BOSTON REGION METROPOLITAN PLANNING ORGANIZATION

Stephanie Pollack, MassDOT Secretary and CEO and MPO Chairman
Karl H. Quackenbush, Executive Director, MPO Staff

TECHNICAL MEMORANDUM

DATE: **May 21, 2015**
TO: **Owen MacDonald, Traffic Engineer, Weymouth**
FROM: **Seth Asante, MPO Staff**
RE: **Safety and Operations Analyses—Weymouth**
Selected Intersection: Washington Street at Broad Street in Weymouth

This memorandum summarizes the analyses and improvement strategies developed for the intersection of Washington Street (Route 53) and Broad Street in Weymouth. The opening sections of the memorandum give a background of the study and describe the existing conditions and problems of concern to the community. After that is an assessment of the safety and operations problems and the potential improvement strategies. The final sections of the memorandum present the study findings and recommendations. The memo also includes technical appendices that contain methods and data applied in the study and detailed reports of the intersection capacity analyses.

1. BACKGROUND

The purpose of the Safety and Operations Analyses at Selected Intersections study is to examine safety and mobility issues at major intersections in the Boston Region Metropolitan Planning Organization (MPO) region's arterial highways—areas where many crashes occur, that experience congestion during peak traffic periods, or are in need of improvements for buses, bicyclists, and pedestrians. For the past ten years, the MPO has been conducting these planning studies, and municipalities in the region are very receptive to them. These studies give communities an opportunity to begin looking at the needs of these locations, starting at the conceptual level, before they commit funds for design and engineering. Eventually, if the project qualifies for federal funds, the study's documentation also is useful to the Massachusetts Department of Transportation (MassDOT). These studies support the MPO's visions and goals, which include increasing transportation safety, maintaining the transportation system, advancing mobility, and reducing congestion.

Based on a selection process,[1] four locations from a short list of 21 intersections were approved for study by the Boston Region MPO based on criteria that included high crash rating, amount of pedestrian and bicycle crashes, transit significance[2], regional significance[3], and implementation potential.[4] The four locations approved for study are:

1. Washington Street (Route 53) and Broad Street in Weymouth
2. Medway Road (Route109) and Kmart Driveway in Milford
3. High Street (Route 109) and Nahatan Street in Westwood
4. High Street (Route 109) and Pond Street in Westwood

The location in Weymouth was selected because it has safety and traffic operations problems. Figure 1 shows the location of the intersection and the surrounding roadways.

1.2 Public Participation

An advisory task force comprising representatives from Weymouth was established to participate in this study. First, MPO staff met with the Weymouth Traffic Engineer, Mr. Owen MacDonald, at the intersection to discuss safety and operations issues and the scope of work for the study. MPO staff then met with the task force to present the existing conditions, problems identified, and proposed improvements. MPO staff addressed comments from the task force and incorporated them into this memorandum. Appendix A includes the list of task force members and comments about the study.

2 ROADWAY, INTERSECTIONS, AND LAND USES

2.1 Roadway

Washington Street/Route 53

Route 53 is a predominantly two-lane, two-way arterial roadway that passes through eight communities from south to north: Kingston, Duxbury, Pembroke, Hanover, Norwell, Hingham, Weymouth, and Quincy. Although Route 53 is a state-numbered route, the portion north of Broad Street is locally controlled. The roadway, functionally classified as a principal arterial, is part of the National

1 Seth Asante, memorandum to Boston Region MPO, Safety and Operations Analyses at Selected Intersections—FFY 2013, Task 1: Intersection Selection Procedure, December 19, 2013.

2 Transit Significance: Location carries bus route(s) or is adjacent to a transit stop or station.

3 Regional Significance: Location carries high proportion of regional traffic or noticeable commuter bicycle traffic.

4 Implementation Potential: Location either is under MassDOT jurisdiction, has a Transportation Improvement Program (TIP) “conceptual” status, or a strong commitment from a city or town.

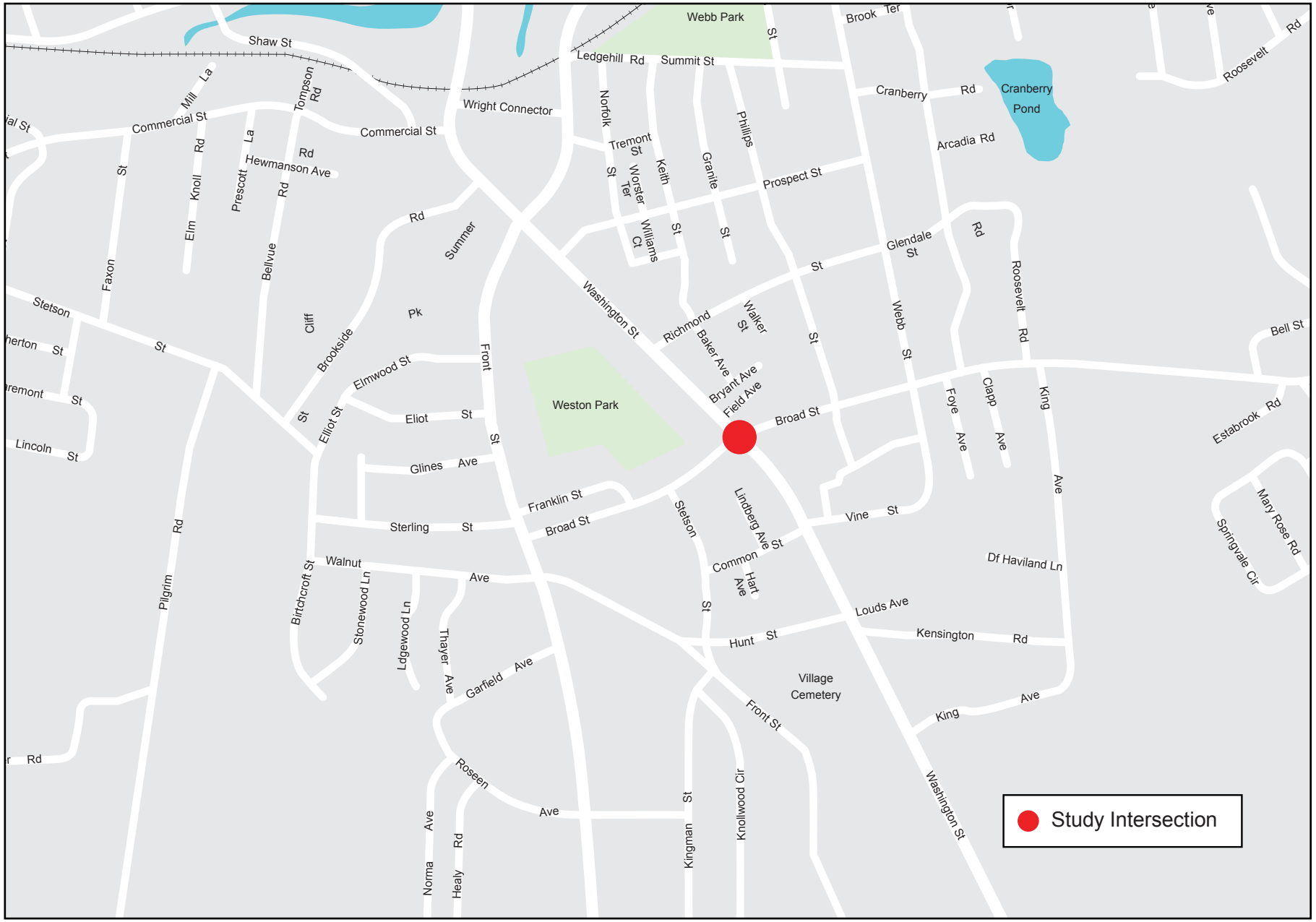

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FIGURE 1
Study Intersection
Washington Street and Broad Street Intersection

Safety and Operations Analyses at Selected Intersections–FFY 2014

Highway System (NHS) program and is eligible for federal funds provided for the program. In Weymouth, Route 53 is called Washington Street and it provides access to/from several locations in Weymouth as well as communities to the north and east of it.

Washington Street near the Broad Street intersection has right-of-way width of approximately 50-to-60 feet. It features five-to-six foot continuous and connected sidewalks on both sides, and a posted speed limit of 30 miles per hour (mph) in both directions. On-street parking is prohibited at the intersection. To the south of the intersection, Washington Street has a six-foot shoulder on each side of the roadway to accommodate bicyclists, and on-street parking is prohibited in this section. To the north of the intersection, Washington Street has no shoulder because on-street parking is allowed here—bicyclists share the roadway with motor vehicles. Two-hour parking is posted from 7 AM to 4:00 PM.

Broad Street

Broad Street is a town-owned roadway functionally classified as an urban minor arterial, a two-lane, two-way roadway that runs east/west. It is federal-aid eligible and qualifies for funds under the Surface Transportation Program. The right-of-way is approximately 40 feet wide and comprised of two 11-foot travel lanes, two- to four-foot-wide shoulders, and five-foot-wide continuous and connected sidewalk on both sides. The posted speed limit is 30 mph in both directions.

2.2 Intersection

Washington Street and Broad Street Intersection

Washington Street and Broad Street forms a four-legged signalized intersection (Figure 2), with the primary traffic flow along Washington Street. Each approach on Washington Street widens to 23 feet approximately 175 feet prior to the intersection, and continues the same width through the intersection for approximately 175 feet past the intersection, but it is not striped as two travel lanes. Similarly, the westbound approach lane of Broad Street widens to approximately 22 feet for a distance of 100 feet prior to the intersection.

The intersection has traffic signal control but the signal equipment is outdated and may not have all of the functionality to operate efficiently. Pedestrian signals are functioning, well with adequate time for crossing the street curb to curb but they are not accessible pedestrian signals. Accessible pedestrian signals communicate information about the walk- and don’t-walk intervals in non-visual formats to pedestrians who are blind or who have low vision. In addition, the signal equipment lacks Opticom receivers to handle emergency services such as preemption of traffic queues. The signal heads are mast-arm mounted, however they lack backplates that would improve visibility.

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FIGURE 2
Turning Movement Volumes
Washington Street and Broad Street Intersection

Safety and Operations Analyses at Selected Intersections–FFY 2014

There are crosswalks with curb ramps on all four legs of the intersection. The curb ramps lack detectable warning plates and cross slopes of some of them are too steep and do not comply with Americans with Disabilities Act (ADA) standards. The intersection curb radii are adequate for trucks and school buses servicing commercial/retail business and schools in the area.

The Massachusetts Bay Transportation Authority (MBTA) operates the Route 225 bus—Quincy Center-Weymouth Landing via Quincy Avenue and Shaw Street/Desmoines Road—within the study area. Route 225 has stops at the study intersection and connects commuter rail stations, major shopping centers, apartments, and schools. Route 225 operates Monday to Friday every 20 minutes from 5:30 AM to 11:57 PM; Saturday every 30 minutes from 6:30 AM to 11:56 PM; and Sunday every 60 minutes from 7:50 AM to 11:51 PM. MBTA buses are accessible to persons with disabilities.[5] In addition, some commuter rail riders who board the MBTA's Greenbush Line at the Weymouth Landing/Braintree station go through the intersection to reach the train station.

The land use near the study intersection is mixed (residential, educational, and business). The S Bank, Stop and Save store, and Union Towers apartments are located at the intersection. In addition, the South Shore Christian Academy and Tufts Library are located on Broad Street, approximately 500 feet west of the intersection.

3 VEHICLE, PEDESTRIAN, AND BICYCLE COUNTS

MPO staff collected traffic volume data to assess the operational characteristics of the study intersection (included in Appendix B). Staff collected turning-movement counts (TMCs) at the Washington Street and Broad Street intersection in April 2014 during weekday morning (7:00 to 9:00 AM) and evening (3:00 to 6:00 PM) peak travel periods. Pedestrian and bicycle counts were conducted simultaneously with the TMCs; heavy vehicles, including trucks, transit, and school buses were counted separately. Based on the counts, the estimated average daily traffic (ADT) on Washington Street was between 18,500-and-22,700 vehicles per day. The ADT on Broad Street ranged from 3,200 vehicles per day west of the intersection to 8,500 vehicles per day east of the intersection. Figure 2 shows the turning movement volumes at the intersection.

During the AM peak travel period, the primary traffic flow (peak direction) is northbound on Washington Street. In addition, a high volume of traffic southbound on Washington Street turns left onto Broad Street during the AM

[5] Massachusetts Bay Transportation Authority, Bus Schedule, Effective March 21, 2015, http://www.mbta.com/schedules_and_maps/bus/routes/?route=225

peak travel period. During the PM peak travel period, the primary traffic flow direction is reversed—southbound on Washington Street. Staff observed 66 pedestrians and 18 bicyclists crossing the intersection during the counting period. The percentage of trucks driving through the intersection during the AM and PM peak travel periods ranged between 3.0-and-4.0 percent, which is not considered high for peak-period traffic conditions. Staff did not detect any roadway geometry—such as turning radii, which would inhibit truck traffic flow—other than the peak-period congestion that affects all traffic.

4 SAFETY CONDITIONS

4.1 Crash Summary

The intersection is ranked 179th on the 2009–2011 Statewide Top-200 Intersection Crash List. Staff analyzed 2009–2012 crash records from the MassDOT Registry of Motor Vehicles (included in Appendix C). Crashes at the intersection form part of a Highway Safety Improvement Program (HSIP) crash cluster. This HSIP crash cluster is comprised of 55 crashes (including those near the Shell Gas Station), and 34 of which occurred at the intersection of Washington and Broad Streets. A summary of crashes at the intersection in terms of severity, manner of collision, weather conditions, ambient light conditions, and time of occurrence is presented in Table 1.

4.2 Crash Rate and Pattern

Staff calculated intersection crash rates per MassDOT Highway Division's methodology, based on the entire four-year period. The most recent statewide average crash rate for signalized intersections in MassDOT Highway Division District 6, which includes the Town of Weymouth, is 0.76 crashes per million entering vehicles (mev).[6] The average crash rate of 0.84 mev for the study intersection exceeded that of a signalized intersection in District 6.

4.3 Collison Diagram

MPO staff used police crash reports obtained from the Weymouth Police Department to prepare a collision diagram that is useful for examining patterns and developing safety strategies. Figure 3 shows the collision diagram of the crashes. The numbers in the collision diagram uniquely identify each crash and, for more detail about the crash, may be used to cross reference the crash records provided in Appendix C. Prevalent crash patterns in the study area were rear-end-type crashes at the Washington Street approaches and Broad Street westbound approach and angle-type crashes involving Washington Street left-

[6] Based on MassDOT Registry of Motor Vehicles crash information queried on January 23, 2013.

turn movements and opposing through movements. One-third of the crashes resulted in injury.

TABLE 1
Crash Summary (2009 to 2012)

Crash Variable	Washington Street and Broad Street Intersection
Crash Severity	--
Non-fatal injury	11
Property damage only	21
Not reported/unknown	2
Manner of Collision	--
Angle	16
Rear-end	9
Sideswipe, same direction	4
Sideswipe, opposite direction	1
Single vehicle crash	4
Road Surface Condition	--
Dry	25
Wet	7
Snow	2
Ambient Light Conditions	--
Daylight	21
Dark - lighted roadway	12
Dusk	1
Weather Conditions	--
Clear	22
Cloudy	4
Rain	6
Snow	2
Travel Period	--
Peak Period	13
Off Peak	21
Total Crashes (2009-2012)	34
Four-year average (rounded)	9
Average Crash Rate	0.84
MassDOT Highway District 6 average crash rate for signalized intersection	0.76

* The AM peak period is 7:00 AM to 9:00 AM, and the PM peak period is 4:00 PM to 6:00 PM.
Source: Central Transportation Planning Staff.

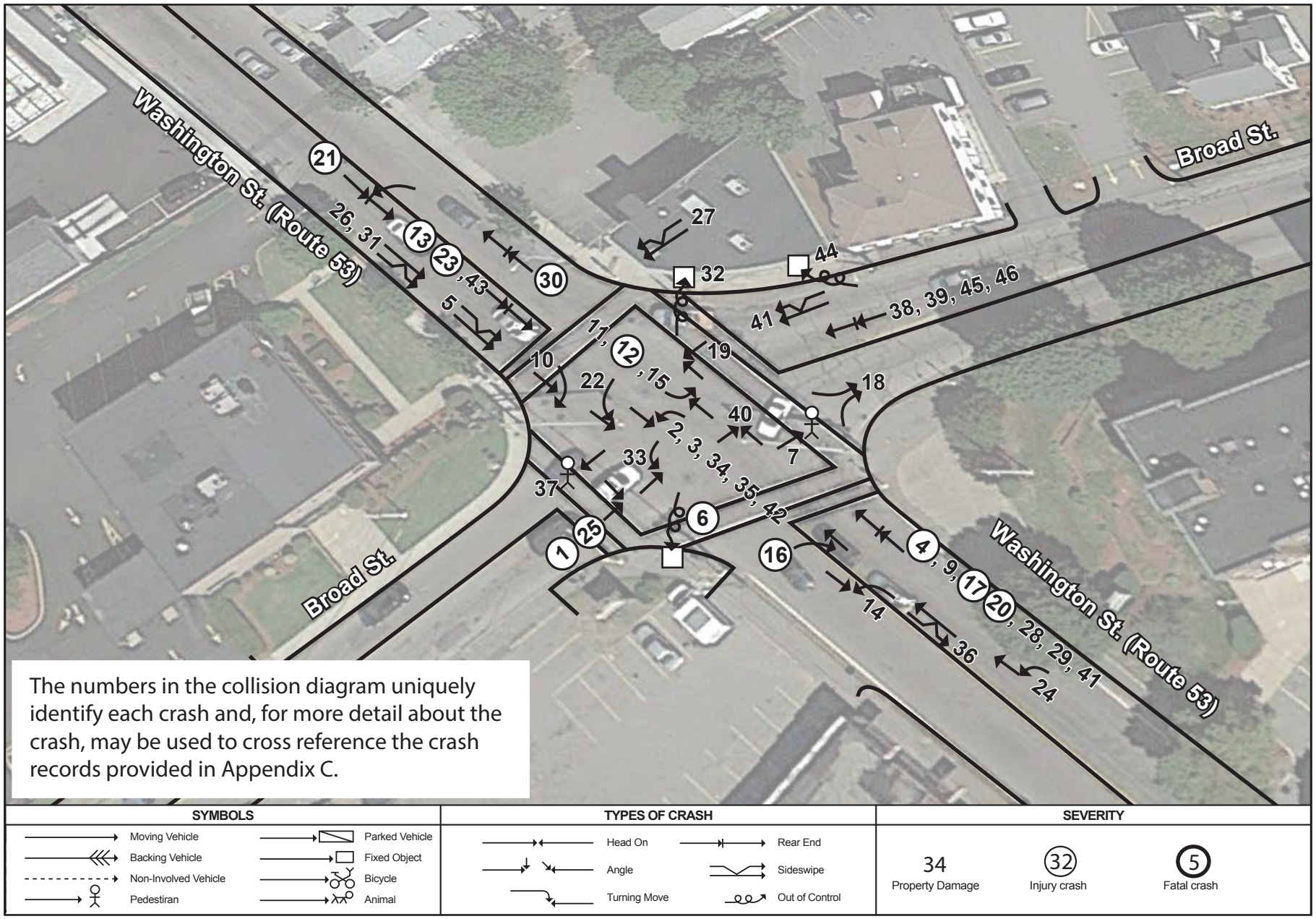

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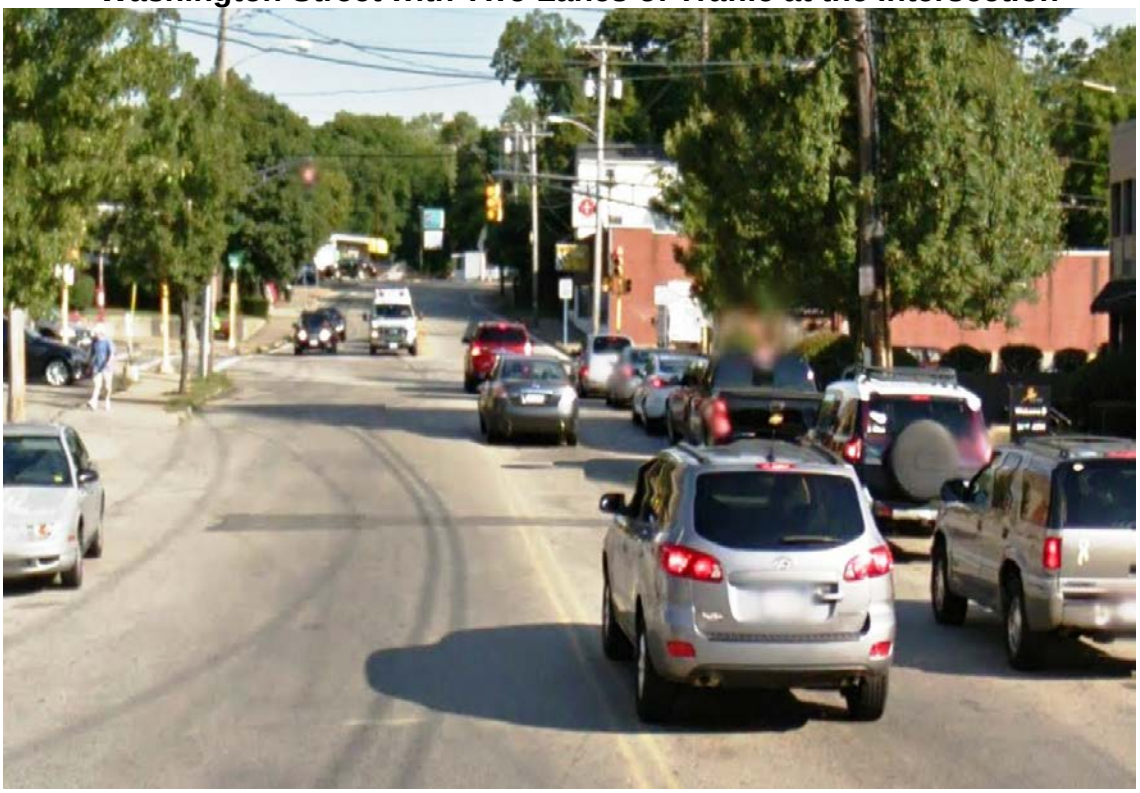
FIGURE 3
Collision Diagram 2009–2013
Washington Street and Broad Street Intersection

Safety and Operations Analyses at Selected Intersections–FFY 2014

Most of the angle crashes on Washington Street resulted from failing to yield the right-of-way, following too closely, and not paying attention. In addition, the behavior of forming two travel lanes on Washington Street during peak travel periods and a single traffic lane during off-peak travel periods creates confusion for drivers, especially for those turning left onto Broad Street, as they do not see or expect a through vehicle to pass by a vehicle waiting to turn left in the opposing direction (Figure 4).

The absence of left-turn signal signs at the intersection also contributes to the angle-type crashes. For example, Washington Street southbound left-turn movements have a leading protected-left-turn, while northbound left-turn movements are permitted-left-turn; however, there are no traffic signal signs to convey this information to drivers. Another safety issue is driver awareness and visibility of the intersection because of the horizontal and vertical curvatures on Washington and Broad Streets.

FIGURE 4
Washington Street with Two Lanes of Traffic at the Intersection



Source: Google Earth.

5 EXISTING TRAFFIC OPERATIONS CONDITIONS

Using the data and information collected, MPO staff built a traffic analysis network (with Synchro[7]) for the AM and PM peak periods to assess the capacity and quality of traffic flow at the intersections. The analyses were conducted in a manner consistent with Highway Capacity Manual (HCM) methodologies (detailed worksheets of the analyses are included in Appendix D)[8]. The HCM methodology demonstrates the driving conditions at signalized and unsignalized intersections in terms of levels of service (LOS) ratings A through F. LOS A represents the best operating conditions (little to no delay), while LOS F represents the worst operating conditions (very long delay). LOS E represents operating conditions at capacity (limit of acceptable delay). Table 2 shows the control delays associated with each LOS for signalized and unsignalized intersections.

TABLE 2
Levels of Service and Control Delays at Intersections

Level of Service	Signalized Intersections Control Delay (seconds per vehicle)	Unsignalized Intersections Control Delay (seconds per vehicle)
A	≤ 10	≤ 10
B	> 10-20	> 10-15
C	> 20-35	> 15-25
D	> 35-55	> 25-35
E	> 55-80	> 35-50
F	> 80	> 50

Source: Central Transportation Planning Staff.

Table 3 presents peak-hour performance in terms of LOS, delay, and queues for existing conditions. The intersection operates satisfactorily during the AM and PM peak periods (LOS D or better). Washington Street northbound and southbound movements currently operate at desirable LOS D during peak travel hours because of motorists forming two travel lanes to enter the intersection during peak periods. In addition, during PM peak hours there are queues on the Washington Street southbound approach that extend to Richmond Street. The large volume of traffic on Washington Street and absence of left-turn lanes make it difficult and unsafe for left-turning drivers to turn onto Broad Street. During the AM peak hour, traffic on the Broad Street westbound approach operates at LOS E with moderate queues; during the PM peak hour, traffic on Broad Street eastbound approach operates at LOS E.

[7] Trafficware Inc., Synchro Studio 8, Synchro plus SimTraffic, Build 801, Version 563, Sugar Land, Texas.

[8] Highway Capacity Manual, HCM 2010, Volume 3: Interrupted Flow, Transportation Research Board of the National Academies, Washington DC, December 2010.

TABLE 3
Washington Street and Broad Street Intersection,
Peak Hour Level of Service

Improvement Alternative	Movement	AM LOS	AM Delay[a]	AM Queue[b]	PM LOS	PM Delay	PM Queue
Existing Conditions (2014)	--	--	--	--	--	--	--
Washington St. Northbound	L+T+R	B	12.6	250	B	16.5	267
Washington St. Southbound	L+T+R	B	12.8	162	D	43.8	#551
Broad St. Eastbound	L+T+R	D	42.8	#262	E	56.6	#378
Broad St. Westbound	L+T	E	55.9	#404	D	51.8	#333
Broad St. Westbound	R	D	36.9	#286	D	35.5	163
Total intersection	All	C	25.5	--	D	37.1	--
No-Build Conditions (2024)	--	--	--	--	--	--	--
Washington St. Northbound	L+T+R	B	12.9	266	B	16.9	#285
Washington St. Southbound	L+T+R	B	13.3	173	E	60.2	#594
Broad St. Eastbound	L+T+R	D	45.1	#281	E	61.9	#402
Broad St. Westbound	L+T+R	E	63.0	#428	E	55.7	#354
Broad St. Westbound	R	D	38.3	#306	D	36.0	#171
Total intersection	All	C	27.2	--	D	44.9	--
Add Left-turn Lane with a Protected/Permissive Left-Turn Phase on Southbound Washington Street (2024)	--	--	--	--	--	--	--
Washington St. Northbound	L+T+R	C	28.9	#393	C	27.2	#415
Washington St. Southbound	L	C	24.0	#118	D	35.4	#256
Washington St. Southbound	T+R	B	17.5	280	D	36.7	#907
Broad St. Eastbound	L+T+R	C	25.9	196	D	36.6	#364
Broad St. Westbound	L+T	C	33.1	#366	D	52.8	#370
Broad St. Westbound	R	C	27.5	241	C	27.7	165
Total intersection	All	C	26.8	--	C	34.7	--
Add Left-turn Lane with a Protected Only Left-Turn Phase on Southbound Washington Street (2024)	--	--	--	--	--	--	--
Washington St. Northbound	L+T+R	D	40.6	#421	E	72.2	#467
Washington St. Southbound	L	D	49.8	#177	E	58.8	#301
Washington St. Southbound	T+R	B	16.8	267	D	38.5	#854
Broad St. Eastbound	L+T+R	C	24.7	185	D	39.0	#361
Broad St. Westbound	L+T	C	33.0	#354	E	60.8	#356
Broad St. Westbound	R	C	26.6	#250	C	26.4	156
Total intersection	All	C	32.5	--	D	52.4	--

[a] Delay in seconds per vehicle. [b] 95th percentile queue length in feet. # = The 95th percentile volume exceeds capacity.
Source: Central Transportation Planning Staff.

6 MAJOR ISSUES/CONCERNS

Based on existing conditions, analysis of traffic and crash data, field reconnaissance, and discussions with the town officials, staff identified the following problems:

Pedestrian Safety Issues

- Many pedestrians (including students, elderly people, and persons with disabilities) use the intersection – there have been complaints about pedestrian safety, especially for the elderly.
- Two pedestrian-related crashes in crosswalks – supports the need to increase safety for pedestrians
- Lack of accessible pedestrian signals – creates problems for people with disabilities, especially those with visual or hearing impairment
- Curb ramps not ADA compliant – creates problems for wheelchair users
- Crumbled sidewalks – creates poor walking conditions
- Lack of high-visibility crosswalks – to alert drivers to an often-used pedestrian crossing
- Long crossing distance on east leg of Broad Street – increases the likelihood of pedestrian-vehicle crashes and conflicts

Intersection Safety Issues

- Intersection crash rate exceeds MassDOT District 6 average crash rate for signalized intersection
- Intersection ranks 179th on the 2009−2011 Top-200 Intersection Crash List; part of an HSIP crash cluster

Traffic Operations Issues

- Vehicle-detection problems – creates inefficient traffic operations
- Outdated signal equipment – creates inefficient traffic operations where signal equipment does not have capability to adjust the timing of red, yellow and green lights to accommodate changing traffic patterns and ease traffic congestion.
- Wide approach lane – used as two lanes during peak travel periods and as single lane during off-peak travel periods—creates confusion for left-turning drivers

7 FUTURE TRAFFIC GROWTH

Staff used a planning model to forecast future traffic-volume changes systematically that could result from changes in the transportation network or land use. The model used in this study is the Boston Region MPO's most recently adopted regional travel demand model set used for the Long-Range

Transportation Plan. Its socioeconomic components are based on forecasts produced by the Metropolitan Area Planning Council. Using TransCAD software, the model is calibrated at a regional level for 164 cities and towns, including all 101 cities and towns in the MPO region. Based on this regional planning model, traffic on Washington Street is expected to grow at 0.4 percent per year, which results in total growth of 5 percent between 2014 and 2024.

8 IMPROVEMENT STRATEGIES

MPO staff developed and analyzed short- and long-term strategies to improve safety and traffic operations at the study intersection. The projected growth factor from the regional model set was used to expand existing peak-hour turning-movement volumes to 2024 future turning-movement volumes for testing the improvement strategies.

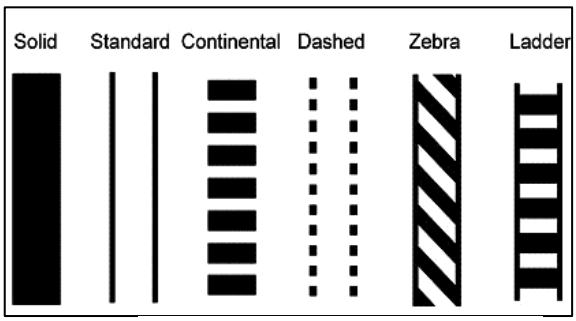
8.1 Short-Term Improvements

The list below addresses low-cost improvements for safety and operations that involve repairing, replacing, or installing minor geometric elements such as curb ramps, signage, and pavement markings. The suggested improvements could be implemented in phases depending on the urgency of the problem.

Improvements to Increase Safety for Pedestrians

- Reconstruct all curb ramps to comply with ADA standards
- Tighten curb radii to reduce crossing distance on east leg of Broad Street
- Curbs should be designed to accommodate the frequent emergency-response vehicles in the area
- Upgrade sidewalks at the intersection to improve walking conditions
- Install pedestrian accessible pedestrian signals to improve safety for the elderly and people with disabilities
- Convert standard crosswalk markings to high-visibility markings (ladder type) to ensure they are visible to both drivers and pedestrians

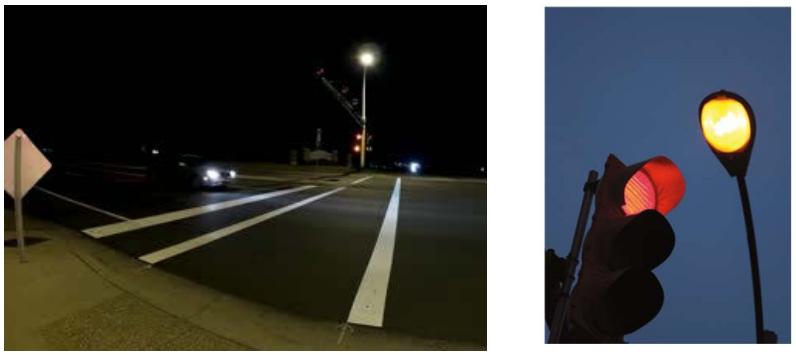
Accessible pedestrian signal



Crosswalk marking patterns

Source: Manual on Uniform Traffic Control Devices for Streets and Highways, U.S. Department of Transportation, Federal Highway Administration, 2009 Edition

- Add countdown timers to pedestrian signals – can reduce pedestrian-vehicle conflicts
- Provide intersection lighting—can increase safety and security for pedestrians, and make drivers aware of the intersection, helping to reduce nighttime crashes
- Continue exclusive pedestrian phasing because students and the elderly who use the intersection



Examples of providing lighting at intersections
Source: safety.fhwa.dot.gov

Estimated effectiveness of pedestrian safety improvements:[9]

- Approximately 37 percent reduction in vehicle/pedestrian crashes by installing high-visibility crosswalk with curb ramps
- Approximately 70 percent reduction in vehicle/pedestrian crashes by installing accessible pedestrian signals with countdown timer
- Between 42 and 59 percent reduction in vehicle/pedestrian crashes and approximately 38% reduction in nighttime crashes by providing intersection illumination
- Between 37 and 52 percent reduction in vehicle/pedestrian crashes by providing exclusive pedestrian phasing

Estimated cost to implement safety improvements for pedestrians is approximately $50,000 (including curb ramps, accessible pedestrian signals, illumination, countdown timers, and high-visibility crosswalks)

Improve Safety for Bicyclists

- Install bicycle detectors and bicycle-detector pavement markings at the intersections – can improve safety and reduce delays for bicyclists
- Provide shared-lane markings (sharrows) and bicycle signs on the segment of Washington Street north of the intersection – can provide awareness for bicyclists

[9] Crash Modification Factors Clearinghouse, US Department of Transportation Federal Highway Administration.

Bicycle detector pavement marking

Shared-lane markings (sharrows)

Source: https://ladotbikeblog.wordpress.com/bfs/ and https://beaconarts.org/

Improve Traffic Operations

Reconfigure Approach Lanes on Washington Street

- Reconfigure travel lanes at Washington Street approaches to streamline traffic operations
- Add left-turn-only lane at Washington Street southbound approach along with new signal head to improve safety and operations
- Reconfigure Washington Street northbound approach into two travel lanes (one left/through and one right/through) from approximately 150 feet to intersection. (Would require parking prohibition on Washington Street northbound for a short distance north of intersection to allow traffic on the two-lane approach to merge.)
- Install intersection lane-control signs and pavement markings to direct drivers through intersection, reduce confusion, and improve safety for left-turn drivers (e.g., left-lane-must-turn-left signs)

The results of the 2024 future year analysis presented in Table 3 show that reconfiguring approach lanes would improve traffic operations; the intersection would operate at LOS C during the AM peak hour and LOS D during the PM peak hour. Estimates of the efficacy of providing a left-turn lane on one major road approach suggest a 24-to-44 percent reduction in all crashes.[10] It would cost approximately $20,000 to implement the improvements, including lane stripping, new signal heads for left-turn movements, new signal timings, and signs.

Clarify signal control and improve driver awareness of the intersection

- Add traffic signal signs (left turn yield on green) above a symbolic green disc (R10-12) to the overhead signal head to clarify signal control for

[10] Ibid.

Washington Street left-turn drivers. Staff recommends a structural review of the signal equipment to ensure that the mast-arm would be able to accommodate additional wind loads.

- Install backplates on signal heads to improve visibility of traffic signals and signs. (Backplates enhance contrast between traffic signals and their surroundings for both day and night conditions; helpful to elderly drivers.)
- Install advance traffic control sign such as the signal ahead (W3-3) sign on Washington Street northbound to warn drivers and improve awareness of the intersection and signal control.

R10-12,
Traffic signal sign

W3-3
Advance traffic control sign

Signal head with a backplate

Source: Manual on Uniform Traffic Control Devices for Streets and Highways, U.S. Department of Transportation, Federal Highway Administration, 2009 Edition

Installing left-turn signs suggests a 9-to-29 percent reduction in left-turn related crashes;[11] installing advance traffic control signs suggests as much as a 35-percent decrease in crashes; installing backplates suggests as much as a 15-percent reduction in crashes. It would cost approximately $10,000 to implement the improvements.

8.2 Long-Term Improvement

Reconstruct Intersection

Because long-term improvements involve engineering and design work, they generally cost more than short-term improvements, and take from five-to-ten years to implement. A logical and cost-effective strategy for the improving the intersection would be a complete renovation (Figure 5), which would include the following:

- Improve traffic signals, upgrade equipment to MassDOT Highway Division standards for efficient traffic operations
- Add turn lanes and reconfigure intersection approach lanes to improve safety and traffic operations
- Install Opticom traffic receivers and strobes to handle emergency services
- Upgrade sidewalks to improve walking conditions
- Upgrade curb ramps to ADA standards to improve safety for people with disabilities and the elderly

[11] Ibid.

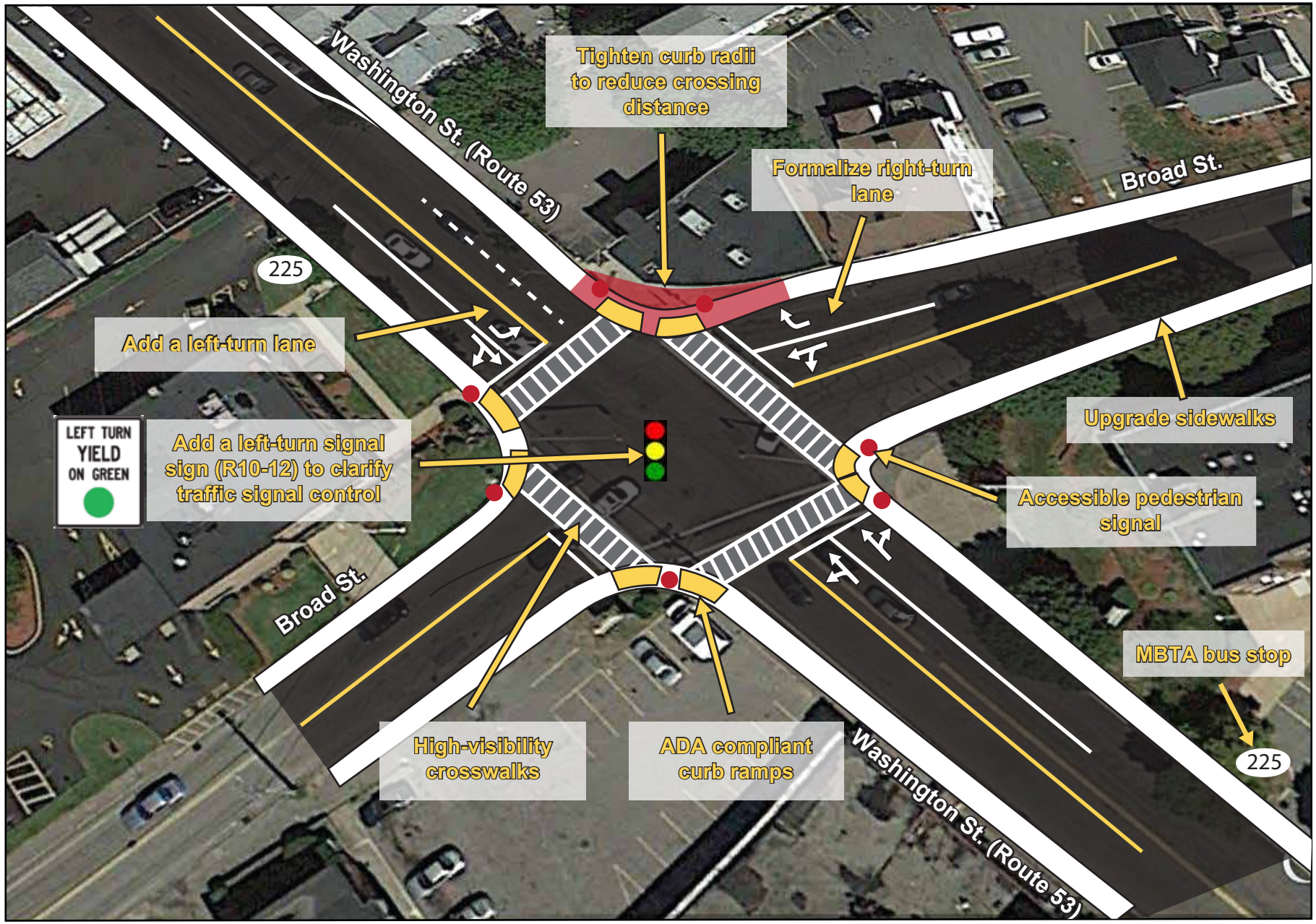


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FIGURE 5
Proposed Improvements
Washington Street and Broad Street Intersection

Safety and Operations Analyses at Selected Intersections–FFY 2014

- Convert standard crosswalk markings to high-visibility markings (ladder type) to ensure they are visible to both drivers and pedestrians
- Install accessible pedestrian signals to increase safety for the elderly and people with disabilities
- Install bicycle detection, signs, and markings to increase safety and awareness for bicyclists
- Reduce crossing distance on Broad Street westbound approach to lessen pedestrian-vehicle conflicts and crashes
- Provide transit amenities such as shelters and benches to protect transit riders from adverse weather conditions

The design year (2024) analysis results are presented in Table 3 above for a protected/permissive phase and a protected-only phase for Washington Street southbound left turns. The analyses show that traffic would operate at LOS D or better during the AM and PM peak travel periods for a protected/permissive left-turn phase. The analysis show that with a protected-only left phase, traffic would operate at LOS D during the AM peak travel period and LOS E during the PM peak travel periods. Reconstructing the intersection suggests as much as an 80-percent reduction in total crashes may be expected.[12] The reconstruction should cost approximately $1.5-to-2.0 million.

9 RECOMMENDATIONS AND DISCUSSION

The above analyses and evaluation indicates that the intersection of Washington Street and Broad Street needs enhancements to improve safety and mobility for motorists, pedestrians, and bicyclists MPO staff recommends a total reconstruction of the intersection because of the many safety and operations improvements needed there. Weymouth officials concur with this recommendation. However, implementing some of the low-cost short-term improvements, such as converting standard crosswalk markings to high-visibility markings, reconstructing curb ramps to ADA standards, and clarifying signal control would provide immediate benefits.

9.1 Next Steps

This study gives Weymouth an opportunity to look at the needs of the intersection and plan for design and engineering. Next steps would be to implement the preferred low-cost, short-term improvements. Implementation of the long-term, high-cost improvements hinge upon cooperation between MassDOT, Weymouth and the MPO to begin the project notification and review process, complete project initiation form, and start preliminary design and

[12] Crash Modification Factors Clearinghouse, U.S. Department of Transportation Federal Highway Administration.

engineering to place the project on the Transportation Improvement Program(TIP). MassDOT project development process is included in Appendix E. This study also supports the MPO's visions and goals, which include increasing transportation safety, maintaining the transportation system, and advancing mobility, access, and congestion reduction.

SA/sa

cc: Raj Kulen, Traffic Engineer, MassDOT Highway Division, District 6

APPENDIX A

Public Participation

Safety and Operations Analyses of Selected Intersection—FFY 2014
Washington Street (Route 53) and Broad Street Intersection

Weymouth Town Hall
75 Middle Street

Name	Affiliation	Email
Seth Asante	Boston Region MPO (CTPS)	sasante@ctps.org
Nick Bulens	Weymouth Planning	nbulens@weymouth.ma.us
Owen MacDonald	" "	omacdonald@weymouth.ma.us
Greg Hayford	Weymouth PD	ghayford@weymouth.MA.US
JIM CLARKE	PLANNING	JCLARKE@WEYMOUTH.MA.US
CHIP FONTAINE	TOWN ENGINEER	CFONTAINE " " " "
Keith Stark	Fire Chief	KSTARK@WEYmouth.Ma.US

Seth Asante

Subject:	Washington Street (Route 53)/ Broad Street: Proposed Intersection Improvements
Location:	Town Hall, 75 Middle St.; Room TBA
Start:	Tue 12/2/2014 11:00 AM
End:	Tue 12/2/2014 12:00 PM
Recurrence:	(none)
Meeting Status:	Accepted
Organizer:	omacdonald@weymouth.ma.us

When: Tuesday, December 02, 2014 11:00 AM-12:00 PM (GMT-05:00) Eastern Time (US & Canada).

Where: Town Hall, 75 Middle St.; Room TBA

Note: The GMT offset above does not reflect daylight saving time adjustments.

~~*~*~*~*~*~*~*~*~*

Meeting postponed due to schedule conflicts. Please respond to new date.

The Central Transportation Planning Staff (CTPS) has prepared a study of the subject intersection. Seth Asante, CTPS Project Manager, will present the findings.

Please respond.

Town of Weymouth, 75 Middle Street, Weymouth, MA, 02189
www.weymouth.ma.us

Seth Asante

From: OMacDonald@weymouth.ma.us
Sent: Thursday, December 04, 2014 3:17 PM
To: Seth Asante
Cc: JClarke@weymouth.ma.us; GHayford@weymouth.ma.us; cfontaine@weymouth.ma.us; KStark@weymouth.ma.us; NBulens@weymouth.ma.us
Subject: Weymouth: Rte. 53 (Washington St.)/ Broad St. Proposed Intersection Improvements

Seth,

Thank you again for the presentation.

Comments as I remember them (other recipients – please add as needed):

- **Planning Director**: Surprised at the difference between AM Peak Hour southbound through volume and PM Peak Hour Northbound through volume.
- **Police:** Would exclusive protected left turn for Washington Street southbound be superior to Protected – Permissive?
- **Fire:** Concerned that tightening the curb radius on the southeast corner (adjacent to Union Towers) would impede fire apparatus turning.
- **Engineering:** Parking would need to be prohibited on Washington Street northbound for a short distance north of the intersection to allow traffic on the 2-lane northbound intersection approach to merge.
- **Traffic Engineer**:
  - Please check the westbound 2 lane Broad St. approach as through – left and through – right (Base case is through – left and exclusive right).
  - Please send a copy of SYNCHRO outputs.

Owen
Town of Weymouth, Department of Planning and Community Development

Owen J. MacDonald, P.E., PTOE
Traffic Engineer
75 Middle Street
East Weymouth, MA 02189-1359
781-340-5015
OMacDonald@weymouth.ma.us

Seth Asante

From: OMacDonald@weymouth.ma.us
Sent: Wednesday, January 14, 2015 10:34 AM
To: Seth Asante
Cc: JClarke@weymouth.ma.us; GHayford@weymouth.ma.us; cfontaine@weymouth.ma.us; KStark@weymouth.ma.us; NBulens@weymouth.ma.us
Subject: RE: Washington Street and Broad Street Intersection Study

Seth,

Traffic Engineer Comments:

- Concur that intersection reconstruction, substantially as proposed, is the optimum means to address the existing deficiencies, and that higher visibility crosswalk markings and curb ramps rebuilt to standards, and possibly an advance warning sign facing northbound traffic, would be good short term solutions. We are concerned, however, that adding any wind load to old, Type I aluminum mast arms would not be feasible.
- Synchro:
  - Would prefer to see the more complete output, including the lane and phasing data, as well as the volume and timing data.
  - If alternatives have been analyzed (i.e.: protected vs. protected – permissive southbound left), would like to see all alternatives shown.

Other Town recipients – please add as appropriate.

Thank you.

Owen
Town of Weymouth, Department of Planning and Community Development

Owen J. MacDonald, P.E., PTOE
Traffic Engineer
75 Middle Street
East Weymouth, MA 02189-1359
781-340-5015
OMacDonald@weymouth.ma.us

APPENDIX B

Turning-Movement Count Data

Washington Street and Broad Street
Turning Movement Counts
05/20/14 AM and PM

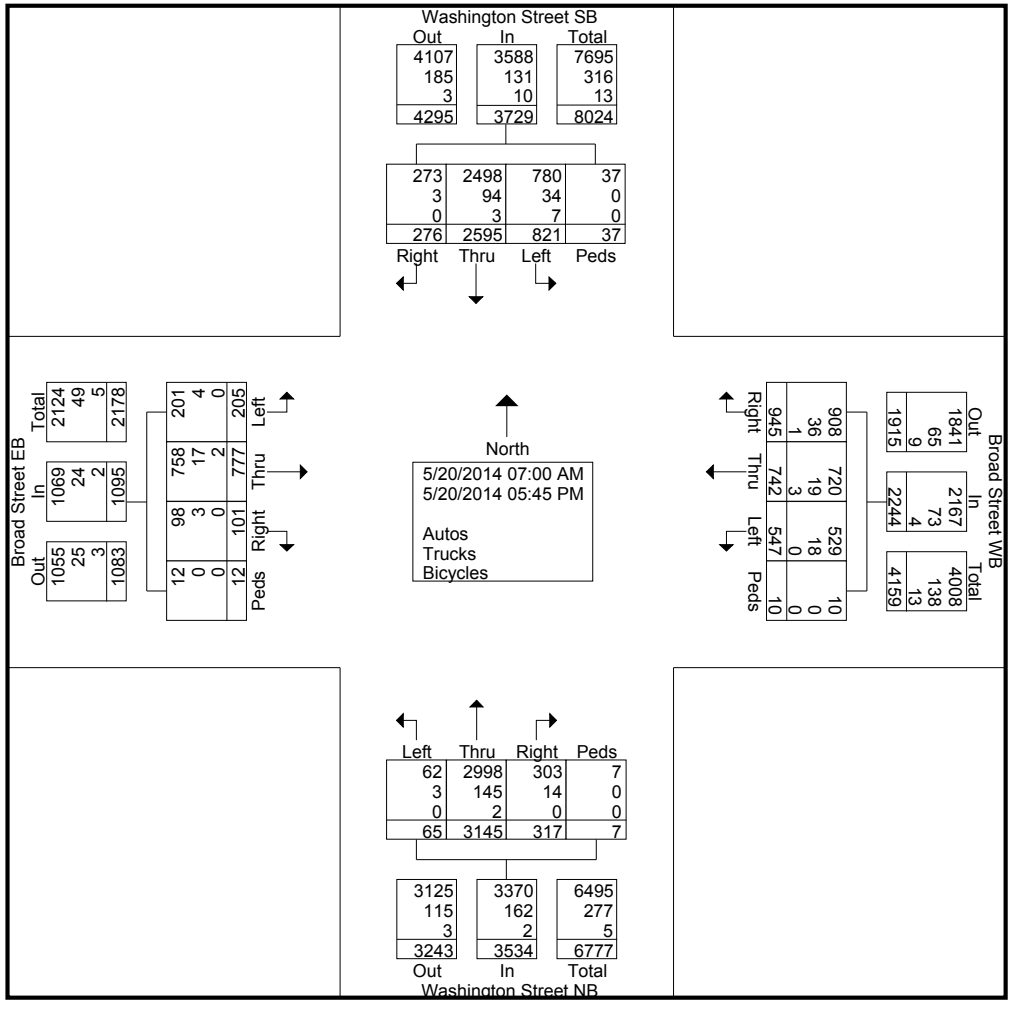
File Name : Washington_Broad AM+PM
Site Code : 05201411
Start Date : 5/20/2014
Page No : 1

Groups Printed- Autos - Trucks - Bicycles

	Washington Street SB From North					Broad Street WB From East					Washington Street NB From South					Broad Street EB From West					
Start Time	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Int. Total
07:00 AM	9	84	28	1	122	71	40	28	0	139	5	155	1	1	162	2	12	4	0	18	441
07:15 AM	21	54	23	0	98	58	46	23	0	127	7	193	4	0	204	11	32	15	0	58	487
07:30 AM	13	71	25	3	112	61	65	24	1	151	10	167	1	0	178	1	44	8	0	53	494
07:45 AM	6	76	33	1	116	67	42	27	1	137	9	164	3	0	176	0	31	9	0	40	469
Total	49	285	109	5	448	257	193	102	2	554	31	679	9	1	720	14	119	36	0	169	1891
08:00 AM	14	79	32	0	125	52	52	19	1	124	11	166	0	0	177	4	22	11	2	39	465
08:15 AM	9	90	21	1	121	54	31	22	1	108	9	164	0	0	173	1	14	12	1	28	430
08:30 AM	16	94	31	0	141	57	33	32	0	122	11	161	1	0	173	3	28	19	0	50	486
08:45 AM	11	96	30	2	139	48	36	23	0	107	13	158	4	1	176	4	34	12	1	51	473
Total	50	359	114	3	526	211	152	96	2	461	44	649	5	1	699	12	98	54	4	168	1854
*** BREAK ***																					
03:00 PM	18	129	52	0	199	26	34	29	0	89	28	120	6	0	154	9	31	9	1	50	492
03:15 PM	14	154	37	3	208	49	29	29	0	107	26	118	6	1	151	5	45	12	0	62	528
03:30 PM	14	135	40	1	190	46	31	33	1	111	29	109	2	0	140	4	41	10	0	55	496
03:45 PM	16	161	51	2	230	46	39	39	1	125	25	117	4	0	146	5	45	9	0	59	560
Total	62	579	180	6	827	167	133	130	2	432	108	464	18	1	591	23	162	40	1	226	2076
04:00 PM	9	162	58	1	230	37	37	30	0	104	16	171	2	0	189	6	56	9	1	72	595
04:15 PM	13	152	44	3	212	47	30	25	1	103	13	172	6	0	191	2	34	5	0	41	547
04:30 PM	18	153	47	7	225	32	29	28	0	89	12	149	4	0	165	8	46	10	2	66	545
04:45 PM	15	182	44	3	244	38	39	26	0	103	17	185	1	1	204	6	51	13	1	71	622
Total	55	649	193	14	911	154	135	109	1	399	58	677	13	1	749	22	187	37	4	250	2309
05:00 PM	13	183	55	1	252	37	36	33	1	107	19	176	3	1	199	7	61	14	0	82	640
05:15 PM	15	175	60	4	254	46	26	34	1	107	19	166	4	1	190	10	57	7	1	75	626
05:30 PM	19	182	53	2	256	36	37	23	0	96	19	173	2	1	195	6	51	8	1	66	613
05:45 PM	13	183	57	2	255	37	30	20	1	88	19	161	11	0	191	7	42	9	1	59	593
Total	60	723	225	9	1017	156	129	110	3	398	76	676	20	3	775	30	211	38	3	282	2472
Grand Total	276	2595	821	37	3729	945	742	547	10	2244	317	3145	65	7	3534	101	777	205	12	1095	10602
Apprch %	7.4	69.6	22	1		42.1	33.1	24.4	0.4		9	89	1.8	0.2		9.2	71	18.7	1.1		
Total %	2.6	24.5	7.7	0.3	35.2	8.9	7	5.2	0.1	21.2	3	29.7	0.6	0.1	33.3	1	7.3	1.9	0.1	10.3	
Autos	273	2498	780	37	3588	908	720	529	10	2167	303	2998	62	7	3370	98	758	201	12	1069	10194
% Autos	98.9	96.3	95	100	96.2	96.1	97	96.7	100	96.6	95.6	95.3	95.4	100	95.4	97	97.6	98	100	97.6	96.2
Trucks	3	94	34	0	131	36	19	18	0	73	14	145	3	0	162	3	17	4	0	24	390
% Trucks	1.1	3.6	4.1	0	3.5	3.8	2.6	3.3	0	3.3	4.4	4.6	4.6	0	4.6	3	2.2	2	0	2.2	3.7
Bicycles	0	3	7	0	10	1	3	0	0	4	0	2	0	0	2	0	2	0	0	2	18
% Bicycles	0	0.1	0.9	0	0.3	0.1	0.4	0	0	0.2	0	0.1	0	0	0.1	0	0.3	0	0	0.2	0.2

Washington Street and Broad Street
Turning Movement Counts
05/20/14 AM and PM

File Name : Washington_Broad AM+PM
Site Code : 05201411
Start Date : 5/20/2014
Page No : 2



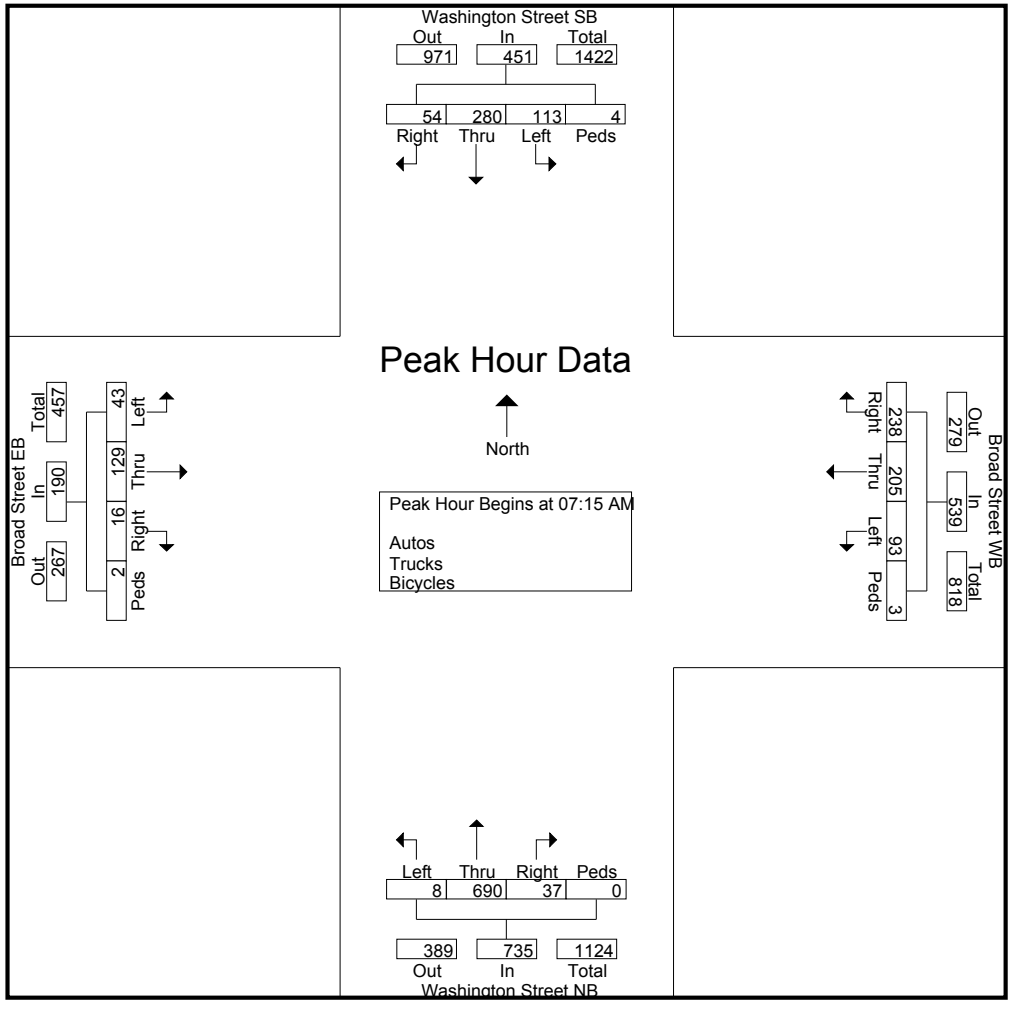
Washington Street and Broad Street
Turning Movement Counts
05/20/14 AM and PM

File Name : Washington_Broad AM+PM
Site Code : 05201411
Start Date : 5/20/2014

	Washington Street SB From North					Broad Street WB From East					Washington Street NB From South					Broad Street EB From West					
Start Time	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Int. Total
Peak Hour Analysis From 07:00 AM to 11:45 AM - Peak 1 of 1																					
Peak Hour for Entire Intersection Begins at 07:15 AM																					
07:15 AM	**21**	54	23	0	98	58	46	23	0	127	7	**193**	**4**	0	**204**	**11**	32	**15**	0	**58**	487
07:30 AM	13	71	25	**3**	112	61	**65**	24	**1**	**151**	10	167	1	0	178	1	**44**	8	0	53	**494**
07:45 AM	6	76	**33**	1	116	**67**	42	**27**	1	137	9	164	3	0	176	0	31	9	0	40	469
08:00 AM	14	**79**	32	0	**125**	52	52	19	1	124	**11**	166	0	0	177	4	22	11	**2**	39	465
Total Volume	54	280	113	4	451	238	205	93	3	539	37	690	8	0	735	16	129	43	2	190	1915
% App. Total	12	62.1	25.1	0.9		44.2	38	17.3	0.6		5	93.9	1.1	0		8.4	67.9	22.6	1.1		
PHF	.643	.886	.856	.333	.902	.888	.788	.861	.750	.892	.841	.894	.500	.000	.901	.364	.733	.717	.250	.819	.969

Washington Street and Broad Street
Turning Movement Counts
05/20/14 AM and PM

File Name : Washington_Broad AM+PM
Site Code : 05201411
Start Date : 5/20/2014
Page No : 5



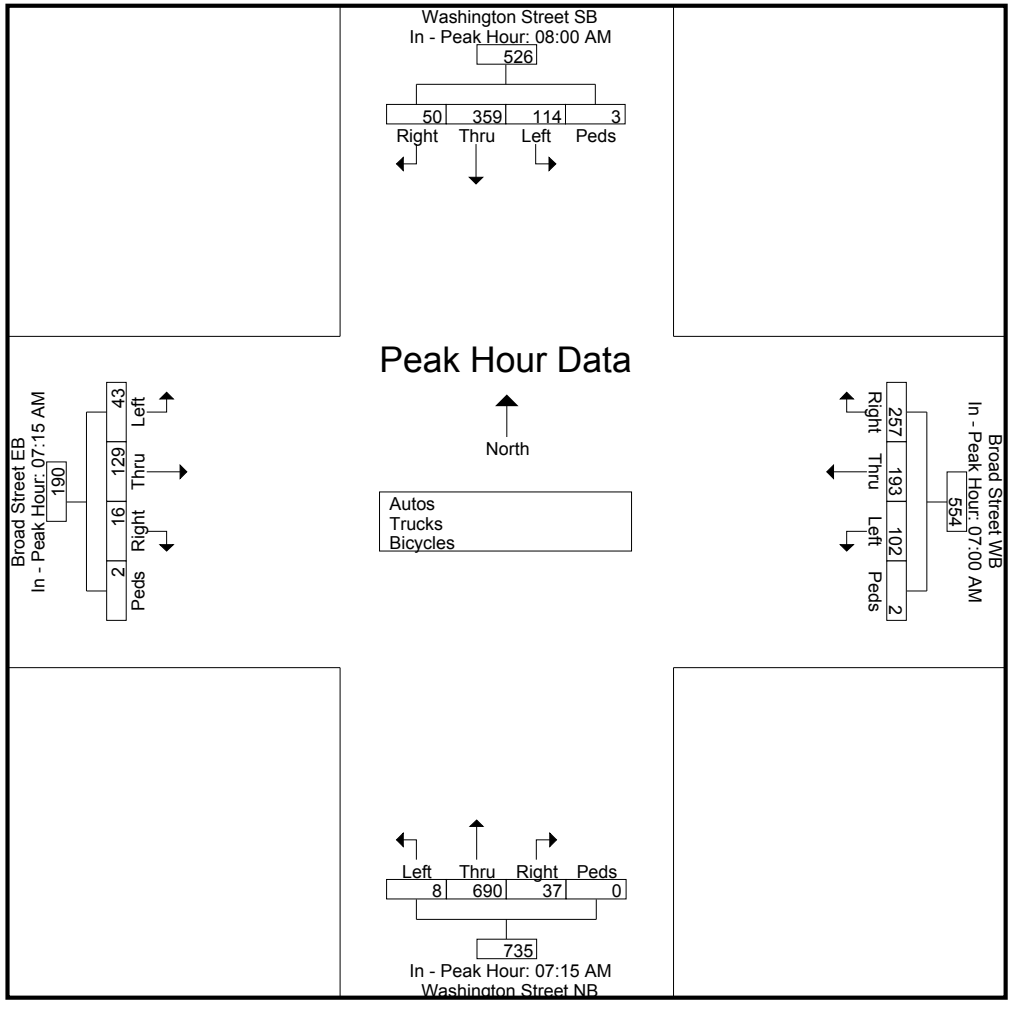
Washington Street and Broad Street
Turning Movement Counts
05/20/14 AM and PM

File Name : Washington_Broad AM+PM
Site Code : 05201411
Start Date : 5/20/2014
Page No : 7

	Washington Street SB From North					Broad Street WB From East					Washington Street NB From South					Broad Street EB From West					
Start Time	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Int. Total
Peak Hour Analysis From 07:00 AM to 11:45 AM - Peak 1 of 1																					
Peak Hour for Each Approach Begins at:																					
	08:00 AM					07:00 AM					07:15 AM					07:15 AM					
+0 mins.	14	79	**32**	0	125	**71**	40	**28**	0	139	7	**193**	**4**	0	**204**	**11**	32	**15**	0	**58**	
+15 mins.	9	90	21	1	121	58	46	23	0	127	10	167	1	0	178	1	**44**	8	0	53	
+30 mins.	**16**	94	31	0	**141**	61	**65**	24	**1**	**151**	9	164	3	0	176	0	31	9	0	40	
+45 mins.	11	**96**	30	**2**	139	67	42	27	1	137	**11**	166	0	0	177	4	22	11	**2**	39	
Total Volume	50	359	114	3	526	257	193	102	2	554	37	690	8	0	735	16	129	43	2	190	
% App. Total	9.5	68.3	21.7	0.6		46.4	34.8	18.4	0.4		5	93.9	1.1	0		8.4	67.9	22.6	1.1		
PHF	.781	.935	.891	.375	.933	.905	.742	.911	.500	.917	.841	.894	.500	.000	.901	.364	.733	.717	.250	.819	

Washington Street and Broad Street
Turning Movement Counts
05/20/14 AM and PM

File Name : Washington_Broad AM+PM
Site Code : 05201411
Start Date : 5/20/2014
Page No : 8



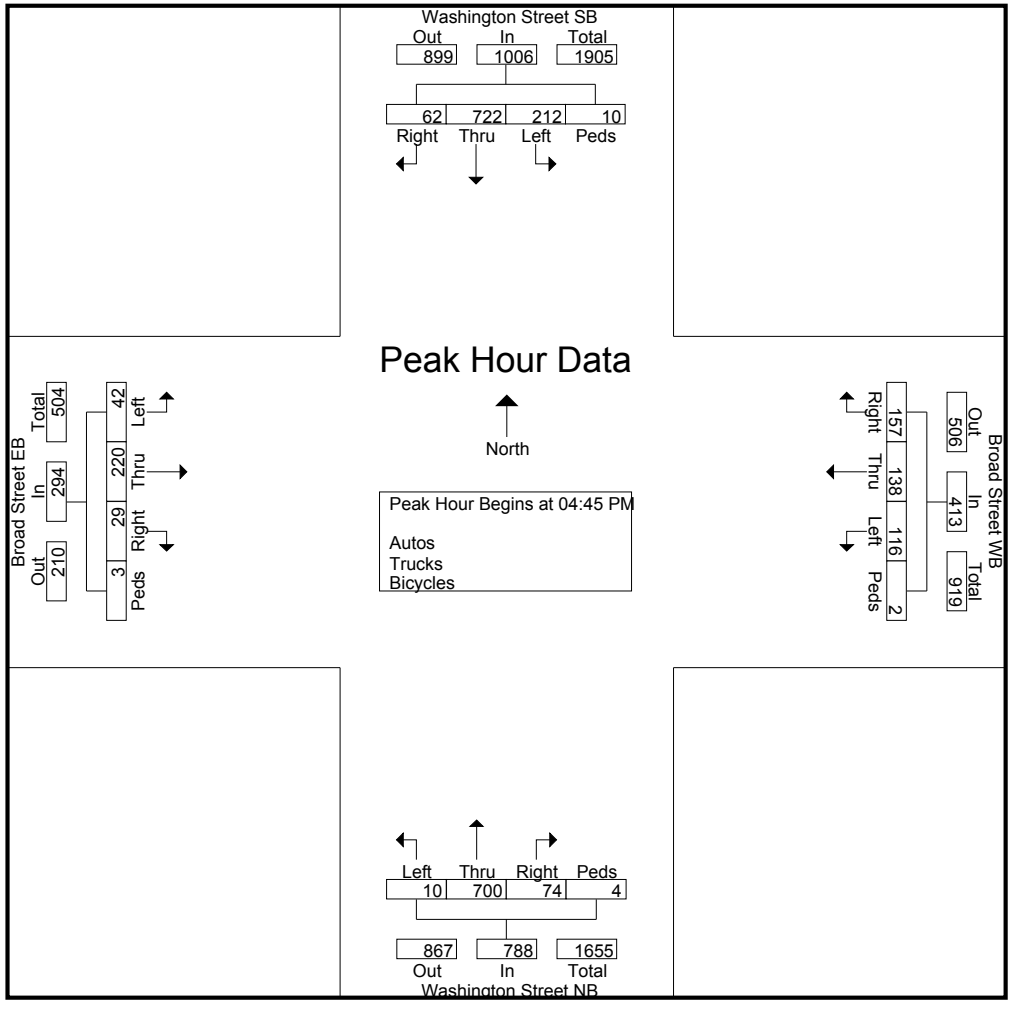
Washington Street and Broad Street
Turning Movement Counts
05/20/14 AM and PM

File Name : Washington_Broad AM+PM
Site Code : 05201411
Start Date : 5/20/2014

	Washington Street SB From North					Broad Street WB From East					Washington Street NB From South					Broad Street EB From West					
Start Time	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Int. Total
Peak Hour Analysis From 12:00 PM to 05:45 PM - Peak 1 of 1																					
Peak Hour for Entire Intersection Begins at 04:45 PM																					
04:45 PM	15	182	44	3	244	38	**39**	26	0	103	17	**185**	1	**1**	**204**	6	51	13	**1**	71	622
05:00 PM	13	**183**	55	1	252	37	36	33	**1**	**107**	**19**	176	3	1	199	7	**61**	**14**	0	**82**	**640**
05:15 PM	15	175	**60**	**4**	254	**46**	26	**34**	1	107	19	166	**4**	1	190	**10**	57	7	1	75	626
05:30 PM	**19**	182	53	2	**256**	36	37	23	0	96	19	173	2	1	195	6	51	8	1	66	613
Total Volume	62	722	212	10	1006	157	138	116	2	413	74	700	10	4	788	29	220	42	3	294	2501
% App. Total	6.2	71.8	21.1	1		38	33.4	28.1	0.5		9.4	88.8	1.3	0.5		9.9	74.8	14.3	1		
PHF	.816	.986	.883	.625	.982	.853	.885	.853	.500	.965	.974	.946	.625	1.00	.966	.725	.902	.750	.750	.896	.977

Washington Street and Broad Street
Turning Movement Counts
05/20/14 AM and PM

File Name : Washington_Broad AM+PM
Site Code : 05201411
Start Date : 5/20/2014
Page No : 11



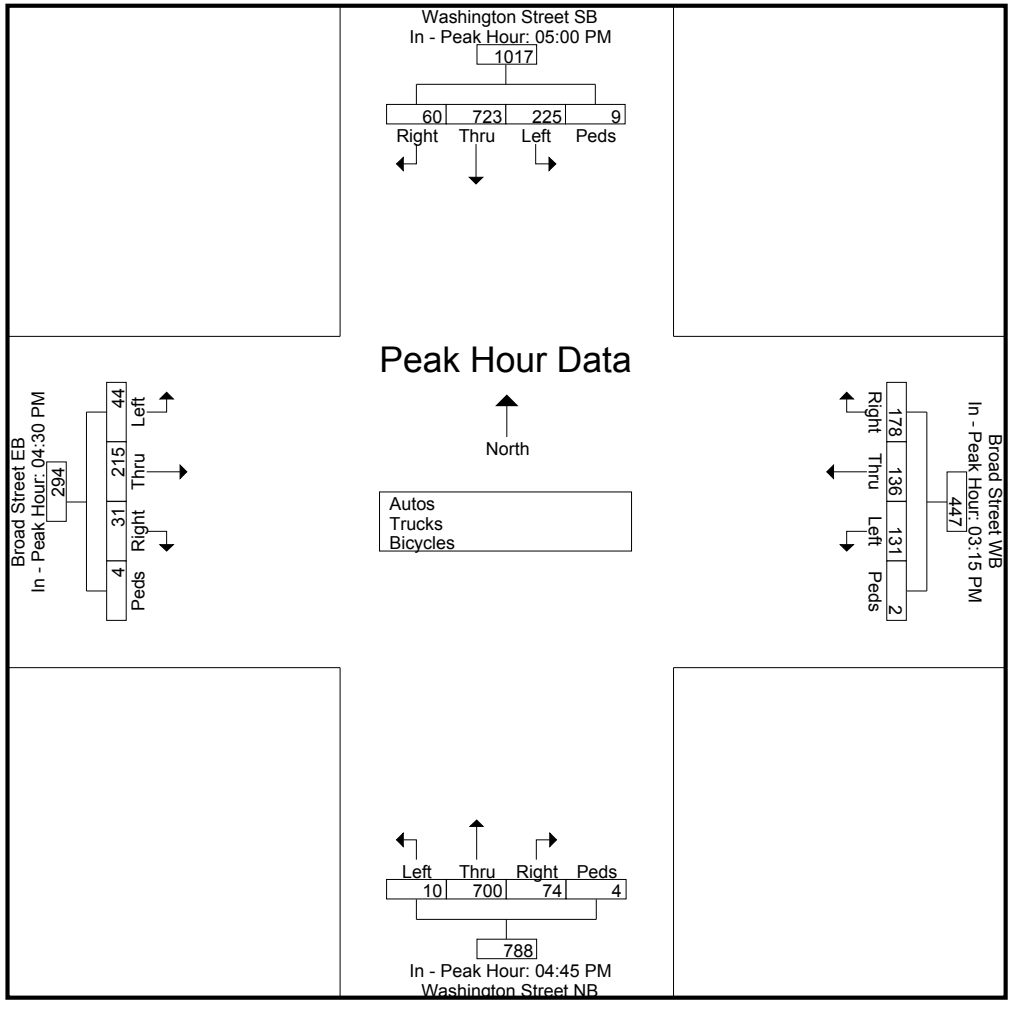
Washington Street and Broad Street
Turning Movement Counts
05/20/14 AM and PM

File Name : Washington_Broad AM+PM
Site Code : 05201411
Start Date : 5/20/2014

	Washington Street SB From North					Broad Street WB From East					Washington Street NB From South					Broad Street EB From West					
Start Time	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Right	Thru	Left	Peds	App. Total	Int. Total
Peak Hour Analysis From 12:00 PM to 05:45 PM - Peak 1 of 1																					
Peak Hour for Each Approach Begins at:																					
	05:00 PM					03:15 PM					04:45 PM					04:30 PM					
+0 mins.	13	**183**	55	1	252	**49**	29	29	0	107	17	**185**	1	**1**	**204**	8	46	10	**2**	66	
+15 mins.	15	175	**60**	**4**	254	46	31	33	**1**	111	**19**	176	3	1	199	6	51	13	1	71	
+30 mins.	**19**	182	53	2	**256**	46	**39**	**39**	1	**125**	19	166	**4**	1	190	7	**61**	**14**	0	**82**	
+45 mins.	13	183	57	2	255	37	37	30	0	104	19	173	2	1	195	**10**	57	7	1	75	
Total Volume	60	723	225	9	1017	178	136	131	2	447	74	700	10	4	788	31	215	44	4	294	
% App. Total	5.9	71.1	22.1	0.9		39.8	30.4	29.3	0.4		9.4	88.8	1.3	0.5		10.5	73.1	15	1.4		
PHF	.789	.988	.938	.563	.993	.908	.872	.840	.500	.894	.974	.946	.625	1.000	.966	.775	.881	.786	.500	.896	

Washington Street and Broad Street
Turning Movement Counts
05/20/14 AM and PM

File Name : Washington_Broad AM+PM
Site Code : 05201411
Start Date : 5/20/2014
Page No : 14



APPENDIX C

Crash Data

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Weymouth COUNT DATE : 4/10/2014

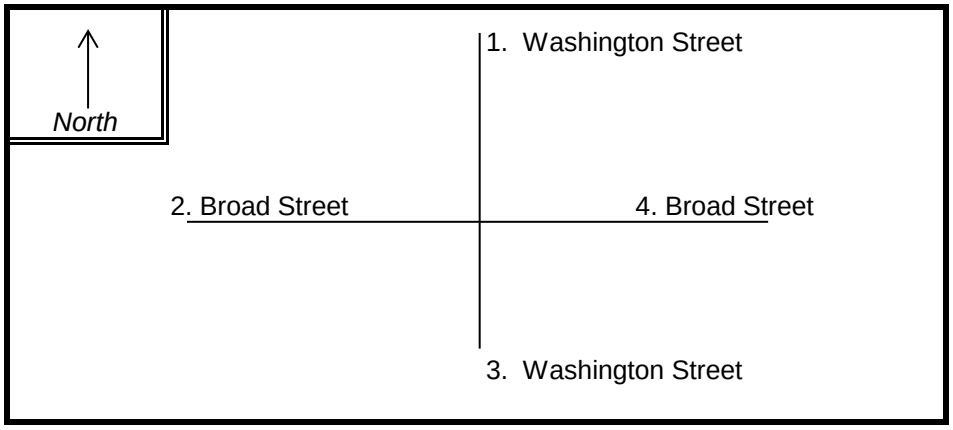
DISTRICT : 3 UNSIGNALIZED : SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : Washington Street (Route 53)

MINOR STREET(S) : Broad Street

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4		Total Peak Hourly Approach Volume
DIRECTION :	SB	EB	NB	WB		
PEAK HOURLY VOLUMES (AM/PM) :	1,004	295	785	420		**2,504**

" K " FACTOR : **0.090** INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **27,822**

TOTAL # OF CRASHES : 34 # OF YEARS : 4 AVERAGE # OF CRASHES PER YEAR (**A**) : **8.50**

CRASH RATE CALCULATION : **0.84** RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments : Calculated crash rate is higher than average crash rate for MassDOT D6 signalized intersec

Project Title & Date: Safety and Operations Analyses at Selected Intersections--FFY 2014

Crash Data
Washington Street and Broad Street Intersection

Crash ID	Crash Number	Crash Time	Crash Date1	Crash Time1	Crash_Severity	Manner of Collision	Vehicle Travel Directions	Road Surface Condition	Ambient Light	Weather Condition	At Roadway Intersection	Non Motorist Type	Bike Ped	VehicleAction Prior to Crash
1	2484271	9:12 PM	01-May-2009	9:12 PM	Non-fatal injury	Angle	V1:Southbound / V2:Eastbound	Dry	Dark - lighted roadway	Clear	WASHINGTON STREET Rte 53 S / BROAD STREE			V1: Travelling straight ahead / V2:Travelli
2	2484393	1:58 PM	12-May-2009	1:58 PM	Property damage only (no	Angle	V1:Southbound / V2:Northbound	Dry	Daylight	Clear	WASHINGTON STREET / BROAD STREET			V1: Travelling straight ahead / V2:Turning
3	2484427	1:20 PM	14-May-2009	1:20 PM	Non-fatal injury	Rear-end	V1:Northbound / V2:Northbound	Dry	Daylight	Clear				V1: Slowing or stopped in traffic / V2:Trav
4	2484423	7:28 PM	14-May-2009	7:28 PM	Property damage only (no	Angle	V1:Southbound / V2:Northbound	Wet	Dusk	Cloudy/Rain	WASHINGTON STREET Rte 53 / BROAD STREET			V1: Travelling straight ahead / V2:Turning
5	2504398	10:17 PM	23-Jun-2009	10:17 PM	Property damage only (no	Sideswipe, same directio	V1:Southbound / V2:Southbound	Wet	Dark - lighted roadway	Cloudy/Rain				V1: Travelling straight ahead / V2:Travelli
6	2541791	3:03 PM	10-Oct-2009	3:03 PM	Property damage only (no	Rear-end	V1:Northbound / V2:Northbound	Dry	Daylight	Clear	WASHINGTON STREET Rte 53 / BROAD STREET			V1: Travelling straight ahead / V2:Slowing
7	2541973	8:29 AM	20-Oct-2009	8:29 AM	Property damage only (no	Sideswipe, same directio	V1:Southbound / V2:Southbound	Dry	Daylight	Clear	BROAD STREET / WASHINGTON STREET			V1: Turning right / V2:Turning right
8	2546060	11:20 PM	27-Nov-2009	11:20 PM	Property damage only (no	Angle	V1:Northbound / V2:Eastbound	Wet	Dark - lighted roadway	Rain	WASHINGTON STREET / BROAD STREET			V1: Travelling straight ahead / V2:Turning
9	2551469	5:53 PM	08-Dec-2009	5:53 PM	Non-fatal injury	Angle	V1:Southbound / V2:Northbound	Dry	Dark - lighted roadway	Clear	WASHINGTON STREET / BROAD STREET			V1: Turning left / V2:Travelling straight ah
10	2591289	9:07 AM	04-Feb-2010	9:07 AM	Property damage only (no	Angle	V1:Westbound / V2:Northbound	Dry	Daylight	Clear	WASHINGTON STREET Rte 53 N / BROAD STREE			V1: Travelling straight ahead / V2:Travelli
11	2570952	8:59 AM	29-Jan-2010	8:59 AM	Property damage only (no	Angle	V1:Southbound / V2:Eastbound	Dry	Daylight	Clear	BROAD STREET / WASHINGTON STREET			V1: Travelling straight ahead / V2:Turning
12	2571003	8:38 PM	03-Jan-2010	8:38 PM	Property damage only (no	Angle	V1:Southbound / V2:Northbound	Snow	Dark - lighted roadway	Cloudy/Snow	WASHINGTON STREET / BROAD STREET			V1: Turning left / V2:Travelling straight ah
13	2571033	11:14 PM	07-Jan-2010	11:14 PM	Non-fatal injury	Angle	V1:Northbound / V2:Southbound	Dry	Dark - lighted roadway	Cloudy	BROAD STREET / WASHINGTON STREET			V1: Turning right / V2:Slowing or stopped
14	2571297	7:29 AM	21-Jan-2010	7:29 AM	Non-fatal injury	Rear-end	V1:Northbound / V2:Northbound	Dry	Daylight	Clear				V1: Parked / V2:Travelling straight ahead
15	2570842	6:38 PM	24-Jan-2010	6:38 PM	Non-fatal injury	Rear-end	V1:Southbound / V2:Southbound	Dry	Dark - lighted roadway	Clear	WASHINGTON STREET / BROAD STREET			V1: Slowing or stopped in traffic / V2:Slow
16	2590334	5:55 PM	07-Feb-2010	5:55 PM	Non-fatal injury	Rear-end	V1:Northbound / V2:Northbound	Dry	Dark - lighted roadway	Clear	WASHINGTON STREET / BROAD STREET			V1: Slowing or stopped in traffic / V2:Trav
17	2589594	5:54 PM	12-Feb-2010	5:54 PM	Property damage only (no	Angle	V1:Northbound / V2:Eastbound	Dry	Dark - lighted roadway	Clear	WASHINGTON ST Rte 53 / BROAD ST			V1: Turning right / V2:Travelling straight a
18	2614905	2:50 PM	09-Apr-2010	2:50 PM	Non-fatal injury	Sideswipe, opposite dire	V1:Southbound / V2:Southbound / V3	Wet	Daylight	Rain				V1: Slowing or stopped in traffic / V2:Slow
19	2622725	1:43 PM	18-Jun-2010	1:43 PM	Property damage only (no	Single vehicle crash	V1:Southbound / V2:Northbound	Dry	Daylight	Clear	WASHINGTON STREET / BROAD STREET			V1: Turning left / V2:Travelling straight ah
20	2642984	7:37 PM	01-Jul-2010	7:37 PM	Non-fatal injury	Rear-end	V1:Southbound / V2:Southbound	Dry	Daylight	Clear				V1: Slowing or stopped in traffic / V2:Slow
21	2643292	5:04 PM	03-Jul-2010	5:04 PM	Property damage only (no	Angle	V1:Eastbound / V2:Southbound	Dry	Daylight	Clear	WASHINGTON STREET / BROAD STREET			V1: Travelling straight ahead / V2:Travelli
22	2643012	11:33 PM	14-Jul-2010	11:33 PM	Property damage only (no	Angle	V1:Northbound / V2:Northbound	Dry	Dark - lighted roadway	Cloudy	WASHINGTON ST / BROAD ST			V1: Travelling straight ahead / V2:Slowing
23	2662756	8:08 PM	23-Sep-2010	8:08 PM	Property damage only (no	Sideswipe, same directio	V1:Southbound / V2:Southbound	Dry	Dark - lighted roadway	Cloudy	WASHINGTON ST / BROAD ST			V1: Slowing or stopped in traffic / V2:Trav
24	2715087	7:41 PM	03-Feb-2011	7:41 PM	Not Reported	Angle	V1:Not reported	Snow	Daylight	Snow				V1: Parked
25	2721716	8:03 AM	04-Mar-2011	8:03 AM	Property damage only (no	Rear-end	V1:Southbound / V2:Southbound	Dry	Daylight	Clear	WASHINGTON ST / BROAD ST			V1: Slowing or stopped in traffic / V2:Trav
26	2737631	12:28 PM	08-May-2011	12:28 PM	Property damage only (no	Rear-end	V1:Northbound / V2:Northbound	Dry	Daylight	Clear				V1: Travelling straight ahead / V2:Slowing
27	2739167	8:09 AM	06-Jun-2011	8:09 AM	Property damage only (no	Rear-end	V1:Northbound / V2:Northbound	Dry	Daylight	Clear	BROAD STREET / WASHINGTON STREET			V1: Slowing or stopped in traffic / V2:Trav
28	2759595	1:53 AM	09-Aug-2011	1:53 AM	Unknown	Single vehicle crash	V1:Northbound	Dry	Dark - lighted roadway	Clear	WASHINGTON STREET / BROAD STREET			V1: Other
29	2759437	6:04 PM	11-Aug-2011	6:04 PM	Property damage only (no	Sideswipe, same directio	V1:Southbound / V2:Southbound	Dry	Daylight	Clear	WASHINGTON ST Rte 53 S / BROAD ST			V1: Slowing or stopped in traffic / V2:Leav
30	2759473	4:09 PM	31-Aug-2011	4:09 PM	Property damage only (no	Angle	V1:Westbound / V2:Eastbound	Dry	Daylight	Clear	WASHINGTON ST / BROAD ST			V1: Turning left / V2:Travelling straight ah
31	2784389	5:21 PM	06-Sep-2011	5:21 PM	Property damage only (no	Angle	V1:Southbound / V2:Eastbound / V3:	Wet	Daylight	Cloudy/Rain	WASHINGTON STREET / BROAD STREET			V1: Travelling straight ahead / V2:Slowing
32	3293754	10:19 AM	10-Oct-2012	10:19 AM	Non-fatal injury	Angle	V1:Eastbound	Wet	Daylight	Cloudy/Rain	BROAD ST / WASHINGTON ST Rte 53	Pedalcyclist	cyc	V1: Travelling straight ahead
33	3293845	7:10 AM	19-Oct-2012	7:10 AM	Non-fatal injury	Single vehicle crash	V1:Eastbound	Wet	Daylight	Cloudy				V1: Turning left
34	3302129	2:36 PM	09-Nov-2012	2:36 PM	Property damage only (no	Single vehicle crash	V1:Westbound	Dry	Daylight	Clear		Pedestrian	ped	V1: Travelling straight ahead

Source: MassDOT Registry of Motor Vehicles

APPENDIX D

Level of Service Analysis

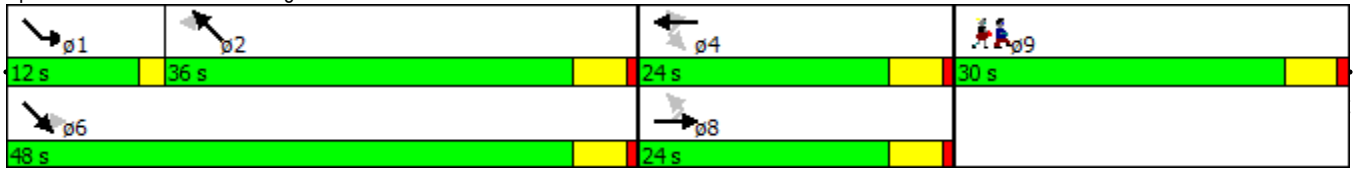
Washington Street and Broad Street 12/11/2014
AM Existing Conditions

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations												
Volume (vph)	45	130	20	95	205	240	115	280	55	10	690	40
Satd. Flow (prot)	0	1938	0	0	1821	1583	0	3292	0	0	3330	0
Flt Permitted		*0.605			*0.772			0.636			0.949	
Satd. Flow (perm)	0	1185	0	0	1428	1583	0	2122	0	0	3163	0
Satd. Flow (RTOR)												
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	2%	2%	2%	2%	3%	2%	0%	4%	2%	2%	4%	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	201	0	0	309	247	0	465	0	0	762	0
Turn Type	Perm	NA		Perm	NA	Perm	pm+pt	NA		Perm	NA	
Protected Phases		8			4		1	6			2	
Permitted Phases	8			4		4	6			2		
Total Split (s)	24.0	24.0		24.0	24.0	24.0	12.0	48.0		36.0	36.0	
Total Lost Time (s)		5.0			5.0	5.0		5.0			5.0	
Act Effct Green (s)		19.4			19.4	19.4		43.8			43.8	
Actuated g/C Ratio		0.25			0.25	0.25		0.56			0.56	
v/c Ratio		0.68			0.87	0.63		0.39			0.43	
Control Delay		42.8			55.9	36.9		12.8			12.6	
Queue Delay		0.0			0.0	0.0		0.0			0.0	
Total Delay		42.8			55.9	36.9		12.8			12.6	
LOS		D			E	D		B			B	
Approach Delay		42.8			47.5			12.8			12.6	
Approach LOS		D			D			B			B	
Queue Length 50th (ft)		79			129	95		50			84	
Queue Length 95th (ft)		#262			#404	#286		162			250	
Internal Link Dist (ft)		493			473			154			136	
Turn Bay Length (ft)						50						
Base Capacity (vph)		294			354	393		1194			1780	
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			0.87	0.63		0.39			0.43	

Intersection Summary

Cycle Length: 102
Actuated Cycle Length: 77.8
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 0.87
Intersection Signal Delay: 25.5 Intersection LOS: C
Intersection Capacity Utilization 76.7% ICU Level of Service D
Analysis Period (min) 15
* User Entered Value
\# 95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

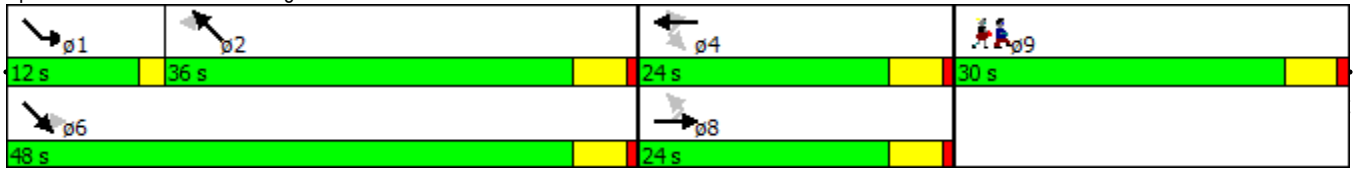
Splits and Phases: 1: Washington Street & Broad Street



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations												
Volume (vph)	45	220	30	120	140	160	215	725	65	10	700	75
Satd. Flow (prot)	0	1943	0	0	1810	1583	0	3317	0	0	3312	0
Flt Permitted		*0.781			*0.781			0.600			0.940	
Satd. Flow (perm)	0	1530	0	0	1447	1583	0	2012	0	0	3116	0
Satd. Flow (RTOR)												
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	2%	2%	2%	2%	3%	2%	0%	4%	2%	2%	4%	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	301	0	0	265	163	0	1025	0	0	801	0
Turn Type	Perm	NA		Perm	NA	Perm	pm+pt	NA		Perm	NA	
Protected Phases		8			4		1	6			2	
Permitted Phases	8			4		4	6			2		
Total Split (s)	24.0	24.0		24.0	24.0	24.0	12.0	48.0		36.0	36.0	
Total Lost Time (s)		5.0			5.0	5.0		5.0			5.0	
Act Effct Green (s)		19.5			19.5	19.5		44.2			44.2	
Actuated g/C Ratio		0.23			0.23	0.23		0.53			0.53	
v/c Ratio		0.84			0.79	0.44		0.96			0.49	
Control Delay		56.6			51.8	35.5		43.8			16.5	
Queue Delay		0.0			0.0	0.0		0.0			0.0	
Total Delay		56.6			51.8	35.5		43.8			16.5	
LOS		E			D	D		D			B	
Approach Delay		56.6			45.6			43.8			16.5	
Approach LOS		E			D			D			B	
Queue Length 50th (ft)		122			106	59		175			91	
Queue Length 95th (ft)		#378			#333	163		#551			267	
Internal Link Dist (ft)		446			477			154			136	
Turn Bay Length (ft)						50						
Base Capacity (vph)		357			337	369		1063			1646	
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		0.84			0.79	0.44		0.96			0.49	

Intersection Summary	
Cycle Length: 102	
Actuated Cycle Length: 83.6	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.96	
Intersection Signal Delay: 37.1	Intersection LOS: D
Intersection Capacity Utilization 96.9%	ICU Level of Service F
Analysis Period (min) 15	
* User Entered Value	
# 95th percentile volume exceeds capacity, queue may be longer.	
Queue shown is maximum after two cycles.	

Splits and Phases: 1: Washington Street & Broad Street

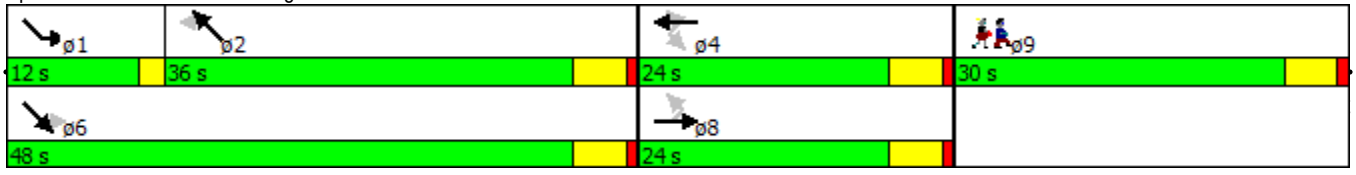


Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations												
Volume (vph)	45	130	20	95	205	240	115	280	55	10	690	40
Satd. Flow (prot)	0	1938	0	0	1821	1583	0	3292	0	0	3330	0
Flt Permitted		*0.605			*0.772			0.619			0.948	
Satd. Flow (perm)	0	1185	0	0	1428	1583	0	2065	0	0	3160	0
Satd. Flow (RTOR)												
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Growth Factor	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%
Heavy Vehicles (%)	2%	2%	2%	2%	3%	2%	0%	4%	2%	2%	4%	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	212	0	0	325	260	0	487	0	0	801	0
Turn Type	Perm	NA		Perm	NA	Perm	pm+pt	NA		Perm	NA	
Protected Phases		8			4		1	6			2	
Permitted Phases	8			4		4	6			2		
Total Split (s)	24.0	24.0		24.0	24.0	24.0	12.0	48.0		36.0	36.0	
Total Lost Time (s)		5.0			5.0	5.0		5.0			5.0	
Act Effct Green (s)		19.4			19.4	19.4		43.8			43.8	
Actuated g/C Ratio		0.25			0.25	0.25		0.56			0.56	
v/c Ratio		0.72			0.92	0.66		0.42			0.45	
Control Delay		45.1			63.0	38.3		13.3			12.9	
Queue Delay		0.0			0.0	0.0		0.0			0.0	
Total Delay		45.1			63.0	38.3		13.3			12.9	
LOS		D			E	D		B			B	
Approach Delay		45.1			52.0			13.3			12.9	
Approach LOS		D			D			B			B	
Queue Length 50th (ft)		84			138	102		53			90	
Queue Length 95th (ft)		#281			#428	#306		173			266	
Internal Link Dist (ft)		493			473			154			136	
Turn Bay Length (ft)						50						
Base Capacity (vph)		294			354	393		1162			1779	
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		0.72			0.92	0.66		0.42			0.45	

Intersection Summary

Cycle Length: 102
Actuated Cycle Length: 77.8
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 0.92
Intersection Signal Delay: 27.2 Intersection LOS: C
Intersection Capacity Utilization 79.7% ICU Level of Service D
Analysis Period (min) 15
* User Entered Value
\# 95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 1: Washington Street & Broad Street

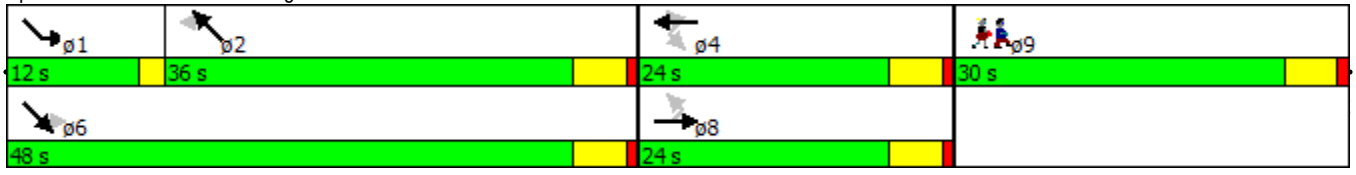


Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations												
Volume (vph)	45	220	30	120	140	160	215	725	65	10	700	75
Satd. Flow (prot)	0	1943	0	0	1810	1583	0	3317	0	0	3312	0
Flt Permitted		*0.781			*0.781			0.589			0.937	
Satd. Flow (perm)	0	1530	0	0	1447	1583	0	1975	0	0	3107	0
Satd. Flow (RTOR)												
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Growth Factor	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%
Heavy Vehicles (%)	2%	2%	2%	2%	3%	2%	0%	4%	2%	2%	4%	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	316	0	0	279	171	0	1077	0	0	841	0
Turn Type	Perm	NA		Perm	NA	Perm	pm+pt	NA		Perm	NA	
Protected Phases		8			4		1	6			2	
Permitted Phases	8			4		4	6			2		
Total Split (s)	24.0	24.0		24.0	24.0	24.0	12.0	48.0		36.0	36.0	
Total Lost Time (s)		5.0			5.0	5.0		5.0			5.0	
Act Effct Green (s)		19.5			19.5	19.5		44.2			44.2	
Actuated g/C Ratio		0.23			0.23	0.23		0.53			0.53	
v/c Ratio		0.89			0.83	0.46		1.03			0.51	
Control Delay		61.9			55.7	36.0		60.2			16.9	
Queue Delay		0.0			0.0	0.0		0.0			0.0	
Total Delay		61.9			55.7	36.0		60.2			16.9	
LOS		E			E	D		E			B	
Approach Delay		61.9			48.2			60.2			16.9	
Approach LOS		E			D			E			B	
Queue Length 50th (ft)		130			113	63		199			96	
Queue Length 95th (ft)		#402			#354	171		#594			285	
Internal Link Dist (ft)		446			477			154			136	
Turn Bay Length (ft)						50						
Base Capacity (vph)		357			337	369		1043			1642	
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		0.89			0.83	0.46		1.03			0.51	

Intersection Summary

Cycle Length: 102
Actuated Cycle Length: 83.6
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 1.03
Intersection Signal Delay: 44.9 Intersection LOS: D
Intersection Capacity Utilization 101.0% ICU Level of Service G
Analysis Period (min) 15
* User Entered Value
\# 95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 1: Washington Street & Broad Street



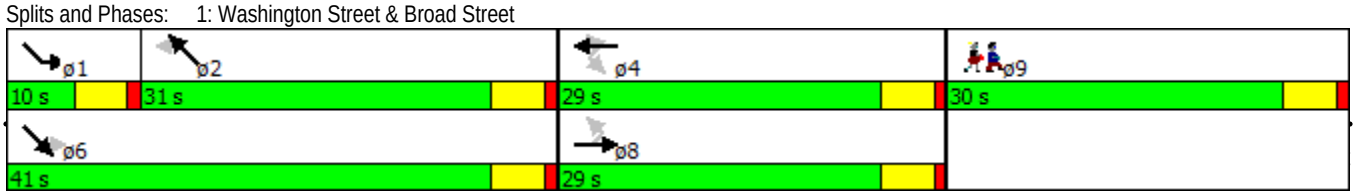
Washington Street and Broad Street 12/11/2014
2024 AM Retimed with Protected/Permissive Phase for Washington Street Southbound Left Turns

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations												
Volume (vph)	45	130	20	95	205	240	115	280	55	10	690	40
Satd. Flow (prot)	0	1938	0	0	1821	1583	1745	1727	0	0	3330	0
Flt Permitted		0.787			0.806		0.165				0.949	
Satd. Flow (perm)	0	1542	0	0	1491	1583	303	1727	0	0	3163	0
Satd. Flow (RTOR)												
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Growth Factor	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%
Heavy Vehicles (%)	2%	2%	2%	2%	3%	2%	0%	4%	2%	2%	4%	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	212	0	0	325	260	124	363	0	0	801	0
Turn Type	Perm	NA		Perm	NA	Perm	pm+pt	NA		Perm	NA	
Protected Phases		8			4		1	6			2	
Permitted Phases	8			4		4	6			2		
Total Split (s)	29.0	29.0		29.0	29.0	29.0	10.0	41.0		31.0	31.0	
Total Lost Time (s)		5.0			5.0	5.0	5.0	5.0			5.0	
Act Effct Green (s)		24.6			24.6	24.6	36.0	36.0			25.8	
Actuated g/C Ratio		0.33			0.33	0.33	0.48	0.48			0.34	
v/c Ratio		0.42			0.67	0.50	0.51	0.44			0.74	
Control Delay		25.9			33.1	27.5	24.0	17.5			28.9	
Queue Delay		0.0			0.0	0.0	0.0	0.0			0.0	
Total Delay		25.9			33.1	27.5	24.0	17.5			28.9	
LOS		C			C	C	C	B			C	
Approach Delay		25.9			30.6			19.1			28.9	
Approach LOS		C			C			B			C	
Queue Length 50th (ft)		68			116	86	26	89			148	
Queue Length 95th (ft)		196			#366	241	#118	280			#393	
Internal Link Dist (ft)		686			473			154			136	
Turn Bay Length (ft)						50						
Base Capacity (vph)		502			486	516	242	844			1117	
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		0.42			0.67	0.50	0.51	0.43			0.72	

Intersection Summary

Cycle Length: 100
Actuated Cycle Length: 75.3
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 0.74
Intersection Signal Delay: 26.8 Intersection LOS: C
Intersection Capacity Utilization 85.2% 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: 1: Washington Street & Broad Street



Washington Street and Broad Street 2/18/2015
2024 PM Retimed with Protected/Permissive Phase for Washington Street Southbound Left Turns

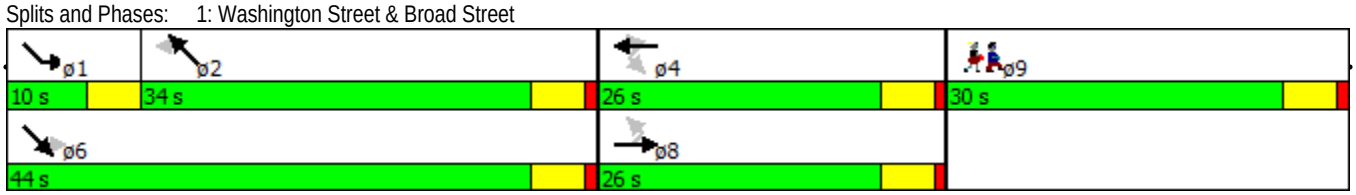
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations												
Volume (vph)	45	220	30	120	140	160	215	725	65	10	700	75
Satd. Flow (prot)	0	1943	0	0	1810	1583	1745	1748	0	0	3312	0
Flt Permitted		0.823			*0.630		0.182	*0.630			0.877	
Satd. Flow (perm)	0	1612	0	0	1167	1583	334	1101	0	0	2908	0
Satd. Flow (RTOR)												
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Growth Factor	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%
Heavy Vehicles (%)	2%	2%	2%	2%	3%	2%	0%	4%	2%	2%	4%	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%	
Adj. Flow (vph)	48	236	32	129	150	171	230	777	70	11	750	80
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	316	0	0	279	171	230	847	0	0	841	0
Turn Type	Perm	NA		Perm	NA	Perm	pm+pt	NA		Perm	NA	
Protected Phases		8			4		1	6			2	
Permitted Phases	8			4		4	6			2		
Total Split (s)	26.0	26.0		26.0	26.0	26.0	10.0	44.0		34.0	34.0	
Total Lost Time (s)		5.0			5.0	5.0	4.0	5.0			5.0	
Act Effct Green (s)		21.4			21.4	21.4	40.8	39.8			29.6	
Actuated g/C Ratio		0.28			0.28	0.28	0.54	0.52			0.39	
v/c Ratio		0.70			0.85	0.38	0.79	0.93			0.74	
Control Delay		36.6			52.8	27.7	35.4	36.7			27.2	
Queue Delay		0.0			0.0	0.0	0.0	0.0			0.0	
Total Delay		36.6			52.8	27.7	35.4	36.7			27.2	
LOS		D			D	C	D	D			C	
Approach Delay		36.6			43.2			36.4			27.2	
Approach LOS		D			D			D			C	
Queue Length 50th (ft)		117			109	57	44	286			151	
Queue Length 95th (ft)		#364			#370	165	#256	#907			#415	
Internal Link Dist (ft)		436			474			165			126	
Turn Bay Length (ft)						50						
Base Capacity (vph)		454			329	446	292	915			1132	
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		0.70			0.85	0.38	0.79	0.93			0.74	

Intersection Summary	
Cycle Length: 100	
Actuated Cycle Length: 76	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.93	
Intersection Signal Delay: 34.7	Intersection LOS: C
Intersection Capacity Utilization 115.4%	ICU Level of Service H
Analysis Period (min) 15	

* User Entered Value

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

Splits and Phases: 1: Washington Street & Broad Street



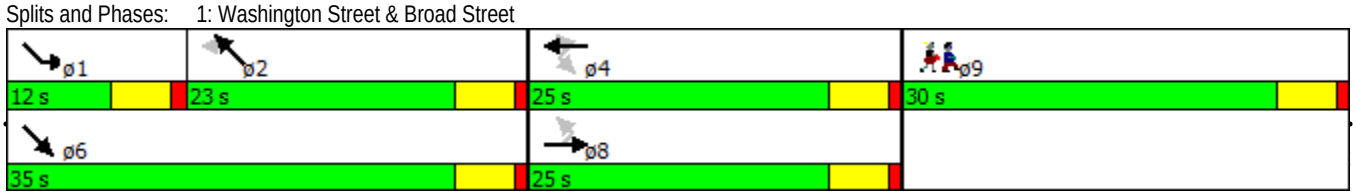
Washington Street and Broad Street 2/17/2015
2024 Build AM Retimed with Protected-Only Phase for Washington Street Southbound Left Turns

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations												
Volume (vph)	45	130	20	95	205	240	115	280	55	10	690	40
Satd. Flow (prot)	0	1938	0	0	1821	1583	1745	1727	0	0	3330	0
Flt Permitted		0.776			0.806		0.950				0.948	
Satd. Flow (perm)	0	1520	0	0	1491	1583	1745	1727	0	0	3160	0
Satd. Flow (RTOR)												
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Growth Factor	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%
Heavy Vehicles (%)	2%	2%	2%	2%	3%	2%	0%	4%	2%	2%	4%	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	212	0	0	325	260	124	363	0	0	801	0
Turn Type	Perm	NA		Perm	NA	Perm	Prot	NA		Perm	NA	
Protected Phases		8			4		1	6			2	
Permitted Phases	8			4		4				2		
Total Split (s)	25.0	25.0		25.0	25.0	25.0	12.0	35.0		23.0	23.0	
Total Lost Time (s)		5.0			5.0	5.0	5.0	5.0			5.0	
Act Effct Green (s)		20.5			20.5	20.5	7.2	30.8			18.5	
Actuated g/C Ratio		0.31			0.31	0.31	0.11	0.47			0.28	
v/c Ratio		0.45			0.70	0.53	0.66	0.45			0.91	
Control Delay		24.7			33.0	26.6	49.8	16.8			40.6	
Queue Delay		0.0			0.0	0.0	0.0	0.0			0.0	
Total Delay		24.7			33.0	26.6	49.8	16.8			40.6	
LOS		C			C	C	D	B			D	
Approach Delay		24.7			30.1			25.2			40.6	
Approach LOS		C			C			C			D	
Queue Length 50th (ft)		58			98	73	44	77			141	
Queue Length 95th (ft)		185			#354	#250	#177	267			#421	
Internal Link Dist (ft)		686			473			154			136	
Turn Bay Length (ft)						50						
Base Capacity (vph)		472			464	492	189	805			885	
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		0.45			0.70	0.53	0.66	0.45			0.91	

Intersection Summary

Cycle Length: 90
Actuated Cycle Length: 66
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 0.91
Intersection Signal Delay: 32.5 Intersection LOS: C
Intersection Capacity Utilization 85.2% 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: 1: Washington Street & Broad Street



Washington Street and Broad Street 2/18/2015
2024 PM Retimed with Protected-Only Phase for Washington Street Southbound Left Turns

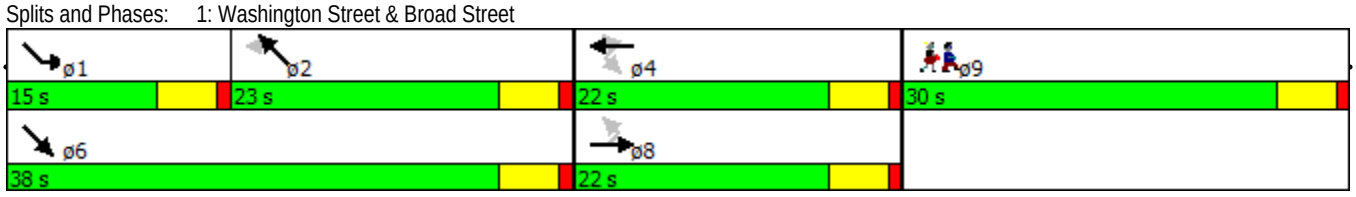
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations												
Volume (vph)	45	220	30	120	140	160	215	725	65	10	700	75
Satd. Flow (prot)	0	1943	0	0	1810	1583	1745	1748	0	0	3312	0
Flt Permitted		0.804			*0.630		0.950	*0.630			0.864	
Satd. Flow (perm)	0	1575	0	0	1167	1583	1745	1101	0	0	2864	0
Satd. Flow (RTOR)												
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Growth Factor	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%	105%
Heavy Vehicles (%)	2%	2%	2%	2%	3%	2%	0%	4%	2%	2%	4%	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%	
Adj. Flow (vph)	48	236	32	129	150	171	230	777	70	11	750	80
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	316	0	0	279	171	230	847	0	0	841	0
Turn Type	Perm	NA		Perm	NA	Perm	Prot	NA		Perm	NA	
Protected Phases		8			4		1	6			2	
Permitted Phases	8			4		4				2		
Total Split (s)	22.0	22.0		22.0	22.0	22.0	15.0	38.0		23.0	23.0	
Total Lost Time (s)		5.0			5.0	5.0	5.0	5.0			5.0	
Act Effct Green (s)		17.5			17.5	17.5	10.3	33.9			18.5	
Actuated g/C Ratio		0.27			0.27	0.27	0.16	0.51			0.28	
v/c Ratio		0.76			0.91	0.41	0.85	0.94			1.05	
Control Delay		39.0			60.8	26.4	58.8	38.5			72.2	
Queue Delay		0.0			0.0	0.0	0.0	0.0			0.0	
Total Delay		39.0			60.8	26.4	58.8	38.5			72.2	
LOS		D			E	C	E	D			E	
Approach Delay		39.0			47.8			42.9			72.2	
Approach LOS		D			D			D			E	
Queue Length 50th (ft)		102			94	49	81	240			156	
Queue Length 95th (ft)		#361			#356	156	#301	#854			#467	
Internal Link Dist (ft)		436			474			165			126	
Turn Bay Length (ft)						50						
Base Capacity (vph)		416			308	418	271	897			802	
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		0.76			0.91	0.41	0.85	0.94			1.05	

Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 66	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 1.05	
Intersection Signal Delay: 52.4	Intersection LOS: D
Intersection Capacity Utilization 115.4%	ICU Level of Service H
Analysis Period (min) 15	

* User Entered Value

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

Splits and Phases: 1: Washington Street & Broad Street



APPENDIX E

MassDOT Highway Division
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. Table 8 gives the schematic timetable of the project development process.

Project Development Schematic Timetable

Step	Schedule Influence	Typical Duration
Step I: Problem/Need/Opportunity Identification The proponent completes a PNF. This form is reviewed by the MassDOT district office, which guides the proponent in subsequent steps of the process.	The PNF may be prepared quickly by the proponent to include any readily available supporting data. The district office will return comments to the proponent within one month of receiving the PNF.	One-to-three months
Step II: Planning Project planning can range from agreeing on a clear solution to a detailed analysis of alternatives and their impacts.	For some projects, no planning beyond preparation of the PNF is required. Some projects require a planning study centered on specific issues associated with a proposed solution or a narrow family of alternatives. Complex projects likely would require a detailed alternatives analysis.	Project Planning Report: three-to-24+ months
Step III: Project Initiation The proponent prepares and submits a PIF and a TEC form. The MPO and MassDOT district office informally review the PIF and TEC; and the PRC formally reviews them.	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, is included with the PIF and TEC. The schedule is determined by PRC staff (depending on project complexity) and meeting schedule.	One-to-four 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 permit applications. Any right-of-way needed for the project is identified and the acquisition process begins.	The schedule depends upon the size of the project and the complexity of the design, permitting, and right-of-way issues. The MassDOT district and appropriate sections complete the design review.	Three- to-48+ months
Step V: Programming The MPO considers the project in terms of its regional priorities and determines whether to include the project in the draft TIP, which is made available for public comment, and 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 possible that the MPO will not include a project in its draft TIP based on its review and approval procedures.	Three-to-12+ months

Step	Schedule Influence	Typical Duration
Step VI: Procurement The project is advertised for construction and a contract is awarded.	Administration of competing projects can influence the advertising schedule.	One-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 of this step is entirely dependent upon project complexity and phasing.	Three-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 of this step is dependent upon the proponent's approach and any required follow-up.	One month

Source: MassDOT Highway Division Project Development and Design Guide.