459	1469	717	463	1530		463	488	705		478	490
Starvation Cap Reductn	0	0	0	0	0		0	0	0		0	0
Spillback Cap Reductn	0	0	0	0	0		0	0	0		0	0
Storage Cap Reductn	0	0	0	0	0		0	0	0		0	0
Reduced v/c Ratio	0.10	0.35	0.15	0.86	0.64		0.30	0.14	0.41		0.30	0.11

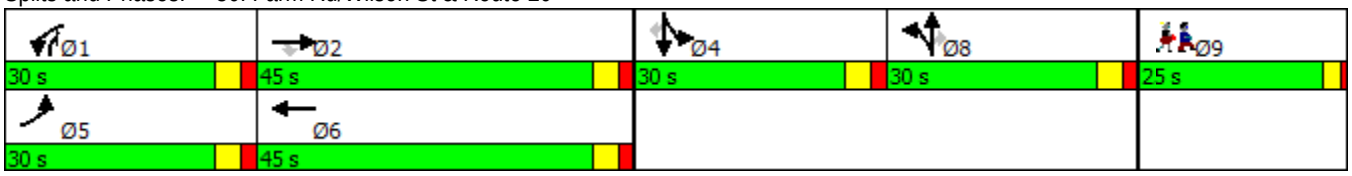
Intersection Summary	
Cycle Length: 160	
Actuated Cycle Length: 101.4	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.86	
Intersection Signal Delay: 37.0	Intersection LOS: D
Intersection Capacity Utilization 61.3%	ICU Level of Service B
Analysis Period (min) 15	

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	25.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

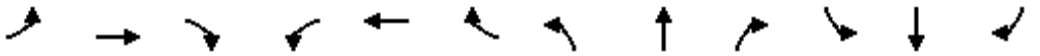
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 30: Farm Rd/Wilson St & Route 20



Intersection Capacity Analysis
Route 20 at Dicenzo Boulevard/Pomphrey Drive, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	29	595	123	62	1087	25	220	6	25	13	6	6
Future Volume (vph)	29	595	123	62	1087	25	220	6	25	13	6	6
Satd. Flow (prot)	1728	3365	0	1711	3411	0	3173	1510	0	1636	1593	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1728	3365	0	1711	3411	0	3173	1510	0	1636	1593	0
Satd. Flow (RTOR)		16			2			27			9	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.89	0.89	0.89	0.98	0.98	0.98	0.94	0.94	0.94	0.70	0.70	0.70
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	3%	3%	3%	3%	3%	3%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	33	807	0	63	1135	0	234	33	0	19	18	0
Turn Type	Prot	NA		Prot	NA		Split	NA		Split	NA	
Protected Phases	5	2		1	6		8	8		4	4	
Permitted Phases												
Total Split (s)	30.0	45.0		30.0	45.0		30.0	30.0		17.0	17.0	
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	
Act Effct Green (s)	7.8	39.7		9.2	44.2		12.2	12.2		7.2	7.2	
Actuated g/C Ratio	0.09	0.47		0.11	0.52		0.14	0.14		0.09	0.09	
v/c Ratio	0.21	0.51		0.34	0.63		0.51	0.14		0.14	0.12	
Control Delay	47.7	22.0		47.1	22.6		41.3	20.2		48.8	36.1	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	47.7	22.0		47.1	22.6		41.3	20.2		48.8	36.1	
LOS	D	C		D	C		D	C		D	D	
Approach Delay		23.0			23.9			38.7			42.6	
Approach LOS		C			C			D			D	
Queue Length 50th (ft)	17	155		32	245		61	3		10	5	
Queue Length 95th (ft)	60	385		97	#647		137	36		32	24	
Internal Link Dist (ft)		536			775			209			131	
Turn Bay Length (ft)	120			400								
Base Capacity (vph)	556	1757		551	1792		1022	505		253	254	
Starvation Cap Reductn	0	0		0	0		0	0		0	0	
Spillback Cap Reductn	0	0		0	0		0	0		0	0	
Storage Cap Reductn	0	0		0	0		0	0		0	0	
Reduced v/c Ratio	0.06	0.46		0.11	0.63		0.23	0.07		0.08	0.07	

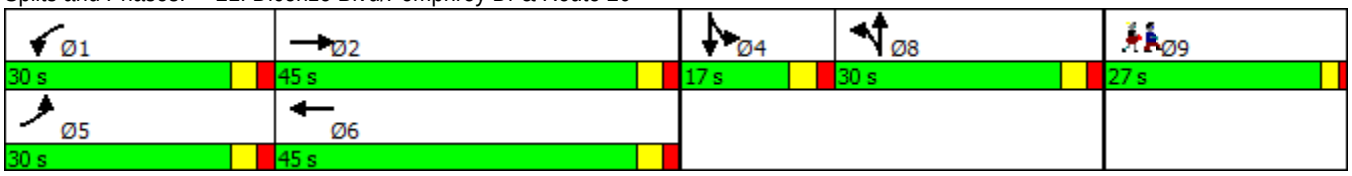
Intersection Summary			
Cycle Length: 149			
Actuated Cycle Length: 84.2			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.63			
Intersection Signal Delay: 25.5		Intersection LOS: C	
Intersection Capacity Utilization 61.3%		ICU Level of Service B	
Analysis Period (min) 15			

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	27.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

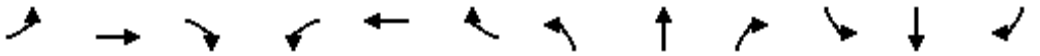
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 21: Dicenzo Blvd/Pomphrey Dr & Route 20



Intersection Capacity Analysis
Route 20 at Raytheon Driveway, Marlborough

11/7/2016

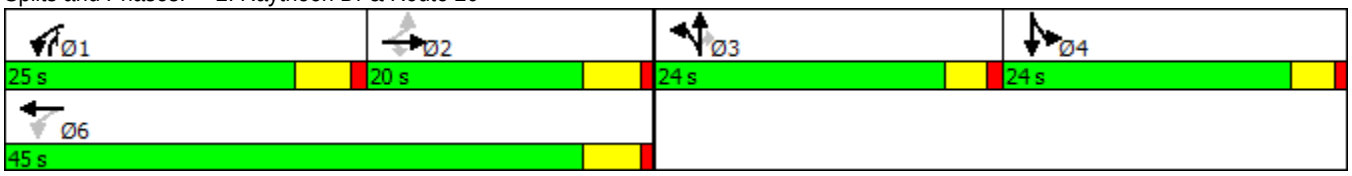


Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	29	545	3	1	925	15	240	0	141	12	0	41
Future Volume (vph)	29	545	3	1	925	15	240	0	141	12	0	41
Satd. Flow (prot)	0	3411	1583	1728	1877	0	0	1787	1599	0	1649	0
Flt Permitted		0.719		0.299				0.950			0.989	
Satd. Flow (perm)	0	2460	1583	544	1877	0	0	1787	1599	0	1649	0
Satd. Flow (RTOR)			117		1				155		129	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.93	0.93	0.93	0.97	0.97	0.97	0.91	0.91	0.91	0.66	0.66	0.66
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	2%	2%	2%	1%	1%	1%	1%	1%	1%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	617	3	1	969	0	0	264	155	0	80	0
Turn Type	Perm	NA	Perm	pm+pt	NA		Split	NA	pm+ov	Split	NA	
Protected Phases		2		1	6		3	3	1	4	4	
Permitted Phases	2		2	6					3			
Total Split (s)	20.0	20.0	20.0	25.0	45.0		24.0	24.0	25.0	24.0	24.0	
Total Lost Time (s)		5.0	5.0	5.0	5.0			4.0	5.0		4.0	
Act Effct Green (s)		29.2	29.2	40.5	40.5			15.6	22.0		6.2	
Actuated g/C Ratio		0.40	0.40	0.56	0.56			0.21	0.30		0.09	
v/c Ratio		0.63	0.00	0.00	0.93			0.69	0.26		0.31	
Control Delay		22.6	0.0	10.0	34.7			37.2	3.4		5.5	
Queue Delay		0.0	0.0	0.0	0.0			0.0	0.0		0.0	
Total Delay		22.6	0.0	10.0	34.7			37.2	3.4		5.5	
LOS		C	A	A	C			D	A		A	
Approach Delay		22.5			34.6			24.7			5.5	
Approach LOS		C			C			C			A	
Queue Length 50th (ft)		121	0	0	408			114	0		0	
Queue Length 95th (ft)		196	0	3	#752			192	26		0	
Internal Link Dist (ft)		655			163			102			237	
Turn Bay Length (ft)			300									
Base Capacity (vph)		986	705	630	1042			495	868		551	
Starvation Cap Reductn		0	0	0	0			0	0		0	
Spillback Cap Reductn		0	0	0	0			0	0		0	
Storage Cap Reductn		0	0	0	0			0	0		0	
Reduced v/c Ratio		0.63	0.00	0.00	0.93			0.53	0.18		0.15	

Intersection Summary			
Cycle Length: 93			
Actuated Cycle Length: 72.9			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.93			
Intersection Signal Delay: 27.9		Intersection LOS: C	
Intersection Capacity Utilization 77.1%		ICU Level of Service D	
Analysis Period (min) 15			

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 2: Raytheon Dr & Route 20



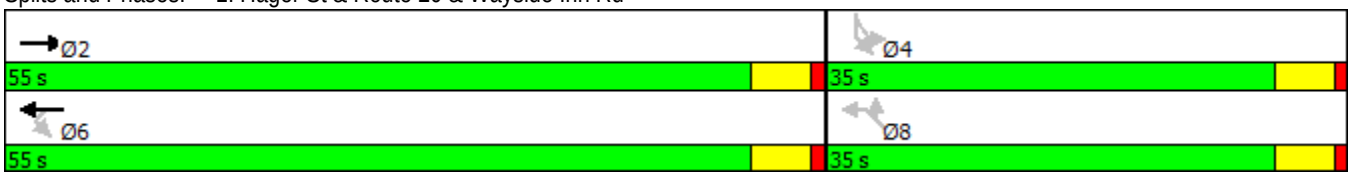
Intersection Capacity Analysis
Route 20 at Wayside Inn Road/Hager Street, Marlborough

11/7/2016

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	SBL2	SBL	SBR	NWL	NWR	NWR2
Lane Configurations												
Traffic Volume (vph)	0	520	0	4	702	5	5	23	79	118	166	3
Future Volume (vph)	0	520	0	4	702	5	5	23	79	118	166	3
Satd. Flow (prot)	0	1881	0	0	1879	0	0	1657	0	1787	1599	0
Flt Permitted					0.998			0.980		0.841		
Satd. Flow (perm)	0	1881	0	0	1876	0	0	1645	0	1582	1599	0
Satd. Flow (RTOR)					1			92			24	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.91	0.91	0.91	0.86	0.86	0.86	0.94	0.94	0.94
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	2%	2%	2%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%		0%		
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	536	0	0	780	0	0	125	0	126	180	0
Turn Type		NA		Perm	NA		Perm	Perm		Perm	Perm	
Protected Phases		2			6							
Permitted Phases				6			4	4		8	8	
Total Split (s)		55.0		55.0	55.0		35.0	35.0		35.0	35.0	
Total Lost Time (s)		5.0			5.0			5.0		5.0	5.0	
Act Effct Green (s)		25.6			25.6			10.4		10.4	10.4	
Actuated g/C Ratio		0.55			0.55			0.22		0.22	0.22	
v/c Ratio		0.52			0.76			0.29		0.36	0.48	
Control Delay		8.9			14.0			9.4		20.5	20.2	
Queue Delay		0.0			0.0			0.0		0.0	0.0	
Total Delay		8.9			14.0			9.4		20.5	20.2	
LOS		A			B			A		C	C	
Approach Delay		8.9			14.0			9.4		20.3		
Approach LOS		A			B			A		C		
Queue Length 50th (ft)		71			127			6		25	32	
Queue Length 95th (ft)		175			315			45		87	109	
Internal Link Dist (ft)		190			594			403		33		
Turn Bay Length (ft)												
Base Capacity (vph)		1766			1761			1159		1087	1106	
Starvation Cap Reductn		0			0			0		0	0	
Spillback Cap Reductn		0			0			0		0	0	
Storage Cap Reductn		0			0			0		0	0	
Reduced v/c Ratio		0.30			0.44			0.11		0.12	0.16	

Intersection Summary			
Cycle Length: 90			
Actuated Cycle Length: 46.6			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.76			
Intersection Signal Delay: 13.2		Intersection LOS: B	
Intersection Capacity Utilization 65.9%		ICU Level of Service C	
Analysis Period (min) 15			

Splits and Phases: 1: Hager St & Route 20 & Wayside Inn Rd



APPENDIX D

Preliminary Traffic Signal Warrants Analysis
Route 20 at Concord Road, Marlborough

Table D-1
Summary of Hourly Volumes and Warrant Analyses
Route 20 (East Main Street) at Concord Road, Marlborough

Hourly period starting	Route 20 (main street)		Concord Road (minor street)	Sum of main street	Maximum of minor street	Volumes above the required minimum on main/minor street		
	EB	WB	SB			Warrant 1	Warrant 2	Warrant 7
6:00	837	340	105	1177	105	√		√
7:00	986	618	225	1604	225	√	√	√
8:00	920	593	182	1513	182	√	√	√
9:00	753	558	131	1311	131	√	√	√
10:00	657	583	103	1240	103	√		√
11:00	604	681	112	1285	112	√		√
12:00	691	688	100	1379	100	√		√
13:00	663	680	107	1343	107	√		√
14:00	773	764	115	1537	115	√	√	√
15:00	746	857	130	1603	130	√	√	√
16:00	774	936	156	1710	156	√	√	√
17:00	870	951	157	1821	157	√	√	√
18:00	725	921	137	1646	137	√	√	√
19:00	625	718	85	1343	85	√		√

Warrants 1, 2, and 7 in MUTCD Chapter 4C were applied to this intersection.

Warrant 1 (8-Hour Volume) is fulfilled. It requires that the traffic conditions (observed vehicular volumes higher than the specified minimum volumes) exist for each of any 8 hours of an average day. The interruption of continuous traffic (Conditions B) was applied in this case. The volume threshold for a major street (assuming two lanes) is 900 vehicles per hour (vph) and for a minor street of one lane is 75 vph.

Warrant 2 (4-Hour Volume) is fulfilled. It requires that the traffic conditions (main street combined/minor street maximum volume falling above an applicable curve) exist for each of any 4 hours of an average day. The lower threshold volume for a minor street of one lane is 80 vph.

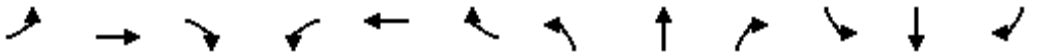
Warrant 7 (Crash Experience) is fulfilled. Traffic conditions in more than eight hours met the 80% threshold in Warrant 1. Meanwhile, there were five correctable crashes in the recent 12-month period.

APPENDIX E

Intersection Capacity Analyses
Saturday Midday Peak Hour
2016 Existing Conditions

Intersection Capacity Analysis
Route 20 at Lincoln Street, Marlborough

11/7/2016

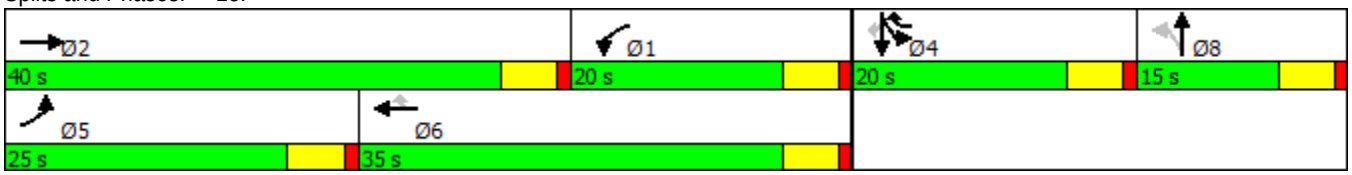


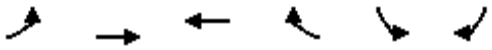
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	236	855	49	67	887	117	43	78	82	135	56	242
Future Volume (vph)	236	855	49	67	887	117	43	78	82	135	56	242
Satd. Flow (prot)	1728	3423	0	1728	3455	1546	0	1703	0	1658	1708	1561
Flt Permitted	0.950			0.950				0.895		0.950	0.979	
Satd. Flow (perm)	1725	3423	0	1723	3455	1500	0	1536	0	1658	1708	1521
Satd. Flow (RTOR)		7				127		29				272
Confl. Peds. (#/hr)	2		3	3		2	5					5
Confl. Bikes (#/hr)												
Peak Hour Factor	0.98	0.98	0.98	0.92	0.92	0.92	0.86	0.86	0.86	0.89	0.89	0.89
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	0%	0%	0%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)										30%		
Lane Group Flow (vph)	241	922	0	73	964	127	0	236	0	106	109	272
Turn Type	Prot	NA		Prot	NA	pm+ov	Perm	NA		Split	NA	Perm
Protected Phases	5	2		1	6	4		8		4	4	
Permitted Phases						6	8					4
Total Split (s)	25.0	40.0		20.0	35.0	20.0	15.0	15.0		20.0	20.0	20.0
Total Lost Time (s)	5.0	5.0		5.0	5.0	5.0		5.0		5.0	5.0	5.0
Act Effct Green (s)	16.1	33.0		13.0	27.1	37.4		10.2		10.3	10.3	10.3
Actuated g/C Ratio	0.19	0.39		0.15	0.32	0.44		0.12		0.12	0.12	0.12
v/c Ratio	0.73	0.68		0.27	0.87	0.17		1.12		0.52	0.52	0.64
Control Delay	46.7	26.1		36.3	37.4	2.9		132.2		45.9	45.5	12.3
Queue Delay	0.0	0.0		0.0	0.0	0.0		0.0		0.0	0.0	0.0
Total Delay	46.7	26.1		36.3	37.4	2.9		132.2		45.9	45.5	12.3
LOS	D	C		D	D	A		F		D	D	B
Approach Delay		30.4			33.5			132.2			27.1	
Approach LOS		C			C			F			C	
Queue Length 50th (ft)	126	234		35	255	0		~145		58	61	0
Queue Length 95th (ft)	216	320		81	#402	26		#295		113	116	67
Internal Link Dist (ft)		686			186			446			263	
Turn Bay Length (ft)	360			175		175				75		125
Base Capacity (vph)	418	1455		319	1256	826		211		301	310	499
Starvation Cap Reductn	0	0		0	0	0		0		0	0	0
Spillback Cap Reductn	0	0		0	0	0		0		0	0	0
Storage Cap Reductn	0	0		0	0	0		0		0	0	0
Reduced v/c Ratio	0.58	0.63		0.23	0.77	0.15		1.12		0.35	0.35	0.55

Intersection Summary		
Cycle Length: 95		
Actuated Cycle Length: 84.1		
Control Type: Actuated-Uncoordinated		
Maximum v/c Ratio: 1.12		
Intersection Signal Delay: 38.9	Intersection LOS: D	
Intersection Capacity Utilization 68.3%	ICU Level of Service C	
Analysis Period (min) 15		

~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 18:



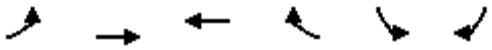


Lane Group	EBL	EBT	WBT	WBR	SBL	SBR	Ø9
Lane Configurations							
Traffic Volume (vph)	224	842	890	236	279	217	
Future Volume (vph)	224	842	890	236	279	217	
Satd. Flow (prot)	1728	3455	3455	1546	1728	1546	
Flt Permitted	0.950				0.950		
Satd. Flow (perm)	1726	3455	3455	1511	1728	1523	
Satd. Flow (RTOR)				149		155	
Confl. Peds. (#/hr)	1			1		3	
Confl. Bikes (#/hr)							
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	
Growth Factor	100%	100%	100%	100%	100%	100%	
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	
Bus Blockages (#/hr)	0	0	0	0	0	0	
Parking (#/hr)							
Mid-Block Traffic (%)		0%	0%		0%		
Shared Lane Traffic (%)							
Lane Group Flow (vph)	236	886	937	248	294	228	
Turn Type	Prot	NA	NA	Perm	Prot	pm+ov	
Protected Phases	5	2	6		7	5	9
Permitted Phases				6		7	
Total Split (s)	25.0	75.0	50.0	50.0	25.0	25.0	30.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	
Act Effct Green (s)	18.6	57.7	33.9	33.9	20.8	39.4	
Actuated g/C Ratio	0.20	0.62	0.36	0.36	0.22	0.42	
v/c Ratio	0.69	0.41	0.75	0.39	0.76	0.31	
Control Delay	49.0	10.9	31.2	11.8	51.6	6.6	
Queue Delay	0.0	0.1	0.0	0.0	0.0	0.0	
Total Delay	49.0	11.0	31.2	11.8	51.6	6.6	
LOS	D	B	C	B	D	A	
Approach Delay		19.0	27.1		31.9		
Approach LOS		B	C		C		
Queue Length 50th (ft)	119	104	230	36	155	20	
Queue Length 95th (ft)	#349	289	455	132	#464	64	
Internal Link Dist (ft)		238	316		471		
Turn Bay Length (ft)	300			150		100	
Base Capacity (vph)	385	2698	1734	832	385	770	
Starvation Cap Reductn	0	502	0	0	0	0	
Spillback Cap Reductn	0	0	0	0	0	0	
Storage Cap Reductn	0	0	0	0	0	0	
Reduced v/c Ratio	0.61	0.40	0.54	0.30	0.76	0.30	

Intersection Summary	
Cycle Length: 130	
Actuated Cycle Length: 93.2	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.76	
Intersection Signal Delay: 24.8	Intersection LOS: C
Intersection Capacity Utilization 65.0%	ICU Level of Service C
Analysis Period (min) 15	

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 14:



Lane Group	EBL	EBT	WBT	WBR	SBL	SBR	Ø9
Lane Configurations							
Traffic Volume (vph)	224	842	890	236	279	217	
Future Volume (vph)	224	842	890	236	279	217	
Satd. Flow (prot)	1728	3455	3455	1546	1728	1546	
Flt Permitted	0.950				0.950		
Satd. Flow (perm)	1726	3455	3455	1511	1728	1523	
Satd. Flow (RTOR)				149		155	
Confl. Peds. (#/hr)	1			1		3	
Confl. Bikes (#/hr)							
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	
Growth Factor	100%	100%	100%	100%	100%	100%	
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	
Bus Blockages (#/hr)	0	0	0	0	0	0	
Parking (#/hr)							
Mid-Block Traffic (%)		0%	0%		0%		
Shared Lane Traffic (%)							
Lane Group Flow (vph)	236	886	937	248	294	228	
Turn Type	Prot	NA	NA	Perm	Prot	pm+ov	
Protected Phases	5	2	6		7	5	9
Permitted Phases				6		7	
Total Split (s)	25.0	75.0	50.0	50.0	25.0	25.0	30.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	
Act Effct Green (s)	18.6	57.7	33.9	33.9	20.8	39.4	
Actuated g/C Ratio	0.20	0.62	0.36	0.36	0.22	0.42	
v/c Ratio	0.69	0.41	0.75	0.39	0.76	0.31	
Control Delay	49.0	10.9	31.2	11.8	51.6	6.6	
Queue Delay	0.0	0.1	0.0	0.0	0.0	0.0	
Total Delay	49.0	11.0	31.2	11.8	51.6	6.6	
LOS	D	B	C	B	D	A	
Approach Delay		19.0	27.1		31.9		
Approach LOS		B	C		C		
Queue Length 50th (ft)	119	104	230	36	155	20	
Queue Length 95th (ft)	#349	289	455	132	#464	64	
Internal Link Dist (ft)		238	316		471		
Turn Bay Length (ft)	300			150		100	
Base Capacity (vph)	385	2698	1734	832	385	770	
Starvation Cap Reductn	0	502	0	0	0	0	
Spillback Cap Reductn	0	0	0	0	0	0	
Storage Cap Reductn	0	0	0	0	0	0	
Reduced v/c Ratio	0.61	0.40	0.54	0.30	0.76	0.30	

Intersection Summary			
Cycle Length: 130			
Actuated Cycle Length: 93.2			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.76			
Intersection Signal Delay: 24.8		Intersection LOS: C	
Intersection Capacity Utilization 65.0%		ICU Level of Service C	
Analysis Period (min) 15			

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 14:

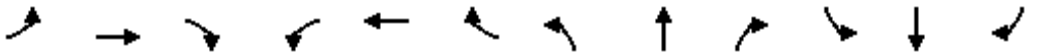
Movement	EBL	EBT	WBT	WBR	SWL	SWR
Lane Configurations						
Traffic Volume (veh/h)	136	951	987	48	47	138
Future Volume (Veh/h)	136	951	987	48	47	138
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.96	0.96	0.98	0.98	0.91	0.91
Hourly flow rate (vph)	142	991	1007	49	52	152
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						4
Median type		None	None			
Median storage veh)						
Upstream signal (ft)		783				
pX, platoon unblocked					0.78	
vC, conflicting volume	1056				2282	1007
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	1056				2502	1007
tC, single (s)	4.1				6.4	6.2
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	79				0	48
cM capacity (veh/h)	663				20	294

Direction, Lane #	EB 1	EB 2	WB 1	WB 2	SW 1
Volume Total	142	991	1007	49	204
Volume Left	142	0	0	0	52
Volume Right	0	0	0	49	152
cSH	663	1700	1700	1700	67
Volume to Capacity	0.21	0.58	0.59	0.03	3.05
Queue Length 95th (ft)	20	0	0	0	Err
Control Delay (s)	11.9	0.0	0.0	0.0	Err
Lane LOS	B				F
Approach Delay (s)	1.5		0.0		Err
Approach LOS					F

Intersection Summary			
Average Delay	853.1		
Intersection Capacity Utilization	72.8%	ICU Level of Service	C
Analysis Period (min)	15		

Intersection Capacity Analysis
Route 20 at Farm Road, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	97	703	64	254	732	61	99	53	309	80	64	83
Future Volume (vph)	97	703	64	254	732	61	99	53	309	80	64	83
Satd. Flow (prot)	1787	3574	1599	1787	3528	0	1770	1863	1583	0	1830	1599
Flt Permitted	0.950			0.950			0.950				0.973	
Satd. Flow (perm)	1784	3574	1599	1787	3528	0	1767	1863	1563	0	1829	1577
Satd. Flow (RTOR)			102		5							102
Confl. Peds. (#/hr)	2					2	1		1	1		1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.94	0.94	0.94	0.92	0.92	0.92	0.88	0.88	0.88	0.83	0.83	0.83
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	2%	2%	2%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	103	748	68	276	862	0	113	60	351	0	173	100
Turn Type	Prot	NA	Perm	Prot	NA		Split	NA	pm+ov	Split	NA	Perm
Protected Phases	5	2		1	6		8	8	1	4	4	
Permitted Phases			2						8			4
Total Split (s)	30.0	45.0	45.0	30.0	45.0		30.0	30.0	30.0	30.0	30.0	30.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0		5.0	5.0	5.0		5.0	5.0
Act Effct Green (s)	12.4	28.8	28.8	25.5	41.9		13.1	13.1	38.7		16.4	16.4
Actuated g/C Ratio	0.11	0.27	0.27	0.24	0.39		0.12	0.12	0.36		0.15	0.15
v/c Ratio	0.50	0.79	0.14	0.66	0.63		0.53	0.27	0.62		0.63	0.31
Control Delay	58.9	45.5	2.9	49.9	32.7		58.7	52.0	32.9		57.4	12.0
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0
Total Delay	58.9	45.5	2.9	49.9	32.7		58.7	52.0	32.9		57.4	12.0
LOS	E	D	A	D	C		E	D	C		E	B
Approach Delay		43.8			36.9			40.6			40.8	
Approach LOS		D			D			D			D	
Queue Length 50th (ft)	64	234	0	162	226		70	36	168		106	0
Queue Length 95th (ft)	164	460	14	#470	518		172	101	312		228	42
Internal Link Dist (ft)		394			534			205			111	
Turn Bay Length (ft)	350		50				75		150			
Base Capacity (vph)	433	1387	683	433	1430		429	451	573		444	459
Starvation Cap Reductn	0	0	0	0	0		0	0	0		0	0
Spillback Cap Reductn	0	0	0	0	0		0	0	0		0	0
Storage Cap Reductn	0	0	0	0	0		0	0	0		0	0
Reduced v/c Ratio	0.24	0.54	0.10	0.64	0.60		0.26	0.13	0.61		0.39	0.22

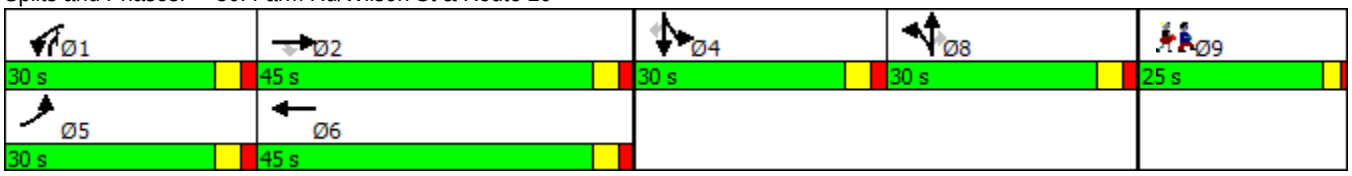
Intersection Summary		
Cycle Length: 160		
Actuated Cycle Length: 108.3		
Control Type: Actuated-Uncoordinated		
Maximum v/c Ratio: 0.79		
Intersection Signal Delay: 40.2	Intersection LOS: D	
Intersection Capacity Utilization 60.5%	ICU Level of Service B	
Analysis Period (min) 15		

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	25.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

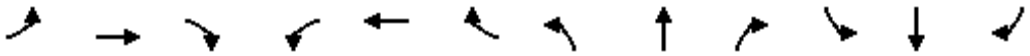
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 30: Farm Rd/Wilson St & Route 20



Intersection Capacity Analysis
Route 20 at Dicenzo Boulevard/Pomphrey Drive, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	29	726	214	109	645	27	347	12	64	8	13	27
Future Volume (vph)	29	726	214	109	645	27	347	12	64	8	13	27
Satd. Flow (prot)	1711	3305	0	1711	3401	0	3204	1520	0	1685	1594	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1711	3305	0	1711	3401	0	3204	1520	0	1685	1594	0
Satd. Flow (RTOR)		25			3			68			39	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.89	0.89	0.89	0.98	0.98	0.98	0.94	0.94	0.94	0.70	0.70	0.70
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	2%	2%	2%	0%	0%	0%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	33	1056	0	111	686	0	369	81	0	11	58	0
Turn Type	Prot	NA		Prot	NA		Split	NA		Split	NA	
Protected Phases	5	2		1	6		8	8		4	4	
Permitted Phases												
Total Split (s)	30.0	45.0		30.0	45.0		30.0	30.0		17.0	17.0	
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	
Act Effct Green (s)	7.9	42.0		12.3	52.0		17.1	17.1		7.6	7.6	
Actuated g/C Ratio	0.08	0.42		0.12	0.52		0.17	0.17		0.08	0.08	
v/c Ratio	0.25	0.76		0.53	0.39		0.68	0.26		0.09	0.37	
Control Delay	55.7	32.5		55.4	21.1		48.3	16.4		53.6	31.7	
Queue Delay	0.0	0.0		0.0	0.0		0.1	0.0		0.0	0.0	
Total Delay	55.7	32.5		55.4	21.1		48.4	16.4		53.6	31.7	
LOS	E	C		E	C		D	B		D	C	
Approach Delay		33.2			25.9			42.6			35.2	
Approach LOS		C			C			D			D	
Queue Length 50th (ft)	19	270		64	139		108	7		6	11	
Queue Length 95th (ft)	65	#716		162	344		224	59		24	41	
Internal Link Dist (ft)		391			775			209			131	
Turn Bay Length (ft)	120			400								
Base Capacity (vph)	445	1390		445	1755		833	445		210	233	
Starvation Cap Reductn	0	0		0	0		44	0		0	0	
Spillback Cap Reductn	0	0		0	0		0	0		0	0	
Storage Cap Reductn	0	0		0	0		0	0		0	0	
Reduced v/c Ratio	0.07	0.76		0.25	0.39		0.47	0.18		0.05	0.25	

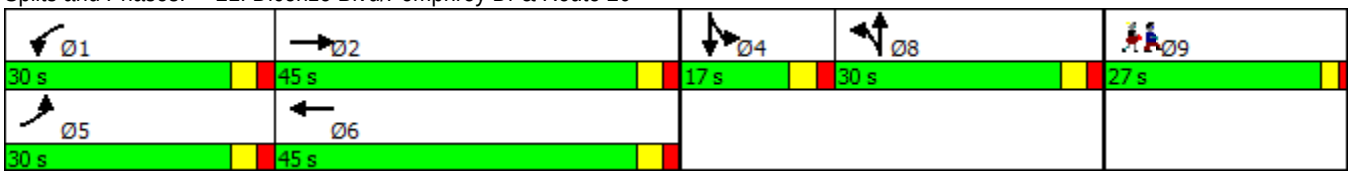
Intersection Summary		
Cycle Length: 149		
Actuated Cycle Length: 100.8		
Control Type: Actuated-Uncoordinated		
Maximum v/c Ratio: 0.76		
Intersection Signal Delay: 32.6	Intersection LOS: C	
Intersection Capacity Utilization 62.0%	ICU Level of Service B	
Analysis Period (min) 15		

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	27.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 21: Dicenzo Blvd/Pomphrey Dr & Route 20



APPENDIX F

Corridor and Segment Crash Rate Worksheets

SEGMENT CRASH RATE WORKSHEET

CITY/TOWN : Marlborough COUNT DATE : NA (2012)

DISTRICT : 3

~ SEGMENT DATA ~

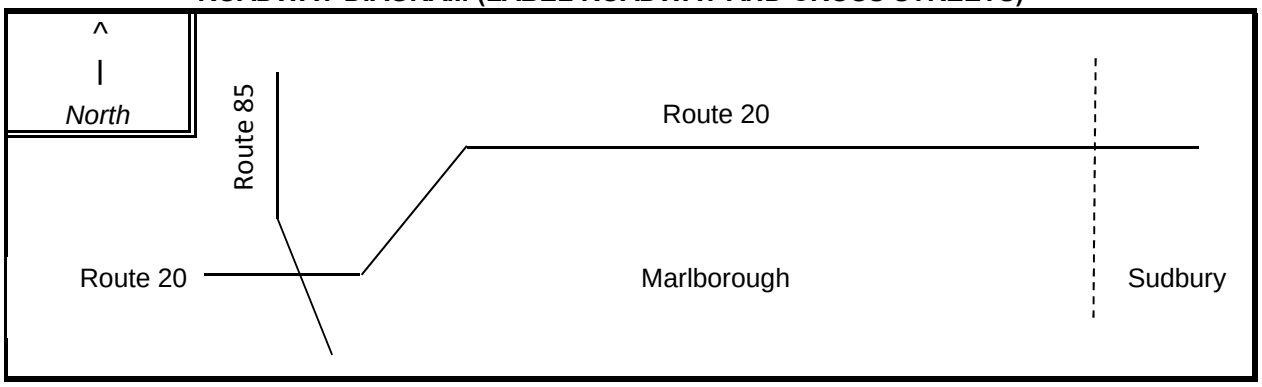
ROADWAY NAME: Route 20 Corridor

START POINT: West of Route 85 (South Bolton Street)

END POINT: Sudbury Town Line

FUNCTIONAL CLASSIFICATION OF ROADWAY: Urban Principal Arterial - Other

ROADWAY DIAGRAM (LABEL ROADWAY AND CROSS STREETS)



AVERAGE DAILY TRAFFIC

SEGMENT LENGTH IN MILES (**L**):	**3.65**
AVERAGE DAILY TRAFFIC VOLUME (**V**):	20,500

TOTAL # OF CRASHES:	997	# OF YEARS :	5	AVERAGE # OF CRASHES PER YEAR (**A**) :	**199.40**

CRASH RATE CALCULATION : **7.30**

$$\text{RATE} = \frac{(A * 1{,}000{,}000)}{(L * V * 365)}$$

Comments : 2013 State Average for Urban Principal Arterial (Other) = 3.49

Project Title & Date: Route 20 East Corridor Study

SEGMENT CRASH RATE WORKSHEET

CITY/TOWN : Marlborough COUNT DATE : 4/6-8/2016

DISTRICT : 3

~ SEGMENT DATA ~

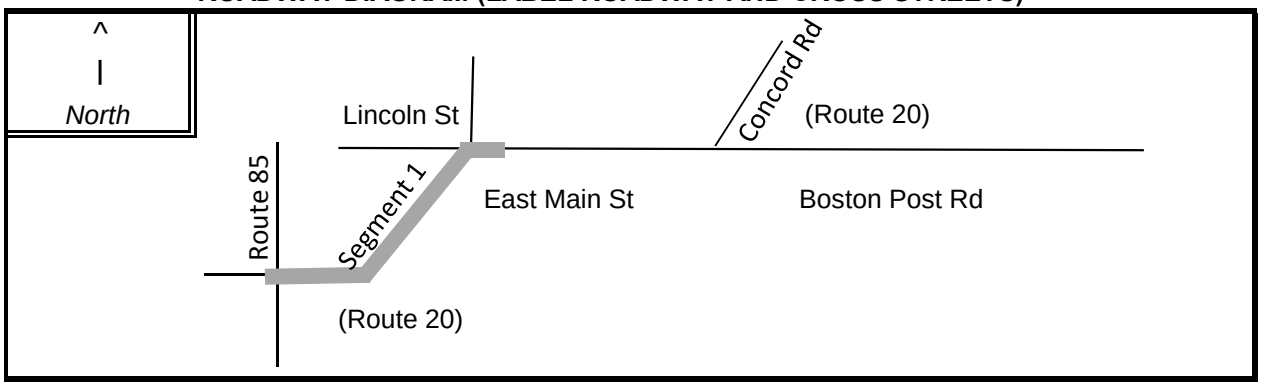
ROADWAY NAME: Route 20 Segment 1

START POINT: About 100 feet west of Route 85 (South Bolton Street)

END POINT: About 100 feet east of Lincoln Street

FUNCTIONAL CLASSIFICATION OF ROADWAY: Urban Principal Arterial - Other

ROADWAY DIAGRAM (LABEL ROADWAY AND CROSS STREETS)



AVERAGE DAILY TRAFFIC

SEGMENT LENGTH IN MILES (**L**):	0.50
AVERAGE DAILY TRAFFIC VOLUME (**V**):	20,500

TOTAL # OF CRASHES:	152	# OF YEARS :	5	AVERAGE # OF CRASHES PER YEAR (**A**) :	**30.40**

CRASH RATE CALCULATION : **8.09**

$$\text{RATE} = \frac{(A * 1{,}000{,}000)}{(L * V * 365)}$$

Comments : 2013 State Average for Urban Principal Arterial (Other) = 3.49

Project Title & Date: Route 20 East Corridor Study

SEGMENT CRASH RATE WORKSHEET

CITY/TOWN : Marlborough COUNT DATE : 4/6-8/2016

DISTRICT : 3

~ SEGMENT DATA ~

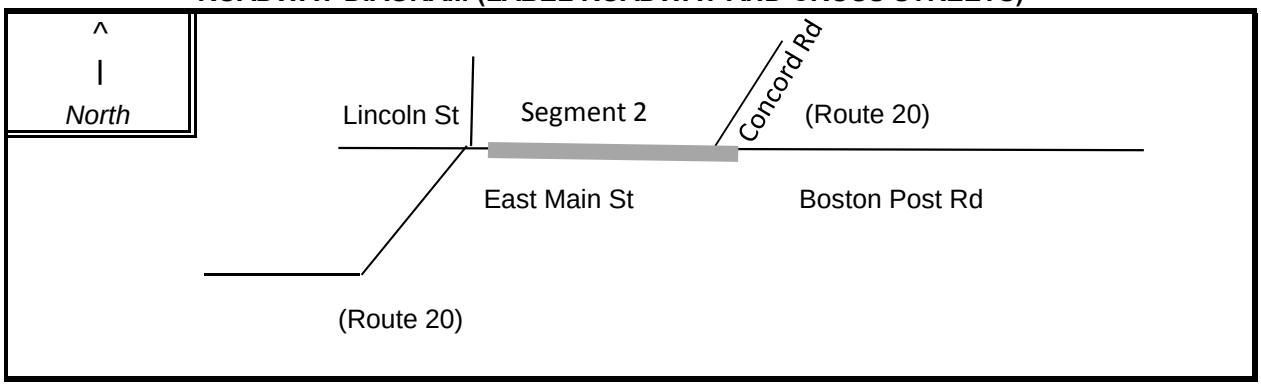
ROADWAY NAME: Route 20 Segment 2

START POINT: About 200 feet east of Lincoln Street

END POINT: About 200 feet east of Concord Road

FUNCTIONAL CLASSIFICATION OF ROADWAY: Urban Principal Arterial - Other

ROADWAY DIAGRAM (LABEL ROADWAY AND CROSS STREETS)



AVERAGE DAILY TRAFFIC

SEGMENT LENGTH IN MILES (**L**):	0.55
AVERAGE DAILY TRAFFIC VOLUME (**V**):	26,000

TOTAL # OF CRASHES:	313	# OF YEARS :	5	AVERAGE # OF CRASHES PER YEAR (**A**) :	**62.60**

CRASH RATE CALCULATION : **12.05**

$$\text{RATE} = \frac{(A * 1{,}000{,}000)}{(L * V * 365)}$$

Comments : 2013 State Average for Urban Principal Arterial (Other) = 3.49

Project Title & Date: Route 20 East Corridor Study

SEGMENT CRASH RATE WORKSHEET

CITY/TOWN : Marlborough COUNT DATE : 4/6-8/2016

DISTRICT : 3

~ SEGMENT DATA ~

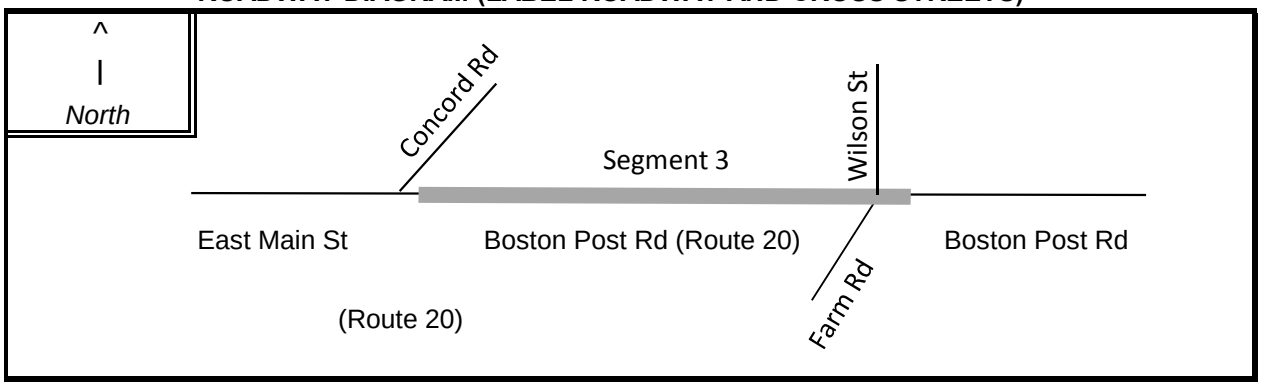
ROADWAY NAME: Route 20 Segment 3

START POINT: About 200 feet east of Concord Road

END POINT: About 300 feet east of Farm Road

FUNCTIONAL CLASSIFICATION OF ROADWAY: Urban Principal Arterial - Other

ROADWAY DIAGRAM (LABEL ROADWAY AND CROSS STREETS)



AVERAGE DAILY TRAFFIC

SEGMENT LENGTH IN MILES (**L**):	1.30
AVERAGE DAILY TRAFFIC VOLUME (**V**):	21,000

TOTAL # OF CRASHES:	347	# OF YEARS :	5	AVERAGE # OF CRASHES PER YEAR (**A**) :	**69.40**

CRASH RATE CALCULATION : **6.99**

$$RATE = \frac{(A * 1{,}000{,}000)}{(L * V * 365)}$$

Comments : 2013 State Average for Urban Principal Arterial (Other) = 3.49

Project Title & Date: Route 20 East Corridor Study

SEGMENT CRASH RATE WORKSHEET

CITY/TOWN : Marlborough COUNT DATE : 4/6-8/2016

DISTRICT : 3

~ SEGMENT DATA ~

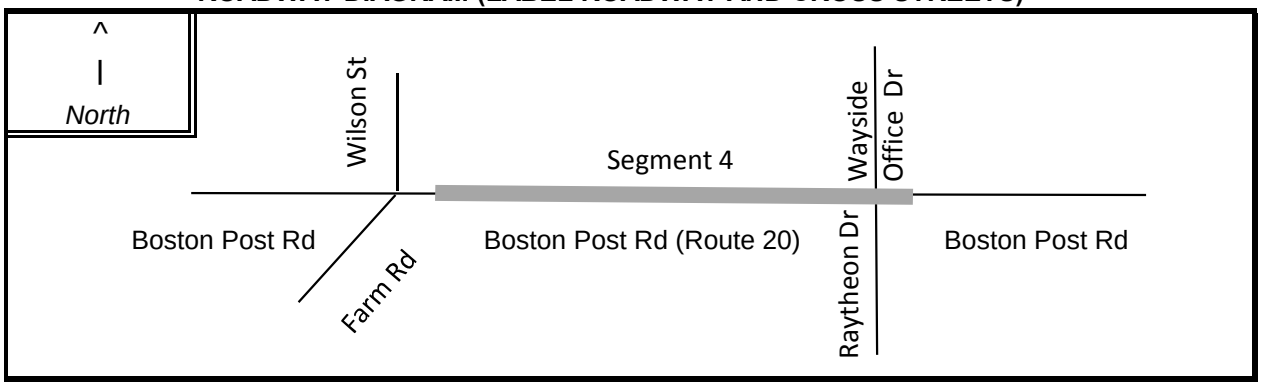
ROADWAY NAME: Route 20 Segment 4

START POINT: About 300 feet east of Farm Road

END POINT: About 100 feet east of Raytheon Driveway

FUNCTIONAL CLASSIFICATION OF ROADWAY: Urban Principal Arterial - Other

ROADWAY DIAGRAM (LABEL ROADWAY AND CROSS STREETS)



AVERAGE DAILY TRAFFIC

SEGMENT LENGTH IN MILES (**L**):	0.80
AVERAGE DAILY TRAFFIC VOLUME (**V**):	18,200

TOTAL # OF CRASHES:	124	# OF YEARS :	5	AVERAGE # OF CRASHES PER YEAR (**A**) :	**24.80**

CRASH RATE CALCULATION : **4.69**

$$\text{RATE} = \frac{(A * 1{,}000{,}000)}{(L * V * 365)}$$

Comments : 2013 State Average for Urban Principal Arterial (Other) = 3.49

Project Title & Date: Route 20 East Corridor Study

SEGMENT CRASH RATE WORKSHEET

CITY/TOWN : Marlborough COUNT DATE : 4/6-8/2016

DISTRICT : 3

~ SEGMENT DATA ~

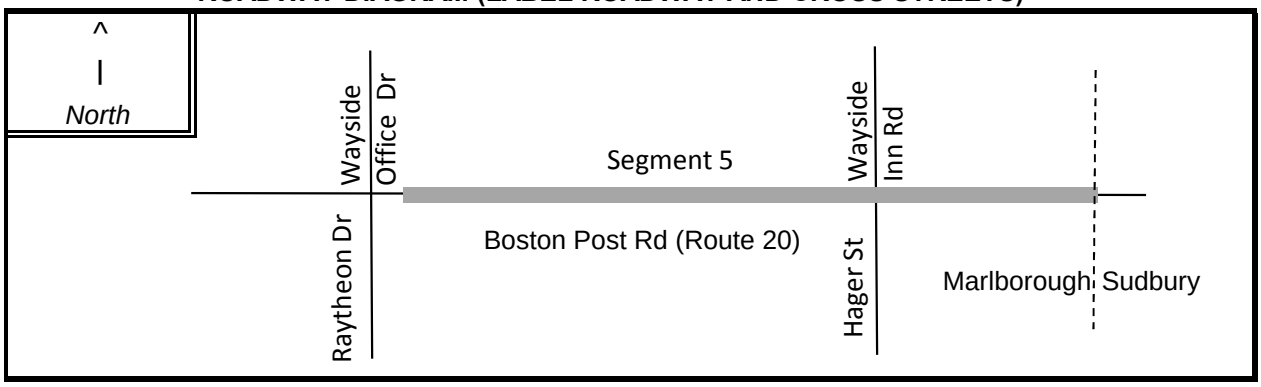
ROADWAY NAME: Route 20 Segment 5

START POINT: About 100 feet east of Raytheon Driveway

END POINT: Sudbury Town Line

FUNCTIONAL CLASSIFICATION OF ROADWAY: Urban Principal Arterial - Other

ROADWAY DIAGRAM (LABEL ROADWAY AND CROSS STREETS)



AVERAGE DAILY TRAFFIC

SEGMENT LENGTH IN MILES (**L**):	0.50
AVERAGE DAILY TRAFFIC VOLUME (**V**):	16,500

TOTAL # OF CRASHES:	61	# OF YEARS :	5	AVERAGE # OF CRASHES PER YEAR (**A**) :	**12.20**

CRASH RATE CALCULATION : **4.04**

$$\text{RATE} = \frac{(A * 1{,}000{,}000)}{(L * V * 365)}$$

Comments : 2013 State Average for Urban Principal Arterial (Other) = 3.49

Project Title & Date: Route 20 East Corridor Study

APPENDIX G

Intersection Crash Rate Worksheets

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

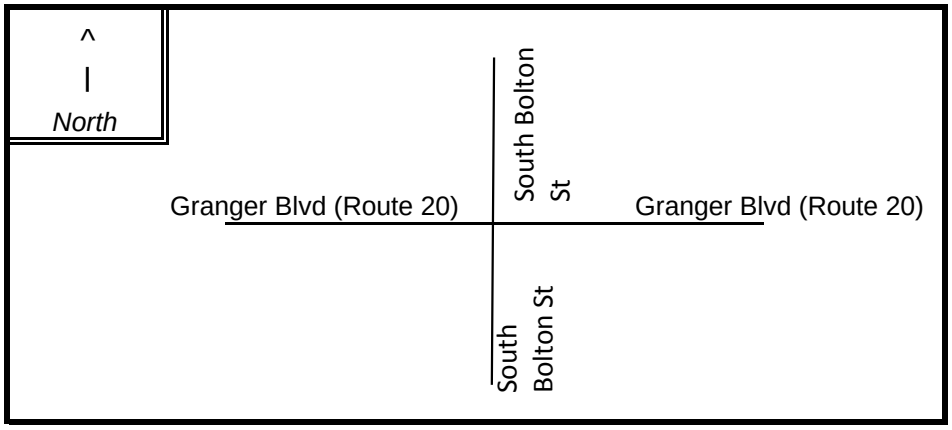
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : Route 20 (Granger Boulevard)

MINOR STREET(S) : Route 85 (South Bolton Street)

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :	EB	NB	SB	WB		
PEAK HOURLY VOLUMES (AM/PM) :	710	860	387	427		**2,384**

" K " FACTOR : **0.090** | INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **26,489**

TOTAL # OF CRASHES : 56 | # OF YEARS : 5 | AVERAGE # OF CRASHES PER YEAR (**A**) : **11.20**

CRASH RATE CALCULATION : **1.33**

RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

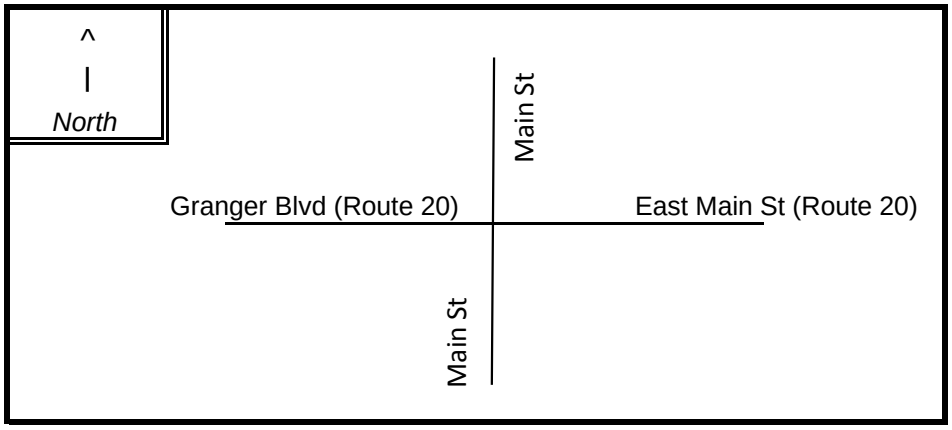
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : Granger Boulevard/East Main Street

MINOR STREET(S) : Main Street

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :	EB	NB	WB	SB		
PEAK HOURLY VOLUMES (AM/PM) :	560	293	443	218		**1,514**

" K " FACTOR : **0.090** | INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **16,822**

TOTAL # OF CRASHES : 20 | # OF YEARS : 5 | AVERAGE # OF CRASHES PER YEAR (**A**) : **4.00**

CRASH RATE CALCULATION : **0.75**

RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

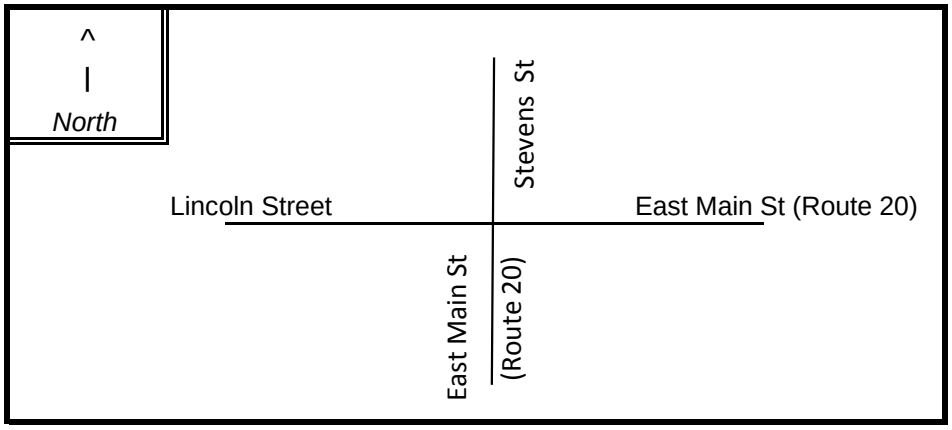
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : East Main Street

MINOR STREET(S) : Lincoln Street/Stevens Street

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :	EB	NB	WB	SB		
PEAK HOURLY VOLUMES (AM/PM) :	383	569	1,060	267		**2,279**

" K " FACTOR : **0.090** | INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **25,322**

TOTAL # OF CRASHES : 35 | # OF YEARS : 5 | AVERAGE # OF CRASHES PER YEAR (**A**) : **7.00**

CRASH RATE CALCULATION : **0.87**

RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

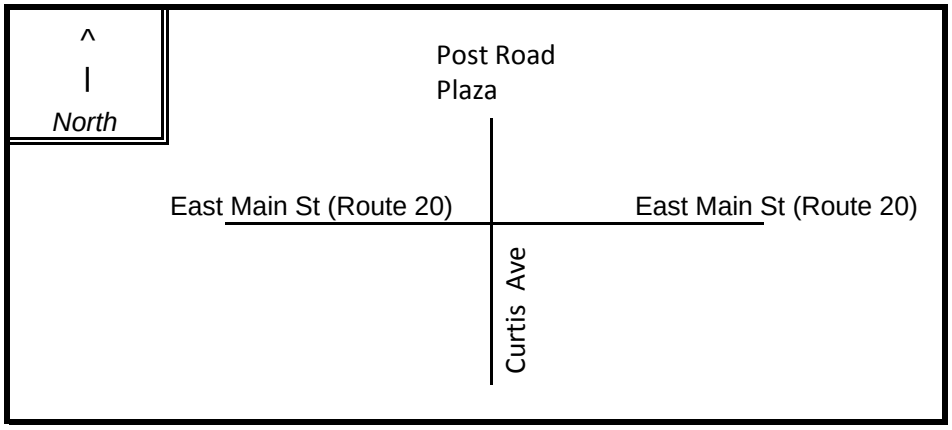
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : East Main Street (Route 20)

MINOR STREET(S) : Curtis Avenue/Post Road Plaza

INTERSECTION DIAGRAM
(Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :						
PEAK HOURLY VOLUMES (AM/PM) :						2,683

" K " FACTOR : **0.090**

INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **29,811**

TOTAL # OF CRASHES : 66

OF YEARS : 5

AVERAGE # OF CRASHES PER YEAR (**A**) : **13.20**

CRASH RATE CALCULATION : **1.39**

RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

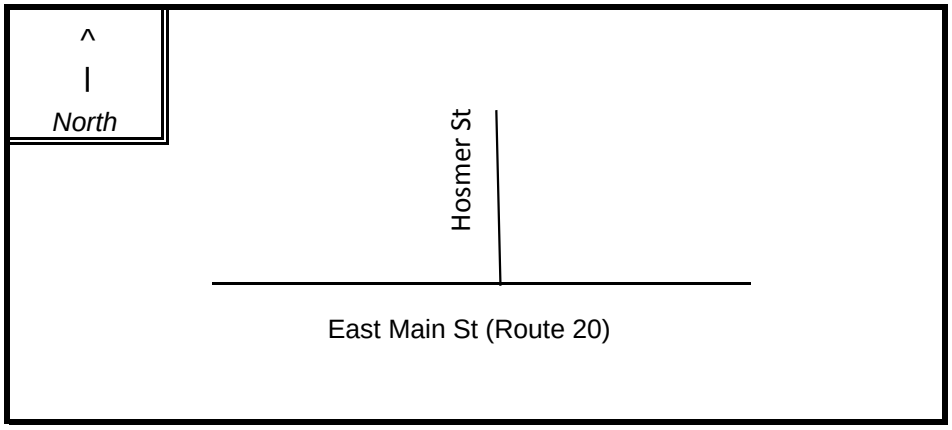
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : East Main Street (Route 20)

MINOR STREET(S) : Hosmer Street

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :						
PEAK HOURLY VOLUMES (AM/PM) :						2,487

" K " FACTOR : 0.090

INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : 27,633

TOTAL # OF CRASHES : 40

OF YEARS : 5

AVERAGE # OF CRASHES PER YEAR (**A**) : 8.00

CRASH RATE CALCULATION : 0.91

RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

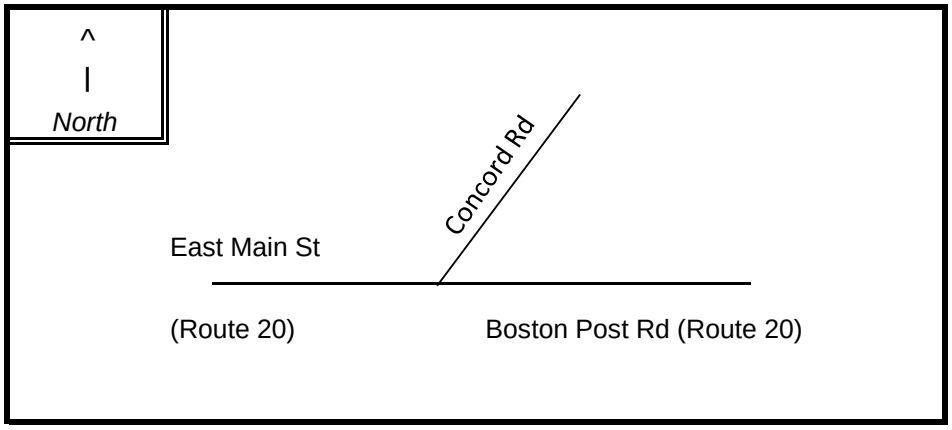
DISTRICT : 3 | UNSIGNALIZED : X | SIGNALIZED :

~ INTERSECTION DATA ~

MAJOR STREET : East Main Street/Boston Post Road (Route 20)

MINOR STREET(S) : Concord Road

INTERSECTION DIAGRAM
(Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :	EB	WB	SB			
PEAK HOURLY VOLUMES (AM/PM) :	917	1,042	179			**2,138**

" K " FACTOR : **0.090**

INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **23,756**

TOTAL # OF CRASHES : 44

OF YEARS : 5

AVERAGE # OF CRASHES PER YEAR (**A**) : **8.80**

CRASH RATE CALCULATION : **1.17**

RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments : 2015 Average Crash Rate for MassDOT District 3 Unsignalized Intersections = 0.65

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

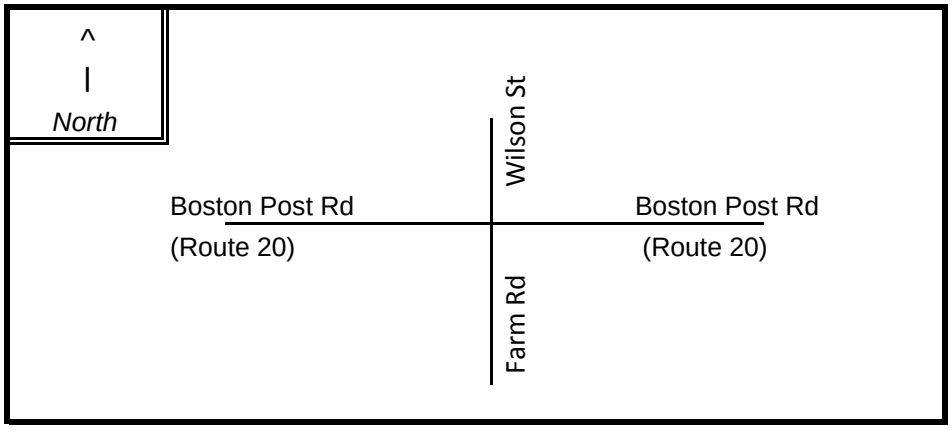
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : Boston Post Road (Route 20)

MINOR STREET(S) : Farm Road/Wilson Street

INTERSECTION DIAGRAM
(Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :						
PEAK HOURLY VOLUMES (AM/PM) :						2,635

" K " FACTOR : **0.090**

INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **29,278**

TOTAL # OF CRASHES : 48

OF YEARS : 5

AVERAGE # OF CRASHES PER YEAR (**A**) : **9.60**

CRASH RATE CALCULATION : **1.03**

RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough COUNT DATE : 4/7/2016

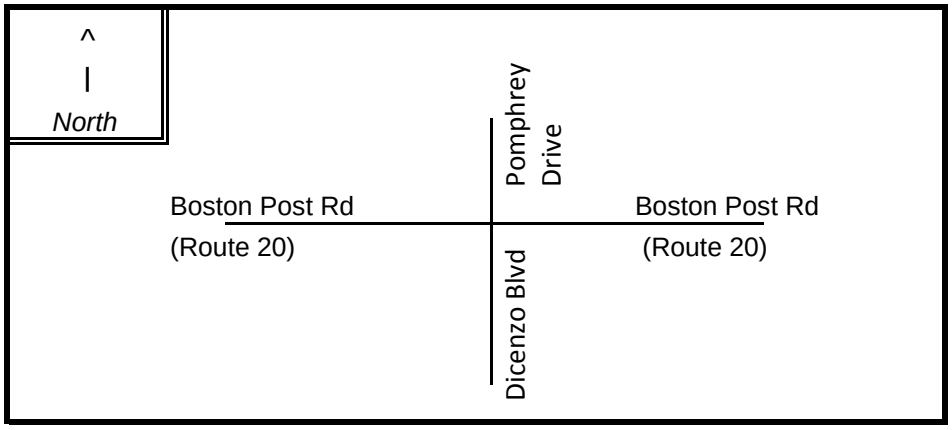
DISTRICT : 3 UNSIGNALIZED : SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : Boston Post Road (Route 20)

MINOR STREET(S) : Dicenzo Boulevard/Pomphrey Drive

INTERSECTION DIAGRAM
(Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :						
PEAK HOURLY VOLUMES (AM/PM) :						2,197

" K " FACTOR : 0.090

INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : 24,411

TOTAL # OF CRASHES : 21

OF YEARS : 5

AVERAGE # OF CRASHES PER YEAR (**A**) : 4.20

CRASH RATE CALCULATION : 0.54

RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

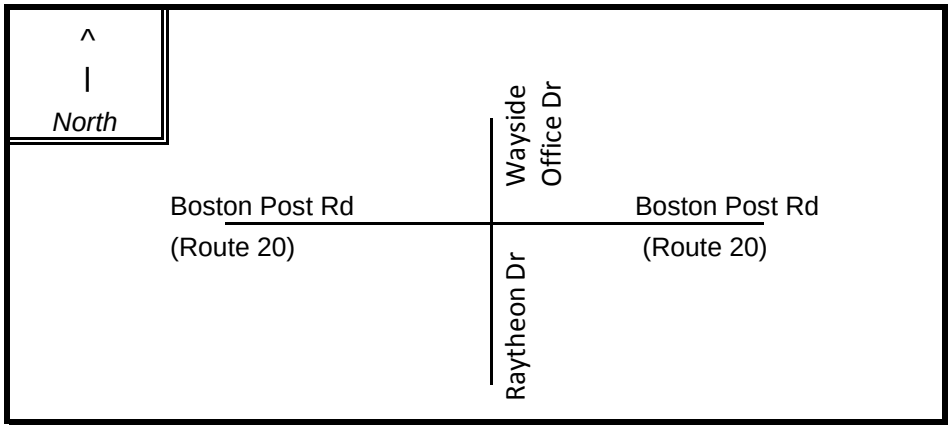
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : Boston Post Road (Route 20)

MINOR STREET(S) : Raytheon Driveway/Wayside Office Driveway

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :						
PEAK HOURLY VOLUMES (AM/PM) :						1,952

" K " FACTOR : **0.090**

INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **21,689**

TOTAL # OF CRASHES : 10

OF YEARS : 5

AVERAGE # OF CRASHES PER YEAR (**A**) : **2.00**

CRASH RATE CALCULATION : 0.29

RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

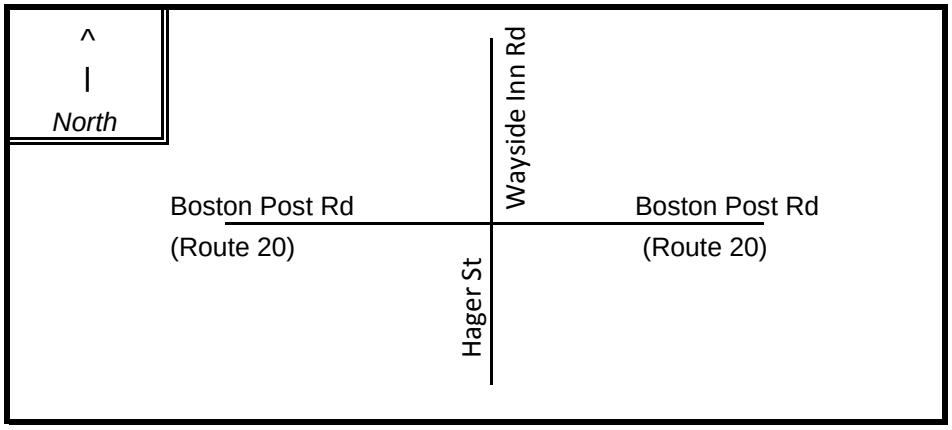
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : Boston Post Road (Route 20)

MINOR STREET(S) : Hager Street/Wayside Inn Road

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :						
PEAK HOURLY VOLUMES (AM/PM) :						1,814

" K " FACTOR : **0.090**

INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **20,156**

TOTAL # OF CRASHES : 27

OF YEARS : 5

AVERAGE # OF CRASHES PER YEAR (**A**) : **5.40**

CRASH RATE CALCULATION : **0.84**

RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

APPENDIX H

Collision Diagrams and Crash Statistics
Major Intersections and Segments in the Corridor

Figure H-1
Collision Diagram: Route 20 at Route 85
Marlborough Police Reports: January 2011–December 2015

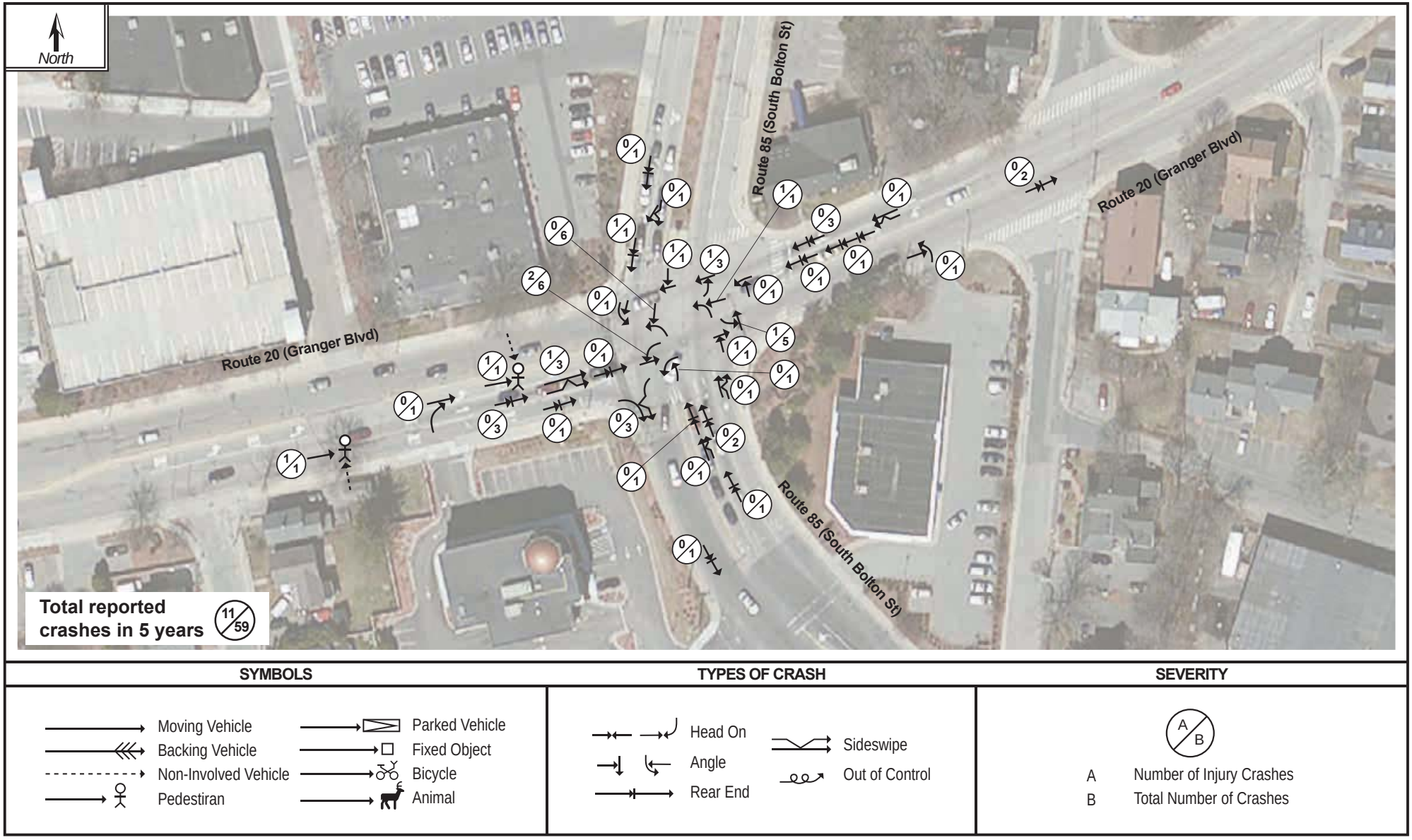
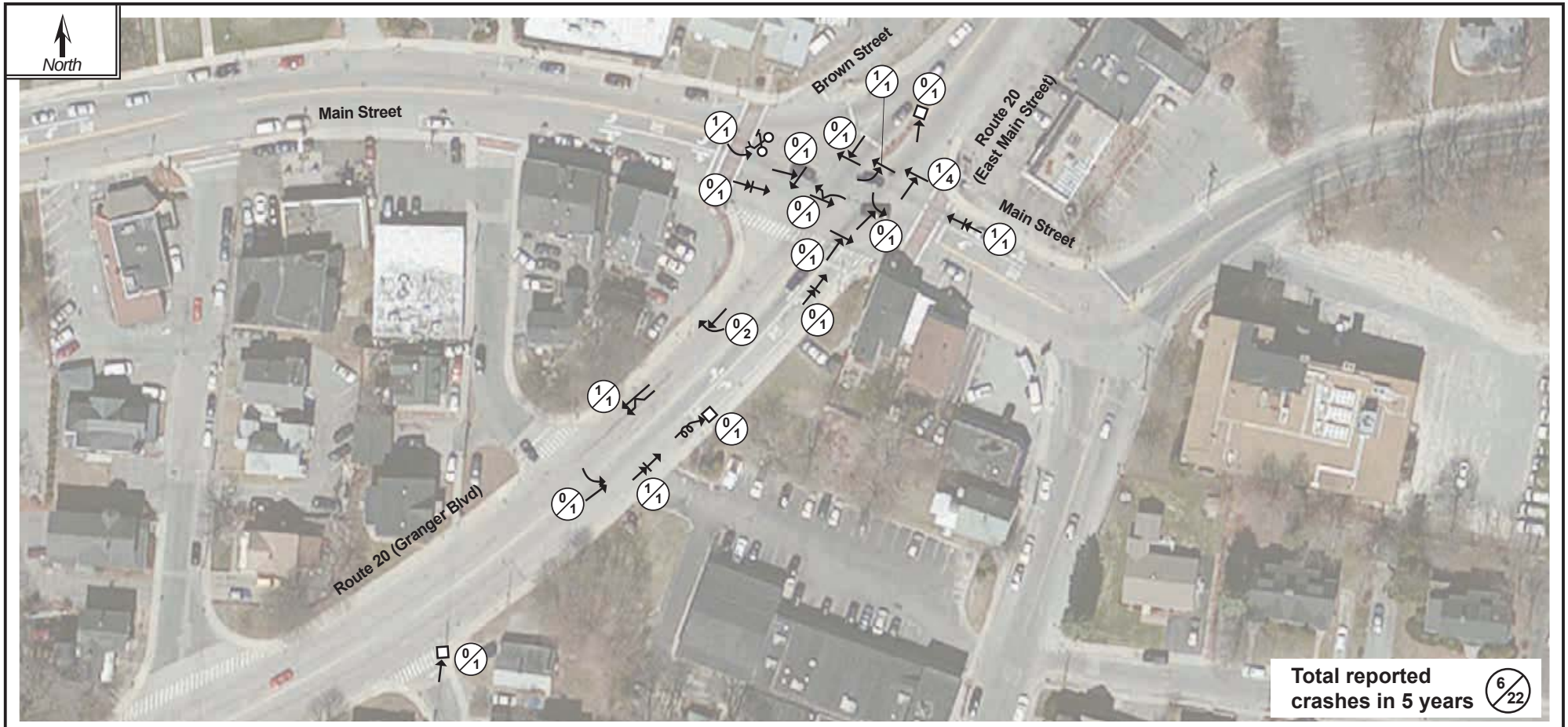


Table H-1
Crash Statistics: Route 20 at Route 85
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		13	8	10	11	17	59	11.8
Severity	Property damage only	10	7	9	10	12	48	9.6
	Non-fatal injury	3	1	1	1	5	11	2.2
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	1	0	0	1	2	0.4
	Rear-end	4	2	4	4	5	19	3.8
	Angle	7	3	3	6	8	27	5.4
	Sideswipe, same direction	0	2	2	0	3	7	1.4
	Sideswipe, opposite direction	1	0	1	1	0	3	0.6
	Head-on	1	0	0	0	0	1	0.2
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	1	0	0	1	2	0.4
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		4	4	1	0	0	9	1.8
Wet or icy pavement conditions		4	1	2	1	3	11	2.2
Dark conditions (lit or unlit)		5	1	2	2	2	12	2.4

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

Figure H-2
Collision Diagram: Route 20 at Main Street
Marlborough Police Reports: January 2011–December 2015



SYMBOLS

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

TYPES OF CRASH

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

SEVERITY

A/B

A Number of Injury Crashes
B Total Number of Crashes

Table H-2
Crash Statistics: Route 20 at Main Street
Marlborough Police Crash Data 2011-15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		5	5	1	6	5	22	4.4
Severity	Property damage only	4	3	0	3	5	15	3.0
	Non-fatal injury	1	1	1	3	0	6	1.2
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	1	0	0	0	1	0.2
Collision type	Single vehicle	0	2	0	1	0	3	0.6
	Rear-end	1	1	1	0	1	4	0.8
	Angle	2	2	0	4	4	12	2.4
	Sideswipe, same direction	1	0	0	1	0	2	0.4
	Sideswipe, opposite direction	1	0	0	0	0	1	0.2
	Head-on	0	0	0	0	0	0	0.0
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	1	0	1	0.2
Occurred during weekday peak periods*		1	3	0	0	0	4	0.8
Wet or icy pavement conditions		1	1	0	2	0	4	0.8
Dark conditions (lit or unlit)		3	1	0	2	1	7	1.4

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

Figure H-3
Collision Diagram: Route 20 between Main Street and Lincoln Street
Marlborough Police Reports: January 2011–December 2015

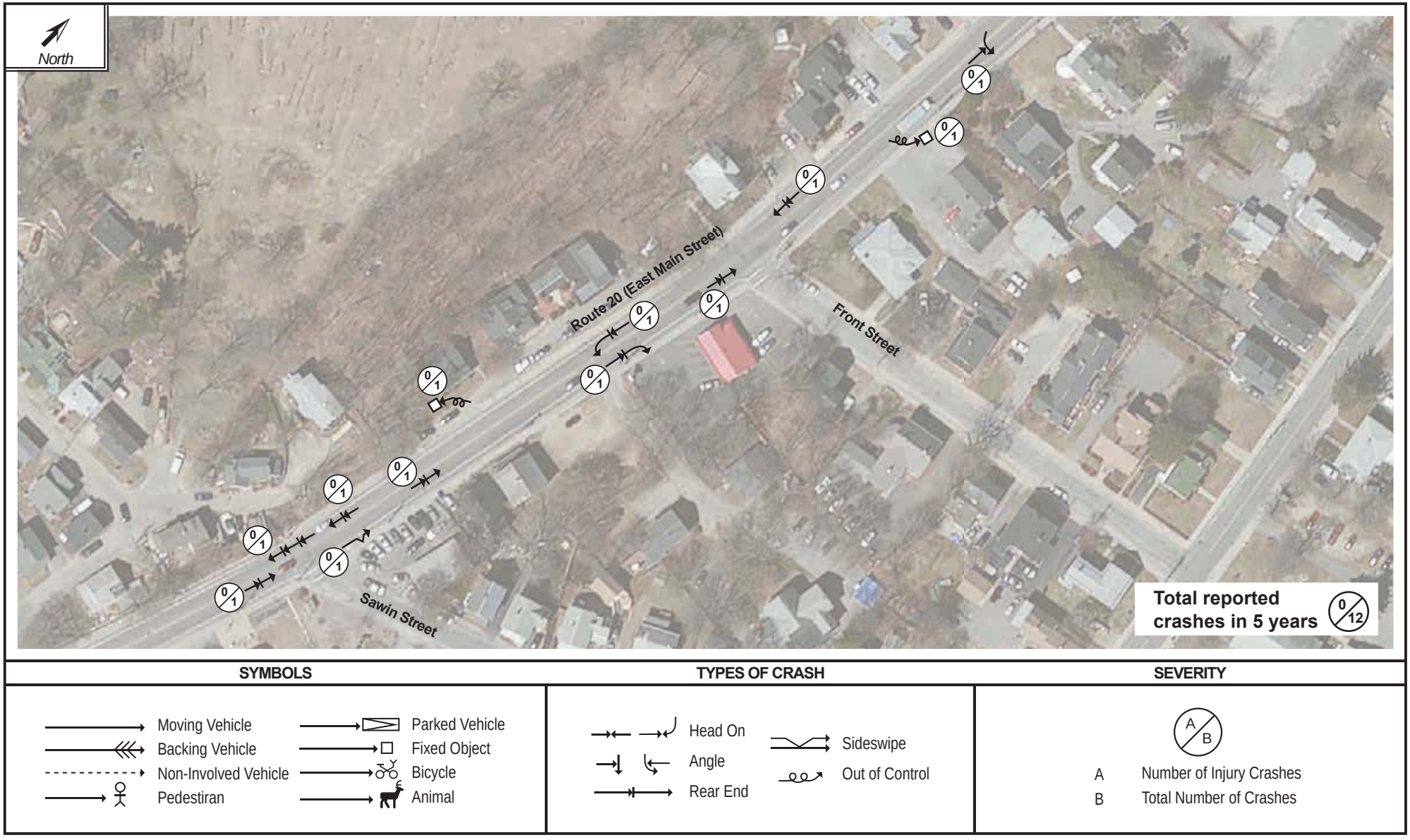
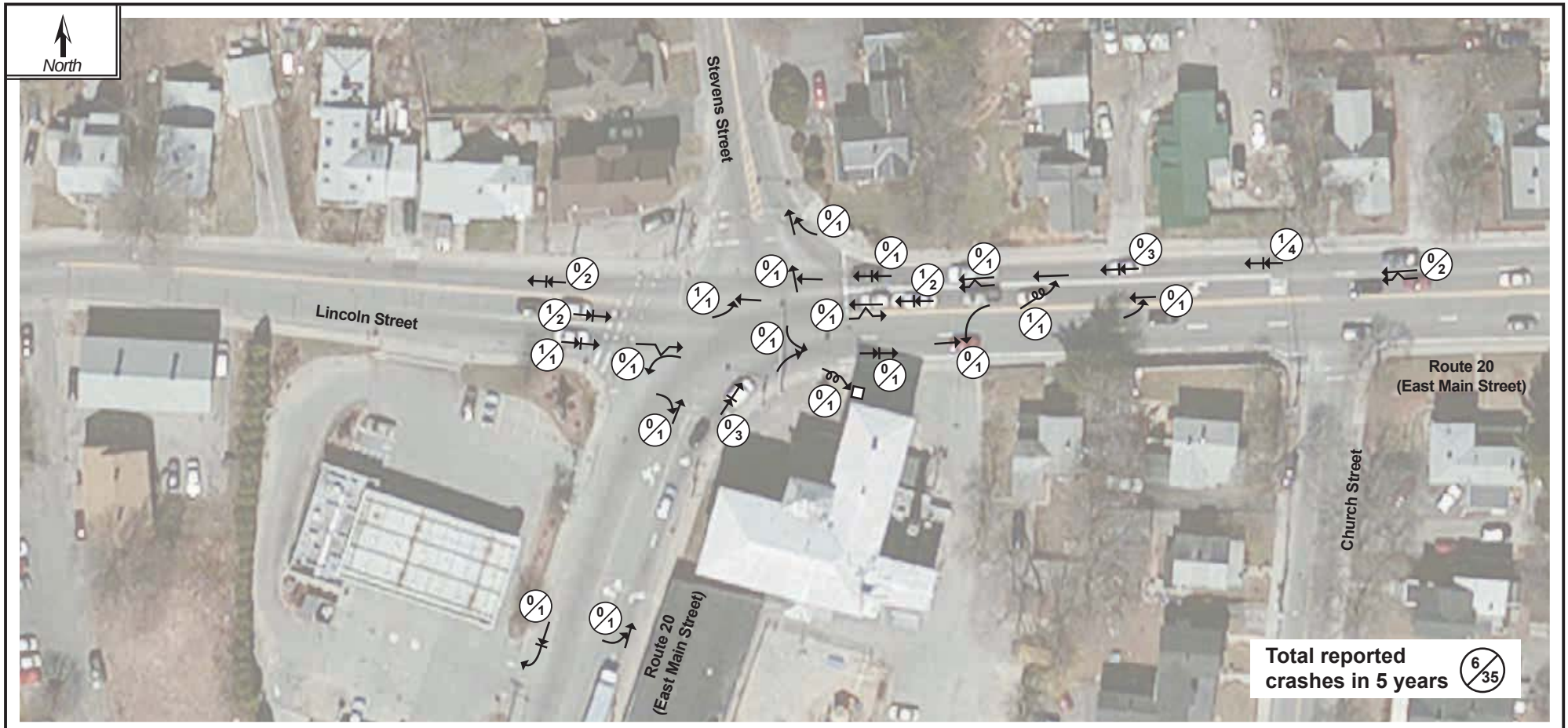


Table H-3
Crash Statistics: Route 20 between Main Street and Lincoln Street
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		1	1	2	4	4	12	2.4
Severity	Property damage only	1	1	2	4	4	12	2.4
	Non-fatal injury	0	0	0	0	0	0	0.0
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	0	0	1	1	2	0.4
	Rear-end	1	1	2	3	1	8	1.6
	Angle	0	0	0	0	2	2	0.4
	Sideswipe, same direction	0	0	0	0	0	0	0.0
	Sideswipe, opposite direction	0	0	0	0	0	0	0.0
	Head-on	0	0	0	0	0	0	0.0
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		1	1	2	3	3	10	2.0
Wet or icy pavement conditions		0	0	1	1	2	4	0.8
Dark conditions (lit or unlit)		0	0	0	2	3	5	1.0

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

Figure H-4
Collision Diagram: Route 20 at Lincoln Street/Stevens Street
Marlborough Police Reports: January 2011–December 2015



SYMBOLS

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

TYPES OF CRASH

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

SEVERITY

A/B

A Number of Injury Crashes
B Total Number of Crashes

Table H-4
Crash Statistics: Route 20 at Lincoln/Stevens Street
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		4	9	7	4	11	35	7.0
Severity	Property damage only	3	7	6	4	9	29	5.8
	Non-fatal injury	1	2	1	0	2	6	1.2
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	0	1	0	0	1	0.2
	Rear-end	3	3	3	4	7	20	4.0
	Angle	0	4	2	0	3	9	1.8
	Sideswipe, same direction	0	1	0	0	0	1	0.2
	Sideswipe, opposite direction	1	0	1	0	0	2	0.4
	Head-on	0	1	0	0	1	2	0.4
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		1	3	1	0	0	5	1.0
Wet or icy pavement conditions		0	3	3	2	4	12	2.4
Dark conditions (lit or unlit)		0	2	3	0	1	6	1.2

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

Figure H-5
Collision Diagram: Route 20 between Lincoln Street and Curtis Avenue
Marlborough Police Reports: January 2011–December 2015

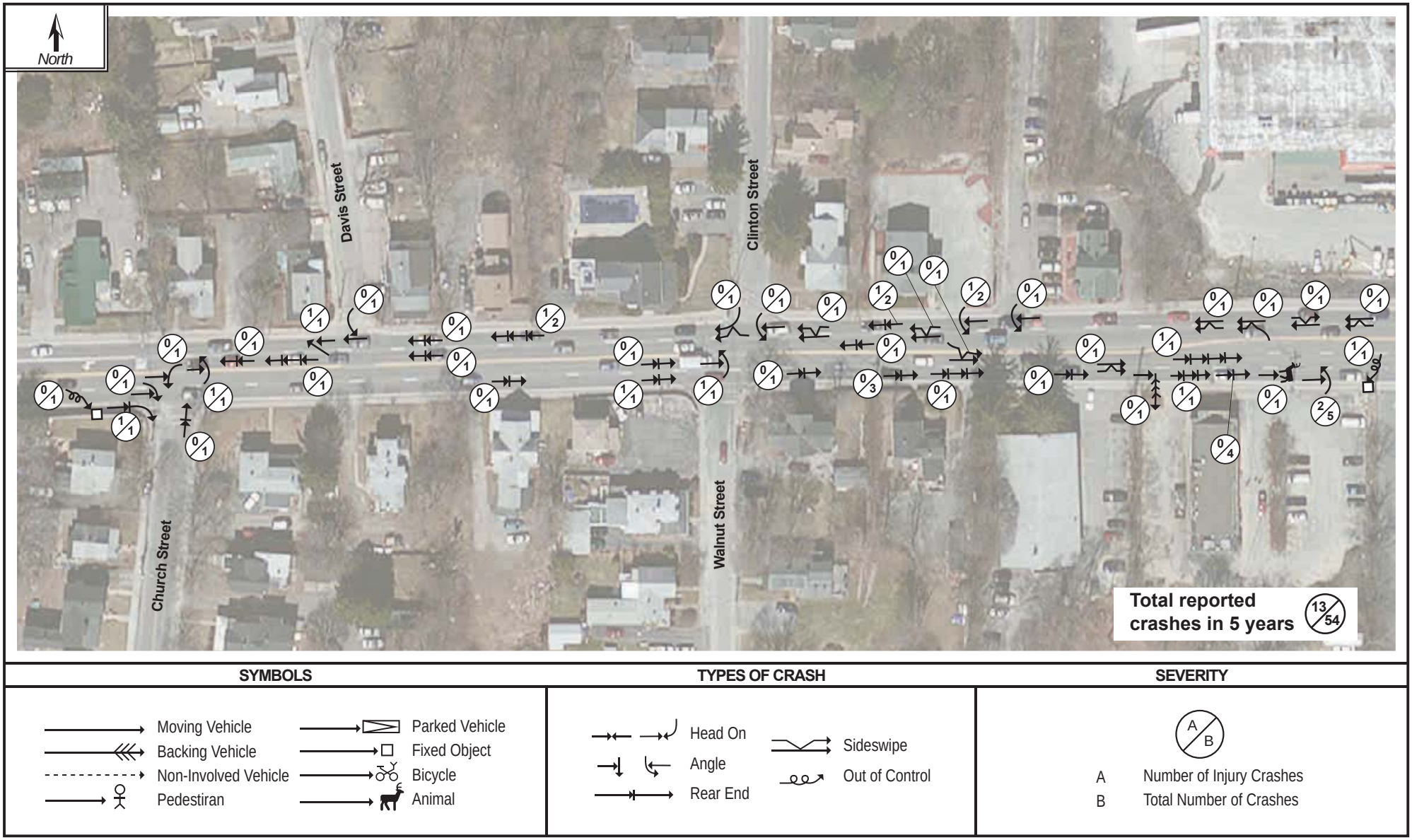
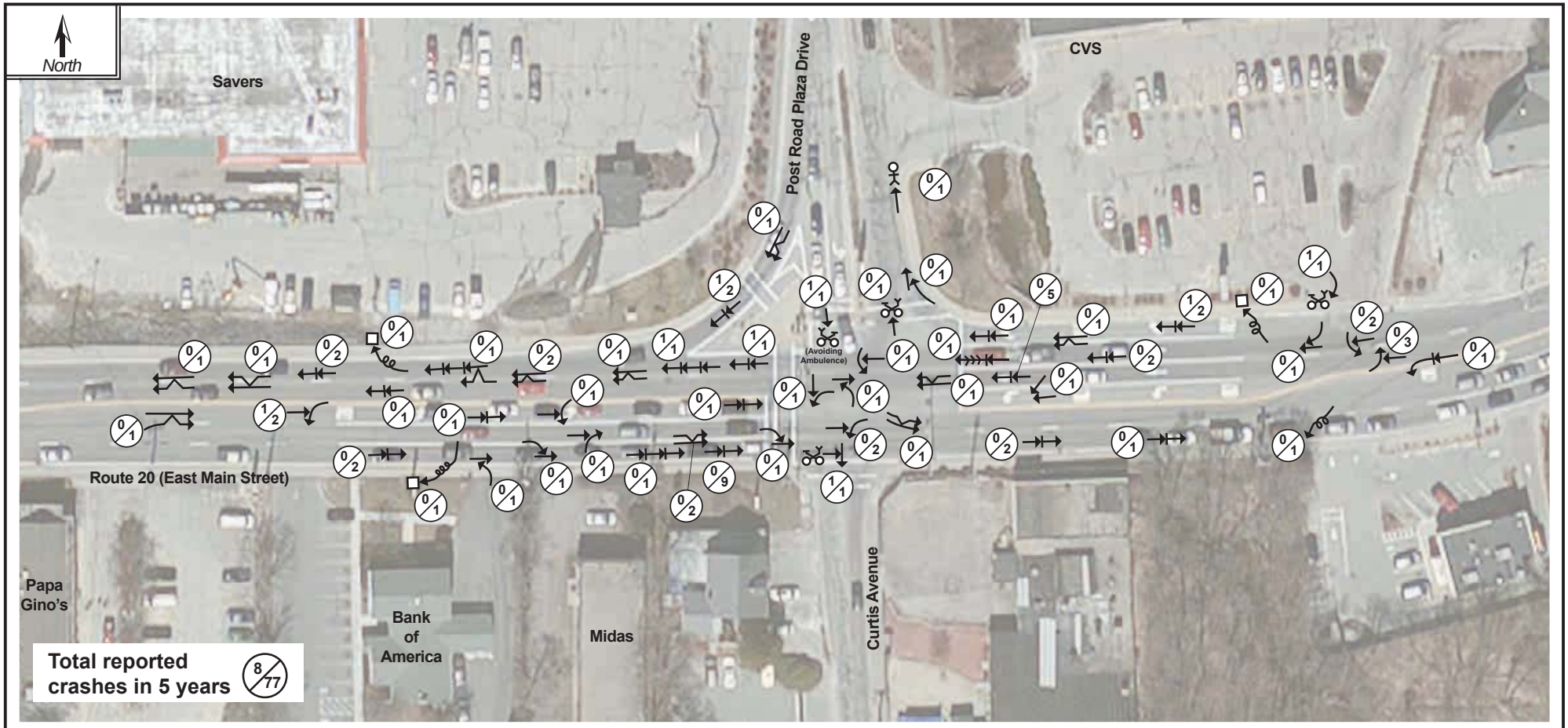


Table H-5
Crash Statistics: Route 20 between Lincoln Street and Curtis Avenue
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		14	4	11	9	16	54	10.8
Severity	Property damage only	12	2	7	7	13	41	8.2
	Non-fatal injury	2	2	4	2	3	13	2.6
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	1	0	1	1	0	3	0.6
	Rear-end	5	2	3	7	8	25	5.0
	Angle	4	2	6	1	4	17	3.4
	Sideswipe, same direction	4	0	1	0	4	9	1.8
	Sideswipe, opposite direction	0	0	0	0	0	0	0.0
	Head-on	0	0	0	0	0	0	0.0
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		4	1	4	0	0	9	1.8
Wet or icy pavement conditions		10	2	3	3	3	21	4.2
Dark conditions (lit or unlit)		4	0	1	3	3	11	2.2

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

Figure H-6
Collision Diagram: Route 20 at Curtis Avenue
Marlborough Police Reports: January 2011–December 2015



SYMBOLS

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

TYPES OF CRASH

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

SEVERITY

A/B

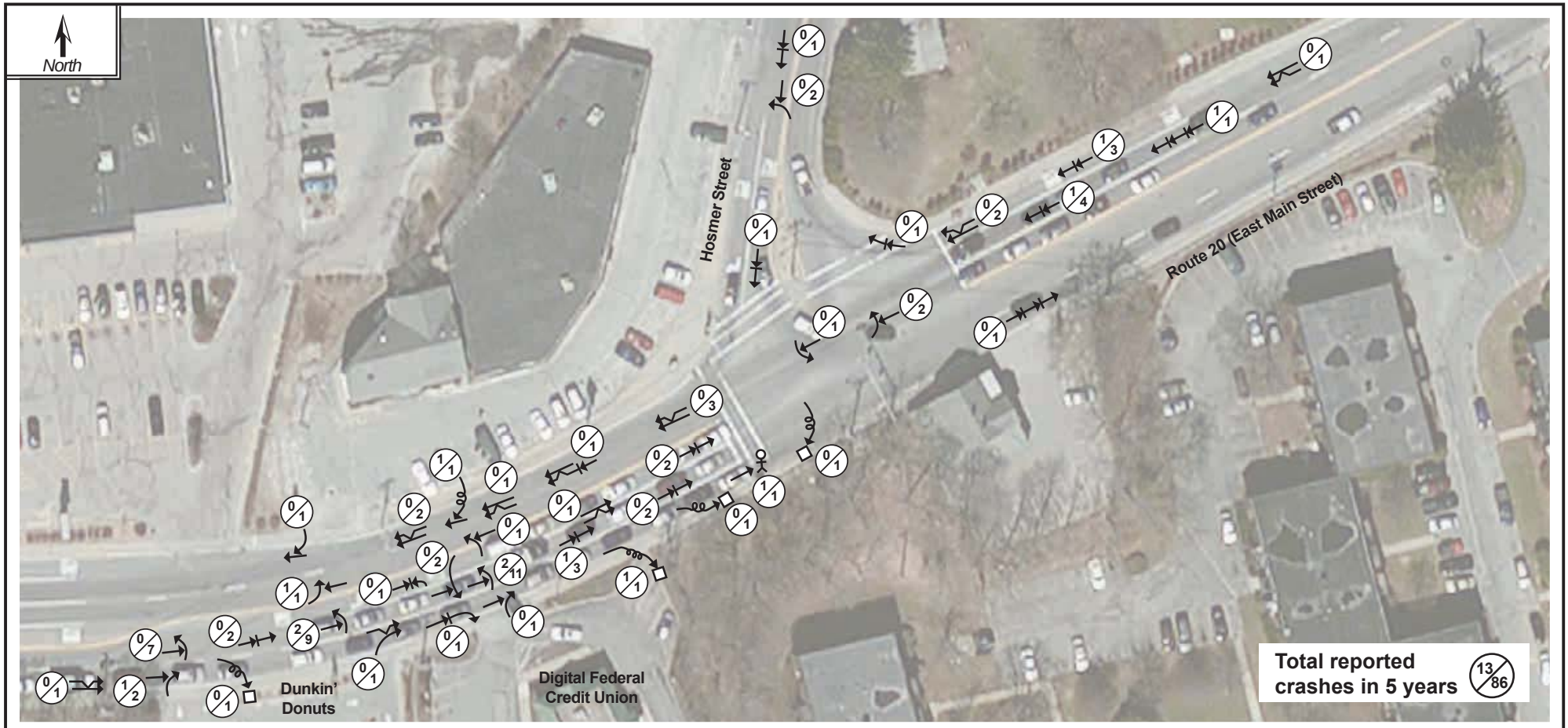
A Number of Injury Crashes
B Total Number of Crashes

Table H-6
Crash Statistics: Route 20 at Curtis Avenue
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		14	18	17	16	12	77	15.4
Severity	Property damage only	13	17	17	13	9	69	13.8
	Non-fatal injury	1	1	0	3	3	8	1.6
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	1	2	1	2	6	1.2
	Rear-end	6	7	8	8	6	35	7.0
	Angle	4	7	5	4	4	24	4.8
	Sideswipe, same direction	2	1	2	3	0	8	1.6
	Sideswipe, opposite direction	1	2	0	0	0	3	0.6
	Head-on	1	0	0	0	0	1	0.2
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	1	0	0	1	0.2
Involved cyclist(s)		0	0	0	1	2	3	0.6
Occurred during weekday peak periods*		2	5	5	0	0	12	2.4
Wet or icy pavement conditions		5	7	9	7	2	30	6.0
Dark conditions (lit or unlit)		3	8	2	0	2	15	3.0

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

Figure H-7
Collision Diagram: Route 20 at Hosmer Street
Marlborough Police Reports: January 2011–December 2015



SYMBOLS

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

TYPES OF CRASH

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

SEVERITY

A/B

A Number of Injury Crashes
B Total Number of Crashes

Table H-1
Crash Statistics: Route 20 at Hosmer Street
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		26	21	13	13	13	86	17.2
Severity	Property damage only	21	18	13	9	11	72	14.4
	Non-fatal injury	4	3	0	4	2	13	2.6
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	1	0	0	0	0	1	0.2
Collision type	Single vehicle	1	0	0	1	3	5	1.0
	Rear-end	6	6	5	4	2	23	4.6
	Angle	14	9	4	6	4	37	7.4
	Sideswipe, same direction	4	4	3	0	3	14	2.8
	Sideswipe, opposite direction	0	1	1	2	0	4	0.8
	Head-on	1	1	0	0	1	3	0.6
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	1	0	1	0.2
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		8	8	5	0	0	21	4.2
Wet or icy pavement conditions		12	3	3	5	4	27	5.4
Dark conditions (lit or unlit)		5	3	2	2	3	15	3.0

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

Figure H-8
Collision Diagram: Route 20 at Concord Road
Marlborough Police Reports: January 2011–December 2015

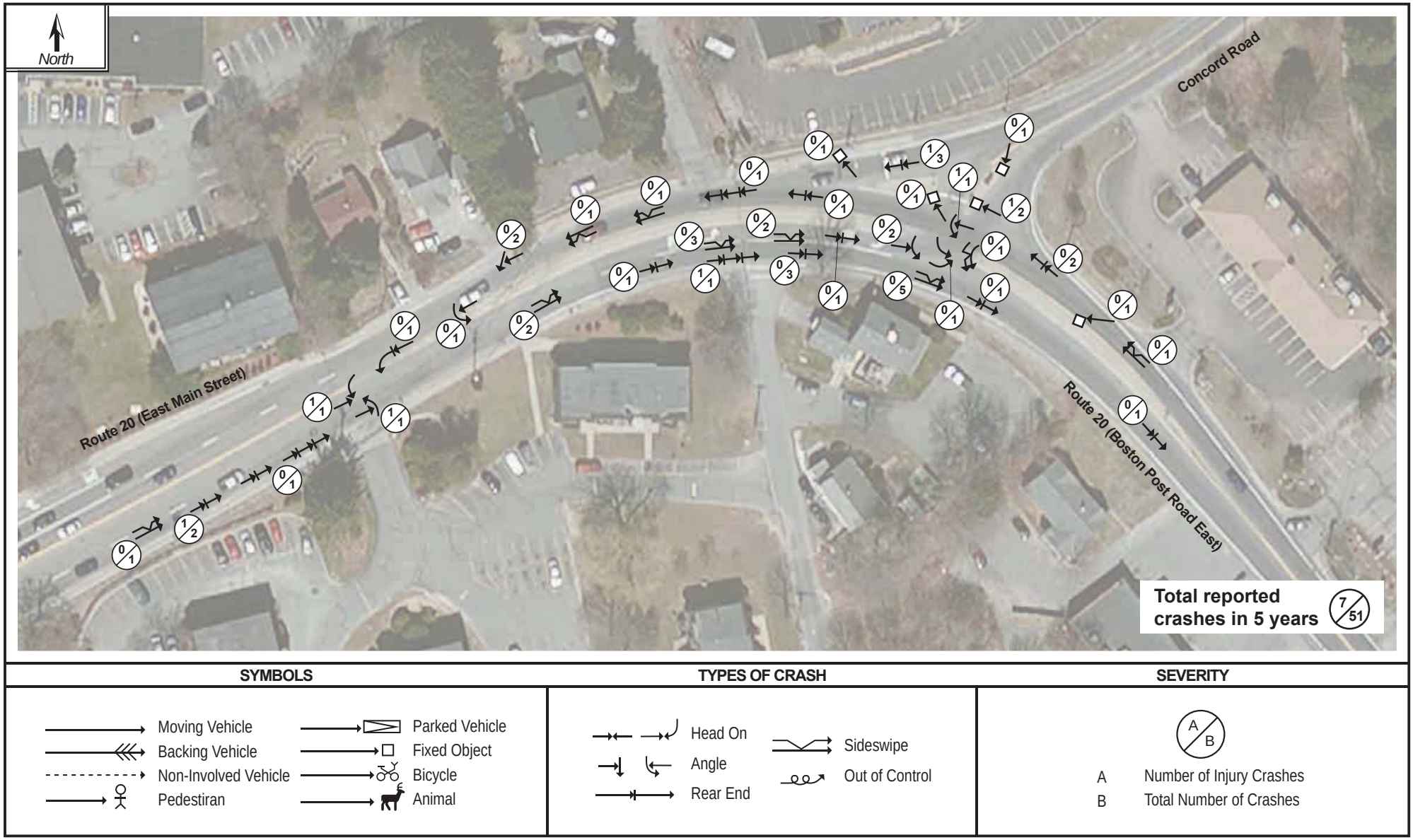
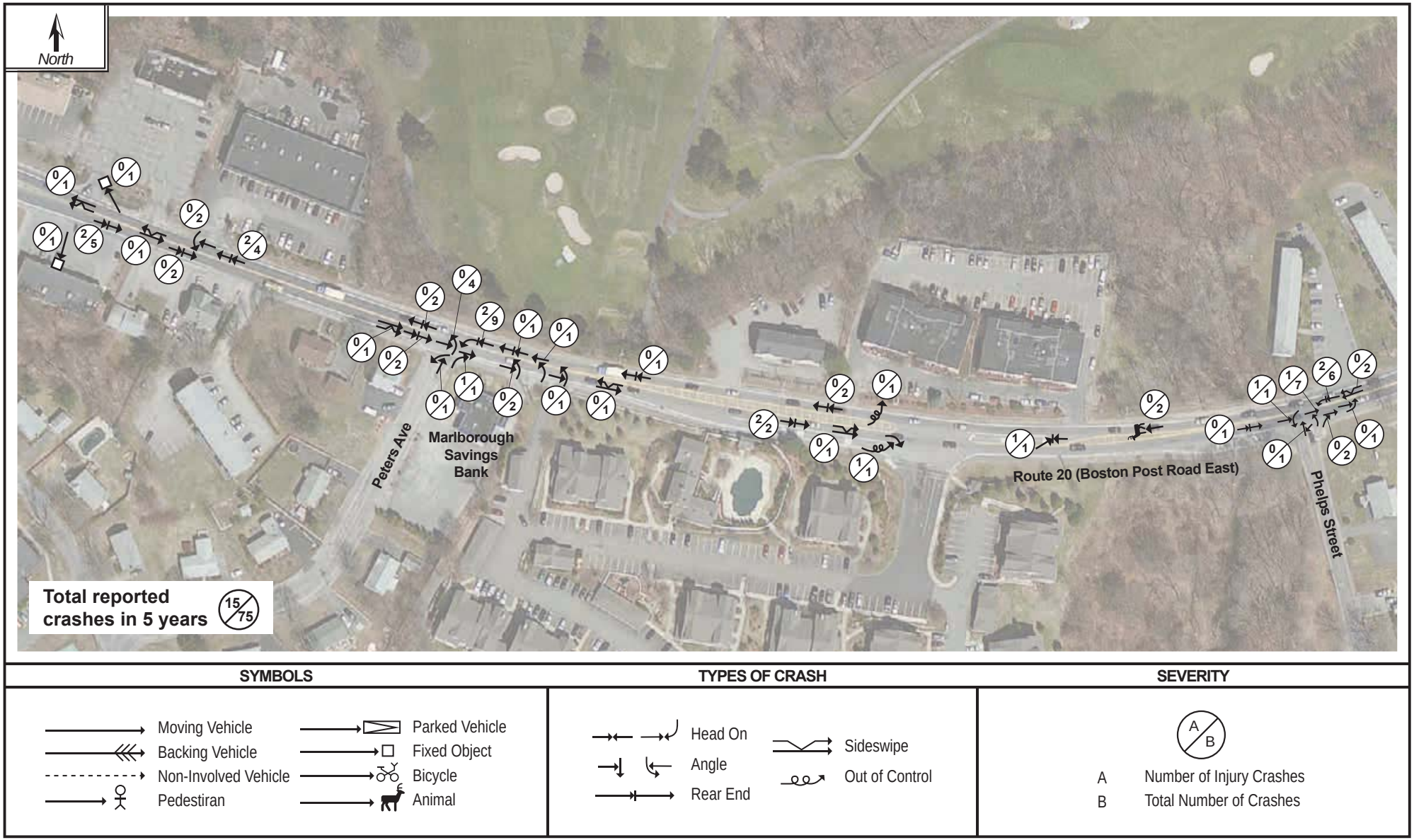


Table H-8
Crash Statistics: Route 20 at Concord Road
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		12	9	18	5	7	51	10.2
Severity	Property damage only	12	6	16	4	6	44	8.8
	Non-fatal injury	0	3	2	1	1	7	1.4
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	1	2	1	0	2	6	1.2
	Rear-end	5	2	5	4	1	17	3.4
	Angle	3	2	5	0	1	11	2.2
	Sideswipe, same direction	3	3	7	1	2	16	3.2
	Sideswipe, opposite direction	0	0	0	0	0	0	0.0
	Head-on	0	0	0	0	0	0	0.0
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	1	1	0.2
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		2	4	8	5	6	25	5.0
Wet or icy pavement conditions		5	2	2	1	3	13	2.6
Dark conditions (lit or unlit)		3	0	1	0	2	6	1.2

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

Figure H-9
Collision Diagram: Route 20 between Concord Road and Phelps Street
Marlborough Police Reports: January 2011–December 2015



SYMBOLS

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

TYPES OF CRASH

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

SEVERITY

A/B

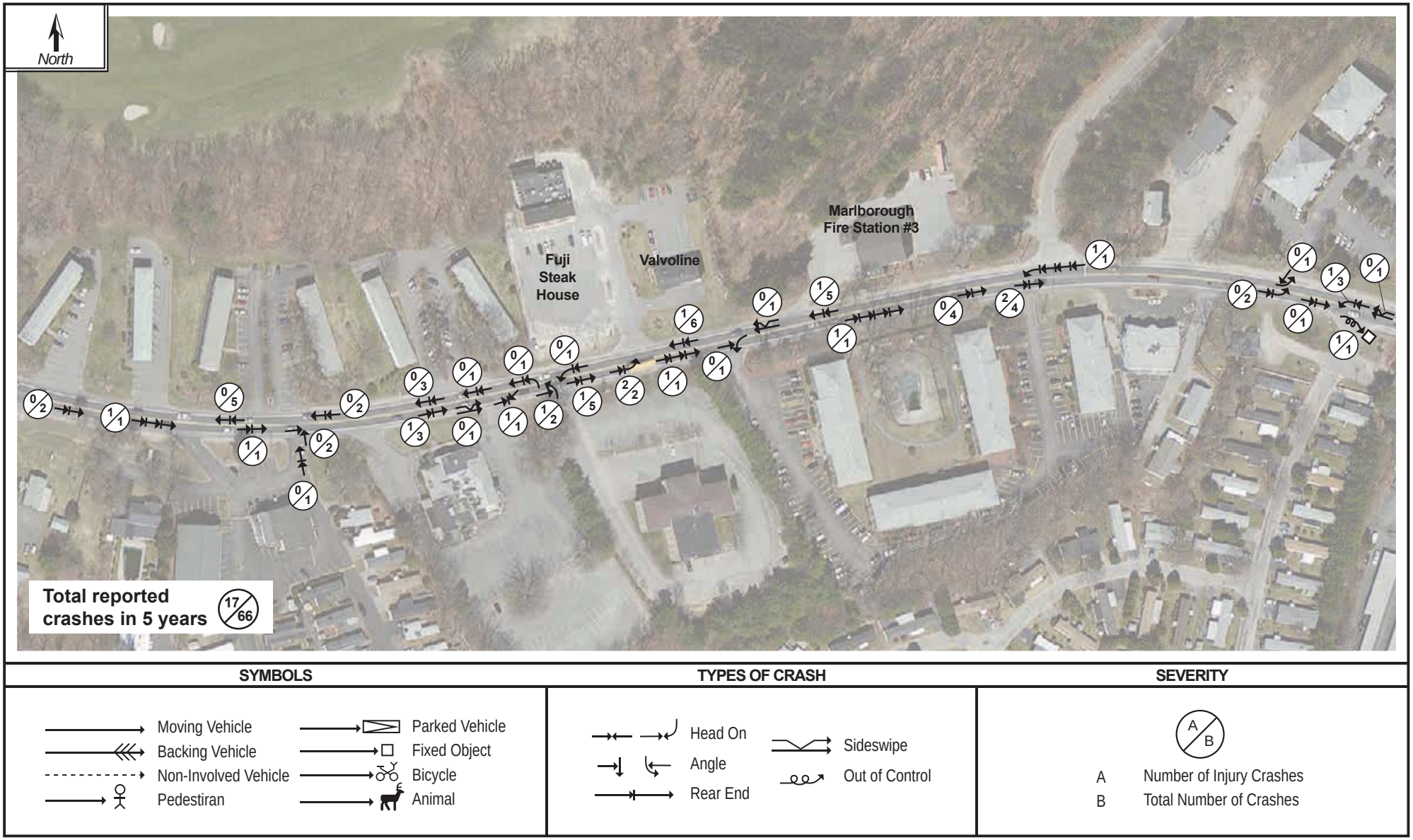
A Number of Injury Crashes
B Total Number of Crashes

Table H-9
Crash Statistics: Route 20 between Concord Road and Phelps Street
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		18	11	7	14	25	75	15.0
Severity	Property damage only	11	10	7	11	21	60	12.0
	Non-fatal injury	7	1	0	3	4	15	3.0
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	1	2	1	2	1	7	1.4
	Rear-end	12	4	5	4	10	35	7.0
	Angle	5	4	1	3	10	23	4.6
	Sideswipe, same direction	0	1	0	2	2	5	1.0
	Sideswipe, opposite direction	0	0	0	1	2	3	0.6
	Head-on	0	0	0	2	0	2	0.4
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		6	4	3	0	0	13	2.6
Wet or icy pavement conditions		7	0	2	4	11	24	4.8
Dark conditions (lit or unlit)		6	1	2	2	4	15	3.0

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

Figure H-10
Collision Diagram: Route 20 between Phelps Street and Victoria Lane
Marlborough Police Reports: January 2011–December 2015



SYMBOLS

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

TYPES OF CRASH

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

SEVERITY

A/B

A Number of Injury Crashes
B Total Number of Crashes

Table H-10
Crash Statistics: Route 20 between Phelps Street and Victoria Lane
Marlboro Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		16	17	13	15	5	66	13.2
Severity	Property damage only	12	11	11	11	4	49	9.8
	Non-fatal injury	4	6	2	4	1	17	3.4
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	1	0	0	0	1	0.2
	Rear-end	13	14	10	14	3	54	10.8
	Angle	2	0	2	0	1	5	1.0
	Sideswipe, same direction	1	0	0	1	0	2	0.4
	Sideswipe, opposite direction	0	0	0	0	0	0	0.0
	Head-on	0	2	1	0	1	4	0.8
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		6	6	8	0	0	20	4.0
Wet or icy pavement conditions		4	4	4	6	2	20	4.0
Dark conditions (lit or unlit)		2	4	1	6	0	13	2.6

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

Figure H-11
Collision Diagram: Route 20 between Victoria Lane and Farm Road
Marlborough Police Reports: January 2011–December 2015

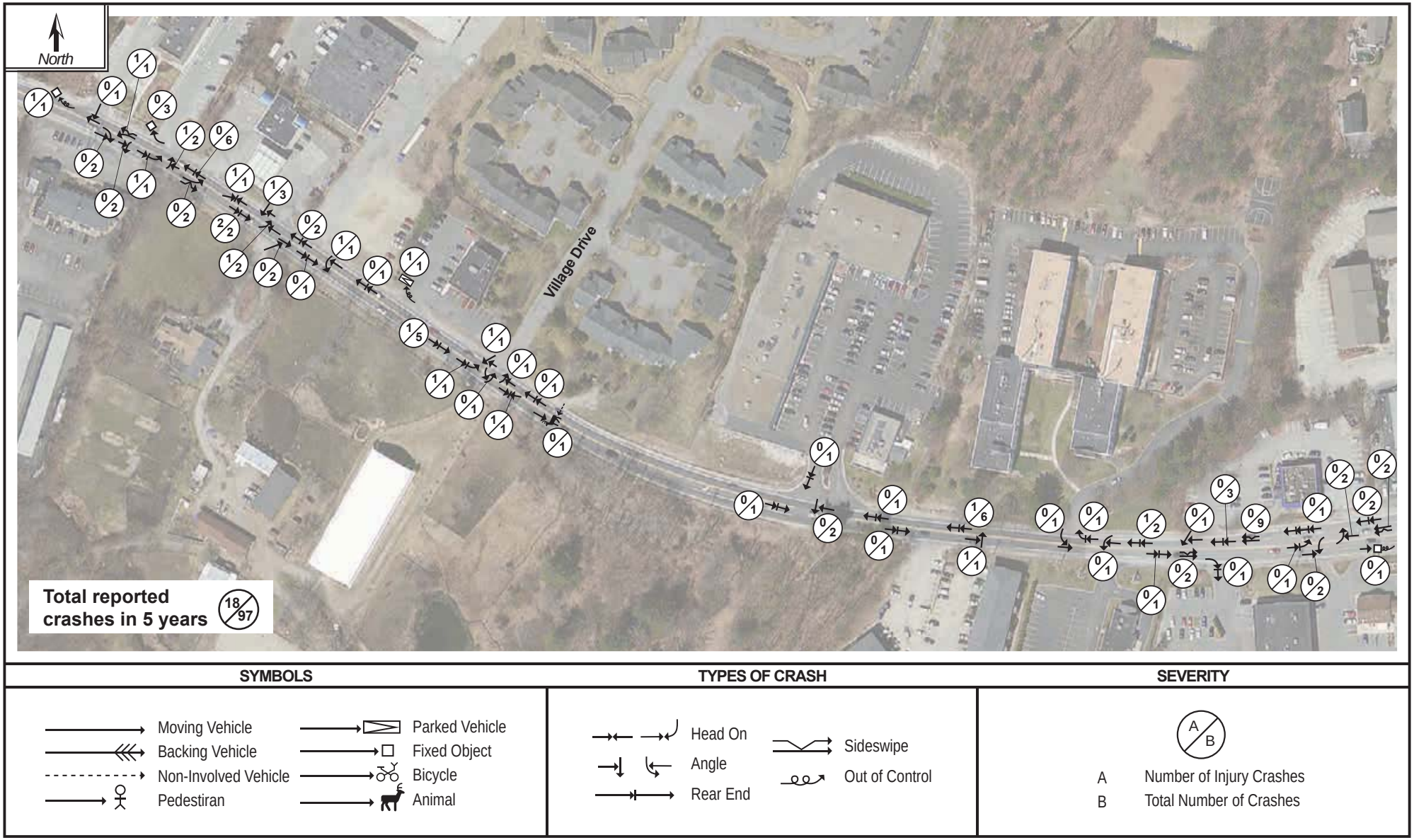
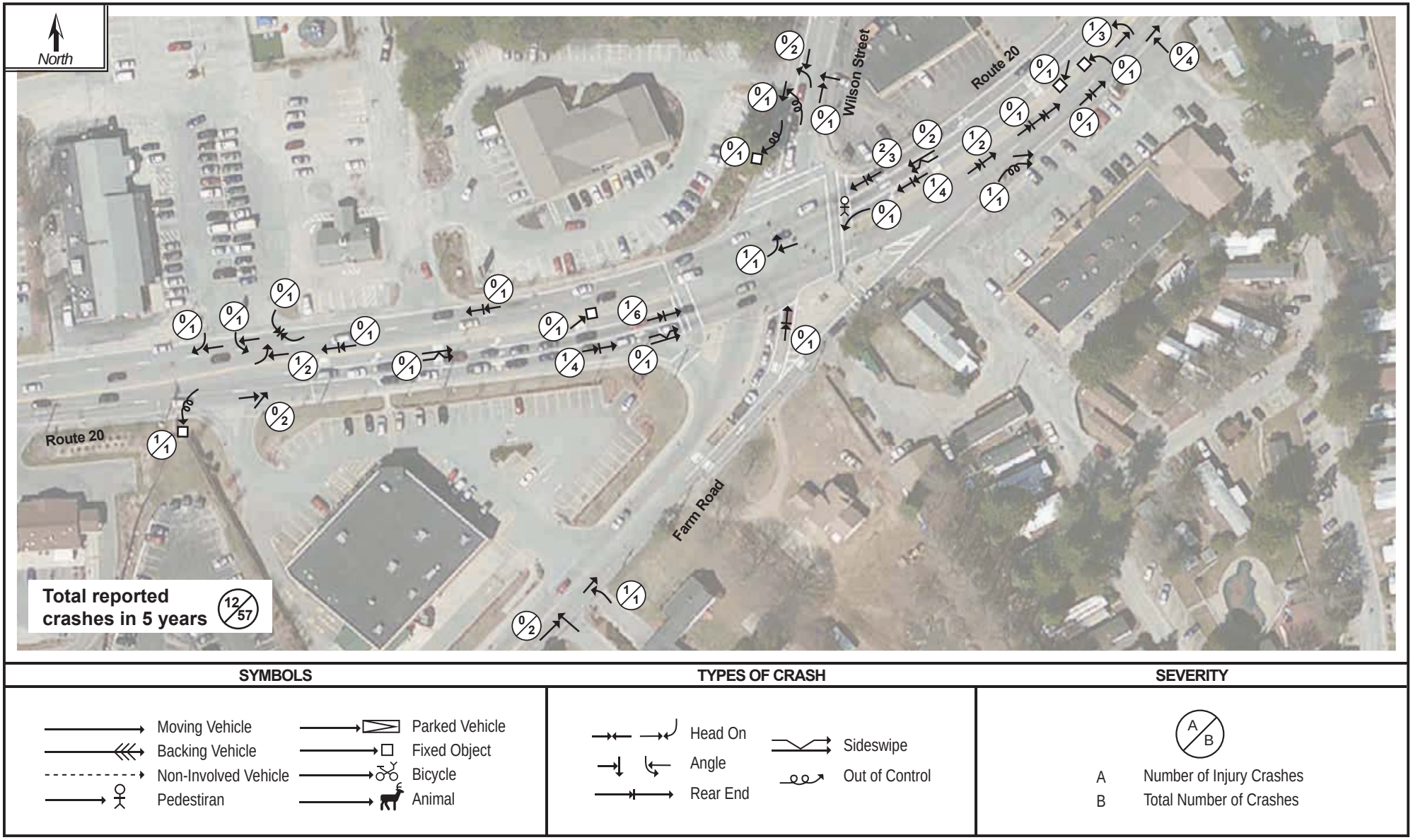


Table H-11
Crash Statistics: Route 20 between Victoria Lane and Farm Road
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		21	14	19	20	23	97	19.4
Severity	Property damage only	16	9	19	20	15	79	15.8
	Non-fatal injury	5	5	0	0	8	18	3.6
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	1	2	2	1	1	7	1.4
	Rear-end	8	8	8	8	7	39	7.8
	Angle	5	2	4	5	11	27	5.4
	Sideswipe, same direction	5	1	5	6	2	19	3.8
	Sideswipe, opposite direction	1	0	0	0	0	1	0.2
	Head-on	1	0	0	0	2	3	0.6
	Rear-to-rear	0	1	0	0	0	1	0.2
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		3	5	8	0	0	16	3.2
Wet or icy pavement conditions		3	3	5	4	7	22	4.4
Dark conditions (lit or unlit)		4	3	3	3	6	19	3.8

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

Figure H-12
Collision Diagram: Route 20 at Farm Road/Wilson Street
Marlborough Police Reports: January 2011–December 2015



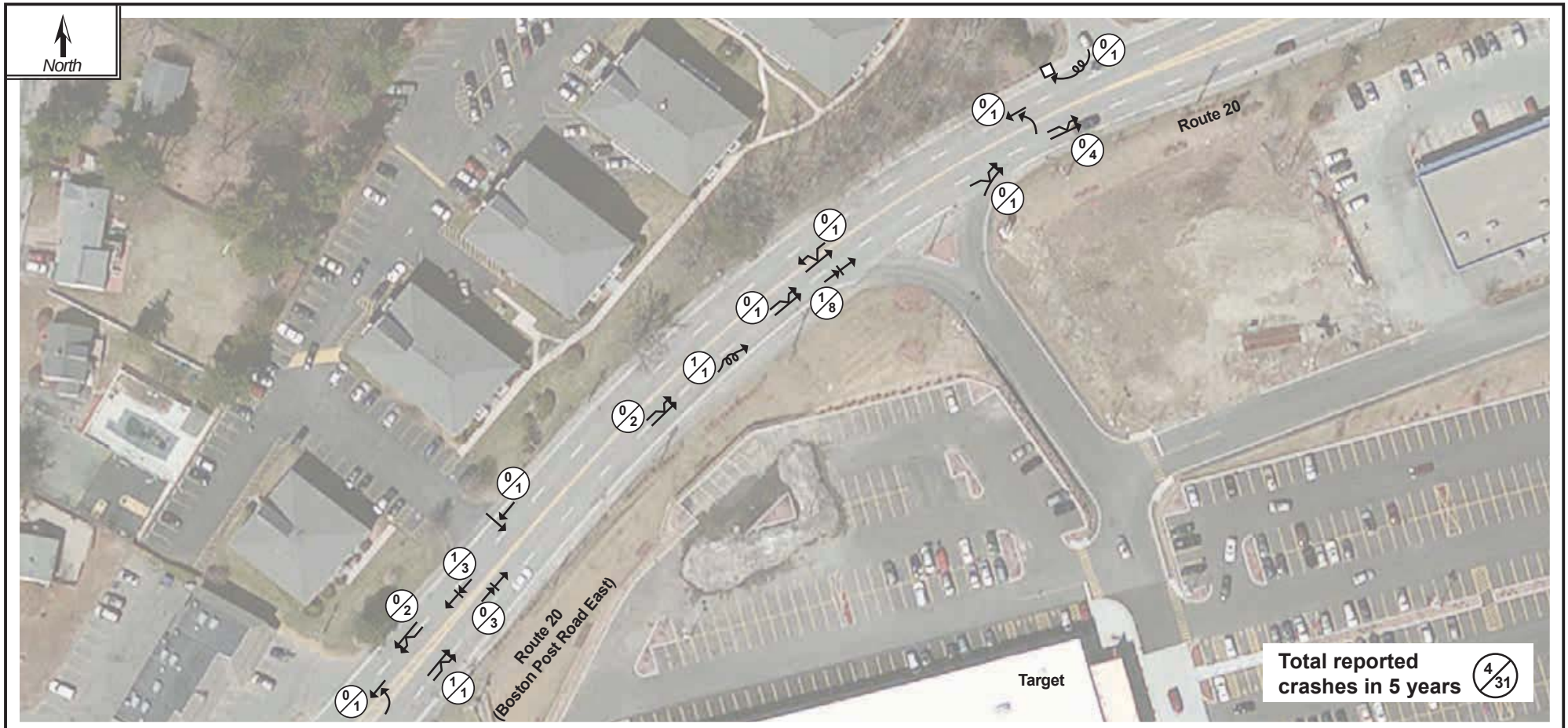
SYMBOLS		TYPES OF CRASH		SEVERITY
Moving Vehicle	Parked Vehicle	Head On	Sideswipe	A/B
Backing Vehicle	Fixed Object	Angle	Out of Control	A Number of Injury Crashes
Non-Involved Vehicle	Bicycle	Rear End		B Total Number of Crashes
Pedestiran	Animal			

Table H-12
Crash Statistics: Route 20 at Farm Road/Wilson Street
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		16	13	9	13	6	57	11.4
Severity	Property damage only	14	8	6	12	5	45	9.0
	Non-fatal injury	2	5	3	1	1	12	2.4
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	2	2	2	0	6	1.2
	Rear-end	8	6	3	5	2	24	4.8
	Angle	4	3	3	4	3	17	3.4
	Sideswipe, same direction	1	1	1	1	1	5	1.0
	Sideswipe, opposite direction	0	0	0	1	0	1	0.2
	Head-on	2	1	0	0	0	3	0.6
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	1	0	0	0	0	1	0.2
Involved pedestrian(s)		1	0	0	0	0	1	0.2
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		5	10	2	9	5	31	6.2
Wet or icy pavement conditions		4	1	0	2	0	7	1.4
Dark conditions (lit or unlit)		2	1	0	3	0	6	1.2

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

Figure H-13
Collision Diagram: Route 20 between Farm Road and Dicenzo Boulevard
Marlborough Police Reports: January 2011–December 2015



SYMBOLS

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

TYPES OF CRASH

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

SEVERITY

A/B

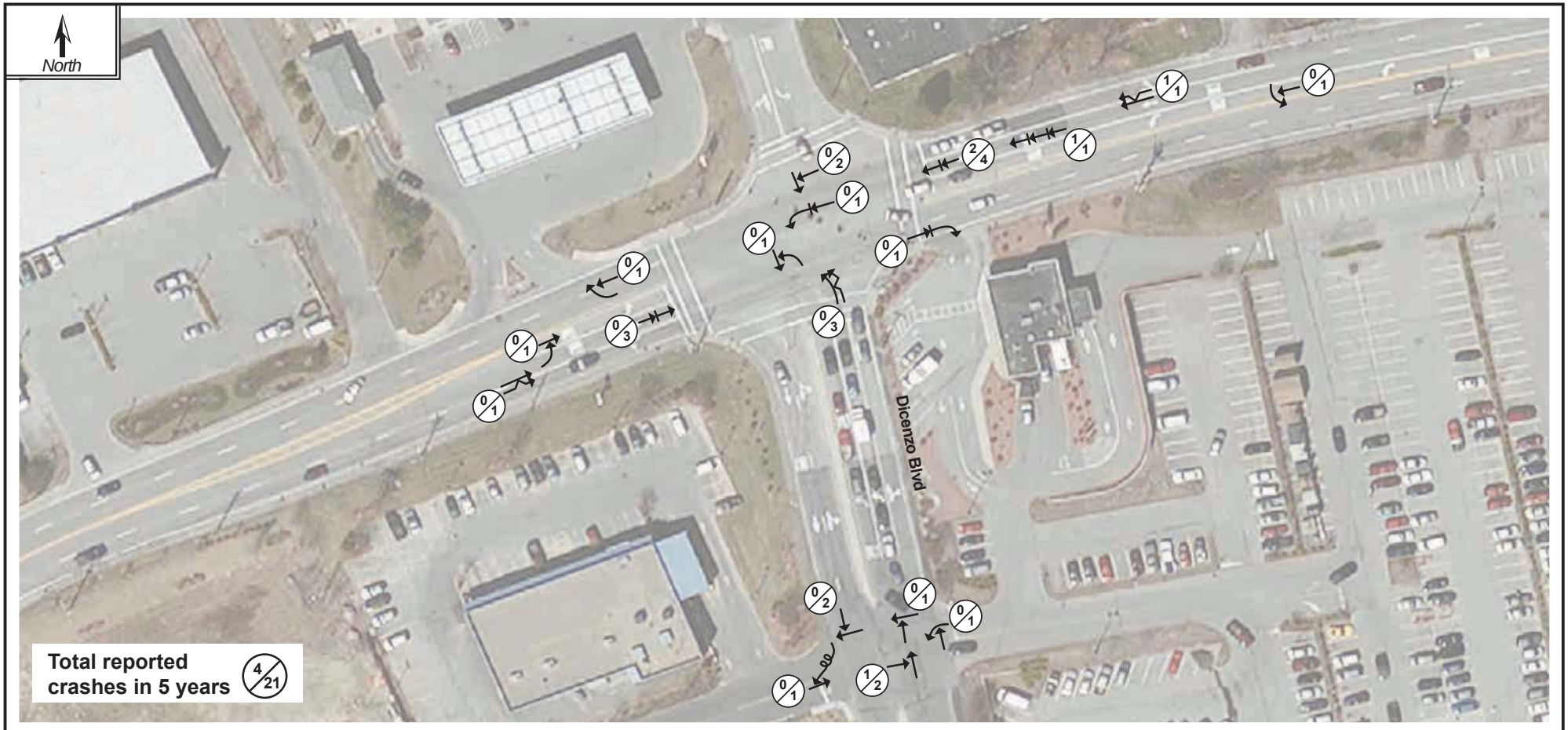
A Number of Injury Crashes
B Total Number of Crashes

Table H-13
Crash Statistics: Route 20 between Farm Road and Dicenzo Boulevard
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		9	6	4	6	6	31	6.2
Severity	Property damage only	9	5	3	4	6	27	5.4
	Non-fatal injury	0	1	1	2	0	4	0.8
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	2	0	0	0	2	0.4
	Rear-end	5	1	2	3	3	14	2.8
	Angle	0	2	0	1	1	4	0.8
	Sideswipe, same direction	4	1	2	2	1	10	2.0
	Sideswipe, opposite direction	0	0	0	0	1	1	0.2
	Head-on	0	0	0	0	0	0	0.0
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		2	4	2	6	2	16	3.2
Wet or icy pavement conditions		1	1	0	0	2	4	0.8
Dark conditions (lit or unlit)		0	0	0	0	1	1	0.2

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

Figure H-14
Collision Diagram: Route 20 at Dicenzo Boulevard
Marlborough Police Reports: January 2011–December 2015



SYMBOLS

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

TYPES OF CRASH

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

SEVERITY

A/B

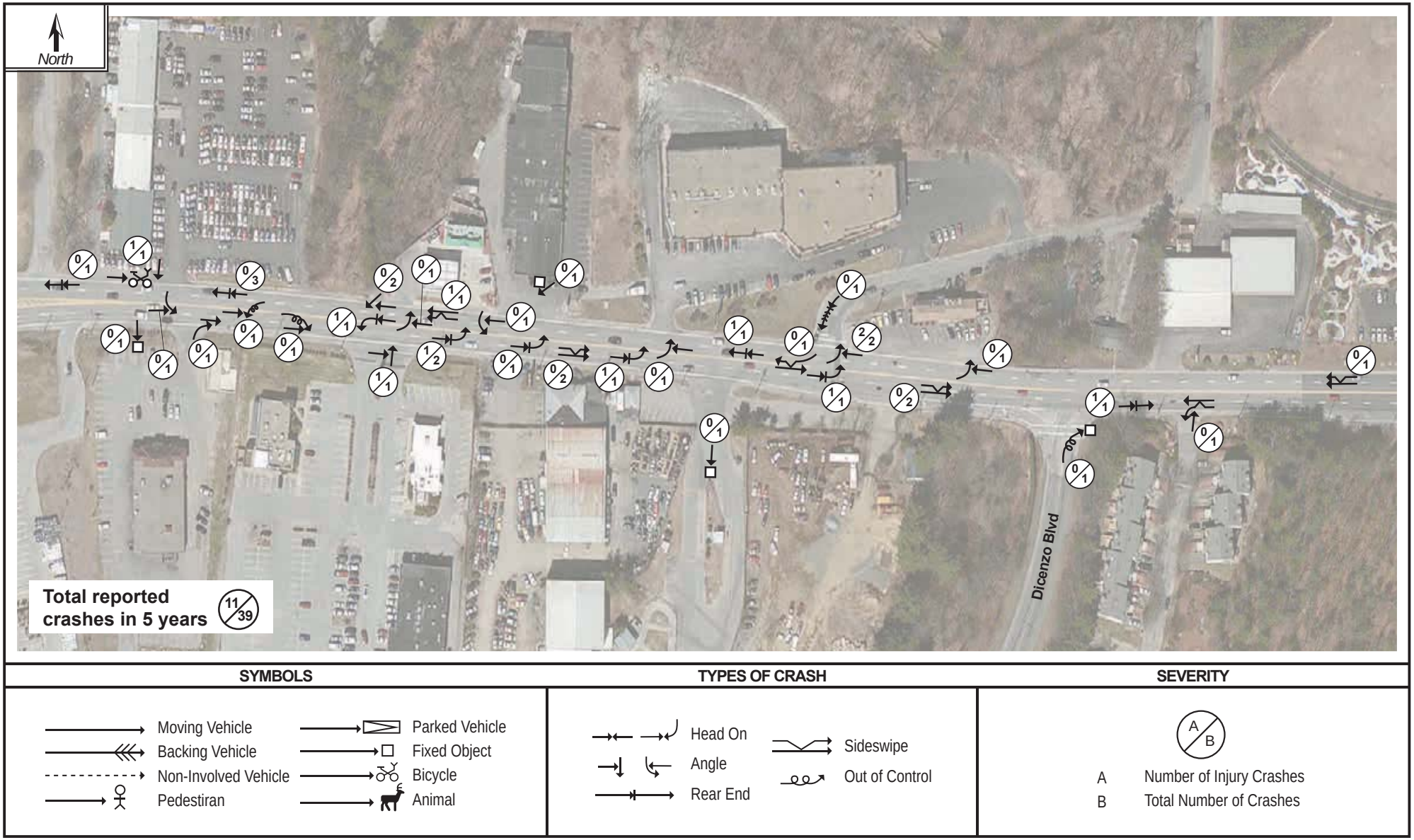
A Number of Injury Crashes
B Total Number of Crashes

Table H-14
Crash Statistics: Route 20 at Dicenzo Boulevard
Marlborough Police Department Crash Data 2011-15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		4	4	4	8	8	28	5.6
Severity	Property damage only	3	3	3	7	7	23	4.6
	Non-fatal injury	1	1	1	1	1	5	1.0
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	0	0	0	0	0	0.0
	Rear-end	2	1	0	4	3	10	2.0
	Angle	2	2	0	2	5	11	2.2
	Sideswipe, same direction	0	1	2	2	0	5	1.0
	Sideswipe, opposite direction	0	0	1	0	0	1	0.2
	Head-on	0	0	0	0	0	0	0.0
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	1	0	0	1	0.2
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		1	1	4	7	6	19	3.8
Wet or icy pavement conditions		3	1	1	2	2	9	1.8
Dark conditions (lit or unlit)		0	0	1	2	0	3	0.6

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

Figure H-15
Collision Diagram: Route 20 between Dicenzo Boulevard and Raytheon Driveway
Marlborough Police Reports: January 2011–December 2015



SYMBOLS

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

TYPES OF CRASH

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

SEVERITY

A/B

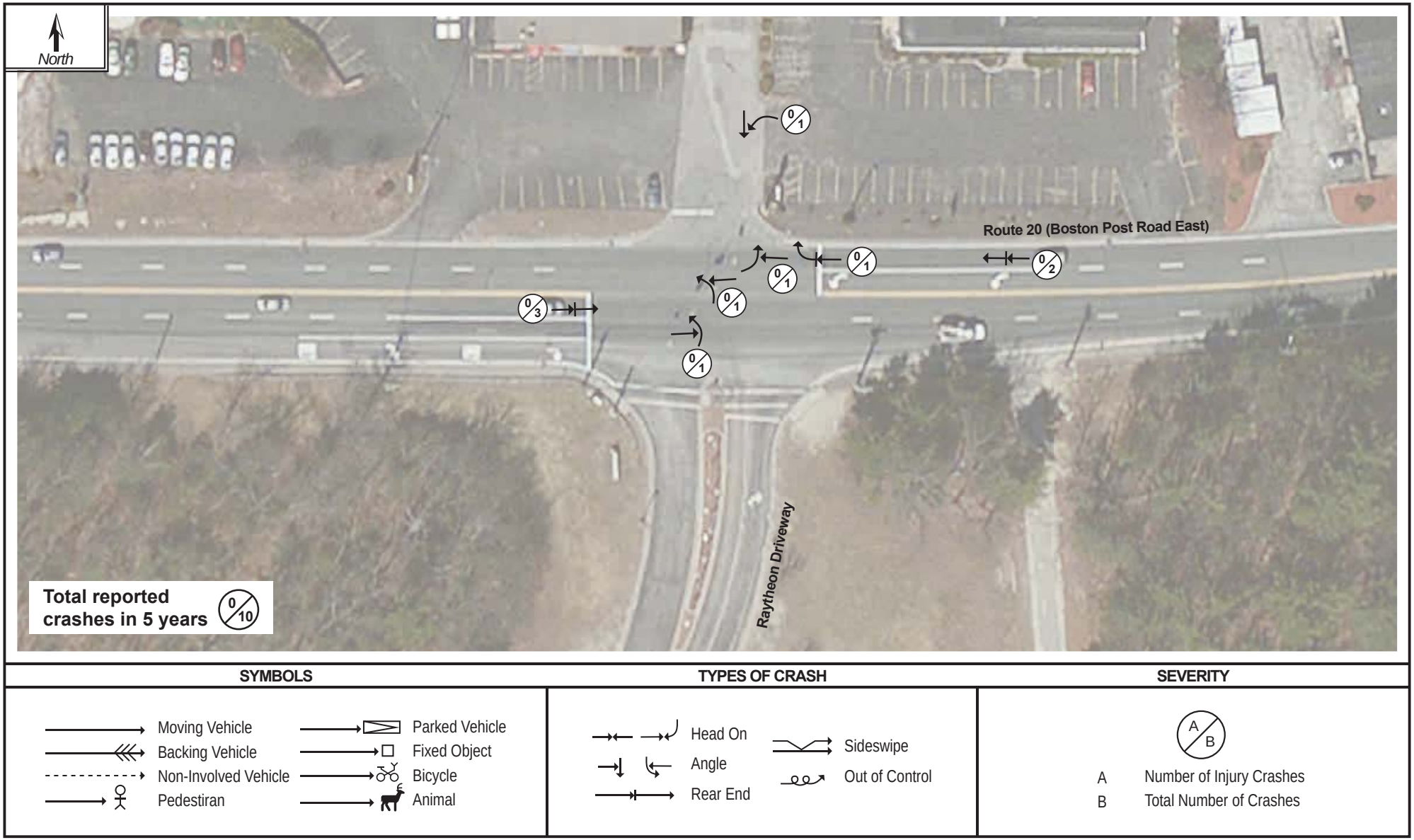
A Number of Injury Crashes
B Total Number of Crashes

Table H-15
Crash Statistics: Route 20 between Dicenzo Boulevard and Raytheon Driveway
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		10	5	8	9	7	39	7.8
Severity	Property damage only	5	4	7	4	7	27	5.4
	Non-fatal injury	5	1	0	5	0	11	2.2
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	1	0	0	1	0.2
Collision type	Single vehicle	1	1	1	0	1	4	0.8
	Rear-end	4	2	1	4	1	12	2.4
	Angle	2	1	3	3	1	10	2.0
	Sideswipe, same direction	1	1	3	1	2	8	1.6
	Sideswipe, opposite direction	1	0	0	0	2	3	0.6
	Head-on	1	0	0	0	0	1	0.2
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	1	0	1	0.2
Occurred during weekday peak periods*		3	2	4	9	5	23	4.6
Wet or icy pavement conditions		1	2	3	2	3	11	2.2
Dark conditions (lit or unlit)		0	2	0	1	3	6	1.2

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

Figure H-16
Collision Diagram: Route 20 at Raytheon Driveway
Marlborough Police Reports: January 2011–December 2015



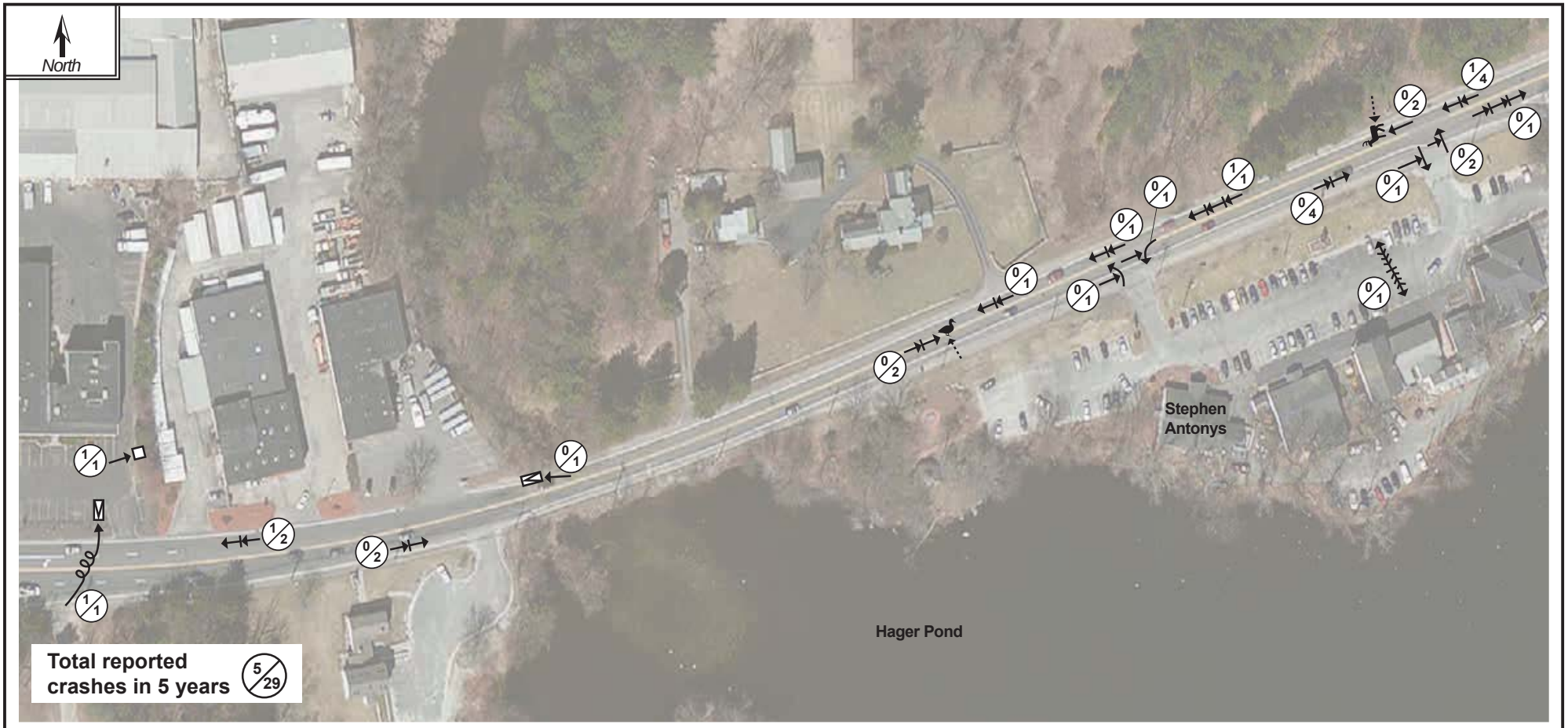
SYMBOLS	TYPES OF CRASH	SEVERITY
Moving Vehicle Backing Vehicle Non-Involved Vehicle Pedestiran Parked Vehicle Fixed Object Bicycle Animal	Head On Angle Rear End Sideswipe Out of Control	A/B A Number of Injury Crashes B Total Number of Crashes

Table H-16
Crash Statistics: Route 20 at Raytheon Driveway
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		2	0	3	2	3	10	2.0
Severity	Property damage only	2	0	3	2	3	10	2.0
	Non-fatal injury	0	0	0	0	0	0	0.0
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	0	0	0	0	0	0.0
	Rear-end	1	0	3	1	1	6	1.2
	Angle	1	0	0	1	2	4	0.8
	Sideswipe, same direction	0	0	0	0	0	0	0.0
	Sideswipe, opposite direction	0	0	0	0	0	0	0.0
	Head-on	0	0	0	0	0	0	0.0
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		2	0	3	1	3	9	1.8
Wet or icy pavement conditions		1	0	2	1	1	5	1.0
Dark conditions (lit or unlit)		0	0	1	0	0	1	0.2

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

Figure H-17
Collision Diagram: Route 20 between Raytheon Driveway and Wayside Inn Road
Marlborough Police Reports: January 2011–December 2015



SYMBOLS

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

TYPES OF CRASH

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

SEVERITY

A/B

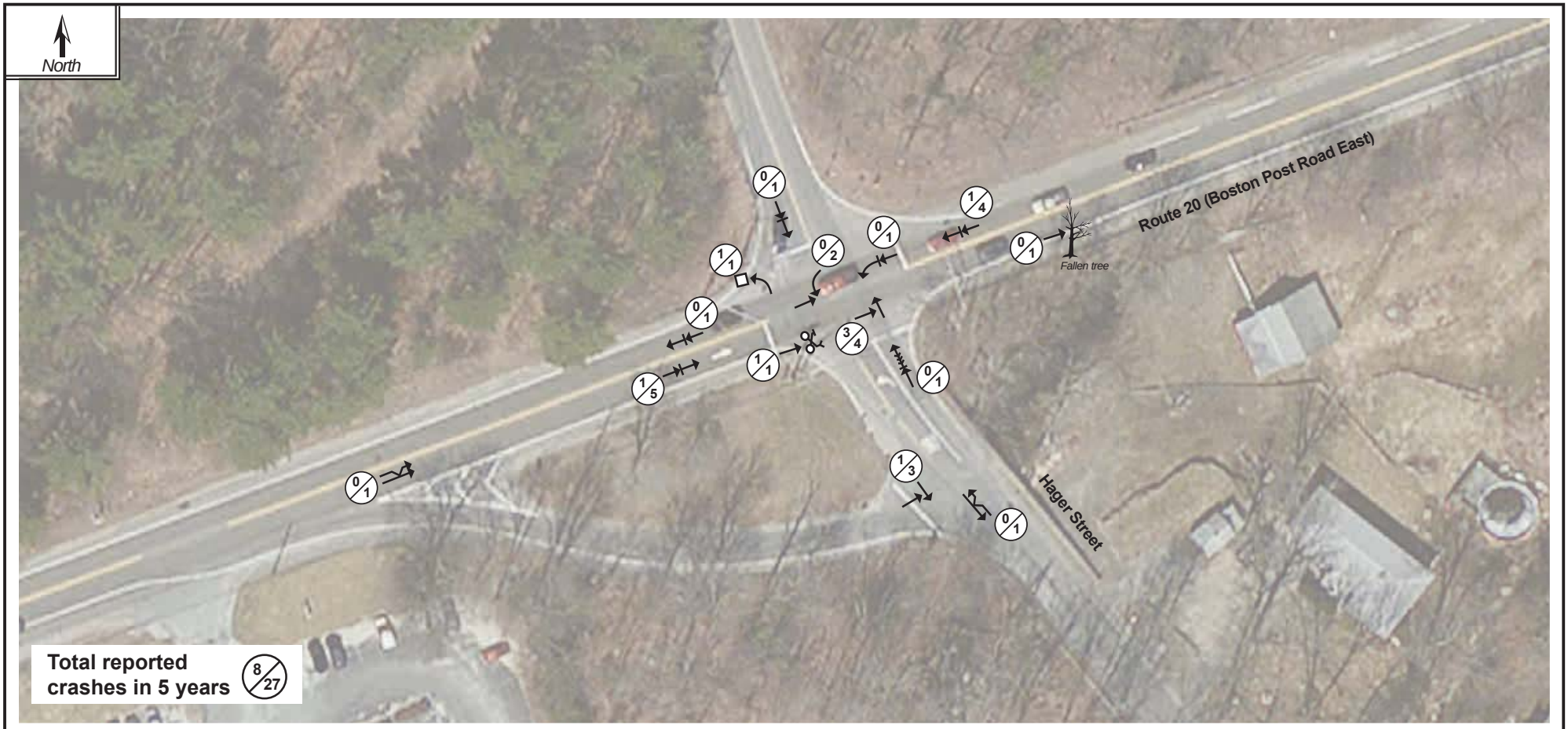
A Number of Injury Crashes
B Total Number of Crashes

Table H-17
Crash Statistics: Route 20 between Raytheon Driveway and Wayside Inn Road
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		8	7	3	6	5	29	5.8
Severity	Property damage only	6	7	3	5	3	24	4.8
	Non-fatal injury	2	0	0	1	2	5	1.0
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	1	0	0	1	2	0.4
	Rear-end	7	3	1	5	3	19	3.8
	Angle	0	1	2	0	1	4	0.8
	Sideswipe, same direction	0	0	0	0	0	0	0.0
	Sideswipe, opposite direction	0	1	0	1	0	2	0.4
	Head-on	1	0	0	0	0	1	0.2
	Rear-to-rear	0	1	0	0	0	1	0.2
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		5	2	0	0	0	7	1.4
Wet or icy pavement conditions		1	2	0	1	0	4	0.8
Dark conditions (lit or unlit)		0	1	0	0	1	2	0.4

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

Figure H-18
Collision Diagram: Route 20 at Wayside Inn Road/Hager Street
Marlborough Police Reports: January 2011–December 2015



SYMBOLS	TYPES OF CRASH	SEVERITY
Moving Vehicle Backing Vehicle Non-Involved Vehicle Pedestiran Parked Vehicle Fixed Object Bicycle Animal	Head On Angle Rear End Sideswipe Out of Control	A/B A Number of Injury Crashes B Total Number of Crashes

Table H-18
Crash Statistics: Route 20 at Wayside Inn Road/Hager Street
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		8	4	3	6	6	27	5.4
Severity	Property damage only	7	2	1	5	4	19	3.8
	Non-fatal injury	1	2	2	1	2	8	1.6
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	0	0	0	1	1	0.2
	Rear-end	2	3	1	3	4	13	2.6
	Angle	4	1	2	2	1	10	2.0
	Sideswipe, same direction	0	0	0	1	0	1	0.2
	Sideswipe, opposite direction	1	0	0	0	0	1	0.2
	Head-on	0	0	0	0	0	0	0.0
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	1	0	0	0	0	1	0.2
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	1	1	0.2
Occurred during weekday peak periods*		4	0	1	6	4	15	3.0
Wet or icy pavement conditions		2	0	1	1	1	5	1.0
Dark conditions (lit or unlit)		2	0	1	0	0	3	0.6

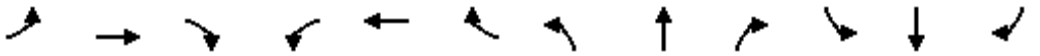
* Peak periods are defined as 7:00–10:00 AM and 3:30–6:30 PM.

APPENDIX I

Intersection Capacity Analyses
Weekday AM Peak Hour
Projected 2040 Traffic Conditions with Proposed Improvements

Intersection Capacity Analysis
Route 20 at Route 85, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	43	318	231	210	246	5	180	333	97	19	439	22
Future Volume (vph)	43	318	231	210	246	5	180	333	97	19	439	22
Satd. Flow (prot)	1646	1733	1473	1678	1761	0	1631	1717	1459	1694	3362	0
Flt Permitted	0.578			0.241			0.241			0.416		
Satd. Flow (perm)	1002	1733	1473	426	1761	0	414	1717	1459	742	3362	0
Satd. Flow (RTOR)			272		1				142		4	
Confl. Peds. (#/hr)							1					1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.93	0.93	0.93
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	6%	6%	6%	4%	4%	4%	7%	7%	7%	3%	3%	3%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	51	374	272	247	295	0	212	392	114	22	530	0
Turn Type	pm+pt	NA	Perm	pm+pt	NA		pm+pt	NA	Perm	pm+pt	NA	
Protected Phases	5	2		1	6		3	8		7	4	
Permitted Phases	2		2	6			8		8	4		
Total Split (s)	8.0	26.0	26.0	12.0	30.0		13.0	26.0	26.0	10.0	23.0	
Total Lost Time (s)	4.0	5.0	5.0	4.0	5.0		4.0	5.0	5.0	4.0	5.0	
Act Effct Green (s)	26.5	21.4	21.4	34.6	29.0		30.6	26.3	26.3	23.7	16.8	
Actuated g/C Ratio	0.34	0.28	0.28	0.44	0.37		0.39	0.34	0.34	0.30	0.22	
v/c Ratio	0.14	0.79	0.45	0.77	0.45		0.69	0.67	0.19	0.07	0.73	
Control Delay	17.5	42.0	6.7	36.6	25.0		33.3	33.1	4.3	18.4	36.4	
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	
Total Delay	17.5	42.0	6.7	36.6	25.0		33.3	33.1	4.3	18.4	36.4	
LOS	B	D	A	D	C		C	C	A	B	D	
Approach Delay		26.4			30.3			28.6			35.7	
Approach LOS		C			C			C			D	
Queue Length 50th (ft)	12	156	0	69	106		61	131	0	6	114	
Queue Length 95th (ft)	49	#436	68	#287	263		#205	#464	29	27	#264	
Internal Link Dist (ft)		424			226			511			208	
Turn Bay Length (ft)	350						220			50		
Base Capacity (vph)	374	475	601	320	656		306	581	587	302	794	
Starvation Cap Reductn	0	0	0	0	0		0	0	0	0	0	
Spillback Cap Reductn	0	0	0	0	0		0	0	0	0	0	
Storage Cap Reductn	0	0	0	0	0		0	0	0	0	0	
Reduced v/c Ratio	0.14	0.79	0.45	0.77	0.45		0.69	0.67	0.19	0.07	0.67	

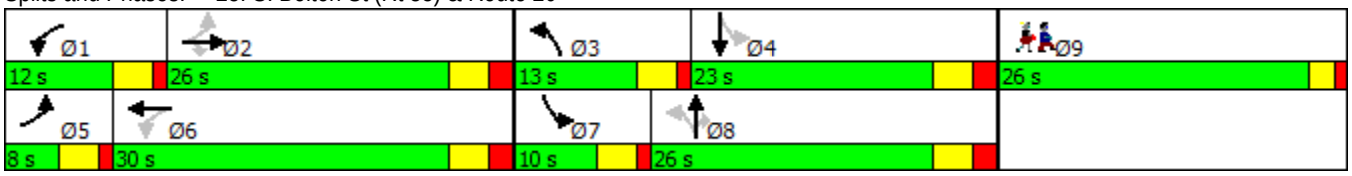
Intersection Summary	
Cycle Length: 100	
Actuated Cycle Length: 77.8	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.79	
Intersection Signal Delay: 29.9	Intersection LOS: C
Intersection Capacity Utilization 69.8%	ICU Level of Service C
Analysis Period (min) 15	

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	26.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 25: S. Bolton St (Rt 85) & Route 20



Intersection Capacity Analysis
Route 20 at Main Street, Marlborough

11/7/2016

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Traffic Volume (vph)	78	67	10	56	174	19	8	376	47	7	372	105
Future Volume (vph)	78	67	10	56	174	19	8	376	47	7	372	105
Satd. Flow (prot)	1678	1726	0	1711	1767	0	1616	1667	0	0	1747	1487
Flt Permitted	0.593			0.690			0.385				0.988	
Satd. Flow (perm)	1037	1726	0	1231	1767	0	655	1667	0	0	1728	1447
Satd. Flow (RTOR)		7			5			9				96
Confl. Peds. (#/hr)	6		4	4		6			5	5		6
Confl. Bikes (#/hr)												
Peak Hour Factor	0.80	0.80	0.80	0.92	0.92	0.92	0.80	0.80	0.80	0.88	0.88	0.88
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	4%	4%	4%	2%	2%	2%	8%	8%	8%	5%	5%	5%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	104	103	0	65	224	0	11	566	0	0	461	128
Turn Type	Perm	NA		Perm	NA		Perm	NA		Perm	NA	Perm
Protected Phases		4			8			2			6	
Permitted Phases	4			8			2			6		6
Total Split (s)	22.0	22.0		22.0	22.0		43.0	43.0		43.0	43.0	43.0
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0	5.0			5.0	5.0
Act Effct Green (s)	14.7	14.7		14.7	14.7		23.8	23.8			23.8	23.8
Actuated g/C Ratio	0.28	0.28		0.28	0.28		0.45	0.45			0.45	0.45
v/c Ratio	0.36	0.21		0.19	0.45		0.04	0.75			0.59	0.18
Control Delay	25.3	20.2		22.1	23.5		11.8	21.2			16.3	5.3
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0			0.0	0.0
Total Delay	25.3	20.2		22.1	23.5		11.8	21.2			16.3	5.3
LOS	C	C		C	C		B	C			B	A
Approach Delay		22.8			23.2			21.0			13.9	
Approach LOS		C			C			C			B	
Queue Length 50th (ft)	21	19		13	46		2	113			85	4
Queue Length 95th (ft)	93	82		70	#198		13	336			295	42
Internal Link Dist (ft)		297			75			453			795	
Turn Bay Length (ft)	150											100
Base Capacity (vph)	378	635		449	648		505	1288			1333	1138
Starvation Cap Reductn	0	0		0	0		0	0			0	0
Spillback Cap Reductn	0	0		0	0		0	0			0	0
Storage Cap Reductn	0	0		0	0		0	0			0	0
Reduced v/c Ratio	0.28	0.16		0.14	0.35		0.02	0.44			0.35	0.11

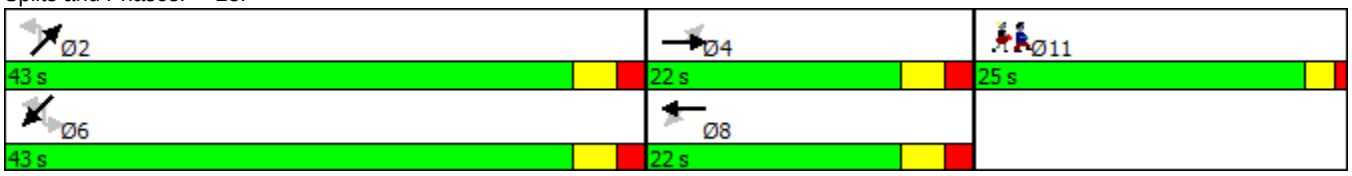
Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 52.7	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.75	
Intersection Signal Delay: 19.1	Intersection LOS: B
Intersection Capacity Utilization 55.5%	ICU Level of Service B
Analysis Period (min) 15	

Lane Group	Ø11
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	11
Permitted Phases	
Total Split (s)	25.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

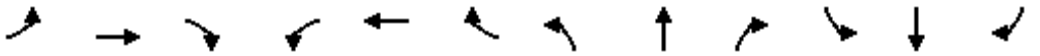
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 23:



Intersection Capacity Analysis
Route 20 at Lincoln Street, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	4	403	8	396	353	251	10	71	437	266	99	8
Future Volume (vph)	4	403	8	396	353	251	10	71	437	266	99	8
Satd. Flow (prot)	0	3441	0	1711	1689	0	0	1790	1531	0	1751	0
Flt Permitted		0.946		0.950				0.938			0.717	
Satd. Flow (perm)	0	3259	0	1711	1689	0	0	1689	1531	0	1300	0
Satd. Flow (RTOR)		2			64				55		1	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.92	0.92	0.92	0.93	0.93	0.93	0.75	0.75	0.75	0.84	0.84	0.84
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	2%	2%	2%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	483	0	456	695	0	0	115	623	0	475	0
Turn Type	Perm	NA		Prot	NA		Perm	NA	pm+ov	Perm	NA	
Protected Phases		2		1	6			4	1		8	
Permitted Phases	2						4		4	8		
Total Split (s)	25.0	25.0		35.0	60.0		35.0	35.0	35.0	35.0	35.0	
Total Lost Time (s)		5.0		5.0	5.0			5.0	5.0		5.0	
Act Effct Green (s)		16.7		26.3	48.1			30.3	61.6		30.3	
Actuated g/C Ratio		0.19		0.30	0.54			0.34	0.70		0.34	
v/c Ratio		0.78		0.90	0.73			0.20	0.58		1.07	
Control Delay		44.1		52.1	18.8			23.9	9.0		93.6	
Queue Delay		0.0		0.0	0.0			0.0	0.0		0.0	
Total Delay		44.1		52.1	18.8			23.9	9.0		93.6	
LOS		D		D	B			C	A		F	
Approach Delay		44.1			32.0			11.3			93.6	
Approach LOS		D			C			B			F	
Queue Length 50th (ft)		142		246	249			49	142		~328	
Queue Length 95th (ft)		198		#423	383			76	172		#484	
Internal Link Dist (ft)		289			228			617			398	
Turn Bay Length (ft)									150			
Base Capacity (vph)		745		585	1083			578	1149		445	
Starvation Cap Reductn		0		0	0			0	0		0	
Spillback Cap Reductn		0		0	0			0	0		0	
Storage Cap Reductn		0		0	0			0	0		0	
Reduced v/c Ratio		0.65		0.78	0.64			0.20	0.54		1.07	

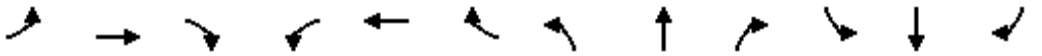
Intersection Summary	
Cycle Length: 95	
Actuated Cycle Length: 88.4	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 1.07	
Intersection Signal Delay: 39.0	Intersection LOS: D
Intersection Capacity Utilization 89.6%	ICU Level of Service E
Analysis Period (min) 15	

~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 21:

Intersection Capacity Analysis
Route 20 at Curtis Avenue, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	78	973	43	29	920	19	42	19	54	27	6	52
Future Volume (vph)	78	973	43	29	920	19	42	19	54	27	6	52
Satd. Flow (prot)	1662	3304	0	1678	3355	1501	0	1641	0	1535	1566	1446
Flt Permitted	0.950			0.950				0.982		0.950	0.969	
Satd. Flow (perm)	1662	3304	0	1678	3355	1501	0	1641	0	1535	1566	1446
Satd. Flow (RTOR)		6				85		39				206
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.89	0.89	0.89	0.98	0.98	0.98	0.82	0.82	0.82	0.71	0.71	0.71
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	5%	5%	5%	4%	4%	4%	3%	3%	3%	8%	8%	8%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)										40%		
Lane Group Flow (vph)	94	1222	0	32	1004	21	0	150	0	25	25	78
Turn Type	Prot	NA		Prot	NA	pm+ov	Split	NA		Split	NA	Perm
Protected Phases	5	2		1	6	4	8	8		4	4	
Permitted Phases						6						4
Total Split (s)	15.0	44.0		11.0	40.0	21.0	14.0	14.0		21.0	21.0	21.0
Total Lost Time (s)	5.0	5.0		5.0	5.0	5.0		5.0		5.0	5.0	5.0
Act Effct Green (s)	9.5	51.9		6.0	46.3	59.5		10.5		8.2	8.2	8.2
Actuated g/C Ratio	0.11	0.58		0.07	0.51	0.66		0.12		0.09	0.09	0.09
v/c Ratio	0.54	0.64		0.29	0.58	0.02		0.66		0.18	0.18	0.25
Control Delay	49.6	18.1		33.2	10.1	0.0		43.6		38.7	38.6	1.8
Queue Delay	0.0	0.0		0.0	0.0	0.0		0.0		0.0	0.0	0.0
Total Delay	49.6	18.1		33.2	10.1	0.0		43.6		38.7	38.6	1.8
LOS	D	B		C	B	A		D		D	D	A
Approach Delay		20.3			10.6			43.6			16.2	
Approach LOS		C			B			D			B	
Queue Length 50th (ft)	51	270		18	88	0		59		14	14	0
Queue Length 95th (ft)	100	403		m29	118	m0		#131		28	28	0
Internal Link Dist (ft)		686			186			446			263	
Turn Bay Length (ft)	360			175		175				75		125
Base Capacity (vph)	193	1907		111	1725	1130		233		272	278	426
Starvation Cap Reductn	0	0		0	0	0		0		0	0	0
Spillback Cap Reductn	0	0		0	0	0		0		0	0	0
Storage Cap Reductn	0	0		0	0	0		0		0	0	0
Reduced v/c Ratio	0.49	0.64		0.29	0.58	0.02		0.64		0.09	0.09	0.18

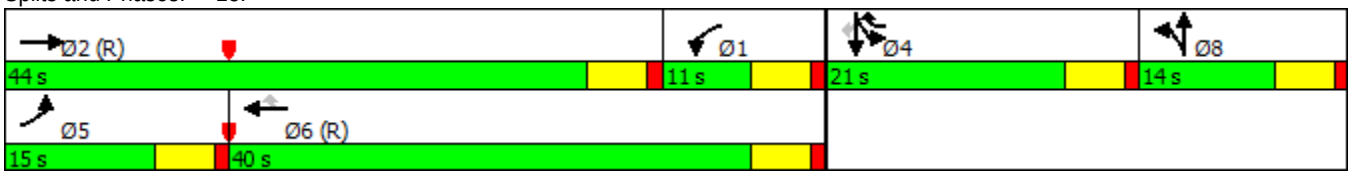
Intersection Summary		
Cycle Length: 90		
Actuated Cycle Length: 90		
Offset: 0 (0%), Referenced to phase 2:EBT and 6:WBT, Start of Green, Master Intersection		
Control Type: Actuated-Coordinated		
Maximum v/c Ratio: 0.66		
Intersection Signal Delay: 17.6	Intersection LOS: B	
Intersection Capacity Utilization 61.5%	ICU Level of Service B	

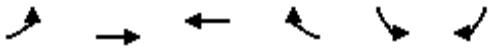
Analysis Period (min) 15

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

m Volume for 95th percentile queue is metered by upstream signal.

Splits and Phases: 18:



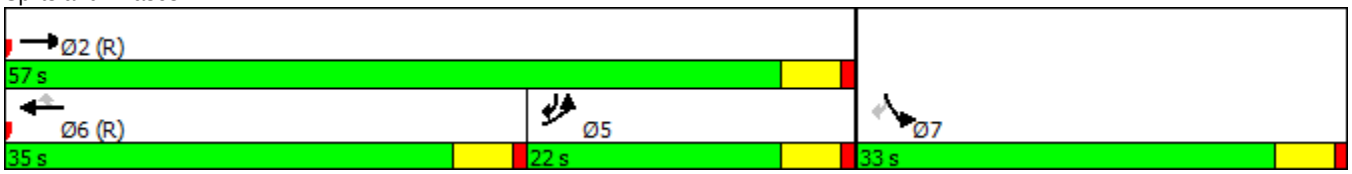


Lane Group	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Traffic Volume (vph)	156	883	681	110	300	265
Future Volume (vph)	156	883	681	110	300	265
Satd. Flow (prot)	1662	3323	3355	1501	1694	1516
Flt Permitted	0.950				0.950	
Satd. Flow (perm)	1662	3323	3355	1501	1694	1516
Satd. Flow (RTOR)				128		45
Confl. Peds. (#/hr)						
Confl. Bikes (#/hr)						
Peak Hour Factor	0.88	0.88	0.92	0.92	0.90	0.90
Growth Factor	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	5%	5%	4%	4%	3%	3%
Bus Blockages (#/hr)	0	0	0	0	0	0
Parking (#/hr)						
Mid-Block Traffic (%)		0%	0%		0%	
Shared Lane Traffic (%)						
Lane Group Flow (vph)	190	1074	792	128	357	315
Turn Type	Prot	NA	NA	Perm	Prot	pm+ov
Protected Phases	5	2	6		7	5
Permitted Phases				6		7
Total Split (s)	22.0	57.0	35.0	35.0	33.0	22.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0
Act Effct Green (s)	14.8	56.7	36.9	36.9	23.3	43.1
Actuated g/C Ratio	0.16	0.63	0.41	0.41	0.26	0.48
v/c Ratio	0.70	0.51	0.58	0.19	0.82	0.42
Control Delay	37.6	2.7	14.5	1.4	46.3	13.7
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	37.6	2.7	14.5	1.4	46.3	13.7
LOS	D	A	B	A	D	B
Approach Delay		7.9	12.6		31.0	
Approach LOS		A	B		C	
Queue Length 50th (ft)	110	27	187	7	188	91
Queue Length 95th (ft)	183	30	92	2	275	133
Internal Link Dist (ft)		239	315		492	
Turn Bay Length (ft)	300			150		100
Base Capacity (vph)	313	2094	1376	691	527	731
Starvation Cap Reductn	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0
Reduced v/c Ratio	0.61	0.51	0.58	0.19	0.68	0.43

Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 90	
Offset: 85 (94%), Referenced to phase 2:EBT and 6:WBT, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.82	
Intersection Signal Delay: 14.9	Intersection LOS: B
Intersection Capacity Utilization 59.7%	ICU Level of Service B

Analysis Period (min) 15

Splits and Phases: 14:



Lane Group	EBL	EBT	WBT	WBR	SWL	SWR
Lane Configurations						
Traffic Volume (vph)	97	1050	621	19	40	191
Future Volume (vph)	97	1050	621	19	40	191
Satd. Flow (prot)	1678	1949	3424	0	1752	1672
Flt Permitted	0.950				0.950	
Satd. Flow (perm)	1678	1949	3424	0	1752	1672
Satd. Flow (RTOR)			5			185
Confl. Peds. (#/hr)						
Confl. Bikes (#/hr)						
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Growth Factor	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	4%	4%	5%	5%	3%	3%
Bus Blockages (#/hr)	0	0	0	0	0	0
Parking (#/hr)						
Mid-Block Traffic (%)		0%	0%		0%	
Shared Lane Traffic (%)						
Lane Group Flow (vph)	113	1221	744	0	47	222
Turn Type	Prot	NA	NA		Prot	pm+ov
Protected Phases	5	2	6		7	5
Permitted Phases						7
Total Split (s)	16.0	69.0	53.0		21.0	16.0
Total Lost Time (s)	4.0	5.0	5.0		5.0	4.0
Act Effct Green (s)	18.4	77.5	53.0		9.1	28.0
Actuated g/C Ratio	0.20	0.86	0.59		0.10	0.31
v/c Ratio	0.33	0.73	0.37		0.27	0.34
Control Delay	21.0	9.3	14.5		39.5	4.7
Queue Delay	0.0	0.0	0.0		0.0	0.0
Total Delay	21.0	9.3	14.5		39.5	4.7
LOS	C	A	B		D	A
Approach Delay		10.2	14.5		10.8	
Approach LOS		B	B		B	
Queue Length 50th (ft)	36	207	125		26	13
Queue Length 95th (ft)	m68	#654	225		53	45
Internal Link Dist (ft)		53	224		402	
Turn Bay Length (ft)						50
Base Capacity (vph)	376	1677	2215		311	676
Starvation Cap Reductn	0	0	0		0	0
Spillback Cap Reductn	0	0	0		0	0
Storage Cap Reductn	0	0	0		0	0
Reduced v/c Ratio	0.30	0.73	0.34		0.15	0.33

Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 90	
Offset: 73 (81%), Referenced to phase 2:EBT and 6:WBT, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.73	
Intersection Signal Delay: 11.6	Intersection LOS: B
Intersection Capacity Utilization 72.5%	ICU Level of Service C

Analysis Period (min) 15

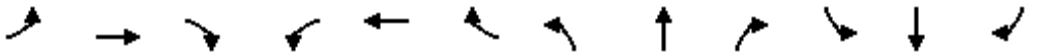
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

m Volume for 95th percentile queue is metered by upstream signal.

Splits and Phases: 11:

Intersection Capacity Analysis
Route 20 at Farm Road, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	37	859	82	198	400	15	91	44	444	62	82	58
Future Volume (vph)	37	859	82	198	400	15	91	44	444	62	82	58
Satd. Flow (prot)	1736	3471	1553	1703	3389	0	1752	1845	1568	0	1824	1583
Flt Permitted	0.950			0.950			0.950				0.979	
Satd. Flow (perm)	1736	3471	1553	1703	3389	0	1752	1845	1568	0	1824	1583
Satd. Flow (RTOR)			136		3							136
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.96	0.96	0.96	0.94	0.94	0.94	0.91	0.91	0.91	0.78	0.78	0.78
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	4%	4%	4%	6%	6%	6%	3%	3%	3%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	41	957	91	225	472	0	107	52	522	0	197	80
Turn Type	Prot	NA	Perm	Prot	NA		Split	NA	pm+ov	Split	NA	Perm
Protected Phases	5	2		1	6		8	8	1	4	4	
Permitted Phases			2						8			4
Total Split (s)	25.0	39.0	39.0	25.0	39.0		14.0	14.0	25.0	17.0	17.0	17.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0		5.0	5.0	5.0		5.0	5.0
Act Effct Green (s)	8.0	32.7	32.7	20.2	49.9		9.0	9.0	33.4		12.1	12.1
Actuated g/C Ratio	0.08	0.33	0.33	0.21	0.51		0.09	0.09	0.34		0.12	0.12
v/c Ratio	0.29	0.83	0.15	0.64	0.27		0.67	0.31	0.98		0.88	0.25
Control Delay	50.6	38.5	2.1	47.5	17.3		66.9	50.5	67.6		80.1	2.8
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0
Total Delay	50.6	38.5	2.1	47.5	17.3		66.9	50.5	67.6		80.1	2.8
LOS	D	D	A	D	B		E	D	E		F	A
Approach Delay		36.0			27.0			66.2			57.8	
Approach LOS		D			C			E			E	
Queue Length 50th (ft)	24	265	0	124	84		63	30	299		118	0
Queue Length 95th (ft)	67	#526	13	#294	189		#184	81	#750		#259	0
Internal Link Dist (ft)		394			914			205			111	
Turn Bay Length (ft)	200			300			75		150			
Base Capacity (vph)	356	1212	631	349	1720		161	170	532		225	314
Starvation Cap Reductn	0	0	0	0	0		0	0	0		0	0
Spillback Cap Reductn	0	0	0	0	0		0	0	0		0	0
Storage Cap Reductn	0	0	0	0	0		0	0	0		0	0
Reduced v/c Ratio	0.12	0.79	0.14	0.64	0.27		0.66	0.31	0.98		0.88	0.25

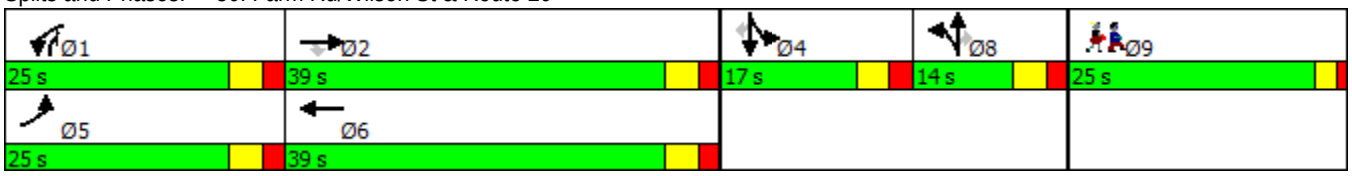
Intersection Summary		
Cycle Length: 120		
Actuated Cycle Length: 98.4		
Control Type: Actuated-Uncoordinated		
Maximum v/c Ratio: 0.98		
Intersection Signal Delay: 43.4	Intersection LOS: D	
Intersection Capacity Utilization 75.6%	ICU Level of Service D	
Analysis Period (min) 15		

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	25.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

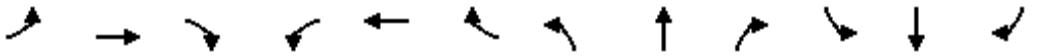
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 30: Farm Rd/Wilson St & Route 20



Intersection Capacity Analysis
Route 20 at Dicenzo Boulevard/Pomphrey Drive, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	24	1257	74	21	441	11	129	10	46	12	2	27
Future Volume (vph)	24	1257	74	21	441	11	129	10	46	12	2	27
Satd. Flow (prot)	1694	3361	0	1662	3310	0	3113	1479	0	1574	1425	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1694	3361	0	1662	3310	0	3113	1479	0	1574	1425	0
Satd. Flow (RTOR)		7			3			61			42	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.83	0.83	0.83	0.81	0.81	0.81	0.68	0.68	0.68
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	3%	3%	3%	5%	5%	5%	5%	5%	5%	7%	7%	7%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	26	1469	0	27	583	0	170	74	0	19	45	0
Turn Type	Prot	NA		Prot	NA		Split	NA		Split	NA	
Protected Phases	5	2		1	6		8	8		4	4	
Permitted Phases												
Total Split (s)	11.0	55.0		11.0	55.0		12.0	12.0		10.0	10.0	
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	
Act Effct Green (s)	6.4	49.7		6.4	49.7		7.4	7.4		5.3	5.3	
Actuated g/C Ratio	0.08	0.62		0.08	0.62		0.09	0.09		0.07	0.07	
v/c Ratio	0.19	0.71		0.21	0.28		0.59	0.39		0.18	0.34	
Control Delay	47.4	17.3		47.6	11.0		49.2	23.0		49.5	24.4	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	47.4	17.3		47.6	11.0		49.2	23.0		49.5	24.4	
LOS	D	B		D	B		D	C		D	C	
Approach Delay		17.8			12.6			41.3			31.9	
Approach LOS		B			B			D			C	
Queue Length 50th (ft)	12	199		12	54		41	6		9	1	
Queue Length 95th (ft)	49	#737		46	179		#111	47		30	23	
Internal Link Dist (ft)		528			1696			203			131	
Turn Bay Length (ft)	120			400								
Base Capacity (vph)	134	2219		131	2184		287	191		103	133	
Starvation Cap Reductn	0	0		0	0		0	0		0	0	
Spillback Cap Reductn	0	0		0	0		0	0		0	0	
Storage Cap Reductn	0	0		0	0		0	0		0	0	
Reduced v/c Ratio	0.19	0.66		0.21	0.27		0.59	0.39		0.18	0.34	

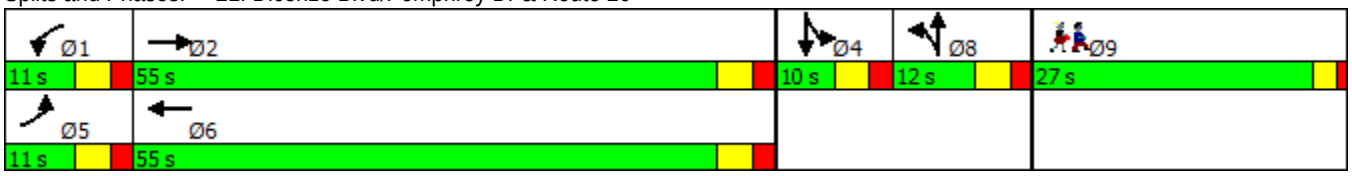
Intersection Summary			
Cycle Length: 115			
Actuated Cycle Length: 80.4			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.71			
Intersection Signal Delay: 19.3		Intersection LOS: B	
Intersection Capacity Utilization 58.6%		ICU Level of Service B	
Analysis Period (min) 15			

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	27.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

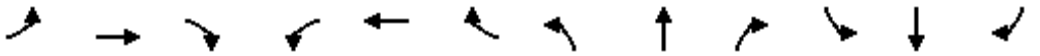
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 21: Dicenzo Blvd/Pomphrey Dr & Route 20



Intersection Capacity Analysis
Route 20 at Raytheon Driveway, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	8	1085	247	159	459	5	3	2	5	3	0	3
Future Volume (vph)	8	1085	247	159	459	5	3	2	5	3	0	3
Satd. Flow (prot)	1678	1766	1553	1662	1806	0	0	1537	1346	0	1152	0
Flt Permitted	0.439			0.067				0.971			0.976	
Satd. Flow (perm)	775	1766	1553	117	1806	0	0	1537	1346	0	1152	0
Satd. Flow (RTOR)			180		1				89		129	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.83	0.83	0.83	0.50	0.50	0.50	0.50	0.50	0.50
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	4%	4%	4%	5%	5%	5%	20%	20%	20%	50%	50%	50%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	9	1197	272	205	598	0	0	10	11	0	12	0
Turn Type	pm+pt	NA	Perm	pm+pt	NA		Split	NA	pm+ov	Split	NA	
Protected Phases	5	2		1	6		3	3	1	4	4	
Permitted Phases	2		2	6					3			
Total Split (s)	9.0	56.0	56.0	11.0	58.0		11.0	11.0	11.0	11.0	11.0	
Total Lost Time (s)	4.0	5.0	5.0	5.0	5.0			4.0	5.0		4.0	
Act Effct Green (s)	57.7	51.6	51.6	62.3	65.5			6.3	7.0		6.1	
Actuated g/C Ratio	0.81	0.72	0.72	0.88	0.92			0.09	0.10		0.09	
v/c Ratio	0.01	0.94	0.23	0.88	0.36			0.07	0.05		0.06	
Control Delay	2.2	25.9	2.5	54.5	4.0			34.4	0.5		0.5	
Queue Delay	0.0	0.0	0.0	0.0	0.0			0.0	0.0		0.0	
Total Delay	2.2	25.9	2.5	54.5	4.0			34.4	0.5		0.5	
LOS	A	C	A	D	A			C	A		A	
Approach Delay		21.5			16.9			16.6			0.5	
Approach LOS		C			B			B			A	
Queue Length 50th (ft)	0	258	7	37	0			4	0		0	
Queue Length 95th (ft)	5	#1043	56	#197	236			12	0		0	
Internal Link Dist (ft)		655			458			102			237	
Turn Bay Length (ft)	100		300	150								
Base Capacity (vph)	691	1280	1175	233	1662			152	213		230	
Starvation Cap Reductn	0	0	0	0	0			0	0		0	
Spillback Cap Reductn	0	0	0	0	0			0	0		0	
Storage Cap Reductn	0	0	0	0	0			0	0		0	
Reduced v/c Ratio	0.01	0.94	0.23	0.88	0.36			0.07	0.05		0.05	

Intersection Summary		
Cycle Length: 110		
Actuated Cycle Length: 71.2		
Control Type: Actuated-Uncoordinated		
Maximum v/c Ratio: 0.94		
Intersection Signal Delay: 19.7	Intersection LOS: B	
Intersection Capacity Utilization 87.2%	ICU Level of Service E	
Analysis Period (min) 15		

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	21.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 2: Raytheon Dr & Route 20

Intersection Capacity Analysis
Route 20 at Wayside Inn Road/Hager Street, Marlborough

11/7/2016

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	SBL2	SBL	SBR	NWL	NWR	NWR2
Lane Configurations												
Traffic Volume (vph)	58	879	152	7	401	1	34	55	120	107	20	2
Future Volume (vph)	58	879	152	7	401	1	34	55	120	107	20	2
Satd. Flow (prot)	1736	1827	1553	1703	1792	0	0	1723	1490	1736	1553	0
Flt Permitted	0.950			0.950				0.961		0.950		
Satd. Flow (perm)	1736	1827	1553	1703	1792	0	0	1723	1490	1736	1553	0
Satd. Flow (RTOR)			145					182	182		182	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.91	0.91	0.91	0.84	0.84	0.84	0.83	0.83	0.83	0.88	0.88	0.88
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	4%	4%	4%	6%	6%	6%	3%	3%	3%	4%	4%	4%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%		0%		
Shared Lane Traffic (%)									17%			
Lane Group Flow (vph)	68	1034	179	9	512	0	0	141	129	130	26	0
Turn Type	Prot	NA	Perm	Prot	NA		Prot	Prot	Perm	Prot	Prot	
Protected Phases	5	2		1	6		8	8		4	4	
Permitted Phases			2						8			
Total Split (s)	14.0	65.0	65.0	9.0	60.0		10.0	10.0	10.0	15.0	15.0	
Total Lost Time (s)	4.0	5.0	5.0	4.0	5.0			5.0	5.0	5.0	5.0	
Act Effct Green (s)	8.5	60.9	60.9	5.1	51.9			5.1	5.1	10.0	10.0	
Actuated g/C Ratio	0.09	0.63	0.63	0.05	0.54			0.05	0.05	0.10	0.10	
v/c Ratio	0.44	0.89	0.17	0.10	0.53			0.54	0.52	0.72	0.08	
Control Delay	53.3	28.3	3.4	50.8	19.0			11.1	9.8	66.4	0.5	
Queue Delay	0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	
Total Delay	53.3	28.3	3.4	50.8	19.0			11.1	9.8	66.4	0.5	
LOS	D	C	A	D	B			B	A	E	A	
Approach Delay		26.1			19.6			10.5		55.4		
Approach LOS		C			B			B		E		
Queue Length 50th (ft)	37	397	6	5	183			0	0	72	0	
Queue Length 95th (ft)	100	#1185	51	23	371			18	8	#214	0	
Internal Link Dist (ft)		190			594			403		273		
Turn Bay Length (ft)	150		100	50					50		100	
Base Capacity (vph)	182	1159	1038	89	1062			263	250	182	326	
Starvation Cap Reductn	0	0	0	0	0			0	0	0	0	
Spillback Cap Reductn	0	0	0	0	0			0	0	0	0	
Storage Cap Reductn	0	0	0	0	0			0	0	0	0	
Reduced v/c Ratio	0.37	0.89	0.17	0.10	0.48			0.54	0.52	0.71	0.08	

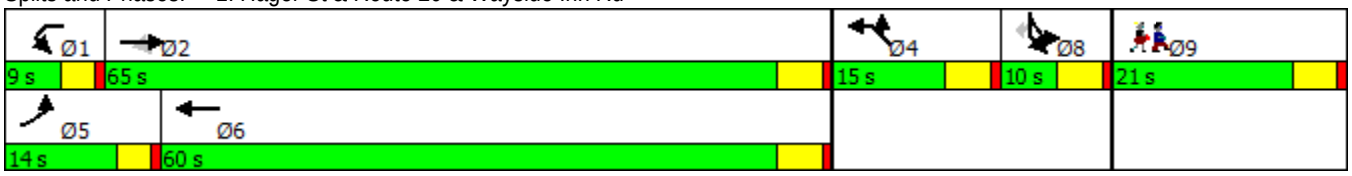
Intersection Summary			
Cycle Length: 120			
Actuated Cycle Length: 96			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.89			
Intersection Signal Delay: 24.7		Intersection LOS: C	
Intersection Capacity Utilization 78.3%		ICU Level of Service D	
Analysis Period (min) 15			

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	21.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 1: Hager St & Route 20 & Wayside Inn Rd

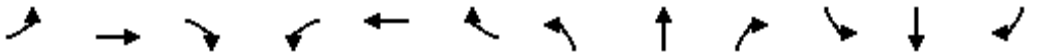


APPENDIX J

Intersection Capacity Analyses
Weekday PM Peak Hour
Projected 2040 Traffic Conditions with Proposed Improvements

Intersection Capacity Analysis
Route 20 at Route 85, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	71	424	215	141	279	7	262	443	155	32	323	32
Future Volume (vph)	71	424	215	141	279	7	262	443	155	32	323	32
Satd. Flow (prot)	1728	1818	1546	1694	1776	0	1728	1818	1546	1711	3369	0
Flt Permitted	0.394			0.155			0.268			0.247		
Satd. Flow (perm)	716	1818	1546	276	1776	0	487	1818	1546	445	3369	0
Satd. Flow (RTOR)			250		1				182		9	
Confl. Peds. (#/hr)							1					1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.93	0.93	0.93	0.91	0.91	0.91	0.90	0.90	0.90	0.85	0.85	0.85
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	3%	3%	3%	1%	1%	1%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	82	492	250	167	339	0	314	532	186	41	451	0
Turn Type	pm+pt	NA	Perm	pm+pt	NA		pm+pt	NA	Perm	pm+pt	NA	
Protected Phases	5	2		1	6		3	8		7	4	
Permitted Phases	2		2	6			8		8	4		
Total Split (s)	8.0	29.0	29.0	8.0	29.0		17.0	29.0	29.0	8.0	20.0	
Total Lost Time (s)	4.0	5.0	5.0	4.0	5.0		4.0	5.0	5.0	4.0	5.0	
Act Effct Green (s)	29.5	24.4	24.4	30.3	26.1		32.8	27.1	27.1	19.6	14.5	
Actuated g/C Ratio	0.38	0.31	0.31	0.39	0.33		0.42	0.35	0.35	0.25	0.18	
v/c Ratio	0.26	0.87	0.38	0.93	0.57		0.76	0.85	0.28	0.23	0.72	
Control Delay	19.5	45.6	5.7	76.2	29.6		33.3	41.5	6.0	21.1	38.4	
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	
Total Delay	19.5	45.6	5.7	76.2	29.6		33.3	41.5	6.0	21.1	38.4	
LOS	B	D	A	E	C		C	D	A	C	D	
Approach Delay		30.9			45.0			32.6			37.0	
Approach LOS		C			D			C			D	
Queue Length 50th (ft)	21	206	0	45	128		93	230	1	10	98	
Queue Length 95th (ft)	72	#563	60	#231	#341		#304	#621	56	39	#212	
Internal Link Dist (ft)		424			226			511			208	
Turn Bay Length (ft)	350						220			50		
Base Capacity (vph)	321	564	652	179	592		412	627	653	176	661	
Starvation Cap Reductn	0	0	0	0	0		0	0	0	0	0	
Spillback Cap Reductn	0	0	0	0	0		0	0	0	0	0	
Storage Cap Reductn	0	0	0	0	0		0	0	0	0	0	
Reduced v/c Ratio	0.26	0.87	0.38	0.93	0.57		0.76	0.85	0.28	0.23	0.68	

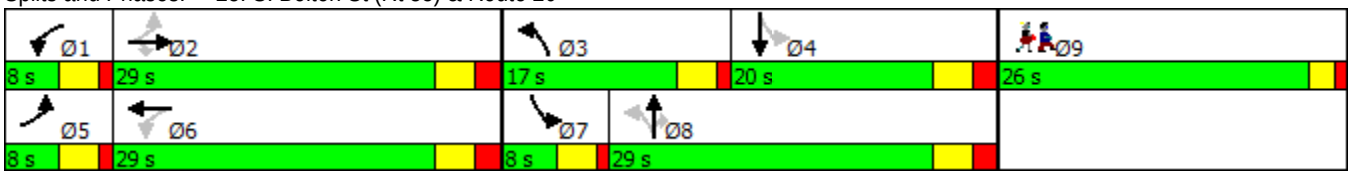
Intersection Summary	
Cycle Length: 100	
Actuated Cycle Length: 78.5	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.93	
Intersection Signal Delay: 35.1	Intersection LOS: D
Intersection Capacity Utilization 76.1%	ICU Level of Service D
Analysis Period (min) 15	

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	26.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 25: S. Bolton St (Rt 85) & Route 20



Intersection Capacity Analysis
Route 20 at Main Street, Marlborough

11/7/2016

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Traffic Volume (vph)	111	98	9	79	178	36	8	460	92	6	312	125
Future Volume (vph)	111	98	9	79	178	36	8	460	92	6	312	125
Satd. Flow (prot)	1728	1790	0	1728	1763	0	1728	1765	0	0	1799	1531
Flt Permitted	0.540			0.676			0.435				0.987	
Satd. Flow (perm)	973	1790	0	1219	1763	0	791	1765	0	0	1777	1489
Satd. Flow (RTOR)		5			10			14				134
Confl. Peds. (#/hr)	6		4	4		6			5	5		6
Confl. Bikes (#/hr)												
Peak Hour Factor	0.92	0.92	0.92	0.94	0.94	0.94	0.91	0.91	0.91	0.85	0.85	0.85
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	130	126	0	91	246	0	9	655	0	0	404	159
Turn Type	Perm	NA		Perm	NA		Perm	NA		Perm	NA	Perm
Protected Phases		4			8			2			6	
Permitted Phases	4			8			2			6		6
Total Split (s)	23.0	23.0		23.0	23.0		42.0	42.0		42.0	42.0	42.0
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0	5.0			5.0	5.0
Act Effct Green (s)	18.1	18.1		18.1	18.1		28.2	28.2			28.2	28.2
Actuated g/C Ratio	0.30	0.30		0.30	0.30		0.47	0.47			0.47	0.47
v/c Ratio	0.45	0.23		0.25	0.46		0.02	0.79			0.49	0.21
Control Delay	29.1	21.6		23.6	24.1		11.9	23.4			15.0	4.5
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0			0.0	0.0
Total Delay	29.1	21.6		23.6	24.1		11.9	23.4			15.0	4.5
LOS	C	C		C	C		B	C			B	A
Approach Delay		25.4			24.0			23.3			12.0	
Approach LOS		C			C			C			B	
Queue Length 50th (ft)	34	30		22	62		1	155			80	4
Queue Length 95th (ft)	#151	112		91	#213		12	#550			240	40
Internal Link Dist (ft)		297			75			453			794	
Turn Bay Length (ft)	150											100
Base Capacity (vph)	309	572		387	567		516	1158			1161	1019
Starvation Cap Reductn	0	0		0	0		0	0			0	0
Spillback Cap Reductn	0	0		0	0		0	0			0	0
Storage Cap Reductn	0	0		0	0		0	0			0	0
Reduced v/c Ratio	0.42	0.22		0.24	0.43		0.02	0.57			0.35	0.16

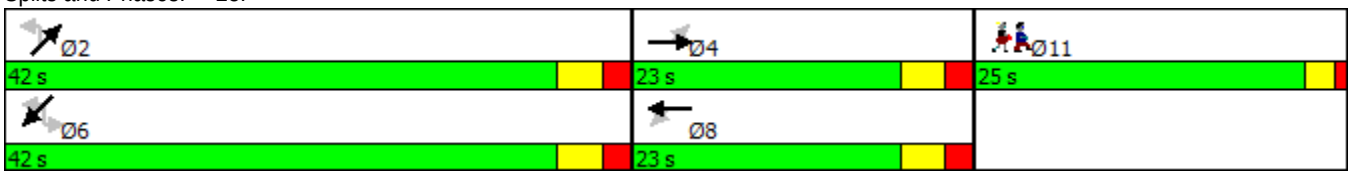
Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 60.2	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.79	
Intersection Signal Delay: 20.2	Intersection LOS: C
Intersection Capacity Utilization 66.4%	ICU Level of Service C
Analysis Period (min) 15	

Lane Group	Ø11
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	11
Permitted Phases	
Total Split (s)	25.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

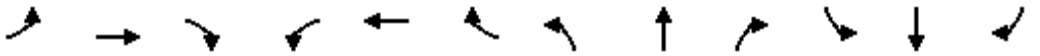
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 23:



Intersection Capacity Analysis
Route 20 at Lincoln Street, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	10	359	14	408	330	322	15	77	475	211	51	5
Future Volume (vph)	10	359	14	408	330	322	15	77	475	211	51	5
Satd. Flow (prot)	0	3431	0	1711	1667	0	0	1786	1531	0	1744	0
Flt Permitted		0.926		0.950				0.925			0.697	
Satd. Flow (perm)	0	3180	0	1711	1667	0	0	1666	1531	0	1264	0
Satd. Flow (RTOR)		4			88				83		1	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.95	0.95	0.95	0.91	0.91	0.91	0.88	0.88	0.88	0.82	0.82	0.82
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	2%	2%	2%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	435	0	484	774	0	0	113	583	0	352	0
Turn Type	Perm	NA		Prot	NA		Perm	NA	pm+ov	Perm	NA	
Protected Phases		2		1	6			4	1		8	
Permitted Phases	2						4		4	8		
Total Split (s)	25.0	25.0		35.0	60.0		35.0	35.0	35.0	35.0	35.0	
Total Lost Time (s)		5.0		5.0	5.0			5.0	5.0		5.0	
Act Effct Green (s)		15.7		27.0	47.9			26.7	58.8		26.7	
Actuated g/C Ratio		0.19		0.32	0.56			0.31	0.69		0.31	
v/c Ratio		0.73		0.89	0.79			0.22	0.54		0.88	
Control Delay		41.4		49.2	20.3			24.3	7.7		54.4	
Queue Delay		0.0		0.0	0.0			0.0	0.0		0.0	
Total Delay		41.4		49.2	20.3			24.3	7.7		54.4	
LOS		D		D	C			C	A		D	
Approach Delay		41.4			31.4			10.4			54.4	
Approach LOS		D			C			B			D	
Queue Length 50th (ft)		125		261	296			47	110		188	
Queue Length 95th (ft)		177		#463	465			90	199		#309	
Internal Link Dist (ft)		289			228			617			398	
Turn Bay Length (ft)									150			
Base Capacity (vph)		773		621	1140			605	1152		459	
Starvation Cap Reductn		0		0	0			0	0		0	
Spillback Cap Reductn		0		0	0			0	0		0	
Storage Cap Reductn		0		0	0			0	0		0	
Reduced v/c Ratio		0.56		0.78	0.68			0.19	0.51		0.77	

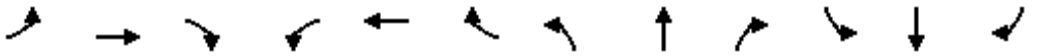
Intersection Summary			
Cycle Length: 95			
Actuated Cycle Length: 84.8			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.89			
Intersection Signal Delay: 30.6		Intersection LOS: C	
Intersection Capacity Utilization 86.6%		ICU Level of Service E	
Analysis Period (min) 15			

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 21:

Intersection Capacity Analysis
Route 20 @ Curtis Avenue/Post Road Plaza, Marlborough

11/9/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	198	858	57	46	890	74	53	63	80	92	35	192
Future Volume (vph)	198	858	57	46	890	74	53	63	80	92	35	192
Satd. Flow (prot)	1728	3424	0	1728	3455	1546	0	1696	0	1625	1673	1546
Flt Permitted	0.950			0.950				0.987		0.950	0.978	
Satd. Flow (perm)	1728	3424	0	1728	3455	1546	0	1696	0	1625	1673	1546
Satd. Flow (RTOR)		9				89		31				221
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.90	0.90	0.90	0.85	0.85	0.85	0.94	0.94	0.94
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)										32%		
Lane Group Flow (vph)	220	1018	0	55	1068	89	0	249	0	72	74	221
Turn Type	Prot	NA		Prot	NA	pm+ov	Split	NA		Split	NA	Perm
Protected Phases	5	2		1	6	4	8	8		4	4	
Permitted Phases						6						4
Total Split (s)	19.0	43.0		11.0	35.0	21.0	15.0	15.0		21.0	21.0	21.0
Total Lost Time (s)	5.0	5.0		5.0	5.0	5.0		5.0		5.0	5.0	5.0
Act Effct Green (s)	13.6	41.4		6.7	30.0	44.6		16.9		9.6	9.6	9.6
Actuated g/C Ratio	0.15	0.46		0.07	0.33	0.50		0.19		0.11	0.11	0.11
v/c Ratio	0.85	0.64		0.43	0.93	0.11		0.73		0.42	0.42	0.61
Control Delay	66.1	21.8		37.8	31.8	0.3		46.3		43.5	43.2	12.7
Queue Delay	0.0	0.0		0.0	0.0	0.0		0.0		0.0	0.0	0.0
Total Delay	66.1	21.8		37.8	31.8	0.3		46.3		43.5	43.2	12.7
LOS	E	C		D	C	A		D		D	D	B
Approach Delay		29.7			29.8			46.3			24.9	
Approach LOS		C			C			D			C	
Queue Length 50th (ft)	122	255		24	95	0		116		42	43	0
Queue Length 95th (ft)	#242	313		m46	#412	m1		#277		78	80	60
Internal Link Dist (ft)		686			186			446			263	
Turn Bay Length (ft)	360			175		175				75		125
Base Capacity (vph)	268	1600		129	1151	914		343		288	297	456
Starvation Cap Reductn	0	0		0	0	0		0		0	0	0
Spillback Cap Reductn	0	0		0	0	0		0		0	0	0
Storage Cap Reductn	0	0		0	0	0		0		0	0	0
Reduced v/c Ratio	0.82	0.64		0.43	0.93	0.10		0.73		0.25	0.25	0.48

Intersection Summary

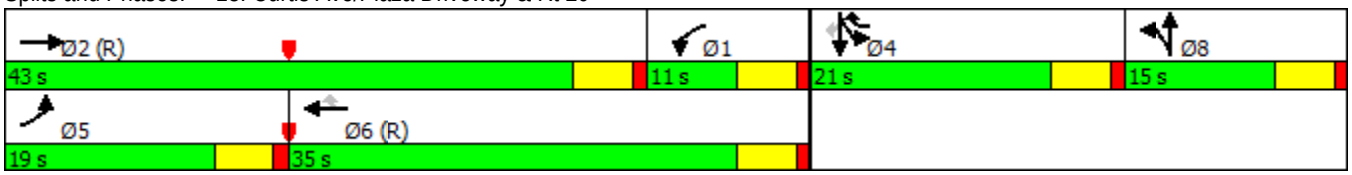
Cycle Length: 90
Actuated Cycle Length: 90
Offset: 0 (0%), Referenced to phase 2:EBT and 6:WBT, Start of Green, Master Intersection
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 0.93
Intersection Signal Delay: 30.5 Intersection LOS: C
Intersection Capacity Utilization 69.6% ICU Level of Service C

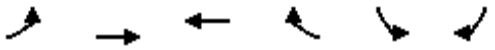
Analysis Period (min) 15

\# 95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

m Volume for 95th percentile queue is metered by upstream signal.

Splits and Phases: 18: Curtis Ave/Plaza Driveway & Rt 20





Lane Group	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Traffic Volume (vph)	277	742	809	285	217	157
Future Volume (vph)	277	742	809	285	217	157
Satd. Flow (prot)	1728	3455	3455	1546	1711	1531
Flt Permitted	0.950				0.950	
Satd. Flow (perm)	1728	3455	3455	1546	1711	1531
Satd. Flow (RTOR)				291		31
Confl. Peds. (#/hr)						
Confl. Bikes (#/hr)						
Peak Hour Factor	0.96	0.96	0.93	0.93	0.94	0.94
Growth Factor	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	1%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0
Parking (#/hr)						
Mid-Block Traffic (%)		0%	0%		0%	
Shared Lane Traffic (%)						
Lane Group Flow (vph)	312	835	939	331	249	180
Turn Type	Prot	NA	NA	Perm	Prot	pm+ov
Protected Phases	5	2	6		7	5
Permitted Phases				6		7
Total Split (s)	28.0	65.0	37.0	37.0	25.0	28.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0
Act Effct Green (s)	20.0	62.9	37.9	37.9	17.1	42.1
Actuated g/C Ratio	0.22	0.70	0.42	0.42	0.19	0.47
v/c Ratio	0.81	0.35	0.65	0.40	0.77	0.25
Control Delay	44.4	2.2	16.3	4.2	50.2	11.4
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	44.4	2.2	16.3	4.2	50.2	11.4
LOS	D	A	B	A	D	B
Approach Delay		13.7	13.2		33.9	
Approach LOS		B	B		C	
Queue Length 50th (ft)	178	23	237	74	133	45
Queue Length 95th (ft)	m#264	37	126	19	212	78
Internal Link Dist (ft)		263	291		481	
Turn Bay Length (ft)	300			150		100
Base Capacity (vph)	441	2415	1454	819	380	719
Starvation Cap Reductn	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0
Reduced v/c Ratio	0.71	0.35	0.65	0.40	0.66	0.25

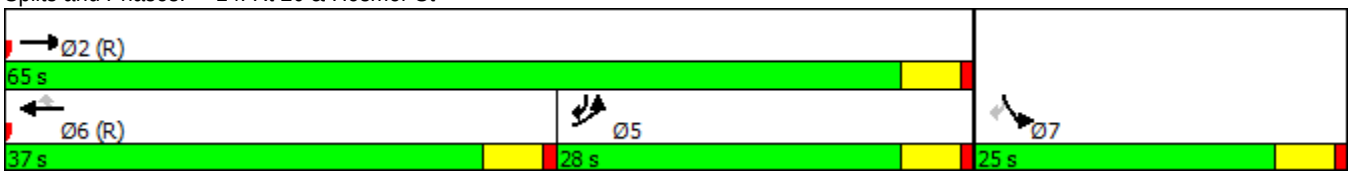
Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 90	
Offset: 84 (93%), Referenced to phase 2:EBT and 6:WBT, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.81	
Intersection Signal Delay: 16.5	Intersection LOS: B
Intersection Capacity Utilization 66.2%	ICU Level of Service C

Analysis Period (min) 15

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

m Volume for 95th percentile queue is metered by upstream signal.

Splits and Phases: 14: Rt 20 & Hosmer St



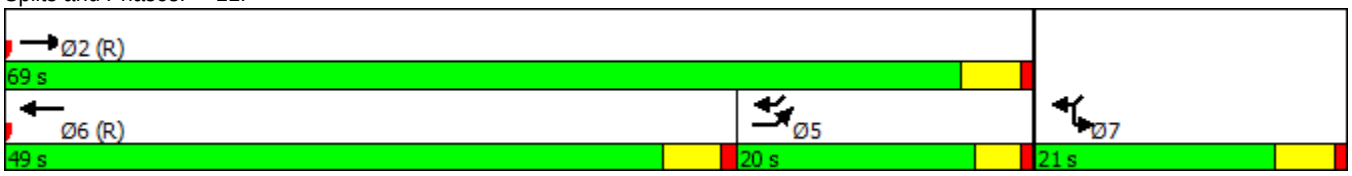
Lane Group	EBL	EBT	WBT	WBR	SWL	SWR
Lane Configurations						
Traffic Volume (vph)	145	772	999	43	38	114
Future Volume (vph)	145	772	999	43	38	114
Satd. Flow (prot)	1728	2007	3518	0	1770	1689
Flt Permitted	0.950				0.950	
Satd. Flow (perm)	1728	2007	3518	0	1770	1689
Satd. Flow (RTOR)			7			48
Confl. Peds. (#/hr)						
Confl. Bikes (#/hr)						
Peak Hour Factor	0.98	0.98	0.95	0.95	0.81	0.81
Growth Factor	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	2%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0
Parking (#/hr)						
Mid-Block Traffic (%)		0%	0%		0%	
Shared Lane Traffic (%)						
Lane Group Flow (vph)	160	851	1185	0	51	152
Turn Type	Prot	NA	NA		Prot	pt+ov
Protected Phases	5	2	6		7	7 5
Permitted Phases						
Total Split (s)	20.0	69.0	49.0		21.0	
Total Lost Time (s)	4.0	5.0	5.0		5.0	
Act Effct Green (s)	13.0	70.8	53.8		9.2	26.2
Actuated g/C Ratio	0.14	0.79	0.60		0.10	0.29
v/c Ratio	0.65	0.54	0.56		0.28	0.29
Control Delay	38.1	4.8	13.4		39.7	16.4
Queue Delay	0.0	0.1	0.0		0.0	0.0
Total Delay	38.1	4.9	13.4		39.7	16.4
LOS	D	A	B		D	B
Approach Delay		10.2	13.4		22.3	
Approach LOS		B	B		C	
Queue Length 50th (ft)	68	132	191		28	45
Queue Length 95th (ft)	m132	39	333		51	67
Internal Link Dist (ft)		53	224		402	
Turn Bay Length (ft)						50
Base Capacity (vph)	307	1578	2107		314	621
Starvation Cap Reductn	0	100	0		0	0
Spillback Cap Reductn	0	0	0		0	0
Storage Cap Reductn	0	0	0		0	0
Reduced v/c Ratio	0.52	0.58	0.56		0.16	0.24

Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 90	
Offset: 69 (77%), Referenced to phase 2:EBT and 6:WBT, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.65	
Intersection Signal Delay: 12.8	Intersection LOS: B
Intersection Capacity Utilization 57.2%	ICU Level of Service B

Analysis Period (min) 15

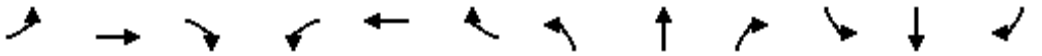
m Volume for 95th percentile queue is metered by upstream signal.

Splits and Phases: 11:



Intersection Capacity Analysis
Route 20 at Farm Road, Marlborough

11/9/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	45	499	106	380	901	44	124	59	259	56	79	51
Future Volume (vph)	45	499	106	380	901	44	124	59	259	56	79	51
Satd. Flow (prot)	1770	3539	1583	1787	3549	0	1787	1881	1599	0	1844	1599
Flt Permitted	0.950			0.950			0.950				0.980	
Satd. Flow (perm)	1770	3539	1583	1787	3549	0	1787	1881	1599	0	1844	1599
Satd. Flow (RTOR)			182		5							182
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96	0.90	0.90	0.90	0.95	0.95	0.95
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	2%	2%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	51	561	119	428	1064	0	149	71	311	0	154	58
Turn Type	Prot	NA	Perm	Prot	NA		Split	NA	pm+ov	Split	NA	Perm
Protected Phases	5	2		1	6		8	8	1	4	4	
Permitted Phases			2						8			4
Total Split (s)	15.0	28.0	28.0	35.0	48.0		16.0	16.0	35.0	16.0	16.0	16.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0		5.0	5.0	5.0		5.0	5.0
Act Effct Green (s)	8.0	19.4	19.4	28.7	42.8		11.2	11.2	44.2		11.2	11.2
Actuated g/C Ratio	0.08	0.20	0.20	0.30	0.45		0.12	0.12	0.47		0.12	0.12
v/c Ratio	0.34	0.77	0.25	0.79	0.66		0.71	0.32	0.42		0.71	0.17
Control Delay	51.2	45.0	2.3	44.2	25.1		62.4	47.2	19.1		61.8	1.0
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0
Total Delay	51.2	45.0	2.3	44.2	25.1		62.4	47.2	19.1		61.8	1.0
LOS	D	D	A	D	C		E	D	B		E	A
Approach Delay		38.4			30.6			35.0			45.1	
Approach LOS		D			C			C			D	
Queue Length 50th (ft)	28	161	0	219	243		85	38	107		88	0
Queue Length 95th (ft)	80	#303	8	#531	481		#244	102	172		#249	0
Internal Link Dist (ft)		387			937			205			111	
Turn Bay Length (ft)	200		200	300			75		150			
Base Capacity (vph)	190	873	527	575	1641		210	222	776		217	349
Starvation Cap Reductn	0	0	0	0	0		0	0	0		0	0
Spillback Cap Reductn	0	0	0	0	0		0	0	0		0	0
Storage Cap Reductn	0	0	0	0	0		0	0	0		0	0
Reduced v/c Ratio	0.27	0.64	0.23	0.74	0.65		0.71	0.32	0.40		0.71	0.17

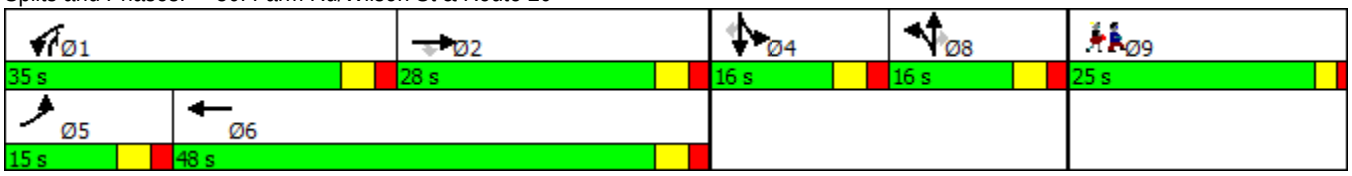
Intersection Summary	
Cycle Length: 120	
Actuated Cycle Length: 94.9	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.79	
Intersection Signal Delay: 34.4	Intersection LOS: C
Intersection Capacity Utilization 64.6%	ICU Level of Service C
Analysis Period (min) 15	

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	25.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

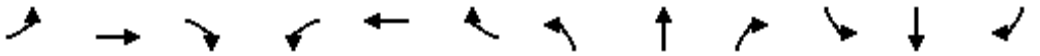
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 30: Farm Rd/Wilson St & Route 20



Intersection Capacity Analysis
Route 20 at Dicentzo Boulevard/Pomphrey Drive, Marlborough

11/9/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	29	595	123	62	1087	25	220	6	25	13	6	6
Future Volume (vph)	29	595	123	62	1087	25	220	6	25	13	6	6
Satd. Flow (prot)	1728	3365	0	1711	3411	0	3173	1513	0	1636	1593	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1728	3365	0	1711	3411	0	3173	1513	0	1636	1593	0
Satd. Flow (RTOR)		23			2			29			9	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.89	0.89	0.89	0.98	0.98	0.98	0.94	0.94	0.94	0.70	0.70	0.70
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	3%	3%	3%	3%	3%	3%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	35	871	0	68	1226	0	253	36	0	20	18	0
Turn Type	Prot	NA		Prot	NA		Split	NA		Split	NA	
Protected Phases	5	2		1	6		8	8		4	4	
Permitted Phases												
Total Split (s)	11.0	46.0		15.0	50.0		16.0	16.0		11.0	11.0	
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	
Act Effct Green (s)	7.0	30.3		9.0	35.7		11.6	11.6		7.0	7.0	
Actuated g/C Ratio	0.10	0.41		0.12	0.49		0.16	0.16		0.10	0.10	
v/c Ratio	0.21	0.62		0.32	0.74		0.50	0.14		0.13	0.11	
Control Delay	46.1	21.6		43.3	22.0		39.5	20.6		46.0	34.2	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	46.1	21.6		43.3	22.0		39.5	20.6		46.0	34.2	
LOS	D	C		D	C		D	C		D	C	
Approach Delay		22.6			23.2			37.1			40.4	
Approach LOS		C			C			D			D	
Queue Length 50th (ft)	17	165		32	258		61	3		9	4	
Queue Length 95th (ft)	59	353		97	#588		#164	37		32	23	
Internal Link Dist (ft)		507			1696			203			131	
Turn Bay Length (ft)	120			400								
Base Capacity (vph)	164	2168		271	2337		554	288		156	159	
Starvation Cap Reductn	0	0		0	0		0	0		0	0	
Spillback Cap Reductn	0	0		0	0		0	0		0	0	
Storage Cap Reductn	0	0		0	0		0	0		0	0	
Reduced v/c Ratio	0.21	0.40		0.25	0.52		0.46	0.13		0.13	0.11	

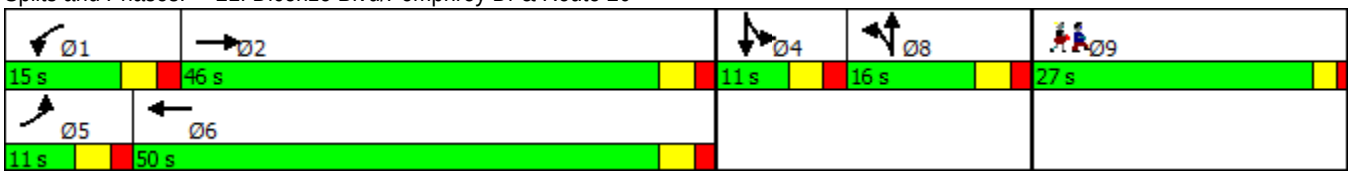
Intersection Summary		
Cycle Length: 115		
Actuated Cycle Length: 73.1		
Control Type: Actuated-Uncoordinated		
Maximum v/c Ratio: 0.74		
Intersection Signal Delay: 24.8	Intersection LOS: C	
Intersection Capacity Utilization 64.3%	ICU Level of Service C	
Analysis Period (min) 15		

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	27.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

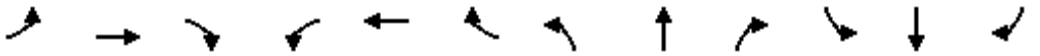
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 21: Dicenzo Blvd/Pomphrey Dr & Route 20



Intersection Capacity Analysis
Route 20 at Raytheon Driveway, Marlborough

11/9/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	29	545	3	1	925	15	240	0	141	12	0	41
Future Volume (vph)	29	545	3	1	925	15	240	0	141	12	0	41
Satd. Flow (prot)	1711	1801	1583	1728	1877	0	0	1787	1599	0	1651	0
Flt Permitted	0.082			0.266				0.950			0.989	
Satd. Flow (perm)	148	1801	1583	484	1877	0	0	1787	1599	0	1651	0
Satd. Flow (RTOR)			119		1				167		129	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.93	0.93	0.93	0.97	0.97	0.97	0.91	0.91	0.91	0.66	0.66	0.66
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	2%	2%	2%	1%	1%	1%	1%	1%	1%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	34	633	3	1	1047	0	0	285	167	0	87	0
Turn Type	pm+pt	NA	Perm	pm+pt	NA		Split	NA	pm+ov	Split	NA	
Protected Phases	5	2		1	6		3	3	1	4	4	
Permitted Phases	2		2	6					3			
Total Split (s)	8.0	52.0	52.0	8.0	52.0		20.0	20.0	8.0	9.0	9.0	
Total Lost Time (s)	4.0	5.0	5.0	4.0	5.0			4.0	4.0		4.0	
Act Effct Green (s)	52.1	47.1	47.1	53.8	50.4			16.0	20.9		5.0	
Actuated g/C Ratio	0.60	0.54	0.54	0.62	0.58			0.18	0.24		0.06	
v/c Ratio	0.21	0.65	0.00	0.00	0.96			0.87	0.33		0.40	
Control Delay	9.5	18.8	0.0	6.0	41.6			62.4	5.2		8.7	
Queue Delay	0.0	0.0	0.0	0.0	0.0			0.0	0.0		0.0	
Total Delay	9.5	18.8	0.0	6.0	41.6			62.4	5.2		8.7	
LOS	A	B	A	A	D			E	A		A	
Approach Delay		18.2			41.6			41.3			8.7	
Approach LOS		B			D			D			A	
Queue Length 50th (ft)	7	244	0	0	~652			158	0		0	
Queue Length 95th (ft)	17	365	0	2	#894			#302	39		0	
Internal Link Dist (ft)		655			458			102			237	
Turn Bay Length (ft)	100		300	150								
Base Capacity (vph)	160	972	909	355	1085			328	510		216	
Starvation Cap Reductn	0	0	0	0	0			0	0		0	
Spillback Cap Reductn	0	0	0	0	0			0	0		0	
Storage Cap Reductn	0	0	0	0	0			0	0		0	
Reduced v/c Ratio	0.21	0.65	0.00	0.00	0.96			0.87	0.33		0.40	

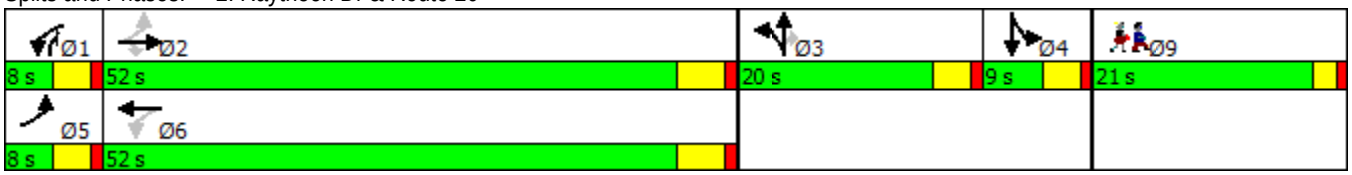
Intersection Summary	
Cycle Length: 110	
Actuated Cycle Length: 87.2	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.96	
Intersection Signal Delay: 33.3	Intersection LOS: C
Intersection Capacity Utilization 82.1%	ICU Level of Service E
Analysis Period (min) 15	

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	21.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 2: Raytheon Dr & Route 20



Intersection Capacity Analysis
Route 20 at Wayside Inn Road/Hager Street, Marlborough

11/9/2016

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	SBL2	SBL	SBR	NWL	NWR	NWR2
Lane Configurations												
Traffic Volume (vph)	106	520	83	4	702	5	5	23	79	118	61	3
Future Volume (vph)	106	520	83	4	702	5	5	23	79	118	61	3
Satd. Flow (prot)	1787	1881	1599	1787	1879	0	0	1770	1583	1787	1599	0
Flt Permitted	0.950			0.950				0.950		0.950		
Satd. Flow (perm)	1787	1881	1599	1787	1879	0	0	1770	1583	1787	1599	0
Satd. Flow (RTOR)			145						182		182	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.91	0.91	0.91	0.86	0.86	0.86	0.94	0.94	0.94
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	2%	2%	2%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%		0%		
Shared Lane Traffic (%)												
Lane Group Flow (vph)	118	579	92	5	839	0	0	35	99	136	73	0
Turn Type	Prot	NA	Perm	Prot	NA		Prot	Prot	Perm	Prot	Prot	
Protected Phases	5	2		1	6		8	8		4	4	
Permitted Phases			2						8			
Total Split (s)	14.0	66.0	66.0	8.0	60.0		10.0	10.0	10.0	15.0	15.0	
Total Lost Time (s)	4.0	5.0	5.0	4.0	5.0			5.0	5.0	5.0	5.0	
Act Effct Green (s)	9.8	63.0	63.0	4.1	50.5			5.1	5.1	10.1	10.1	
Actuated g/C Ratio	0.10	0.64	0.64	0.04	0.51			0.05	0.05	0.10	0.10	
v/c Ratio	0.66	0.48	0.09	0.07	0.87			0.38	0.39	0.74	0.22	
Control Delay	64.1	12.7	0.6	53.4	33.2			62.2	4.5	69.8	1.6	
Queue Delay	0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	
Total Delay	64.1	12.7	0.6	53.4	33.2			62.2	4.5	69.8	1.6	
LOS	E	B	A	D	C			E	A	E	A	
Approach Delay		19.0			33.4			19.5		46.0		
Approach LOS		B			C			B		D		
Queue Length 50th (ft)	71	139	0	3	400			21	0	83	0	
Queue Length 95th (ft)	#193	426	6	18	#902			#63	0	#230	0	
Internal Link Dist (ft)		1291			594			327		483		
Turn Bay Length (ft)	150		100	50					50		100	
Base Capacity (vph)	184	1246	1108	73	1067			91	254	184	328	
Starvation Cap Reductn	0	0	0	0	0			0	0	0	0	
Spillback Cap Reductn	0	0	0	0	0			0	0	0	0	
Storage Cap Reductn	0	0	0	0	0			0	0	0	0	
Reduced v/c Ratio	0.64	0.46	0.08	0.07	0.79			0.38	0.39	0.74	0.22	

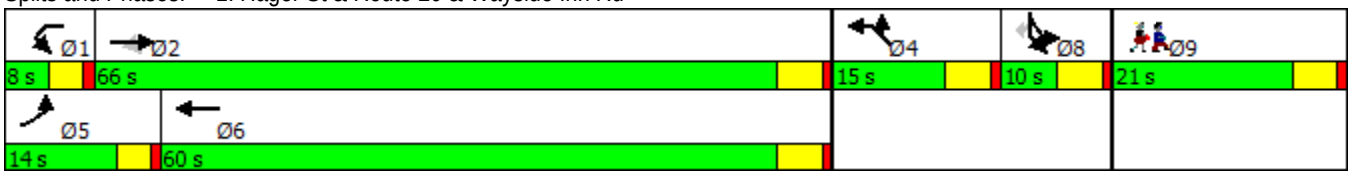
Intersection Summary			
Cycle Length: 120			
Actuated Cycle Length: 98.2			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.87			
Intersection Signal Delay: 28.0		Intersection LOS: C	
Intersection Capacity Utilization 73.6%		ICU Level of Service D	
Analysis Period (min) 15			

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	21.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 1: Hager St & Route 20 & Wayside Inn Rd

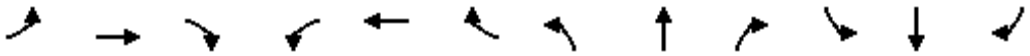


APPENDIX K

Intersection Capacity Analyses
Summer Saturday Midday Peak Hour
Projected 2040 Traffic Conditions with Proposed Improvements

Intersection Capacity Analysis
Route 20 at Lincoln Street, Marlborough

11/9/2016

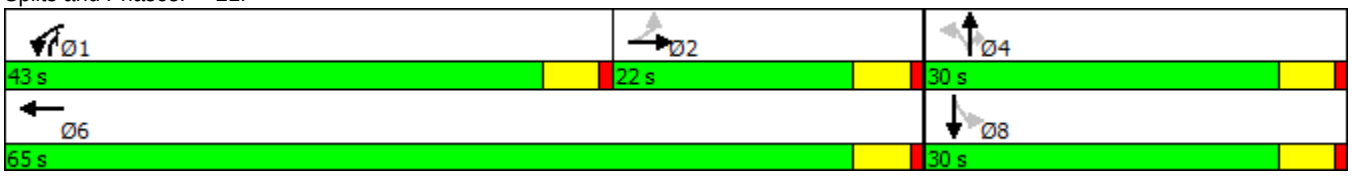


Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	6	376	16	463	410	234	14	49	517	173	28	3
Future Volume (vph)	6	376	16	463	410	234	14	49	517	173	28	3
Satd. Flow (prot)	0	3431	0	1728	1704	0	0	1781	1531	0	1740	0
Flt Permitted		0.938		0.950				0.917			0.707	
Satd. Flow (perm)	0	3221	0	1728	1704	0	0	1651	1506	0	1279	0
Satd. Flow (RTOR)		4			59				41		1	
Confl. Peds. (#/hr)	5					5			2	2		
Confl. Bikes (#/hr)												
Peak Hour Factor	0.93	0.93	0.93	0.86	0.86	0.86	0.91	0.91	0.91	0.86	0.86	0.86
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	2%	2%	2%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	463	0	581	809	0	0	75	614	0	256	0
Turn Type	Perm	NA		Prot	NA		Perm	NA	pm+ov	Perm	NA	
Protected Phases		2		1	6			4	1		8	
Permitted Phases	2						4		4	8		
Total Split (s)	22.0	22.0		43.0	65.0		30.0	30.0	43.0	30.0	30.0	
Total Lost Time (s)		5.0		5.0	5.0			5.0	5.0		5.0	
Act Effct Green (s)		15.1		31.6	52.0			20.2	51.8		20.2	
Actuated g/C Ratio		0.18		0.38	0.63			0.24	0.63		0.24	
v/c Ratio		0.78		0.88	0.74			0.19	0.63		0.82	
Control Delay		44.3		40.9	15.3			28.1	9.8		53.0	
Queue Delay		0.0		0.0	0.0			0.0	0.0		0.0	
Total Delay		44.3		40.9	15.3			28.1	9.8		53.0	
LOS		D		D	B			C	A		D	
Approach Delay		44.3			26.0			11.8			53.0	
Approach LOS		D			C			B			D	
Queue Length 50th (ft)		134		300	267			34	137		138	
Queue Length 95th (ft)		#214		#461	394			72	216		#241	
Internal Link Dist (ft)		289			228			617			398	
Turn Bay Length (ft)									150			
Base Capacity (vph)		695		830	1279			522	1114		405	
Starvation Cap Reductn		0		0	0			0	0		0	
Spillback Cap Reductn		0		0	0			0	0		0	
Storage Cap Reductn		0		0	0			0	0		0	
Reduced v/c Ratio		0.67		0.70	0.63			0.14	0.55		0.63	

Intersection Summary			
Cycle Length: 95			
Actuated Cycle Length: 82.6			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.88			
Intersection Signal Delay: 28.0		Intersection LOS: C	
Intersection Capacity Utilization 82.2%		ICU Level of Service E	
Analysis Period (min) 15			

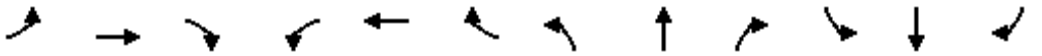
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 21:



Intersection Capacity Analysis
Route 20 at Curtis Avenue/Post Road Plaza, Marlborough

11/9/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	236	855	49	67	887	117	43	78	82	135	56	242
Future Volume (vph)	236	855	49	67	887	117	43	78	82	135	56	242
Satd. Flow (prot)	1728	3422	0	1728	3455	1546	0	1701	0	1658	1708	1561
Flt Permitted	0.950			0.950				0.897		0.950	0.979	
Satd. Flow (perm)	1725	3422	0	1724	3455	1506	0	1539	0	1658	1708	1530
Satd. Flow (RTOR)		8				137		31				294
Confl. Peds. (#/hr)	2		3	3		2	5					5
Confl. Bikes (#/hr)												
Peak Hour Factor	0.98	0.98	0.98	0.92	0.92	0.92	0.86	0.86	0.86	0.89	0.89	0.89
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	0%	0%	0%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)										30%		
Lane Group Flow (vph)	260	996	0	79	1041	137	0	255	0	115	117	294
Turn Type	Prot	NA		Prot	NA	pm+ov	Perm	NA		Split	NA	Perm
Protected Phases	5	2		1	6	4		8		4	4	
Permitted Phases						6	8					4
Total Split (s)	21.0	42.0		11.0	32.0	21.0	16.0	16.0		21.0	21.0	21.0
Total Lost Time (s)	5.0	5.0		5.0	5.0	5.0		5.0		5.0	5.0	5.0
Act Effct Green (s)	15.5	37.4		7.9	27.5	38.8		15.7		11.3	11.3	11.3
Actuated g/C Ratio	0.17	0.42		0.09	0.31	0.43		0.17		0.13	0.13	0.13
v/c Ratio	0.88	0.70		0.53	0.99	0.19		0.87		0.55	0.55	0.65
Control Delay	65.9	25.3		37.6	41.8	1.1		63.6		46.2	45.6	11.8
Queue Delay	0.0	0.0		0.0	0.0	0.0		0.0		0.0	0.0	0.0
Total Delay	65.9	25.3		37.6	41.8	1.1		63.6		46.2	45.6	11.8
LOS	E	C		D	D	A		E		D	D	B
Approach Delay		33.7			37.1			63.6			26.8	
Approach LOS		C			D			E			C	
Queue Length 50th (ft)	145	254		45	~323	3		126		65	66	0
Queue Length 95th (ft)	#277	312		m#67	#433	m0		#291		114	115	65
Internal Link Dist (ft)		686			186			446			263	
Turn Bay Length (ft)	360			175		175				75		125
Base Capacity (vph)	307	1494		150	1055	806		293		294	303	513
Starvation Cap Reductn	0	0		0	0	0		0		0	0	0
Spillback Cap Reductn	0	0		0	0	0		0		0	0	0
Storage Cap Reductn	0	0		0	0	0		0		0	0	0
Reduced v/c Ratio	0.85	0.67		0.53	0.99	0.17		0.87		0.39	0.39	0.57

Intersection Summary		
Cycle Length: 90		
Actuated Cycle Length: 90		
Offset: 0 (0%), Referenced to phase 2:EBT and 6:WBT, Start of Green, Master Intersection		
Control Type: Actuated-Coordinated		
Maximum v/c Ratio: 0.99		
Intersection Signal Delay: 36.2	Intersection LOS: D	
Intersection Capacity Utilization 72.2%	ICU Level of Service C	

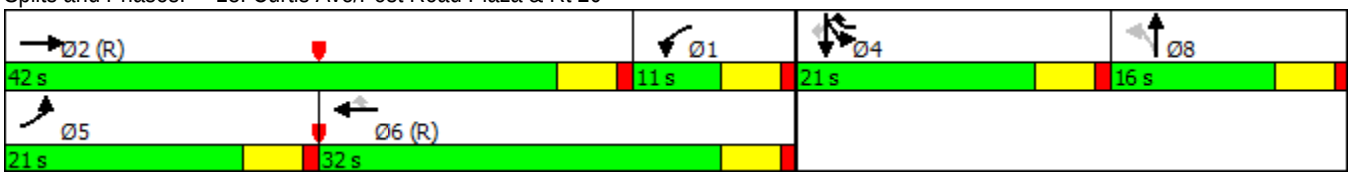
Analysis Period (min) 15

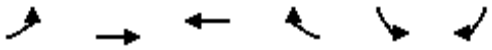
~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

m Volume for 95th percentile queue is metered by upstream signal.

Splits and Phases: 18: Curtis Ave/Post Road Plaza & Rt 20





Lane Group	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Traffic Volume (vph)	224	842	890	236	279	217
Future Volume (vph)	224	842	890	236	279	217
Satd. Flow (prot)	1728	3455	3455	1546	1728	1546
Flt Permitted	0.950				0.950	
Satd. Flow (perm)	1727	3455	3455	1511	1728	1521
Satd. Flow (RTOR)				218		23
Confl. Peds. (#/hr)	1			1		3
Confl. Bikes (#/hr)						
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0
Parking (#/hr)						
Mid-Block Traffic (%)		0%	0%		0%	
Shared Lane Traffic (%)						
Lane Group Flow (vph)	255	957	1012	268	317	247
Turn Type	Prot	NA	NA	Perm	Prot	pm+ov
Protected Phases	5	2	6		7	5
Permitted Phases				6		7
Total Split (s)	25.0	62.0	37.0	37.0	28.0	25.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0
Act Effct Green (s)	17.2	59.8	37.6	37.6	20.2	37.4
Actuated g/C Ratio	0.19	0.66	0.42	0.42	0.22	0.42
v/c Ratio	0.78	0.42	0.70	0.35	0.82	0.38
Control Delay	41.0	3.8	19.4	3.9	50.5	14.3
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	41.0	3.8	19.4	3.9	50.5	14.3
LOS	D	A	B	A	D	B
Approach Delay		11.6	16.1		34.7	
Approach LOS		B	B		C	
Queue Length 50th (ft)	159	53	265	19	168	71
Queue Length 95th (ft)	m233	m65	172	32	#268	113
Internal Link Dist (ft)		253	302		474	
Turn Bay Length (ft)	300			150		100
Base Capacity (vph)	384	2295	1444	758	441	687
Starvation Cap Reductn	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0
Reduced v/c Ratio	0.66	0.42	0.70	0.35	0.72	0.36

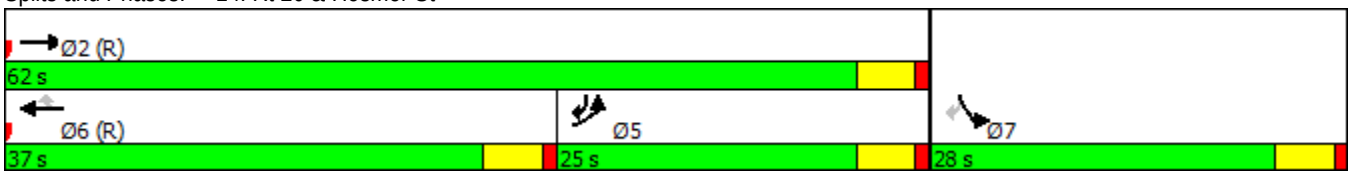
Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 90	
Offset: 72 (80%), Referenced to phase 2:EBT and 6:WBT, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.82	
Intersection Signal Delay: 17.8	Intersection LOS: B
Intersection Capacity Utilization 69.2%	ICU Level of Service C

Analysis Period (min) 15

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

m Volume for 95th percentile queue is metered by upstream signal.

Splits and Phases: 14: Rt 20 & Hosmer St



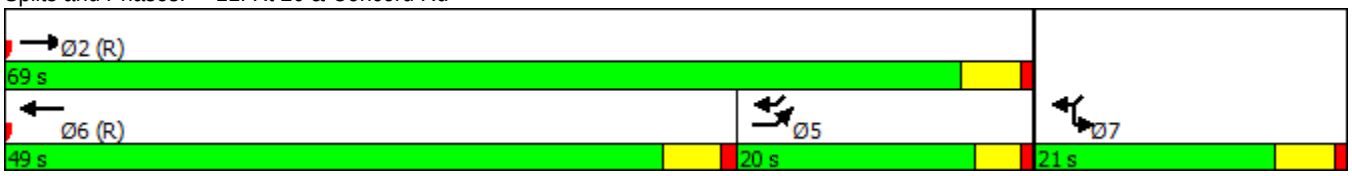
Lane Group	EBL	EBT	WBT	WBR	SWL	SWR
Lane Configurations						
Traffic Volume (vph)	136	951	987	48	47	138
Future Volume (vph)	136	951	987	48	47	138
Satd. Flow (prot)	1728	2007	3549	0	1787	1706
Flt Permitted	0.950				0.950	
Satd. Flow (perm)	1728	2007	3549	0	1787	1706
Satd. Flow (RTOR)			8			55
Confl. Peds. (#/hr)						
Confl. Bikes (#/hr)						
Peak Hour Factor	0.96	0.96	0.98	0.98	0.91	0.91
Growth Factor	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0
Parking (#/hr)						
Mid-Block Traffic (%)		0%	0%		0%	
Shared Lane Traffic (%)						
Lane Group Flow (vph)	153	1070	1141	0	56	164
Turn Type	Prot	NA	NA		Prot	pt+ov
Protected Phases	5	2	6		7	7 5
Permitted Phases						
Total Split (s)	20.0	69.0	49.0		21.0	
Total Lost Time (s)	4.0	5.0	5.0		5.0	
Act Effct Green (s)	12.7	71.8	55.0		8.2	25.0
Actuated g/C Ratio	0.14	0.80	0.61		0.09	0.28
v/c Ratio	0.63	0.67	0.53		0.34	0.32
Control Delay	39.6	6.7	11.9		43.3	17.3
Queue Delay	0.0	0.0	0.0		0.0	0.0
Total Delay	39.6	6.7	11.9		43.3	17.3
LOS	D	A	B		D	B
Approach Delay		10.8	11.9		23.9	
Approach LOS		B	B		C	
Queue Length 50th (ft)	66	189	179		30	47
Queue Length 95th (ft)	m127	26	276		66	89
Internal Link Dist (ft)		44	217		349	
Turn Bay Length (ft)						75
Base Capacity (vph)	307	1600	2173		317	631
Starvation Cap Reductn	0	0	0		0	0
Spillback Cap Reductn	0	0	0		0	0
Storage Cap Reductn	0	0	0		0	0
Reduced v/c Ratio	0.50	0.67	0.53		0.18	0.26

Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 90	
Offset: 68 (76%), Referenced to phase 2:EBT and 6:WBT, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.67	
Intersection Signal Delay: 12.4	Intersection LOS: B
Intersection Capacity Utilization 66.6%	ICU Level of Service C

Analysis Period (min) 15

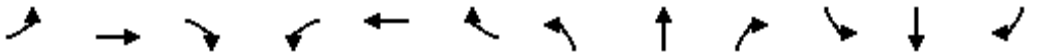
m Volume for 95th percentile queue is metered by upstream signal.

Splits and Phases: 11: Rt 20 & Concord Rd



Intersection Capacity Analysis
Route 20 at Farm Road, Marlborough

11/9/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	97	703	64	254	732	61	99	53	309	80	64	83
Future Volume (vph)	97	703	64	254	732	61	99	53	309	80	64	83
Satd. Flow (prot)	1787	3574	1599	1787	3525	0	1770	1863	1583	0	1830	1599
Flt Permitted	0.950			0.950			0.950				0.973	
Satd. Flow (perm)	1781	3574	1599	1787	3525	0	1764	1863	1562	0	1828	1575
Satd. Flow (RTOR)			190		8							190
Confl. Peds. (#/hr)	2					2	1		1	1		1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.94	0.94	0.94	0.92	0.92	0.92	0.88	0.88	0.88	0.83	0.83	0.83
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	2%	2%	2%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	111	808	74	298	931	0	122	65	379	0	187	108
Turn Type	Prot	NA	Perm	Prot	NA		Split	NA	pm+ov	Split	NA	Perm
Protected Phases	5	2		1	6		8	8	1	4	4	
Permitted Phases			2						8			4
Total Split (s)	14.0	35.0	35.0	25.0	46.0		13.0	13.0	25.0	17.0	17.0	17.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0		5.0	5.0	5.0		5.0	5.0
Act Effct Green (s)	9.0	25.2	25.2	20.1	36.3		8.2	8.2	28.2		12.2	12.2
Actuated g/C Ratio	0.10	0.28	0.28	0.22	0.40		0.09	0.09	0.31		0.14	0.14
v/c Ratio	0.62	0.81	0.13	0.75	0.65		0.76	0.38	0.77		0.75	0.29
Control Delay	58.5	38.3	0.4	48.0	25.1		72.6	49.9	38.9		59.9	1.9
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0
Total Delay	58.5	38.3	0.4	48.0	25.1		72.6	49.9	38.9		59.9	1.9
LOS	E	D	A	D	C		E	D	D		E	A
Approach Delay		37.7			30.7			47.4			38.7	
Approach LOS		D			C			D			D	
Queue Length 50th (ft)	58	206	0	148	197		65	34	161		98	0
Queue Length 95th (ft)	#181	#403	0	#394	389		#209	92	#363		#254	0
Internal Link Dist (ft)		394			534			205			111	
Turn Bay Length (ft)	350		50				75		150			
Base Capacity (vph)	182	1215	669	405	1642		160	169	500		248	378
Starvation Cap Reductn	0	0	0	0	0		0	0	0		0	0
Spillback Cap Reductn	0	0	0	0	0		0	0	0		0	0
Storage Cap Reductn	0	0	0	0	0		0	0	0		0	0
Reduced v/c Ratio	0.61	0.67	0.11	0.74	0.57		0.76	0.38	0.76		0.75	0.29

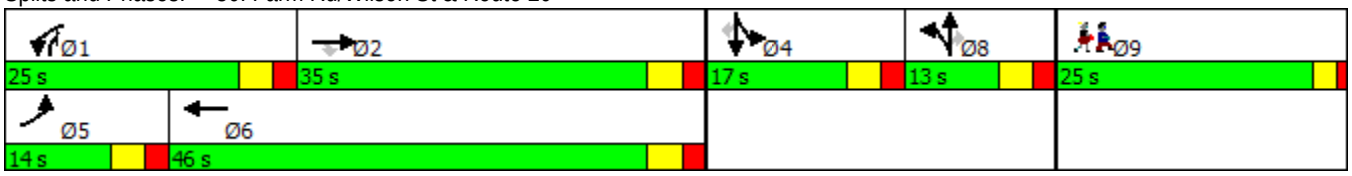
Intersection Summary	
Cycle Length: 115	
Actuated Cycle Length: 89.9	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.81	
Intersection Signal Delay: 36.8	Intersection LOS: D
Intersection Capacity Utilization 63.8%	ICU Level of Service B
Analysis Period (min) 15	

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	25.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

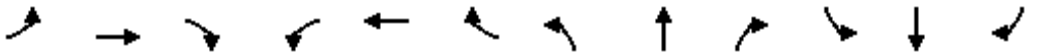
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 30: Farm Rd/Wilson St & Route 20



Intersection Capacity Analysis
Route 20 at Dicenzo Boulevard/Pomphrey Drive, Marlborough

11/9/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	29	595	123	62	1087	25	220	6	25	13	6	6
Future Volume (vph)	29	595	123	62	1087	25	220	6	25	13	6	6
Satd. Flow (prot)	1728	3365	0	1711	3411	0	3173	1513	0	1636	1593	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1728	3365	0	1711	3411	0	3173	1513	0	1636	1593	0
Satd. Flow (RTOR)		23			2			29			9	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.89	0.89	0.89	0.98	0.98	0.98	0.94	0.94	0.94	0.70	0.70	0.70
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	3%	3%	3%	3%	3%	3%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	35	871	0	68	1226	0	253	36	0	20	18	0
Turn Type	Prot	NA		Prot	NA		Split	NA		Split	NA	
Protected Phases	5	2		1	6		8	8		4	4	
Permitted Phases												
Total Split (s)	11.0	46.0		15.0	50.0		16.0	16.0		11.0	11.0	
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	
Act Effct Green (s)	7.0	30.3		9.0	35.7		11.6	11.6		7.0	7.0	
Actuated g/C Ratio	0.10	0.41		0.12	0.49		0.16	0.16		0.10	0.10	
v/c Ratio	0.21	0.62		0.32	0.74		0.50	0.14		0.13	0.11	
Control Delay	46.1	21.6		43.3	22.0		39.5	20.6		46.0	34.2	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	46.1	21.6		43.3	22.0		39.5	20.6		46.0	34.2	
LOS	D	C		D	C		D	C		D	C	
Approach Delay		22.6			23.2			37.1			40.4	
Approach LOS		C			C			D			D	
Queue Length 50th (ft)	17	165		32	258		61	3		9	4	
Queue Length 95th (ft)	59	353		97	#588		#164	37		32	23	
Internal Link Dist (ft)		391			775			209			131	
Turn Bay Length (ft)	120			400								
Base Capacity (vph)	164	2168		271	2337		554	288		156	159	
Starvation Cap Reductn	0	0		0	0		0	0		0	0	
Spillback Cap Reductn	0	0		0	0		0	0		0	0	
Storage Cap Reductn	0	0		0	0		0	0		0	0	
Reduced v/c Ratio	0.21	0.40		0.25	0.52		0.46	0.13		0.13	0.11	

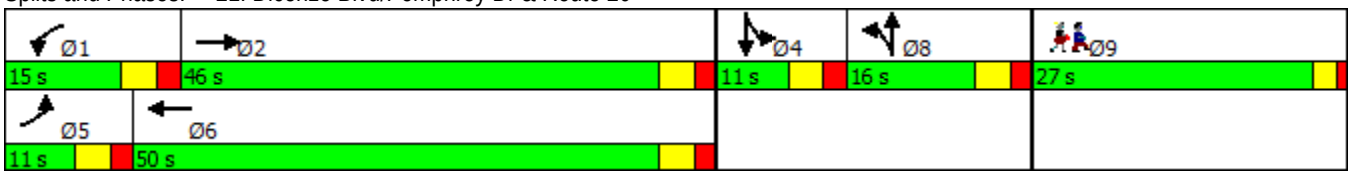
Intersection Summary	
Cycle Length: 115	
Actuated Cycle Length: 73.1	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.74	
Intersection Signal Delay: 24.8	Intersection LOS: C
Intersection Capacity Utilization 64.3%	ICU Level of Service C
Analysis Period (min) 15	

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	27.0
Total Lost Time (s)	
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 21: Dicenzo Blvd/Pomphrey Dr & Route 20



APPENDIX L

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 Highway 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 Highway 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 Highway 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