**MEMORANDUM**

**To:** **Harold Brown, Bolton Director of Public Works** **February 17, 2011**
**Eric Nasimento, MassDOT Highway Division District 3**

**From:** **Chen-Yuan Wang and Efi Pagitsas**

**Re:** **Safety and Operations Analyses at Selected Boston Region MPO Intersections: Main Street (Route 117) at Still River Road (Route 110) in Bolton**

This memorandum summarizes safety and operations analyses and proposes improvement strategies for the intersection of Main Street (Route 117) at Still River Road (Route 110) in Bolton. It contains the following sections:

- Intersection Layout and Traffic Control
- Issues and Concerns
- Crash Data Analysis
- Intersection Capacity Analysis
- Analyses of Improvement Alternatives
- Improvement Recommendations and Discussion

The memorandum also includes a collection of technical appendices that contain methods and data applied in the study and detailed reports of the intersection capacity analysis.

## INTERSECTION LAYOUT AND TRAFFIC CONTROL

This signalized intersection is located about two miles west of Bolton Town Center. Main Street, a two-lane roadway running in the east-west direction, is the major street of the intersection. It is a part of State Route 117 that reaches Route 128/Interstate 95 in Waltham in the east and Interstate 190 in Leominster in the west and it intersects Route 495 in Bolton in the middle. Still River Road is a two-lane roadway running in the north-south direction. It is a part of State Route 110 that reaches Littleton in the north and West Boylston near Worcester in the south, and goes through Bolton, Lancaster, and Clinton in between. Both streets near the intersection are classified as urban principal/rural minor arterials and are under the jurisdiction of the Town.

Figure 1 shows the intersection layout and the area nearby. Approaching the intersection, Main Street (Route 117) widens to add an exclusive right-turn lane of nearly 400 feet in length (including the taper section) in both directions and the main lane therefore is shared by through and left-turn movements. Still River Road (Route 110) remains a single lane shared by all movements on both approaches. Near the intersection it is flared, and the stop lines are set back from the Route 117 traffic. There are no crosswalks or pedestrian signals on the approaches and no sidewalks on either side of the two streets. There is a shoulder about two feet wide on the north side of Main Street and on the east side of Still River Road.


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**FIGURE 1**
**Main Street (Route 117) at Still River Road (Route 110), Bolton**

*Safety and Operations Improvements at Selected Intersections*

The traffic signal is pretimed and operates in two traffic phases: (1) eastbound/westbound (EB/WB) all movements (left turns permitted), and (2) northbound/southbound (NB/SB) all movements. No pedestrian phases are provided in the signal cycles. Right turns on red are allowed on all approaches. Signal heads are hung by a diagonal cable. There are no detectors or conduits on the intersection approaches.

At the intersection, the southeast corner is occupied by a farm market complex (Bolton Orchard) and its parking lots, while the other corners are vacant land. Away from the intersection, in the west is mainly low-lying flat vacant land, and in the east are hilly areas with scattered single-family houses. Still River runs parallel to Route 110 about 500 feet west of this intersection, with its banks and surrounding wetlands designated as Bolton Flats State Wildlife Management Area. Nashoba Regional High School is located on Main Street about a mile east of this intersection. Further east, near Interstate 495, is Bolton Town Center, including the town hall/police station, a church, and a few local shops, located on Main Street.

**ISSUES AND CONCERNS**

Traffic is somewhat busy on Main Street in the eastbound direction in the morning and in the westbound direction in the evening, but the intersection is not extremely congested during daily peak traffic periods. The main concerns at this intersection are the high crash numbers and the severity of the crashes. A review of the crash data from 2006 to 2008 indicates that nearly 45% of the total crashes resulted in personal injuries, and one resulted in a fatality (see the next section for further analyses).

Most sections of Main Street (Route 117) in Bolton have a speed limit of 45 miles per hour (MPH), except the 30-MPH limit in the town center section. At this intersection, it is reduced to 30 MPH in both directions, about 800 feet ahead of the town center. A “Dangerous Intersection Ahead” warning sign is located in the westbound lane, about 1,000 feet ahead of the intersection, followed by a lane-designation sign, the 30-MPH speed limit sign, and a “traffic signal ahead” warning sign. Most sections of Still River Road have a speed limit of 40 MPH. It is reduced to 30 MPH in both directions about 800 feet ahead of the intersection.

Approaching the intersection from the east, Main Street winds through woody area and goes downhill toward the intersection. Although the warning signs and the speed limit signs are appropriately in place ahead of the intersection, drivers tend to travel above the speed limit in this straight section and where there are open surroundings. Approaching from the west, drivers also tend to travel above the speed limit, as that section of Main Street is straight, with open fields and wetlands on both sides.

Above all, the critical issue for this intersection may well be the existing lane designation of both approaches of Main Street. Under the configuration (a left-turn/through shared lane and a right-turn exclusive lane), EB or WB through movements are frequently blocked by left turns during green lights when their opposite through traffic is heavy. During peak hours, sometimes just one stopped left-turn vehicle could deter most vehicles on the same approach from passing the intersection. The traffic blockage may be hazardous for some drivers when they approach the intersection during a green light and do not slow down.

In addition to the usual angle collisions between a left-turning vehicle and an opposite through vehicle at an intersection that permits left turns, the current Main Street layout potentially contribute to an increase in other types of collisions, such as a rear-end collision between a left-turning vehicle and a vehicle immediately following it, or a sideswipe collision between a vehicle attempting to go around a stopped left-turning vehicle and a vehicle immediately following it in the adjacent right-turn lane. Some of these collisions can be serious if one or more of the involved vehicles is traveling at a high speed.

Meanwhile, the configuration is not compatible with the existing traffic conditions, as both approaches of Main Street actually carry a low right-turn volume that may not require an exclusive lane. The recent turning movement counts (June 9, 2010) indicate that it carries a majority of through movements with a relatively low volume of right turns on both approaches (see the section Improvement Alternatives for further analysis).

The issues and concerns for this intersection can be summarized as follows:

- High number of crashes
- Severity of the crashes (nearly half resulting in personal injuries from 2006 to 2008)
- Difficult EB/WB lane configuration causing blockage of the main travel lane shared by left turns and through movements during green lights
- No pedestrian signal heads or push buttons

## CRASH DATA ANALYSIS

Based on the 2006–2008 MassDOT Registry of Motor Vehicles Division crash data, Table 1 shows that on average of about 12 crashes occurred at the intersection each year. Nearly 45% of the total crashes resulted in personal injuries, and one resulted in a fatality. The crash types consist of 25% angle collisions, nearly 45% rear-end collisions, and about 30% sideswipe and single-vehicle collisions. No crashes involved pedestrians or bicycles. About half of the total crashes occurred during peak periods.

A review of the vehicle travel directions indicates that the rear-end collisions mostly involved vehicles traveling in the same direction on Main Street. They were likely the rear-end collisions related to the Main Street layout mentioned above. Both these rear-end collisions and the high proportion of crashes occurring in peak periods indicate that the Main Street layout might have been a factor in causing these rear-end and other types of crashes at the intersection.

Crash rate[1] is another effective tool for examining the relative safety of a particular location. Based on the above data and the recently collected traffic volume data, the crash rate for this intersection is calculated as 1.76 (see Appendix A for the calculation sheet). The rate is much higher than the average rate for the signalized locations in MassDOT Highway Division's District 3, which is estimated to be 0.93.[2]

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[1] Crash rates normalize crash frequency (crashes per year) by vehicle exposure (traffic volumes or miles traveled). Crash rates are expressed as "crashes per million entering vehicles" for intersection locations and as "crashes per million miles traveled" for roadway segments.

[2] The average crash rates estimated by the MassDOT Highway Division are based upon a database that contains intersection crash rates submitted to the Highway Division as part of the review process for an environmental

**TABLE 1**
**Summary of Crash Data (2006–2008)**

| Statistics Period | | 2006 | 2005 | 2006 | 2006–08 | Average |
|---|---|---|---|---|---|---|
| Total number of crashes | | 11 | 13 | 11 | 35 | 12 |
| Severity | Property damage only | 6 | 7 | 6 | 19 | 6 |
| | Personal injury | 3 | 6 | 5 | 14 | 5 |
| | Fatality | 1 | 0 | 0 | 1 | 0 |
| | Not reported | 1 | 0 | 0 | 1 | 0 |
| Collision Type | Angle | 1 | 4 | 4 | 9 | 3 |
| | Rear-end | 8 | 6 | 2 | 16 | 5 |
| | Sideswipe | 0 | 1 | 2 | 3 | 1 |
| | Head-on | 0 | 0 | 0 | 0 | 0 |
| | Single vehicle | 2 | 2 | 3 | 7 | 2 |
| | Not reported | 0 | 0 | 0 | 0 | 0 |
| Crashes involving pedestrian(s) | | 0 | 0 | 0 | 0 | 0 |
| Crashes involving cyclist(s) | | 0 | 0 | 0 | 0 | 0 |
| Occurred during weekday peak periods* | | 6 | 5 | 6 | 17 | 6 |
| Wet or icy pavement conditions | | 2 | 2 | 3 | 7 | 2 |
| Dark/lighted conditions | | 0 | 2 | 4 | 6 | 2 |

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

## INTERSECTION CAPACITY ANALYSIS

Boston Region MPO staff collected turning-movement counts at the intersection on June 9, 2010. The data were recorded in 15-minute intervals for the peak traffic periods in the morning, from 7:00 to 9:00, and in the evening, from 4:00 to 6:00. The intersection carried about 1,500 vehicles in the morning peak hour, from 7:00 to 8:00, and about 1,650 vehicles in the evening peak hour, from 4:45 to 5:45 (see Table 2). No pedestrians were observed during each of the two peak hours.[3] However, in another trip visiting the site in August staff observed two joggers crossing the intersection. Two bicycles were observed in the AM peak hour and two in the PM peak hour.

**TABLE 2**
**AM and PM Peak-Hour Traffic Volumes and Pedestrian Crossings**

| Street name | | Main Street (Route 117) | | | | | | Still River Road (Route 110) | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Direction | | Eastbound | | | Westbound | | | Northbound | | | Southbound | | | |
| Turning movement | | LT | TH | RT | LT | TH | RT | LT | TH | RT | LT | TH | RT | |
| AM peak hour | Turning volume | 23 | 839 | 10 | 31 | 333 | 15 | 10 | 91 | 44 | 28 | 58 | 31 | 1513 |
| | Approach volume | 872 | | | 379 | | | 145 | | | 117 | | | |
| | Pedestrian crossings | 0 | | | 0 | | | 0 | | | 0 | | | 0 |
| PM peak hour | Turning volume | 29 | 365 | 12 | 22 | 897 | 25 | 42 | 65 | 20 | 11 | 112 | 38 | 1638 |
| | Approach volume | 406 | | | 944 | | | 127 | | | 161 | | | |
| | Pedestrian crossings | 0 | | | 0 | | | 0 | | | 0 | | | 0 |

impact report or functional design report. The most recent average crash rates, which are updated on a nearly yearly basis, are based on all entries in the database, not just those entries made within the past year.

[3] In another trip visiting the site in August, staff observed two joggers crossing the intersection at around 8:00 AM.

Based on the turning-movement counts and the signal timings measured at the site, the intersection capacity was analyzed using an intersection capacity analysis program, Synchro.[4] The intersection was modeled as a pretimed two-phase traffic signal with no pedestrian phases. It was evaluated to operate at level of service (LOS) C with an average delay of about 20 seconds per vehicle in both the AM and PM peak hours (see Table 3). The level of service criteria are based on the *Highway Capacity Manual 2000*.[5] Detailed analysis settings and results for both the AM and PM peak hour are included in Appendix B.

**TABLE 3**
**Intersection Capacity Analysis, Existing Conditions**

| **Street name** | | **Main Street (Route 117)** | | | | | | **Still River Road (Route 110)** | | | | | | **Overall** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Direction** | | **Eastbound** | | | **Westbound** | | | **Northbound** | | | **Southbound** | | | |
| **Turning movement** | | LT | TH | RT | LT | TH | RT | LT | TH | RT | LT | TH | RT | |
| **AM peak hour** | LOS | **C** | | **A** | **B** | | **A** | **C** | | | **C** | | | **C** |
| | Delay (sec/veh) | 24 | | 4 | 13 | | 4 | 24 | | | 23 | | | 21 |
| **PM peak hour** | LOS | **B** | | **A** | **C** | | **A** | **C** | | | **C** | | | **C** |
| | Delay (sec/veh) | 15 | | 4 | 27 | | 3 | 26 | | | 26 | | | 23 |

Although the analysis shows that the intersection operates at a desirable level of service with acceptable delays, it does not reflect the occasional blockages of the Main Street main lane by the stopped left-turning traffic during the green lights. Review of traffic simulations did show the blockages at times in the westbound direction in the AM peak hour and in the eastbound direction in the PM peak hour. The blockages in turn could increase crashes at the intersection, which was not reflected in the capacity analysis.

## ANALYSES OF IMPROVEMENT ALTERNATIVES

The existing traffic signal is pretimed and operates in two phases: (1) EB/WB (Main Street) all movements with permissive left turns, and (2) NB/SB (Still River Road) all movements, with no exclusive or concurrent pedestrian phases. Field measurements obtained using a stopwatch estimate that each signal cycle consists of an EB/WB (Main Street) phase of 50 seconds of green time plus 6 seconds of clearance (yellow plus all red) time and a NB/SB (Still River Road) phase of 21 seconds of green time plus 7 seconds of clearance time. The system is outdated and needs to be upgraded into a fully actuated system with pedestrian signal heads and push buttons.

Meanwhile, the existing lane configuration on Main Street is not compatible with the existing traffic conditions and may need to be reconfigured in order to improve traffic operations and the intersection safety. The recent turning movement counts (June 9, 2010) indicate that Main Street carries a majority of through movements and a relatively low number and low percentage of right turns on both approaches in the AM and PM peak periods. On the other hand, the counts show a somewhat higher number and percentage of left turns from both approaches in both time

[4] Synchro 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.

[5] Transportation Research Board, *Highway Capacity Manual 2000*, National Research Council, Washington D.C., 2000.

periods, except an almost equal number and percentage of right and left turns on the westbound approach in the PM peak period (see Table 4). These findings indicated that one potential improvement option is to convert the two existing approach lanes into a left-turn exclusive lane and a through/right-turn shared lane on both approaches of Main Street.

**TABLE 4**
**Main Street Right-Turn and Left-Turn Proportions**
**Based on June 6, 2010, Turning-Movement Counts**

| Turning-Movement Counts | | Right-Turn | Left-Turn | All Movements | Right-Turn Percentage | Left-Turn Percentage |
|---|---|---|---|---|---|---|
| AM Peak Period 7:00 - 9:00 | Eastbound | 29 | 58 | 1,560 | 2% | 4% |
| | Westbound | 34 | 47 | 711 | 5% | 7% |
| PM Peak Period 4:00 - 6:00 | Eastbound | 28 | 45 | 724 | 4% | 6% |
| | Westbound | 43 | 40 | 1,802 | 2% | 2% |

Based on the above analyses, two alternatives were examined for this intersection:

1) Upgrade the Traffic Signal to a Fully Actuated System with Pedestrian Signals and Operate Main Street Traffic under Existing Lane Configuration (a Left-Turn/Through Shared Lane and a Right-Turn Exclusive Lane)
2) Upgrade the Traffic Signal to a Fully Actuated System with Pedestrian Signals and Change Main Street Lane Configuration into a Left-Turn Exclusive Lane and a Through/Right-Turn Shared Lane

Both alternatives were examined as a fully actuated uncoordinated traffic signal. The signal cycle consists of an EB/WB (Main Street) phase of 48 seconds maximum green time plus 6 seconds clearance time, an NB/SB (Still River Road) phase of 11 seconds maximum green time plus 7 seconds clearance time, and an on-call exclusive pedestrian phase of 28 seconds. Table 5 summarizes the results from the intersection capacity analyses for both alternatives and the existing conditions. Details of the signal settings and analysis results for both peak hours are included in Appendix C for Alternative 1 and in Appendix D for Alternative 2.

As Table 5 shows, both alternatives would improve the intersection operation from LOS C to LOS B with the new actuated signal system. Alternative 2 is estimated to have similar or slightly less overall and approach delays than Alternative 1. Traffic simulations of Alternative 1 still show the left-turn blockages at times during Main Street green lights, while simulations of Alternative 2 show a continuous traffic flow on the main lane (shared by through movements and right turns) in both directions and left turns mostly clear of the intersection during the green lights. Though not shown in the capacity analyses, the new lane configuration of Alternative 2 would potentially reduce some crashes that are caused by the existing Main Street layout.

The above alternatives analyses indicate that Alternative 2 is more advantageous than Alternative 1. A future-year scenario of 15% growth[6] over a 20-year planning horizon was also tested for Alternative 2. The tests show that with the projected traffic growth Alternative 2 would maintain at LOS B with an average delay of about 18 seconds in the AM peak hour and would operate at an acceptable LOS C with an average delay of about 22 seconds in the PM peak hour.

**TABLE 5**
**Intersection Capacity Analysis of Alternative Improvements**
**Existing Traffic Volumes**

| **Street name** | | **Main Street (Route 117)** | | **Still River Road (Route 110)** | | **Overall** |
|---|---|---|---|---|---|---|
| **Approach** | | **Eastbound** | **Westbound** | **Northbound** | **Southbound** | |
| **AM peak hour** | Existing | C/23 | B/12 | C/24 | C/23 | C/21 |
| | Alternative 1 | B/13 | A/6 | C/34 | C/32 | B/15 |
| | Alternative 2 | B/12 | A/6 | C/34 | C/32 | B/14 |
| **PM peak hour** | Existing | B/14 | C/26 | C/26 | C/26 | C/23 |
| | Alternative 1 | A/7 | B/14 | C/35 | C/35 | B/16 |
| | Alternative 2 | A/6 | B/14 | C/35 | C/35 | B/16 |

Note: Performance measures: Level of Service (A to F)/Average Delay (seconds per vehicle)
Alternative 1: Upgrade Signal System and Maintain Main Street Existing Lane Configuration
Alternative 2: Upgrade Signal System and Change Main Street Lane Configuration

## IMPROVEMENT RECOMMENDATIONS AND DISCUSSION

The above safety and operations analyses indicate that the existing traffic signal system and the layout of Main Street (Route 117) approaches are not adequate for the traffic conditions at this intersection. To improve the safety and operations, this study examined two improvement alternatives: (1) upgrade the traffic signal to a fully actuated system with pedestrian signals and operate Main Street traffic under the existing lane configuration, and (2) upgrade the traffic signal to a fully actuated system with pedestrian signals and change Main Street lane configuration into a left-turn exclusive lane and a through/right-turn shared lane. Alternative 2 was found to be more advantageous in traffic operations and would potentially reduce some crashes related to the existing intersection layout.

We therefore recommend upgrading the traffic signal system and reconfiguring the existing layout of the Main Street approaches. The upgrade of signal system and the intersection should include the following features:

- A fully actuated traffic signal system with pedestrian signal heads and push buttons
- Sidewalks on all corners, where pedestrians can wait for the opportunity to cross
- Crosswalks (and curb cuts) for crossing the WB and NB approaches

[6] The growth assumption is based on a review of the traffic projections in the intersection vicinity from the Boston Region MPO's transportation-planning model.

Figure 2 shows the conceptual diagram for the intersection reconfiguration. Each of the reconfigured Main Street approaches should include the following features:

- A shared through/right-turn lane
- An exclusive left-turn lane (with a storage length of about 100 feet)
- A traffic median next to the left-turn lane to separate traffic from the opposite direction
- Necessary signage changes (lane designation signs, etc.)

In addition, each of the Still River Road approaches should be channelized for right turns (see Figure 2). The channelization would not only protect the right turners but would also provide a refuge island for pedestrians and shorten the crossing distances for pedestrians on both streets.

Currently there are five driveways for the business at the southeast corner. In order to preserve the intersection's functional area and to reduce crashes at the intersection, we propose closing the two driveways that are closest to the intersection from both streets (see Figure 2).

A brief review of the intersection's aerial photograph (Figure 1) indicates that the conversion may not require additional land takings. The future left-turn exclusive lane (the inside lane) can be shifted slightly inward and aligned straight to the traffic median on the opposite approach. This would allow left turns on Main Street to be protected when they are waiting for traffic gaps at the intersection. The extensive length of the existing right-turn exclusive lane (nearly 400 feet, including the taper) would potentially allow the conversion to provide sufficient left-turn storage space of about 100 feet in length.[7]

More precise horizontal and vertical alignments for the reconfiguration should be carefully examined in the functional design stage for the intersection. In the meantime, potential improvements to enhance the safety and operations for pedestrians and bicyclists should be explored:

- Investigate pedestrian activities in the area and examine the potential for adding sidewalks on both streets or either street.
- Maintain or expand the existing shoulder (preferably 4 feet wide) for bicycle travel on Route 117.

The reconfiguration of the Main Street approaches is essential for improving the operations and safety at this intersection. Currently Main Street and Still River Road are both under the jurisdiction of the Town of Bolton. The implementation of the proposed improvements would require the Town to advance this study and to work closely with MassDOT through the project implantation process (see Appendix E). At this preliminary stage, the cost of the signal system upgrade and the reconstruction of the intersection and the Main Street approaches can only be roughly estimated as $500,000 to $750,000.

[7] Synchro tests of the future year AM and PM scenarios estimated the 95thpercentile left-turn queue length as no more than 50 feet in both directions. To accommodate the relatively high percentage of heavy vehicles (up to 15% in the AM peak hour for the westbound left turns) and possible unexpected high traffic growth, the left-turn storage length should be about 100 feet.

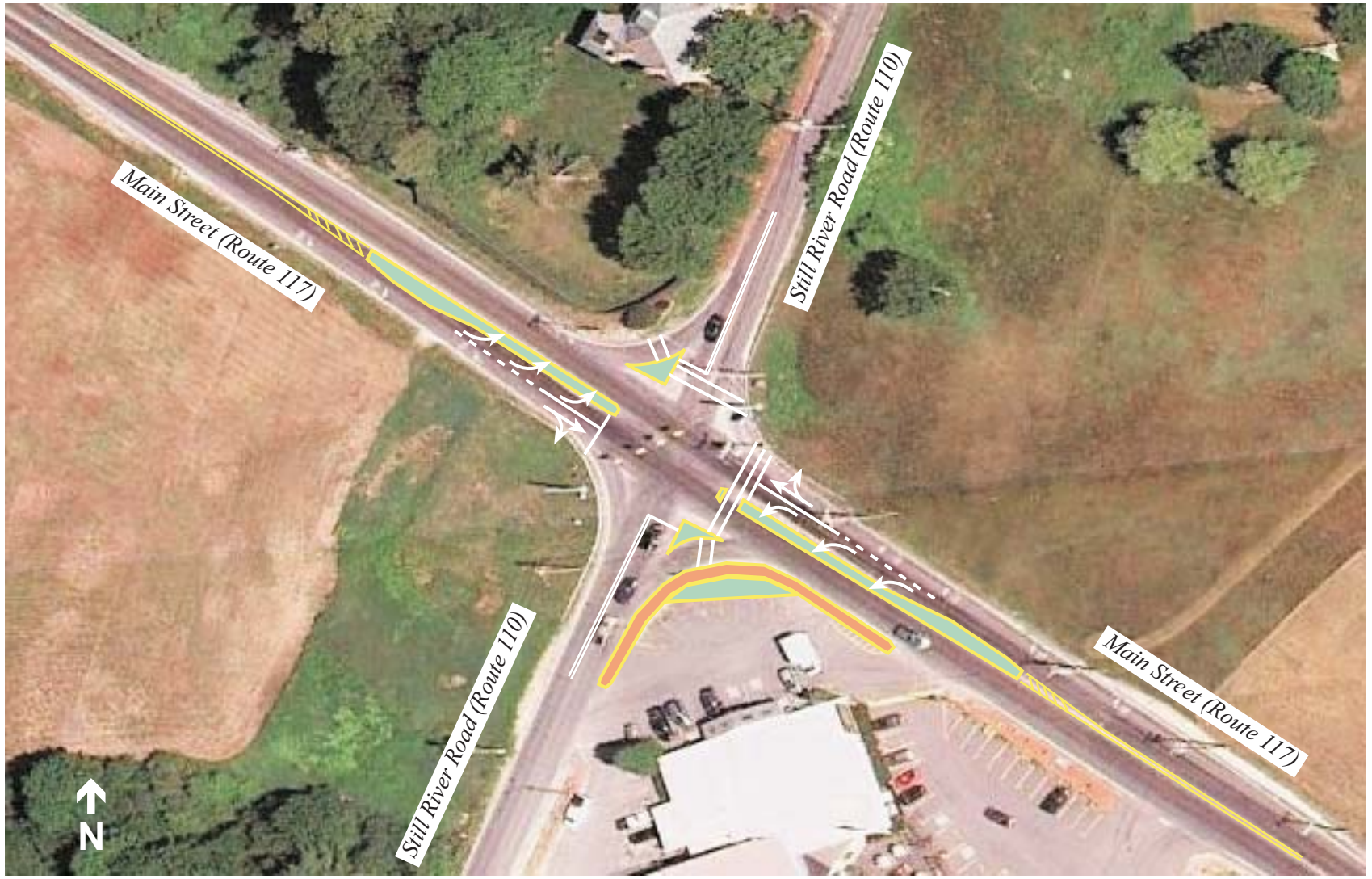


**FIGURE 2**
**Intersection Reconfiguration Conceptual Diagram**
**Main Street (Route 117) at Still River Road (Route 110), Bolton**

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*Safety and Operations Improvements at Selected Intersections*

In the short term, we propose to consider installing backplates for the existing signal heads. Crash reports indicated that motorists at this intersection had been affected by sun glares, especially for the eastbound approach in the morning. The backplates would enhance the contrast between the signal indications and a bright sky or confusing backgrounds, which is also helpful to elderly drivers. However, the blackplates would add extra load (due to not so much the additional weight but the additional wind surface area) to the existing metal poles. They should be examined carefully before the installation.

# Appendix A

## Intersection Crash Rate Calculation
## Main Street (Route 117) at Still River Road (Route 110), Bolton

# INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Bolton | COUNT DATE : 6/9/10

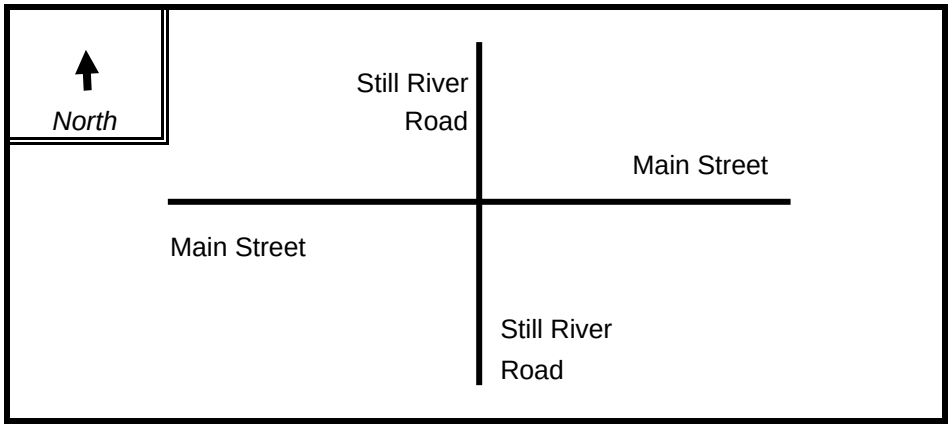
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

**~ INTERSECTION DATA ~**

MAJOR STREET : Main Street (Route 117)

MINOR STREET(S) : Still River Raod (Route 110)

**INTERSECTION DIAGRAM (Label Approaches)**




**PEAK HOUR VOLUMES**

| APPROACH : | 1 | 2 | 3 | 4 | 5 | Total Peak Hourly Approach Volume |
|---|---|---|---|---|---|---|
| DIRECTION : | EB | WB | NB | SB | | |
| PEAK HOURLY VOLUMES (AM/PM) : | 406 | 944 | 127 | 161 | | **1,638** |

" K " FACTOR : **0.090**

INTERSECTION ADT ( **V** ) = TOTAL DAILY APPROACH VOLUME : **18,200**

TOTAL # OF CRASHES : 35

# OF YEARS : 3

AVERAGE # OF CRASHES PER YEAR ( **A** ) : **11.67**

**CRASH RATE CALCULATION : 1.76**

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

Comments : MassDOT District 3 Average Rate = 0.93

Project Title & Date: Safety and Operations Analyses at Selceted Intersections

# Appendix B

## AM/PM Peak Hour Intersection Capacity Analysis
## Existing Traffic Conditions
## Main Street (Route 117) at Still River Road (Route 110), Bolton

# Intersection Capacity Analysis
## Main St @ Still River Rd, Bolton

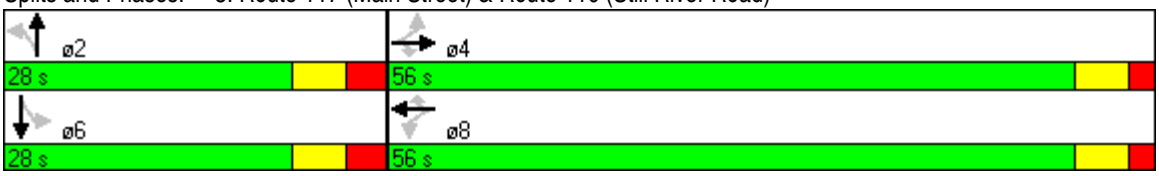
9/13/2010

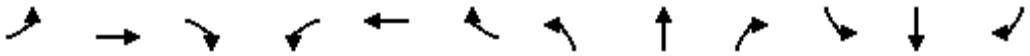
| Lane Group | EBL | EBT | EBR | WBL | WBT | WBR | NBL | NBT | NBR | SBL | SBT | SBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | | | | | | | |
| Volume (vph) | 23 | 839 | 10 | 31 | 333 | 15 | 10 | 91 | 44 | 28 | 58 | 31 |
| Confl. Peds. (#/hr) | | | | | | | | | | | | |
| Confl. Bikes (#/hr) | | | | | | | | | 1 | | | 1 |
| Peak Hour Factor | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| Growth Factor | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Heavy Vehicles (%) | 5% | 5% | 5% | 15% | 8% | 10% | 2% | 2% | 15% | 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 (%) | | | | | | | | | | | | |
| Turn Type | Perm | | Perm | Perm | | Perm | Perm | | | Perm | | |
| Protected Phases | | 4 | | | 8 | | | 2 | | | 6 | |
| Permitted Phases | 4 | | 4 | 8 | | 8 | 2 | | | 6 | | |
| Detector Phase | 4 | 4 | 4 | 8 | 8 | 8 | 2 | 2 | | 6 | 6 | |
| Switch Phase | | | | | | | | | | | | |
| Minimum Initial (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | | 4.0 | 4.0 | |
| Minimum Split (s) | 53.0 | 53.0 | 53.0 | 53.0 | 53.0 | 53.0 | 19.0 | 19.0 | | 19.0 | 19.0 | |
| Total Split (s) | 56.0 | 56.0 | 56.0 | 56.0 | 56.0 | 56.0 | 28.0 | 28.0 | 0.0 | 28.0 | 28.0 | 0.0 |
| Total Split (%) | 66.7% | 66.7% | 66.7% | 66.7% | 66.7% | 66.7% | 33.3% | 33.3% | 0.0% | 33.3% | 33.3% | 0.0% |
| Yellow Time (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | | 4.0 | 4.0 | |
| All-Red Time (s) | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | | 3.0 | 3.0 | |
| Lost Time Adjust (s) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Lost Time (s) | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 7.0 | 7.0 | 4.0 | 7.0 | 7.0 | 4.0 |
| Lead/Lag | | | | | | | | | | | | |
| Lead-Lag Optimize? | | | | | | | | | | | | |
| Recall Mode | Max | Max | Max | Max | Max | Max | Max | Max | | Max | Max | |
| Act Effct Green (s) | | 50.0 | 50.0 | | 50.0 | 50.0 | | 21.0 | | | 21.0 | |
| Actuated g/C Ratio | | 0.60 | 0.60 | | 0.60 | 0.60 | | 0.25 | | | 0.25 | |
| v/c Ratio | | 0.85 | 0.01 | | 0.49 | 0.02 | | 0.33 | | | 0.27 | |
| Control Delay | | 23.6 | 3.9 | | 12.5 | 3.5 | | 23.6 | | | 22.8 | |
| Queue Delay | | 0.0 | 0.0 | | 0.0 | 0.0 | | 0.0 | | | 0.0 | |
| Total Delay | | 23.6 | 3.9 | | 12.5 | 3.5 | | 23.6 | | | 22.8 | |
| LOS | | C | A | | B | A | | C | | | C | |
| Approach Delay | | 23.3 | | | 12.1 | | | 23.6 | | | 22.8 | |
| Approach LOS | | C | | | B | | | C | | | C | |

### Intersection Summary

Cycle Length: 84
Actuated Cycle Length: 84
Offset: 28 (33%), Referenced to phase 4:EBTL and 8:WBTL, Start of Green
Natural Cycle: 75
Control Type: Pretimed
Maximum v/c Ratio: 0.85
Intersection Signal Delay: 20.5 Intersection LOS: C
Intersection Capacity Utilization 87.9% ICU Level of Service E
Analysis Period (min) 15

Splits and Phases: 3: Route 117 (Main Street) & Route 110 (Still River Road)

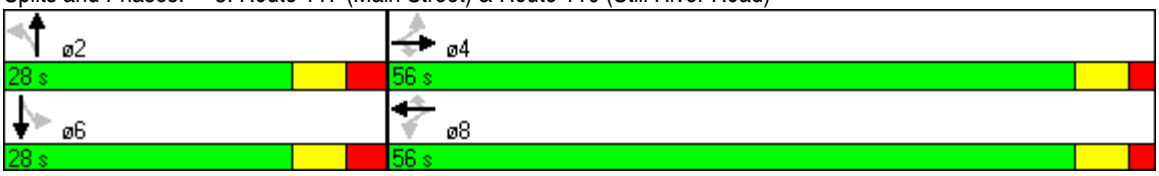




| Lane Group | EBL | EBT | EBR | WBL | WBT | WBR | NBL | NBT | NBR | SBL | SBT | SBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | | | | | | | |
| Volume (vph) | 29 | 365 | 12 | 22 | 897 | 25 | 42 | 65 | 20 | 11 | 112 | 38 |
| Confl. Peds. (#/hr) | | | | | | | | | | | | |
| Confl. Bikes (#/hr) | | | | | | | | | 1 | | | 1 |
| Peak Hour Factor | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 |
| Growth Factor | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Heavy Vehicles (%) | 4% | 4% | 4% | 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 (%) | | | | | | | | | | | | |
| Turn Type | Perm | | Perm | Perm | | Perm | Perm | | | Perm | | |
| Protected Phases | | 4 | | | 8 | | | 2 | | | 6 | |
| Permitted Phases | 4 | | 4 | 8 | | 8 | 2 | | | 6 | | |
| Detector Phase | 4 | 4 | 4 | 8 | 8 | 8 | 2 | 2 | | 6 | 6 | |
| Switch Phase | | | | | | | | | | | | |
| Minimum Initial (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | | 4.0 | 4.0 | |
| Minimum Split (s) | 53.0 | 53.0 | 53.0 | 53.0 | 53.0 | 53.0 | 19.0 | 19.0 | | 19.0 | 19.0 | |
| Total Split (s) | 56.0 | 56.0 | 56.0 | 56.0 | 56.0 | 56.0 | 28.0 | 28.0 | 0.0 | 28.0 | 28.0 | 0.0 |
| Total Split (%) | 66.7% | 66.7% | 66.7% | 66.7% | 66.7% | 66.7% | 33.3% | 33.3% | 0.0% | 33.3% | 33.3% | 0.0% |
| Yellow Time (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | | 4.0 | 4.0 | |
| All-Red Time (s) | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | | 3.0 | 3.0 | |
| Lost Time Adjust (s) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Lost Time (s) | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 7.0 | 7.0 | 4.0 | 7.0 | 7.0 | 4.0 |
| Lead/Lag | | | | | | | | | | | | |
| Lead-Lag Optimize? | | | | | | | | | | | | |
| Recall Mode | Max | Max | Max | Max | Max | Max | Max | Max | | Max | Max | |
| Act Effct Green (s) | | 50.0 | 50.0 | | 50.0 | 50.0 | | 21.0 | | | 21.0 | |
| Actuated g/C Ratio | | 0.60 | 0.60 | | 0.60 | 0.60 | | 0.25 | | | 0.25 | |
| v/c Ratio | | 0.59 | 0.01 | | 0.88 | 0.03 | | 0.31 | | | 0.35 | |
| Control Delay | | 14.8 | 3.6 | | 26.5 | 3.0 | | 25.9 | | | 25.5 | |
| Queue Delay | | 0.0 | 0.0 | | 0.0 | 0.0 | | 0.0 | | | 0.0 | |
| Total Delay | | 14.8 | 3.6 | | 26.5 | 3.0 | | 25.9 | | | 25.5 | |
| LOS | | B | A | | C | A | | C | | | C | |
| Approach Delay | | 14.4 | | | 25.9 | | | 25.9 | | | 25.5 | |
| Approach LOS | | B | | | C | | | C | | | C | |

| Intersection Summary | |
|---|---|
| Cycle Length: 84 | |
| Actuated Cycle Length: 84 | |
| Offset: 28 (33%), Referenced to phase 4:EBTL and 8:WBTL, Start of Green | |
| Natural Cycle: 75 | |
| Control Type: Pretimed | |
| Maximum v/c Ratio: 0.88 | |
| Intersection Signal Delay: 23.0 | Intersection LOS: C |
| Intersection Capacity Utilization 95.3% | ICU Level of Service F |
| Analysis Period (min) 15 | |

Splits and Phases: 3: Route 117 (Main Street) & Route 110 (Still River Road)



# Appendix C

## AM/PM Peak Hour Intersection Capacity Analysis
## Alternative 1
## Upgrade Signal System and Maintain Main Street Existing Lane Configuration
## Main Street (Route 117) at Still River Road (Route 110), Bolton

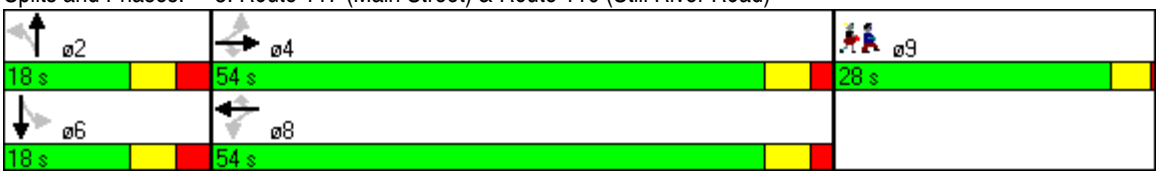
# Intersection Capacity Analysis
## Main St @ Still River Rd, Bolton

9/15/2010

| Lane Group | EBL | EBT | EBR | WBL | WBT | WBR | NBL | NBT | NBR | SBL | SBT | SBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | | | | | | | |
| Volume (vph) | 23 | 839 | 10 | 31 | 333 | 15 | 10 | 91 | 44 | 28 | 58 | 31 |
| Confl. Peds. (#/hr) | | | | | | | | | | | | |
| Confl. Bikes (#/hr) | | | | | | | | | 1 | | | 1 |
| Peak Hour Factor | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| Growth Factor | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Heavy Vehicles (%) | 5% | 5% | 5% | 15% | 8% | 10% | 2% | 2% | 15% | 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 (%) | | | | | | | | | | | | |
| Turn Type | Perm | | Perm | Perm | | Perm | Perm | | | Perm | | |
| Protected Phases | | 4 | | | 8 | | | 2 | | | 6 | |
| Permitted Phases | 4 | | 4 | 8 | | 8 | 2 | | | 6 | | |
| Detector Phase | 4 | 4 | 4 | 8 | 8 | 8 | 2 | 2 | | 6 | 6 | |
| Switch Phase | | | | | | | | | | | | |
| Minimum Initial (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | | 4.0 | 4.0 | |
| Minimum Split (s) | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 15.0 | 15.0 | | 15.0 | 15.0 | |
| Total Split (s) | 54.0 | 54.0 | 54.0 | 54.0 | 54.0 | 54.0 | 18.0 | 18.0 | 0.0 | 18.0 | 18.0 | 0.0 |
| Total Split (%) | 54.0% | 54.0% | 54.0% | 54.0% | 54.0% | 54.0% | 18.0% | 18.0% | 0.0% | 18.0% | 18.0% | 0.0% |
| Yellow Time (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | | 4.0 | 4.0 | |
| All-Red Time (s) | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | | 3.0 | 3.0 | |
| Lost Time Adjust (s) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Lost Time (s) | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 7.0 | 7.0 | 4.0 | 7.0 | 7.0 | 4.0 |
| Lead/Lag | | | | | | | | | | | | |
| Lead-Lag Optimize? | | | | | | | | | | | | |
| Recall Mode | Max | Max | Max | Max | Max | Max | None | None | | None | None | |
| Act Effct Green (s) | | 48.0 | 48.0 | | 48.0 | 48.0 | | 10.0 | | | 10.0 | |
| Actuated g/C Ratio | | 0.68 | 0.68 | | 0.68 | 0.68 | | 0.14 | | | 0.14 | |
| v/c Ratio | | 0.75 | 0.01 | | 0.36 | 0.02 | | 0.57 | | | 0.48 | |
| Control Delay | | 12.7 | 2.9 | | 6.2 | 2.1 | | 34.2 | | | 31.5 | |
| Queue Delay | | 0.0 | 0.0 | | 0.0 | 0.0 | | 0.0 | | | 0.0 | |
| Total Delay | | 12.7 | 2.9 | | 6.2 | 2.1 | | 34.2 | | | 31.5 | |
| LOS | | B | A | | A | A | | C | | | C | |
| Approach Delay | | 12.6 | | | 6.1 | | | 34.2 | | | 31.5 | |
| Approach LOS | | B | | | A | | | C | | | C | |

| Intersection Summary | | | |
|---|---|---|---|
| Cycle Length: 100 | | | |
| Actuated Cycle Length: 71 | | | |
| Natural Cycle: 90 | | | |
| Control Type: Actuated-Uncoordinated | | | |
| Maximum v/c Ratio: 0.75 | | | |
| Intersection Signal Delay: 14.5 | | Intersection LOS: B | |
| Intersection Capacity Utilization 87.9% | | ICU Level of Service E | |
| Analysis Period (min) 15 | | | |

Splits and Phases: 3: Route 117 (Main Street) & Route 110 (Still River Road)



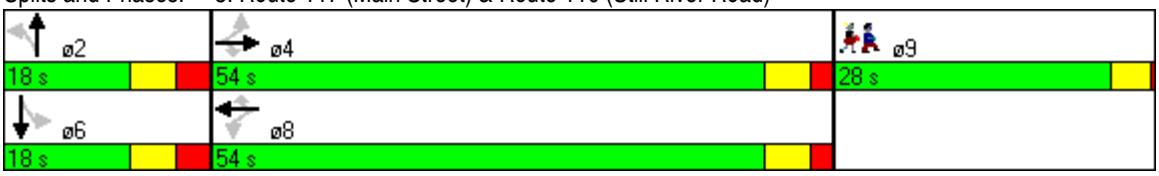

| Lane Group | ø9 |
|---|---|
| Lane Configurations | |
| Volume (vph) | |
| Confl. Peds. (#/hr) | |
| Confl. Bikes (#/hr) | |
| Peak Hour Factor | |
| Growth Factor | |
| Heavy Vehicles (%) | |
| Bus Blockages (#/hr) | |
| Parking (#/hr) | |
| Mid-Block Traffic (%) | |
| Shared Lane Traffic (%) | |
| Turn Type | |
| Protected Phases | 9 |
| Permitted Phases | |
| Detector Phase | |
| Switch Phase | |
| Minimum Initial (s) | 4.0 |
| Minimum Split (s) | 28.0 |
| Total Split (s) | 28.0 |
| Total Split (%) | 28% |
| Yellow Time (s) | 3.5 |
| All-Red Time (s) | 0.5 |
| Lost Time Adjust (s) | |
| Total Lost Time (s) | |
| Lead/Lag | |
| Lead-Lag Optimize? | |
| Recall Mode | None |
| Act Effct Green (s) | |
| Actuated g/C Ratio | |
| v/c Ratio | |
| Control Delay | |
| Queue Delay | |
| Total Delay | |
| LOS | |
| Approach Delay | |
| Approach LOS | |

| Intersection Summary |
|---|

| Lane Group | EBL | EBT | EBR | WBL | WBT | WBR | NBL | NBT | NBR | SBL | SBT | SBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | | | | | | | |
| Volume (vph) | 29 | 365 | 12 | 22 | 897 | 25 | 42 | 65 | 20 | 11 | 112 | 38 |
| Confl. Peds. (#/hr) | | | | | | | | | | | | |
| Confl. Bikes (#/hr) | | | | | | | | | 1 | | | 1 |
| Peak Hour Factor | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 |
| Growth Factor | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Heavy Vehicles (%) | 4% | 4% | 4% | 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 (%) | | | | | | | | | | | | |
| Turn Type | Perm | | Perm | Perm | | Perm | Perm | | | Perm | | |
| Protected Phases | | 4 | | | 8 | | | 2 | | | 6 | |
| Permitted Phases | 4 | | 4 | 8 | | 8 | 2 | | | 6 | | |
| Detector Phase | 4 | 4 | 4 | 8 | 8 | 8 | 2 | 2 | | 6 | 6 | |
| Switch Phase | | | | | | | | | | | | |
| Minimum Initial (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | | 4.0 | 4.0 | |
| Minimum Split (s) | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 15.0 | 15.0 | | 15.0 | 15.0 | |
| Total Split (s) | 54.0 | 54.0 | 54.0 | 54.0 | 54.0 | 54.0 | 18.0 | 18.0 | 0.0 | 18.0 | 18.0 | 0.0 |
| Total Split (%) | 54.0% | 54.0% | 54.0% | 54.0% | 54.0% | 54.0% | 18.0% | 18.0% | 0.0% | 18.0% | 18.0% | 0.0% |
| Yellow Time (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | | 4.0 | 4.0 | |
| All-Red Time (s) | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | | 3.0 | 3.0 | |
| Lost Time Adjust (s) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Lost Time (s) | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 7.0 | 7.0 | 4.0 | 7.0 | 7.0 | 4.0 |
| Lead/Lag | | | | | | | | | | | | |
| Lead-Lag Optimize? | | | | | | | | | | | | |
| Recall Mode | Max | Max | Max | Max | Max | Max | None | None | | None | None | |
| Act Effct Green (s) | | 48.0 | 48.0 | | 48.0 | 48.0 | | 10.9 | | | 10.9 | |
| Actuated g/C Ratio | | 0.67 | 0.67 | | 0.67 | 0.67 | | 0.15 | | | 0.15 | |
| v/c Ratio | | 0.39 | 0.01 | | 0.79 | 0.03 | | 0.54 | | | 0.58 | |
| Control Delay | | 6.8 | 2.2 | | 14.6 | 2.6 | | 35.3 | | | 34.9 | |
| Queue Delay | | 0.0 | 0.0 | | 0.0 | 0.0 | | 0.0 | | | 0.0 | |
| Total Delay | | 6.8 | 2.2 | | 14.6 | 2.6 | | 35.3 | | | 34.9 | |
| LOS | | A | A | | B | A | | D | | | C | |
| Approach Delay | | 6.6 | | | 14.3 | | | 35.3 | | | 34.9 | |
| Approach LOS | | A | | | B | | | D | | | C | |

| Intersection Summary | | | |
|---|---|---|---|
| Cycle Length: 100 | | | |
| Actuated Cycle Length: 71.9 | | | |
| Natural Cycle: 110 | | | |
| Control Type: Actuated-Uncoordinated | | | |
| Maximum v/c Ratio: 0.79 | | | |
| Intersection Signal Delay: 16.0 | | Intersection LOS: B | |
| Intersection Capacity Utilization 95.3% | | ICU Level of Service F | |
| Analysis Period (min) 15 | | | |

Splits and Phases: 3: Route 117 (Main Street) & Route 110 (Still River Road)




| Lane Group | ø9 |
|---|---|
| Lane Configurations | |
| Volume (vph) | |
| Confl. Peds. (#/hr) | |
| Confl. Bikes (#/hr) | |
| Peak Hour Factor | |
| Growth Factor | |
| Heavy Vehicles (%) | |
| Bus Blockages (#/hr) | |
| Parking (#/hr) | |
| Mid-Block Traffic (%) | |
| Shared Lane Traffic (%) | |
| Turn Type | |
| Protected Phases | 9 |
| Permitted Phases | |
| Detector Phase | |
| Switch Phase | |
| Minimum Initial (s) | 4.0 |
| Minimum Split (s) | 28.0 |
| Total Split (s) | 28.0 |
| Total Split (%) | 28% |
| Yellow Time (s) | 3.5 |
| All-Red Time (s) | 0.5 |
| Lost Time Adjust (s) | |
| Total Lost Time (s) | |
| Lead/Lag | |
| Lead-Lag Optimize? | |
| Recall Mode | None |
| Act Effct Green (s) | |
| Actuated g/C Ratio | |
| v/c Ratio | |
| Control Delay | |
| Queue Delay | |
| Total Delay | |
| LOS | |
| Approach Delay | |
| Approach LOS | |

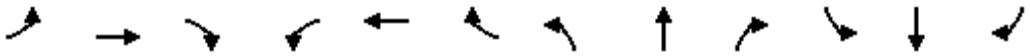
| Intersection Summary |
|---|

# Appendix D

## AM/PM Peak Hour Intersection Capacity Analysis
## Alternative 2
## Upgrade Signal System and Change Main Street Lane Configuration
## Main Street (Route 117) at Still River Road (Route 110), Bolton

# Intersection Capacity Analysis
## Main St @ Still River Rd, Bolton

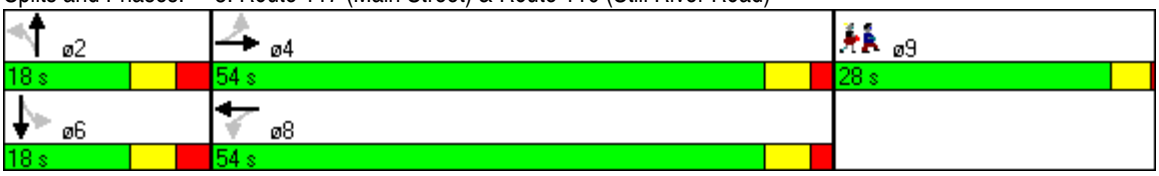
9/15/2010



| Lane Group | EBL | EBT | EBR | WBL | WBT | WBR | NBL | NBT | NBR | SBL | SBT | SBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | | | | | | | |
| Volume (vph) | 23 | 839 | 10 | 31 | 333 | 15 | 10 | 91 | 44 | 28 | 58 | 31 |
| Confl. Peds. (#/hr) | | | | | | | | | | | | |
| Confl. Bikes (#/hr) | | | | | | | | | 1 | | | 1 |
| Peak Hour Factor | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| Growth Factor | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Heavy Vehicles (%) | 5% | 5% | 5% | 15% | 8% | 10% | 2% | 2% | 15% | 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 (%) | | | | | | | | | | | | |
| Turn Type | Perm | | | Perm | | | Perm | | | Perm | | |
| Protected Phases | | 4 | | | 8 | | | 2 | | | 6 | |
| Permitted Phases | 4 | | | 8 | | | 2 | | | 6 | | |
| Detector Phase | 4 | 4 | | 8 | 8 | | 2 | 2 | | 6 | 6 | |
| Switch Phase | | | | | | | | | | | | |
| Minimum Initial (s) | 4.0 | 4.0 | | 4.0 | 4.0 | | 4.0 | 4.0 | | 4.0 | 4.0 | |
| Minimum Split (s) | 21.0 | 21.0 | | 21.0 | 21.0 | | 15.0 | 15.0 | | 15.0 | 15.0 | |
| Total Split (s) | 54.0 | 54.0 | 0.0 | 54.0 | 54.0 | 0.0 | 18.0 | 18.0 | 0.0 | 18.0 | 18.0 | 0.0 |
| Total Split (%) | 54.0% | 54.0% | 0.0% | 54.0% | 54.0% | 0.0% | 18.0% | 18.0% | 0.0% | 18.0% | 18.0% | 0.0% |
| Yellow Time (s) | 4.0 | 4.0 | | 4.0 | 4.0 | | 4.0 | 4.0 | | 4.0 | 4.0 | |
| All-Red Time (s) | 2.0 | 2.0 | | 2.0 | 2.0 | | 3.0 | 3.0 | | 3.0 | 3.0 | |
| Lost Time Adjust (s) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Lost Time (s) | 6.0 | 6.0 | 4.0 | 6.0 | 6.0 | 4.0 | 7.0 | 7.0 | 4.0 | 7.0 | 7.0 | 4.0 |
| Lead/Lag | | | | | | | | | | | | |
| Lead-Lag Optimize? | | | | | | | | | | | | |
| Recall Mode | Max | Max | | Max | Max | | None | None | | None | None | |
| Act Effct Green (s) | 48.0 | 48.0 | | 48.0 | 48.0 | | | 9.9 | | | 9.9 | |
| Actuated g/C Ratio | 0.68 | 0.68 | | 0.68 | 0.68 | | | 0.14 | | | 0.14 | |
| v/c Ratio | 0.04 | 0.72 | | 0.13 | 0.31 | | | 0.57 | | | 0.49 | |
| Control Delay | 4.3 | 11.9 | | 5.8 | 5.7 | | | 34.3 | | | 31.6 | |
| Queue Delay | 0.0 | 0.0 | | 0.0 | 0.0 | | | 0.0 | | | 0.0 | |
| Total Delay | 4.3 | 11.9 | | 5.8 | 5.7 | | | 34.3 | | | 31.6 | |
| LOS | A | B | | A | A | | | C | | | C | |
| Approach Delay | | 11.7 | | | 5.7 | | | 34.3 | | | 31.6 | |
| Approach LOS | | B | | | A | | | C | | | C | |

| Intersection Summary | | | |
|---|---|---|---|
| Cycle Length: 100 | | | |
| Actuated Cycle Length: 71 | | | |
| Natural Cycle: 90 | | | |
| Control Type: Actuated-Uncoordinated | | | |
| Maximum v/c Ratio: 0.72 | | | |
| Intersection Signal Delay: 13.9 | | Intersection LOS: B | |
| Intersection Capacity Utilization 70.0% | | ICU Level of Service C | |
| Analysis Period (min) 15 | | | |

Splits and Phases: 3: Route 117 (Main Street) & Route 110 (Still River Road)




| Lane Group | ø9 |
|---|---|
| Lane Configurations | |
| Volume (vph) | |
| Confl. Peds. (#/hr) | |
| Confl. Bikes (#/hr) | |
| Peak Hour Factor | |
| Growth Factor | |
| Heavy Vehicles (%) | |
| Bus Blockages (#/hr) | |
| Parking (#/hr) | |
| Mid-Block Traffic (%) | |
| Shared Lane Traffic (%) | |
| Turn Type | |
| Protected Phases | 9 |
| Permitted Phases | |
| Detector Phase | |
| Switch Phase | |
| Minimum Initial (s) | 4.0 |
| Minimum Split (s) | 28.0 |
| Total Split (s) | 28.0 |
| Total Split (%) | 28% |
| Yellow Time (s) | 3.5 |
| All-Red Time (s) | 0.5 |
| Lost Time Adjust (s) | |
| Total Lost Time (s) | |
| Lead/Lag | |
| Lead-Lag Optimize? | |
| Recall Mode | None |
| Act Effct Green (s) | |
| Actuated g/C Ratio | |
| v/c Ratio | |
| Control Delay | |
| Queue Delay | |
| Total Delay | |
| LOS | |
| Approach Delay | |
| Approach LOS | |

| Intersection Summary |
|---|

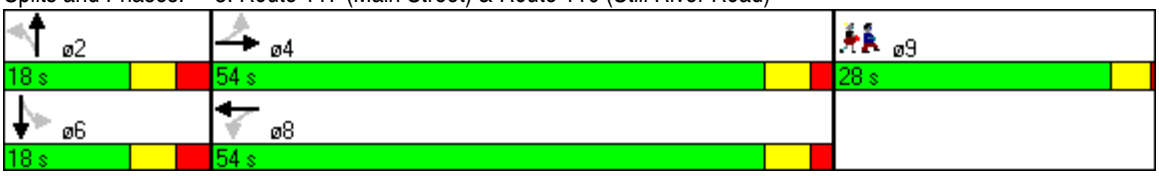
# Intersection Capacity Analysis
## Main St @ Still River Rd, Bolton

9/15/2010

| Lane Group | EBL | EBT | EBR | WBL | WBT | WBR | NBL | NBT | NBR | SBL | SBT | SBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | | | | | | | |
| Volume (vph) | 29 | 365 | 12 | 22 | 897 | 25 | 42 | 65 | 20 | 11 | 112 | 38 |
| Confl. Peds. (#/hr) | | | | | | | | | | | | |
| Confl. Bikes (#/hr) | | | | | | | | | 1 | | | 1 |
| Peak Hour Factor | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 |
| Growth Factor | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Heavy Vehicles (%) | 4% | 4% | 4% | 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 (%) | | | | | | | | | | | | |
| Turn Type | Perm | | | Perm | | | Perm | | | Perm | | |
| Protected Phases | | 4 | | | 8 | | | 2 | | | 6 | |
| Permitted Phases | 4 | | | 8 | | | 2 | | | 6 | | |
| Detector Phase | 4 | 4 | | 8 | 8 | | 2 | 2 | | 6 | 6 | |
| Switch Phase | | | | | | | | | | | | |
| Minimum Initial (s) | 4.0 | 4.0 | | 4.0 | 4.0 | | 4.0 | 4.0 | | 4.0 | 4.0 | |
| Minimum Split (s) | 21.0 | 21.0 | | 21.0 | 21.0 | | 15.0 | 15.0 | | 15.0 | 15.0 | |
| Total Split (s) | 54.0 | 54.0 | 0.0 | 54.0 | 54.0 | 0.0 | 18.0 | 18.0 | 0.0 | 18.0 | 18.0 | 0.0 |
| Total Split (%) | 54.0% | 54.0% | 0.0% | 54.0% | 54.0% | 0.0% | 18.0% | 18.0% | 0.0% | 18.0% | 18.0% | 0.0% |
| Yellow Time (s) | 4.0 | 4.0 | | 4.0 | 4.0 | | 4.0 | 4.0 | | 4.0 | 4.0 | |
| All-Red Time (s) | 2.0 | 2.0 | | 2.0 | 2.0 | | 3.0 | 3.0 | | 3.0 | 3.0 | |
| Lost Time Adjust (s) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Lost Time (s) | 6.0 | 6.0 | 4.0 | 6.0 | 6.0 | 4.0 | 7.0 | 7.0 | 4.0 | 7.0 | 7.0 | 4.0 |
| Lead/Lag | | | | | | | | | | | | |
| Lead-Lag Optimize? | | | | | | | | | | | | |
| Recall Mode | Max | Max | | Max | Max | | None | None | | None | None | |
| Act Effct Green (s) | 48.0 | 48.0 | | 48.0 | 48.0 | | | 10.9 | | | 10.9 | |
| Actuated g/C Ratio | 0.67 | 0.67 | | 0.67 | 0.67 | | | 0.15 | | | 0.15 | |
| v/c Ratio | 0.15 | 0.33 | | 0.04 | 0.78 | | | 0.54 | | | 0.58 | |
| Control Delay | 6.6 | 6.0 | | 4.3 | 14.2 | | | 35.3 | | | 34.9 | |
| Queue Delay | 0.0 | 0.0 | | 0.0 | 0.0 | | | 0.0 | | | 0.0 | |
| Total Delay | 6.6 | 6.0 | | 4.3 | 14.2 | | | 35.3 | | | 34.9 | |
| LOS | A | A | | A | B | | | D | | | C | |
| Approach Delay | | 6.0 | | | 14.0 | | | 35.3 | | | 34.9 | |
| Approach LOS | | A | | | B | | | D | | | C | |

| Intersection Summary | | | |
|---|---|---|---|
| Cycle Length: 100 | | | |
| Actuated Cycle Length: 71.9 | | | |
| Natural Cycle: 100 | | | |
| Control Type: Actuated-Uncoordinated | | | |
| Maximum v/c Ratio: 0.78 | | | |
| Intersection Signal Delay: 15.7 | | Intersection LOS: B | |
| Intersection Capacity Utilization 79.2% | | ICU Level of Service D | |
| Analysis Period (min) 15 | | | |

Splits and Phases: 3: Route 117 (Main Street) & Route 110 (Still River Road)




| Lane Group | ø9 |
|---|---|
| Lane Configurations | |
| Volume (vph) | |
| Confl. Peds. (#/hr) | |
| Confl. Bikes (#/hr) | |
| Peak Hour Factor | |
| Growth Factor | |
| Heavy Vehicles (%) | |
| Bus Blockages (#/hr) | |
| Parking (#/hr) | |
| Mid-Block Traffic (%) | |
| Shared Lane Traffic (%) | |
| Turn Type | |
| Protected Phases | 9 |
| Permitted Phases | |
| Detector Phase | |
| Switch Phase | |
| Minimum Initial (s) | 4.0 |
| Minimum Split (s) | 28.0 |
| Total Split (s) | 28.0 |
| Total Split (%) | 28% |
| Yellow Time (s) | 3.5 |
| All-Red Time (s) | 0.5 |
| Lost Time Adjust (s) | |
| Total Lost Time (s) | |
| Lead/Lag | |
| Lead-Lag Optimize? | |
| Recall Mode | None |
| Act Effct Green (s) | |
| Actuated g/C Ratio | |
| v/c Ratio | |
| Control Delay | |
| Queue Delay | |
| Total Delay | |
| LOS | |
| Approach Delay | |
| Approach LOS | |

| Intersection Summary |
|---|

# Appendix E

# MassDOT Project Implementation Process

The following description of the implementation process is based on Chapter 2 of the *MassDOT Highway Division's Project Development and Design Guide (2005).* The text below borrows heavily from that document.

## 1 NEEDS IDENTIFICATION

For each of the locations at which an improvement is to be implemented, MassDOT Highway Division 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 Highway Division meets with potential participants, such as the Boston Region 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 Highway Division 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, for each improvement, a Project Initiation Form (PIF), 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 Capital Expenditure Program Office (CEPO). 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 Executive Office of Transportation and Public Works'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, 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.

## 5 PROGRAMMING

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, where the MPO receives preliminary information on the proposed project, the proponent requests that the MPO place the project in the region's TIP. The MPO considers the project in terms of 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, 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.