BOSTON REGION METROPOLITAN PLANNING ORGANIZATION

MEMORANDUM

DATE   **January 5, 2012**

TO   **Boston Region Metropolitan Planning Organization**

FROM   **Mark S. Abbott, P.E.**
Steven Andrews

RE   **MBTA Bus Route 1 Transit Signal Priority Study: Task 2 –
TSP and Other Improvements**

The purpose of this MPO-funded study is to evaluate potential transit signal priority (TSP) strategies, including queue jumps, along MBTA bus Route 1, a Key Route. The Task 1 memorandum evaluated the existing conditions at selected signalized intersections along the route. The present memorandum, documenting Task 2 of the study, identifies the intersections most likely to benefit from TSP improvements, develops three improvement alternatives, estimates what the impacts of each alternative would be at each intersection, and makes recommendations on which improvements the MBTA should move forward with to design and implementation.

The analysis in this memorandum demonstrates which intersections along the bus route could feasibly support TSP strategies, including green extension, early green, and queue-jump lanes without significantly impacting general traffic, bicyclists and pedestrians, parking, and side streets. The analysis of the impacts of potential improvements at the intersections includes estimation of delays, travel time for general traffic, queues, bus stop locations, pedestrian movement, parking, and bus travel time.

The Task 1 memorandum, along with the evaluation of existing conditions, provides more background information relevant to this study, describes the existing bus route, and explains how the particular locations to be analyzed were selected.

Nineteen intersections, listed below, were selected to be analyzed for their suitability for TSP or other improvements (in both the inbound and outbound route directions). Many of these intersections are located within roadway segments where the average speeds of the buses are below 10 mph.

- Washington Street and Melnea Cass Boulevard (Boston)
- Melnea Cass Boulevard and Harrison Avenue (Boston)
- Melnea Cass Boulevard and Albany Street (Boston)
- Massachusetts Avenue and Harrison Street (Boston)
- Massachusetts Avenue and Shawmut Avenue (Boston)
- Massachusetts Avenue and Tremont Street (Boston)

- Massachusetts Avenue and St. Botolph Street (Boston)
- Massachusetts Avenue and Belvidere Street (Boston)
- Massachusetts Avenue and Marlborough Street (Boston)
- Massachusetts Avenue and Beacon Street (Boston)
- Massachusetts Avenue and Memorial Drive (Boston)
- Massachusetts Avenue and Pedestrian Signal at MIT (Cambridge)
- Massachusetts Avenue and Vassar Street (Cambridge)
- Massachusetts Avenue and Albany Street (Cambridge)
- Massachusetts Avenue and Brookline Street/Douglas Street (Cambridge)
- Massachusetts Avenue and Essex Street (Cambridge)
- Massachusetts Avenue and Prospect Street (Cambridge)
- Massachusetts Avenue and Pleasant Street/Inman Street (Cambridge)
- Massachusetts Avenue and Hancock Street (Cambridge)

TRAFFIC OPERATIONS ANALYSIS: SUMMARY OF RESULTS FOR EXISTING CONDITIONS AND THREE ALTERNATIVES

Traffic operations at the selected intersections were analyzed using Synchro 7,[1] data provided by the Boston Transportation Department and Cambridge's Parking and Transportation Department, and data collected by MPO staff in the field. Analysis was conducted for the existing intersection conditions and for three alternatives, described below. A summary of the analysis results can be found in Appendix A in Tables A-1 and A-2 for the morning and evening peak hours, respectively. For each intersection, that intersection's individual peak hour was used for the analysis. Tables A-1 and A-2 also show analysis results for other intersections along the route. These other intersections were analyzed as part of determining if signal timing or phasing improvements could help reduce intersection delays for the Route 1 buses.

The following are descriptions of the scenarios examined. The three improvement scenarios assume implementation of the bus stop consolidation recommendations made by the 2009 MBTA Key Routes Initiative.

- **Existing Conditions** – Existing signal timings and phasings were used to evaluate the current operations of the intersection and provide a basis for comparing the alternatives.
- **Alternative 1 (Optimized Intersection Timings)** – Signal timings and phasings were optimized and checked to evaluate whether this would improve bus service by decreasing intersection delays. Some intersections timings are already optimal or very close to optimal. In these cases, no recommendations are made.
- **Alternative 2 (Added Green Time on Bus Approaches)** – Signal timings were adjusted to favor the Route 1 bus approaches to decrease bus delays. This alternative had various levels of impact on the operations of the non-bus approaches, depending on the amount of additional green time allocated to the bus approaches' signal phases. Typically, several seconds were added to the bus approach phases. This time was taken away from the side street phases and other underutilized phases.

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[1] SYNCHRO 7 – Trafficware traffic analysis software, version 7.

- **Alternative 3 (Transit Signal Priority and Queue Jumps)** – Early green and green extensions were simulated to evaluate the benefits for the Route 1 bus. Queue jumps were also analyzed as part of this alternative.

Existing Conditions

The results of the existing conditions analysis indicate that during the morning peak hour there is one intersection operating at level of service (LOS) D and none operating at LOS F. During the evening peak hour, four intersections operate at LOS E and two at LOS F. A full description of the results of the existing condition analysis can be found in the Task 1 memorandum.

Alternative 1: Optimized Intersection Timings

During the analysis of Alternative 1, it was found that for many intersections neither the average delay per vehicle or the overall LOS changed significantly, if at all. This indicates that the existing timings and phasings are optimal or very nearly optimal. However, it was found that at several intersections, improved signal timings could improve operations by one LOS category, and that at a few intersections, permitting left turns where they are currently prohibited helps improve the LOS.

Alternative 2: Added Green Time on Bus Approaches

This alternative, improving signal timings for the bus approaches to the intersection, most consistently reduced delay for buses. However, this alternative frequently added delays to the side street approach lanes, because the added green time for the bus approaches was taken from these lanes' phases.

In some cases no improvements could be made without cutting into the pedestrian crossing time. This was the case with the pedestrian signals in Cambridge (at 77 Massachusetts Avenue, Massachusetts Avenue at Essex Street, and Massachusetts Avenue at Hancock Street) and two intersections in Boston.

Alternative 2 was not beneficial at the intersection of Massachusetts Avenue at Albany Street in Boston. Outbound buses make a left turn from Albany Street to Massachusetts Avenue. In the inbound direction, buses make a right turn from Massachusetts Avenue to Albany Street. Retiming the signals to favor one bus approach or the other does not significantly benefit bus operations at the intersection, since the green time given to either approach is taken away from the other one.

Alternative 3: Transit Signal Priority and Queue Jumps

At most of the intersections that were analyzed simulating TSP, those improvements also decreased delay for the buses. However, as in Alternative 2, there were frequently impacts to the side street traffic as well.

TSP also brought about minor improvements to queuing for most of the bus approaches. Figure 1 presents the various amounts of change in vehicle queue length that occurred and the number of approaches that experienced each amount. For 10% of the bus approaches, queue length remained unchanged with TSP; for 22%, it decreased by two or fewer vehicles; and for 22%, it increased by two or fewer vehicles. Under TSP, 43% of the non-bus approaches had no queue changes due to TSP, 17% had a two-or-fewer-vehicle reduction, and 33% had a two-or-fewer-vehicle increase.

RECOMMENDED IMPROVEMENTS AT SELECTED INTERSECTIONS

Table 1 lists the improvements that are recommended. These are the improvements which this study's analysis showed to provide the greatest benefit for bus route operations; their impacts are discussed in the following two sections. In some cases, the improvement is for both inbound and outbound bus routes; in others, it is only for one direction.

TABLE 1
Recommended Improvements

Intersection	Municipality	Recommended Improvement
Massachusetts Avenue at Brookline Street	Cambridge	• TSP (IB/OB)
Massachusetts Avenue at Beacon Street	Boston	• TSP (IB/OB), afternoon peak period only
Massachusetts Avenue at Newbury Street	Boston	• TSP (IB/OB) • Add queue jump lane (OB), afternoon peak period only

## IMPACTS OF THE RECOMMENDED IMPROVEMENTS ON BUS SERVICE

Bus Delays

Implementing TSP or modifying signal timings for intersections along Route 1 can decrease bus delay. Information about the number of peak hour Route 1 buses can be found in Table 2, and the passenger delays and bus delays are shown in Table 3. The results in Table 3 show the delays per passenger and delays per bus with existing conditions and with all of the possible improvements for all of the intersections. Cambridge does not currently have a system in place to allow for TSP. The values reported in these sections on bus impacts and in the subsequent sections on other impacts are estimates of what the effects would be if both Boston and Cambridge could implement the full set of recommendations.

Total bus delay with the improvements decreases in the outbound direction by approximately 12% in the morning and 7% in the afternoon, and it also decreases in the inbound direction, by approximately 12% in the morning and 9% in the afternoon.

FIGURE 1   Route 1:Estimated Impact of Transit Signal Priority on Queue Lengths, AM and PM Peak Hours Combined

Change in Vehicle Queue Length by Number of Intersection Approaches Experiencing it Due to TSP or other Preferential Treatments

Number of Intersection Approaches

Change in Vehicle Queue Length (in Number of Vehicles)

Inbound   Outbound   Non-Route 1 Approaches
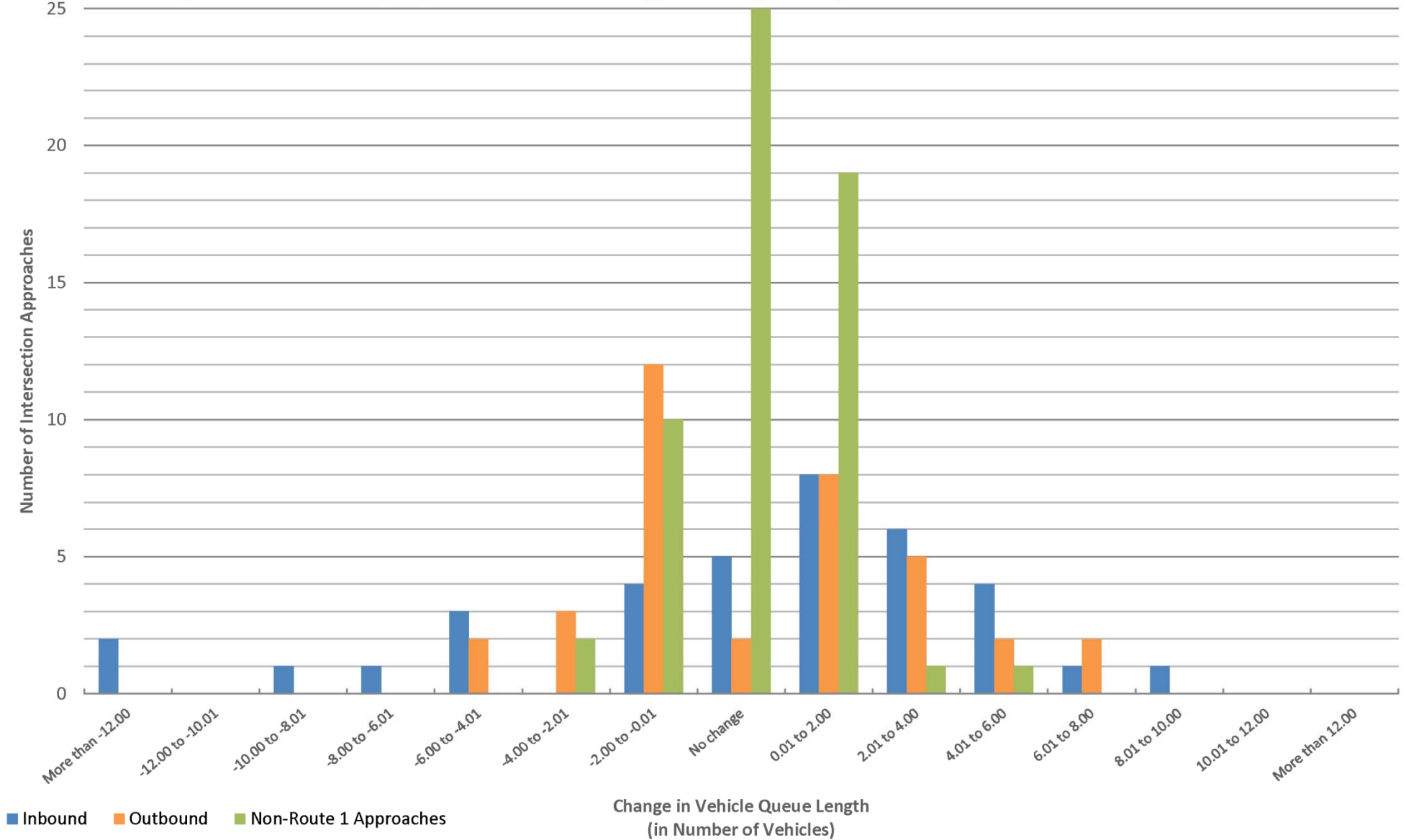
TABLE 2
Number of Peak-Hour Buses and Passengers

Period/Direction	Buses	Passengers
AM Inbound	8	554
AM Outbound	8	535
PM Inbound	9	769
PM Outbound	9	676

TABLE 3
Peak-Hour Bus and Passenger Delays (in Minutes)

Period and Direction	Total: Existing	Total with Recommended Improvements[1]	Per Bus[2]: Existing	Per Bus with Recommended Improvements	Per Bus: Absolute Change with Improvements	Percentage Change with Improvements
AM Inbound						
Passenger-Minutes	1,320	1,223	165	153	12.1	-7%
Bus-Minutes	58	52	7	6	0.9	-12%
AM Outbound						
Passenger-Minutes	1,485	1,313	186	164	21.5	-12%
Bus-Minutes	62	54	8	7	0.9	-12%
PM Inbound						
Passenger-Minutes	2,251	2,031	250	226	24.4	-10%
Bus-Minutes	89	81	10	9	0.9	-9%
PM Outbound						
Passenger-Minutes	1,890	1,737	210	193	17.0	-8%
Bus-Minutes	64	60	7	7	0.5	-7%

1.   Recommended improvements to intersections include intersection signal timing modifications, TSP, and queue jumps.
2.   Per-bus delays are total delays divided by the number of buses per hour.

Bus Travel Times

Under existing conditions, inbound travel times are 25–45 minutes during the morning peak hour and 37–63 minutes during the afternoon peak hour. In the outbound direction, travel times are 26–49 minutes during the morning peak hour and 36–51 minutes in the afternoon peak hour. Likely travel time savings due to the improvements are small for buses operating in off-peak hours; most off-peak trips have fairly quick run times. These buses are not likely to be helped at many intersections, and they experience less delay resulting from stopping to pick up passengers.

Travel times for the longer trips, during the peak hours, on which buses were delayed by queues or stuck at a light because passengers needed to board and alight, decrease as a result of the improvements. These savings are a function of the number of times a bus receives priority when it would otherwise have to wait. Delay decreases by almost 1 minute per trip in the inbound direction during the morning and afternoon peak hours. Delay decreases by almost one minute

per trip in the outbound direction during the morning peak hour and about thirty seconds in the afternoon peak hour.

Passengers

Passenger-minutes of delay for a single intersection were calculated by multiplying the number of passengers on board a bus as it passed through an intersection by the amount of delay the bus incurred at the intersection. To find the total passenger delay for Route 1, the passenger delays for all of the bus approaches at all of the intersections were summed.

Applying TSP, modified signal timings, and modified signal phasings decreases total passenger delay during the morning peak hour by about 12% in the outbound direction and about 7% in the inbound direction and during the evening peak hour by about 8% in the outbound direction and about 10% in the inbound direction. In the outbound direction, the treatments decrease delay about 12 passenger-minutes per bus in the morning and about 8 passenger-minutes per bus in the evening. In the inbound direction, delay is reduced by approximately 12 passenger-minutes per bus in the morning and almost 25 passenger-minutes in the afternoon.

Bus Stops

Where TSP or a shared right-turn/queue jump lane is recommended, the bus stop must be moved to the far side of the intersection. In Cambridge, two inbound bus stops and two outbound bus stops would need to be moved from the near side of the intersection to the far side. Two of these four moves call for special comment: The inbound bus stop between Albany and Vassar Streets would need to be moved to the far side of Vassar Street; however, moving the stop to this location causes stops #74 and #75 to be rather close (about 450 feet). Normally this distance is too small, but unless the stop is moved, signal priority at Albany Street will be rendered ineffective because buses will need to stop before Vassar Street. In the outbound direction, the stop before Albany Street would need to be moved to the far side of the intersection. This move is not parking neutral; three to four metered parking spaces would need to be used.

In Boston, only the stops at Beacon Street would need to be moved. At the new location in the outbound direction, the bus would partially block one of the two lanes of traffic as passengers board and alight, since the shoulder is narrow; however, the benefits outweigh this disadvantage. In the inbound direction, three to four parking spaces would need to be taken in creating the bus stop. Because there is no parking where the bus currently stops, this would not be a parking-neutral change.

OTHER IMPACTS OF THE RECOMMENDED IMPROVEMENTS

General-Traffic Travel Times

On average, traffic traveling along Route 1's route is delayed less at intersections. When a bus receives traffic signal priority, other vehicles traveling on the same approach also receive extra green time. Because queue jump lanes move buses from the main approach (and put them in the right-turn lane), delay decreases for general traffic using the main approach. Biased signal timings benefit vehicles regardless of the presence of a bus. The delays for vehicles traveling on

the same approach as Route 1 buses are shown in Table 4. Total vehicle delay for vehicles traveling along the route is expected to decrease in the outbound direction by about 14% during the morning peak hour and about 8% during the afternoon peak hour. In the inbound direction, delay decreases by about 10% during both the morning and afternoon peak hours.

TABLE 4
Total Peak-Hour Vehicle Delay for General Traffic on Route 1
(Total Vehicle-Minutes at All Intersection Approaches Used)

Period and Direction	Existing Conditions	With Recommended Improvements[1]	Absolute Change	Percentage Change
AM Inbound	4,580	4,084	496.3	-11%
AM Outbound	5,595	4,785	810.5	-14%
PM Inbound	8,061	7,285	776.9	-10%
PM Outbound	5,525	5,087	437.8	-8%

1. Recommended improvements to intersections are intersection signal timing modifications, TSP, and queue jumps.

Parking

As mentioned above in "Bus Stops," moving the outbound stop before Albany Street is not parking-neutral; 3 to 4 metered parking spaces would need to be transformed into a bus stop. Similarly, moving the inbound stop at Beacon Street to the far side of the intersection is not parking-neutral; 3 to 4 metered spaces would need to be turned into a bus stop.

At Newbury Street, in order to bypass the expected morning peak-hour queue along southbound Massachusetts Avenue, 6 to 7 parking spaces would need to be converted to a queue jump. At Marlborough Street, in order to bypass the expected afternoon peak-hour outbound queue, a dedicated bus lane would need to be created that extends the entire block back to Commonwealth Avenue, requiring conversion of approximately 12 parking spaces. Adding a queue jump/dedicated bus lane in the outbound direction does not affect parking, but would limit Massachusetts Avenue to one northbound through lane for general traffic.

Pedestrian

Pedestrians are mostly unaffected by the changes proposed in this memorandum. Dedicated pedestrian phases are not modified. Where pedestrian phases run concurrently with vehicular phases, which is the case at many intersections, more time is given to people crossing with the main road than without the improvements. There is still adequate time for crossing with the side street traffic in the improved scenarios. Under TSP, concurrent pedestrian movements are set to end normally when an extended green phase is called for; that is, the pedestrian phase ends when it usually would end, and pedestrians are shown a solid "don't walk" signal during the extended

phase. In these cases, side street pedestrians have to wait a few seconds longer than usual to receive a walk signal. Exclusive pedestrian phases are left untouched.

SUMMARY OF RECOMMENDATIONS AND FINDINGS

In Cambridge, granting signal priority to buses passing through the intersection at Brookline Street will save Route 1 buses time while only trivially affecting Brookline Street traffic. This intersection is relatively isolated and would serve as a good location for testing TSP in Cambridge. Infrastructure at the intersection would need to be improved to accommodate TSP. Alternatively, this intersection would also benefit from some form of vehicle actuation to make the traffic signal more responsive to traffic.

In Boston, granting priority to buses passing through the intersection at Beacon Street during the afternoon peak period will save buses time, and the amount of resulting delay for Beacon Street traffic is acceptable. At Newbury Street, turning one northbound lane of traffic from a general-purpose lane to a dedicated queue jump lane and providing TSP will enable buses to stay out of queues. The queue jump lane will operate only in the afternoon peak period, because in the morning, queues would be expected to back up to Boylston Street.

The alternative to granting signal priority to buses, biasing signals towards Route 1 approaches (primarily on Massachusetts Avenue), would also help reduce delay along the route. Side streets would be negatively affected, but given the smaller numbers of vehicles on these approaches, it is arguable that the effects would be acceptable. However, granting signal priority to buses will be more beneficial than biasing signals would be.

Other possible improvements that are worthy of consideration are listed below. With each of these improvements, either the benefits are relatively minor, there is some negative impact to the side streets, or (in the case of implementing TSP at the Cambridge intersection) a lack of the type of signal infrastructure required presents an obstacle that would have to be removed.

Cambridge
- *All bus approaches on Massachusetts Avenue along the entire corridor: Give more green time*
- *Massachusetts Avenue at Vassar Street and at Albany Street: Implement TSP*

Boston
- *Massachusetts Avenue at Belvidere Street: Implement TSP*
- *Massachusetts Avenue at Marlborough: Implement TSP*

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APPENDIX A

Level-of-Service Summary

Table A-1: AM Peak Hour
Table A-2: PM Peak Hour

TABLE A-1 AM-Peak-Hour* Level-of-Service Summary

Intersection/Approach[1]	Mvmt	Existing Conditions				Alt. 1 (Intersect. Timings)				Alt. 2 (Bus Timings)				Alt. 3 (TSP)[4]			
		LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]
Boston Intersections																	
Melnea Cass at Washington														*Shared RT lane*			
Melnea Cass Blvd – EB	L	F	204.1	1.28	136	F	98.4	1.01	105	F	98.4	1.01	105	F	245.6	1.38	140
Melnea Cass Blvd – EB	TR	C	29.4	0.78	295	C	22.5	0.68	262	C	22.5	0.68	262	C	31.8	0.81	295
Melnea Cass Blvd – WB	*L*	*C*	*29.2*	*0.73*	*45*	*B*	*17.7*	*0.62*	*39*	*B*	*17.7*	*0.62*	*39*	*D*	*35.5*	*0.77*	*45*
Melnea Cass Blvd – WB	TR	B	18.5	0.69	275	B	13.8	0.62	235	B	13.8	0.62	235	C	21.3	0.70	275
Washington Street – NB	L	C	27.5	0.40	44	D	38.1	0.52	50	D	38.1	0.52	50	C	28.8	0.39	43
Washington Street – NB	T	D	40.2	0.83	294	E	69.9	0.99	326	E	69.9	0.99	326	C	33.9	0.79	284
Washington Street – NB	*R*	*C*	*20.4*	*0.10*	*12*	*C*	*24.6*	*0.11*	*15*	*C*	*24.6*	*0.11*	*15*	*C*	*20.7*	*0.09*	*12*
Washington Street – SB	L	C	23.1	0.17	10	D	38.4	0.34	12	D	38.4	0.34	12	C	24.2	0.17	10
Washington Street – SB	T	C	26.2	0.48	139	C	32.9	0.57	154	C	32.9	0.57	154	C	27.9	0.49	139
Washington Street – SB	R	C	20.3	0.10	12	C	24.0	0.08	4	C	24.0	0.08	4	C	21.1	0.06	0
Overall		**C**	**34.7**	**1.05**	**–**	**C**	**31.2**	**0.98**	**–**	**C**	**31.2**	**0.98**	**–**	**D**	**37.5**	**1.05**	**–**
Melnea Cass at Harrison														*Green extension*			
Melnea Cass Blvd – EB	L	E	79.0	0.88	55	F	90.3	0.92	55	E	79.0	0.88	53	C	27.0	0.73	35
Melnea Cass Blvd – EB	*TR*	*C*	*23.6*	*0.69*	*231*	*C*	*24.0*	*0.70*	*232*	*C*	*23.1*	*0.68*	*223*	*C*	*22.9*	*0.72*	*196*
Melnea Cass Blvd – WB	L	F	111.0	1.06	84	D	41.1	0.83	70	D	38.6	0.82	69	C	31.5	0.81	47
Melnea Cass Blvd – WB	*TR*	*D*	*35.7*	*0.91*	*363*	*C*	*26.4*	*0.84*	*330*	*C*	*25.8*	*0.83*	*323*	*D*	*43.1*	*0.97*	*340*
Harrison Ave – NB	LT	D	42.7	0.86	250	E	66.4	0.96	267	E	79.5	1.01	281	D	42.6	0.88	196
Harrison Ave – NB	R	C	22.6	0.21	0	C	25.0	0.21	0	C	25.6	0.21	0	C	20.5	0.22	2
Harrison Ave – SB	L	C	27.2	0.53	38	D	45.6	0.71	42	E	58.9	0.77	44	C	25.5	0.54	30
Harrison Ave – SB	TR	C	24.6	0.42	102	C	27.5	0.47	109	C	28.3	0.48	112	C	22.4	0.43	80
Overall		**D**	**37.6**	**0.92**	**–**	**C**	**34.9**	**0.90**	**–**	**D**	**36.0**	**0.86**	**–**	**C**	**33.0**	**0.91**	**–**
Melnea Cass at Albany														*Not recommended*			
Melnea Cass Blvd – EB	*LTR*	*E*	*63.6*	*1.06*	*246*	*E*	*62.9*	*1.06*	*220*	*E*	*62.9*	*1.06*	*220*				
Melnea Cass Blvd – WB	LTR	E	65.5	1.06	514	D	38.0	0.97	411	D	38.0	0.97	411				
Albany St – NB	LTR	E	71.4	0.94	185	F	88.0	0.99	193	F	88.0	0.99	193				
Albany St – SB	*LTR*	*C*	*33.2*	*0.48*	*85*	*C*	*34.7*	*0.51*	*90*	*C*	*34.7*	*0.51*	*90*				
Overall		**E**	**63.3**	**1.03**	**–**	**D**	**52.4**	**1.04**	**–**	**D**	**52.4**	**1.04**	**–**				

TABLE A-1 cont.   AM-Peak-Hour* Level-of-Service Summary

Intersection/Approach[1]	Mvmt	Existing Conditions				Alt. 1 (Intersect. Timings)				Alt. 2 (Bus Timings)				Alt. 3 (TSP)[4]			
		LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]
Albany at Northampton										Not recommended							
Northampton St – EB	LT	E	78.7	0.83	100	E	79.7	0.84	100	F	83.8	0.86	100				
Northampton St – EB	R	D	44.5	0.03	0	D	45.0	0.15	7	D	45.3	0.17	9				
Northampton St – WB	LT	D	47.5	0.46	66	D	47.6	0.46	66	D	47.8	0.46	66				
Northampton St – WB	R	D	44.1	0.04	1	D	44.4	0.07	5	D	44.5	0.07	5				
Albany St – NB	*LTR*	*B*	*11.5*	*0.48*	*118*	*B*	*11.6*	*0.48*	*118*	B	11.4	0.48	117				
Albany St – SB	*LTR*	*B*	*12.6*	*0.20*	*53*	*B*	*10.7*	*0.19*	*48*	B	10.6	0.19	47				
Overall		**C**	**24.5**	**0.54**	**–**	**C**	**24.3**	**0.55**	**–**	**C**	**24.7**	**0.55**	**–**				
Massachusetts at Albany										Not recommended				Not recommended			
Massachusetts Ave – SE	L	F	97.1	0.88	92	F	119.9	0.95	93								
Massachusetts Ave – SE	*TR*	*B*	*16.2*	*0.51*	*200*	*B*	*17.8*	*0.53*	*208*								
Massachusetts Ave – NW	T	D	38.1	0.87	426	D	41.5	0.89	433								
Massachusetts Ave – NW	R	C	20.7	0.52	71	B	19.1	0.50	67								
Albany St – NE	*L*	*D*	*37.0*	*0.30*	*42*	*D*	*38.3*	*0.30*	*43*								
Albany St – NE	TR	E	69.0	0.92	276	F	83.8	0.97	283								
Albany St – SW	L	F	219.5	1.31	133	F	90.0	0.97	110								
Albany St – SW	TR	D	36.0	0.57	167	C	33.6	0.53	162								
Overall		**D**	**45.8**	**0.98**	**–**	**D**	**42.0**	**0.93**	**–**								
Massachusetts at Harrison														Green extension (OB)			
Massachusetts Ave – SE	L	C	33.2	0.43	38	C	33.1	0.49	40	C	30.2	0.43	41	C	22.9	0.45	35
Massachusetts Ave – SE	*TR*	*C*	*21.1*	*0.58*	*122*	*C*	*21.1*	*0.58*	*122*	B	18.6	0.54	117	*C*	*21.2*	*0.61*	*187*
Massachusetts Ave – NW	L	C	20.5	0.30	32	B	19.1	0.29	30	B	17.9	0.28	29	C	22.9	0.31	32
Massachusetts Ave – NW	*TR*	*D*	*43.7*	*0.96*	*377*	*D*	*35.3*	*0.92*	*361*	*C*	*29.9*	*0.89*	*345*	*E*	*58.6*	*1.01*	*380*
Harrison Ave – NE	L	C	27.9	0.20	21	C	27.9	0.20	21	C	32.0	0.24	23	C	25.2	0.17	21
Harrison Ave – NE	TR	D	40.5	0.72	196	D	40.5	0.72	196	D	52.3	0.83	208	C	32.9	0.66	196
Harrison Ave – SW	L	D	53.8	0.68	55	D	53.8	0.68	55	F	109.6	0.94	62	C	33.0	0.57	54
Harrison Ave – SW	TR	C	30.6	0.41	98	C	30.6	0.41	98	D	35.0	0.47	104	C	27.2	0.37	98
Overall		**D**	**35.0**	**0.84**	**–**	**C**	**31.5**	**0.83**	**–**	**C**	**32.1**	**0.87**	**–**	**D**	**39.1**	**0.84**	**–**

Intersection/Approach[1]	Mvmt	Existing Conditions				Alt. 1 (Intersect. Timings)				Alt. 2 (Bus Timings)				Alt. 3 (TSP)[4]			
		LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]
Massachusetts at Shawmut						Existing timings optimal								Green extension			
Massachusetts Ave – SE	*TR*	*B*	*16.2*	*0.53*	*268*					*B*	*15.2*	*0.52*	*268*	*B*	*10.5*	*0.51*	*157*
Massachusetts Ave – NW	*L*	*A*	*5.0*	*0.11*	*4*					*A*	*4.2*	*0.11*	*3*	*A*	*4.3*	*0.11*	*5*
Massachusetts Ave – NW	T	A	3.6	0.44	54					A	3.1	0.44	43	A	4.1	0.43	81
Shawmut Ave – SW	LTR	D	39.7	0.56	82					D	39.7	0.56	82	D	45.6	0.62	83
Overall		**B**	**13.4**	**0.53**	**–**					**B**	**12.7**	**0.52**	**–**	**B**	**11.8**	**0.52**	**–**
Massachusetts at Tremont						Existing timings optimal											
Massachusetts Ave – SE	L	C	32.0	0.79	52					C	29.9	0.78	49	C	29.6	0.76	61
Massachusetts Ave – SE	*TR*	*C*	*22.1*	*0.78*	*148*					*B*	*19.8*	*0.77*	*148*	*C*	*27.4*	*0.74*	*261*
Massachusetts Ave – NW	L	B	11.7	0.44	17					B	10.9	0.43	14	B	15.9	0.42	34
Massachusetts Ave – NW	*TR*	*C*	*26.7*	*0.86*	*286*					*C*	*25.4*	*0.84*	*283*	*C*	*30.6*	*0.81*	*281*
Tremont St – NE	L	C	22.4	0.30	33					C	22.9	0.31	33	C	24.3	0.32	33
Tremont St – NE	TR	D	44.0	0.87	216					D	47.2	0.89	217	D	51.7	0.91	217
Tremont St – SW	L	C	34.4	0.72	55					D	37.0	0.74	55	D	42.6	0.77	55
Tremont St – SW	TR	C	30.6	0.52	112					C	31.3	0.53	113	C	33.1	0.54	113
Overall		**C**	**29.6**	**0.84**	**–**					**C**	**29.3**	**0.84**	**–**	**C**	**34.2**	**0.83**	**–**
Massachusetts at St. Botolph						Existing timings optimal								Green extension			
Massachusetts Ave – SE	*LTR*	*A*	*6.7*	*0.49*	*115*					*A*	*6.3*	*0.48*	*110*	*A*	*6.4*	*0.49*	*119*
Massachusetts Ave – NW	*LTR*	*A*	*6.6*	*0.69*	*86*					*A*	*6.3*	*0.69*	*81*	*A*	*7.6*	*0.70*	*80*
St. Botolph St – NE	LTR	E	58.2	0.71	52					E	57.6	0.70	52	D	54.1	0.65	52
St. Botolph St – SW	LTR	D	42.6	0.38	26					D	42.5	0.38	26	D	44.2	0.35	26
Overall		**A**	**9.5**	**0.69**	**–**					**A**	**9.1**	**0.70**	**–**	**A**	**9.7**	**0.70**	**–**
Massachusetts at Westland						Permit LT during NBSB								Not recommended			
Westland – EB	R	C	26.8	0.69	189	C	29.9	0.76	189	C	29.7	0.73	197				
Massachusetts Ave – NB	L	F	133.1	1.18	399	A	3.6	0.45	22	F	150.5	1.22	399				
Massachusetts Ave – NB	*T*	*A*	*4.7*	*0.36*	*71*	*A*	*4.7*	*0.36*	*71*	*A*	*4.7*	*0.36*	*71*				
Massachusetts Ave – SB	*TR*	*D*	*40.3*	*0.86*	*227*	*C*	*31.5*	*0.78*	*219*	*D*	*35.5*	*0.82*	*219*				
Overall		**D**	**41.4**	**1.06**	**–**	**B**	**18.0**	**0.73**	**–**	**D**	**43.1**	**1.05**	**–**				

TABLE A-1 cont.   AM-Peak-Hour* Level-of-Service Summary

Intersection/Approach[1]	Mvmt	Existing Conditions				Alt. 1 (Intersect. Timings)				Alt. 2 (Bus Timings)				Alt. 3 (TSP)[4]			
		LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]
Massachusetts at Belvidere														Green extension			
Belvidere St – EB	LTR	D	39.3	0.56	95	D	46.2	0.64	100	D	50.5	0.69	101	D	38.0	0.54	95
Massachusetts Ave – NB	*LT*	*C*	*24.0*	*0.68*	*213*	*C*	*20.9*	*0.64*	*201*	*C*	*20.0*	*0.63*	*196*	*C*	*21.9*	*0.68*	*212*
Massachusetts Ave – SB	*TR*	*C*	*21.5*	*0.60*	*197*	*B*	*18.9*	*0.56*	*186*	*B*	*18.1*	*0.55*	*182*	*B*	*19.8*	*0.59*	*197*
Overall		**C**	**24.5**	**0.64**	**–**	**C**	**22.7**	**0.64**	**–**	**C**	**22.4**	**0.65**	**–**	**C**	**22.6**	**0.63**	**–**
Massachusetts at Newbury						Permit LT during NBSB				Same as Alternative 1				Not recommended			
Newbury St – WB	LTR	D	43.0	1.07	104	D	43.0	1.07	104	D	43.0	1.07	104	C	31.1	0.29	48
Massachusetts Ave – NB	L	F	241.1	1.36	196	F	9.6	1.36	50	F	9.6	1.36	50	E	79.4	0.96	169
Massachusetts Ave – NB	*T*	*A*	*5.8*	*0.34*	*92*	*A*	*5.8*	*0.34*	*92*	*A*	*5.8*	*0.34*	*92*	*B*	*13.7*	*0.52*	*52*
Massachusetts Ave – NB	*QJ*													*B*	*15.3*	*0.70*	*250*
Massachusetts Ave – SB	*TR*	*B*	*13.4*	*0.38*	*111*	*B*	*13.4*	*0.38*	*111*	*B*	*13.4*	*0.38*	*111*	*A*	*7.6*	*0.02*	*2*
Massachusetts Ave – SB	*QJ*													*B*	*17.6*	*0.43*	*112*
Overall		**D**	**43.9**	**0.60**	**–**	**D**	**17.7**	**0.53**	**–**	**D**	**17.7**	**0.53**	**–**	**B**	**13.0**	**0.02**	**–**
Massachusetts at Marlboro.										No improvement over Alternative 1 without decreasing pedestrian time past minimum				Green extension			
Marlborough St – EB	LTR	D	39.5	0.63	94	D	39.7	0.63	94					D	41.5	0.66	95
Massachusetts Ave – NB	*TR*	*B*	*17.1*	*0.65*	*234*	*B*	*14.0*	*0.61*	*211*					*B*	*15.3*	*0.64*	*234*
Massachusetts Ave – SB	*LT*	*B*	*13.0*	*0.76*	*145*	*B*	*13.6*	*0.78*	*145*					*B*	*12.3*	*0.75*	*145*
Overall		**B**	**18.6**	**0.73**	**–**	**B**	**17.6**	**0.75**	**–**					**C**	**17.9**		**–**
Massachusetts at Beacon										No improvement over Alternative 1 without decreasing pedestrian time past minimum				Green extension			
Beacon St – WB	LT	D	41.1	0.71	118	D	42.0	0.74	118					D	44.6	0.75	118
Beacon St – WB	R	D	38.7	0.57	79	D	39.8	0.59	79					D	41.6	0.60	79
Massachusetts Ave – NB	*LT*	*B*	*18.0*	*0.84*	*154*	*B*	*16.9*	*0.83*	*154*					*B*	*16.9*	*0.83*	*154*
Massachusetts Ave – SB	*TR*	*C*	*26.4*	*0.83*	*319*	*C*	*25.3*	*0.81*	*317*					*C*	*22.8*	*0.79*	*317*
Overall		**C**	**26.0**	**0.81**	**–**	**C**	**25.4**	**0.81**	**–**					**C**	**24.7**	**0.81**	**–**

Intersection/Approach[1]	Mvmt	Existing Conditions				Alt. 1 (Intersect. Timings)				Alt. 2 (Bus Timings)				Alt. 3 (TSP)[4]			
		LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]
Cambridge Intersections																	
Massachusetts at Memorial														Green extension			
North Int. Memorial Dr – WB	R	D	54.0	0.72	103	C	30.9	0.43	88	D	54.0	0.72	103	E	20.9	0.76	103
Massachusetts Ave – NB	L	A	1.3	0.16	0	A	1.5	0.20	0	A	1.3	0.16	0	A	0.1	0.15	12
Massachusetts Ave – NB	*T*	*A*	*0.7*	*0.36*	*0*	*A*	*0.7*	*0.43*	*1*	*A*	*0.7*	*0.36*	*0*	*A*	*0.1*	*0.35*	*70*
Massachusetts Ave – SB	*T*	*B*	*12.9*	*0.41*	*102*	*B*	*19.2*	*0.50*	*128*	*B*	*10.6*	*0.38*	*91*	*B*	*0.25*	*0.40*	*102*
South Int. Memorial Dr – EB	R	F	268.5	1.46	268	D	36.7	0.71	168	F	268.5	1.46	268	F	314.5	1.56	269
Massachusetts Ave – NB	*T*	*A*	*8.0*	*0.62*	*149*	*C*	*22.0*	*0.81*	*269*	*A*	*8.0*	*0.62*	*149*	*A*	*6.7*	*0.61*	*150*
Massachusetts Ave – SB	*T*	*A*	*4.1*	*0.38*	*17*	*A*	*3.8*	*0.49*	*9*	*A*	*3.7*	*0.35*	*17*	*B*	*11.3*	*0.36*	*92*
Overall Note: acts as 2 ints.		–	–	–	–									–	–	–	–
Massachusetts at 77 Mass Av						Existing timings optimal				No improvement without decreasing pedestrian time past minimum				Green extension/QJ			
Massachusetts Ave – EB	*T*	*B*	*15.6*	*0.86*	*430*									*C*	*28.7*	*0.90*	*369*
Massachusetts Ave – EB	*QJ*	*–*	*–*	*–*	*–*									*A*	*8.6*	*0.01*	*0*
Massachusetts Ave – WB	T	A	6.4	0.47	61									B	12.4	0.50	134
Overall		**B**	**10.9**	**0.86**	**–**									**C**	**20.3**	**0.90**	**–**
Massachusetts at Vassar						Existing timings optimal				1 second to Mass Ave				Green extension			
Massachusetts Ave – EB	*LTR*	*A*	*9.2*	*0.58*	*58*					*A*	*8.9*	*8.9*	*58*	*B*	*13.3*	*0.55*	*217*
Massachusetts Ave – WB	*LTR*	*A*	*10.0*	*0.60*	*64*					*A*	*9.1*	*9.1*	*61*	*B*	*13.6*	*0.57*	*223*
Vassar St – NB	L	C	22.0	0.28	39					C	22.9	22.9	40	C	25.1	0.30	89
Vassar St – NB	TR	C	24.4	0.48	138					C	25.4	25.4	141	C	27.8	0.51	243
Vassar St – SB	L	C	27.8	0.49	59					C	29.7	29.7	60	C	33.2	0.54	134
Vassar St – SB	TR	C	22.0	0.34	88					C	22.9	22.9	90	C	25.0	0.36	167
Overall		**B**	**14.0**	**0.55**	**–**					**B**	**13.9**	**0.56**	**–**	**B**	**17.7**	**0.56**	**–**
Massachusetts at Albany						Decrease EB LT by 2s				Decr. EB LT by 2s and 1s bias				Green extension			
Massachusetts Ave – EB	*LTR*	*A*	*6.8*	*0.49*	*100*	*A*	*6.8*	*0.49*	*100*	*A*	*6.7*	*0.47*	*101*	*B*	*13.1*	*0.46*	*140*
Massachusetts Ave – WB	*LTR*	*D*	*53.1*	*0.95*	*280*	*D*	*44.5*	*0.90*	*234*	*D*	*40.1*	*0.87*	*226*	*C*	*33.9*	*0.88*	*249*
Albany St – NB	L	B	17.3	0.04	5	B	17.3	0.04	5	B	17.9	0.04	5	B	19.7	0.04	5
Albany St – NB	TR	C	22.7	0.46	132	C	22.7	0.46	132	C	23.6	0.48	135	C	25.9	0.49	133
Albany St – SB	LTR	D	53.2	0.92	215	D	53.2	0.92	215	E	64.9	0.97	223	F	86.3	1.04	244
Overall		**C**	**33.6**	**0.90**	**–**	**C**	**30.5**	**0.89**	**–**	**C**	**30.9**	**0.89**	**–**	**C**	**34.7**	**0.91**	**–**

Intersection/Approach[1]	Mvmt	Existing Conditions				Alt. 1 (Intersect. Timings)				Alt. 2 (Bus Timings)				Alt. 3 (TSP)[4]			
		LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]
Massachusetts at Brookline						*Actuate signal*				*2 seconds to Mass Ave*				*Green extension*			
Massachusetts Ave – EB	*LT*	*A*	*3.7*	*0.70*	*0*	*A*	*2.4*	*0.65*	*0*	*A*	*3.2*	*0.68*	*0*	*B*	*12.2*	*0.64*	*246*
Massachusetts Ave – WB	*TR*	*C*	*23.1*	*0.30*	*143*	*B*	*18.8*	*0.28*	*138*	*C*	*20.2*	*0.29*	*131*	*A*	*7.9*	*0.28*	*78*
Brookline St – NB	L	C	24.6	0.36	81	C	27.0	0.42	88	C	26.5	0.38	84	C	27.6	0.38	81
Brookline St – NB	TR	C	28.7	0.55	130	C	31.7	0.65	141	C	31.3	0.59	135	C	32.5	0.58	130
Overall		**B**	**16.7**	**0.65**	**–**	**B**	**15.5**	**0.65**	**–**	**B**	**16.2**	**0.65**	**–**	**B**	**15.9**	**0.63**	**–**
Massachusetts at Essex						*Existing timings optimal*				*Not recommended*				*Green extension*			
Massachusetts Ave – EB	L	A	6.1	0.15	6									A	9.9	0.16	9
Massachusetts Ave – EB	*T*	*B*	*10.1*	*0.72*	*145*									*B*	*13.2*	*0.70*	*267*
Massachusetts Ave – WB	*TR*	*B*	*13.3*	*0.70*	*138*									*B*	*12.5*	*0.68*	*248*
Overall		**B**	**11.5**	**0.72**	**–**									**B**	**12.8**	**0.70**	**–**
Massachusetts at Prospect						*Existing timings optimal*				*2 seconds to Mass Ave*				*Queue jump/ RT lane*			
Massachusetts Ave – EB	*T*	*B*	*17.0*	*0.79*	*248*					*B*	*15.7*	*0.75*	*248*	*C*	*34.6*	*0.80*	*257*
Massachusetts Ave – EB	R	A	6.3	0.07	7					A	6.2	0.06	7	B	15.7	0.08	15
Massachusetts Ave – WB	*T*	*C*	*21.6*	*0.42*	*101*					*B*	*18.4*	*0.40*	*86*	*C*	*22.7*	*0.45*	*120*
Massachusetts Ave – WB	R	B	19.3	0.23	38					B	16.6	0.22	34	B	17.0	0.24	46
Western Ave – NB	T	C	28.4	0.83	320					C	33.0	0.87	337	C	32.1	0.85	320
Western Ave – NB	R	C	27.9	0.66	105					C	31.4	0.69	110	C	31.2	0.69	106
Prospect St – SB	TR	C	25.2	0.77	284					C	28.7	0.81	299	C	28.2	0.80	284
Overall		**C**	**23.6**	**0.81**	**–**				**–**	**C**	**25.2**	**0.81**	**–**	**C**	**29.3**	**0.79**	**–**
Massachusetts at Inman						*Add permissive WB LT*				*Perm. WB LT + 2 sec to Mass*				*Green extension*			
Massachusetts Ave – EB	*T*	*C*	*26.4*	*0.72*	*236*	*C*	*26.4*	*0.72*	*236*	*C*	*23.8*	*0.69*	*225*	*C*	*21.6*	*0.67*	*236*
Massachusetts Ave – WB	L	C	21.6	0.16	23	B	15.0	0.11	6	B	17.4	0.11	7	D	36.3	0.17	21
Massachusetts Ave – WB	*T*	*B*	*12.0*	*0.37*	*44*	*B*	*12.0*	*0.37*	*44*	*B*	*11.3*	*0.35*	*50*	*B*	*15.9*	*0.34*	*99*
Inman Street – SB	T	E	80.0	1.03	313	E	80.0	1.03	313	F	93.0	1.07	324	F	103.2	1.09	313
Inman Street – SB	R	C	28.1	0.41	80	C	28.1	0.41	80	C	29.2	0.43	81	C	31.5	0.44	80
Overall		**D**	**41.8**	**0.70**	**–**	**D**	**41.6**	**0.69**	**–**	**D**	**45.1**	**0.69**	**–**	**D**	**49.4**	**0.70**	**–**
Massachusetts at Hancock						*Existing timings optimal*				*No improvement without decreasing pedestrian time past minimum*				*Green extension*			
Massachusetts Ave – EB	*LTR*	*A*	*5.6*	*0.47*	*121*									*A*	*4.3*	*0.45*	*183*
Massachusetts Ave – WB	*LTR*	*A*	*4.7*	*0.36*	*80*									*A*	*3.8*	*0.35*	*124*
Overall		**A**	**5.2**	**0.47**	**–**									**A**	**4.0**	**0.45**	**–**

*For each intersection, that individual intersection's AM peak hour was used in the analysis.
1. Route 66 approaches are shown in bold.
2. Delay is measured in seconds.
3. 50th percentile queue, measured in feet.
4. TSP was modeled by changing the signal from an actuated, coordinated signal to a semi-actuated, uncoordinated signal.

TABLE A-2   PM-Peak-Hour* Level-of-Service Summary

Intersection/Approach[1]	Mvmt	Existing Conditions				Alt. 1 (Intersect. Timings)				Alt. 2 (Bus Timings)				Alt. 3 (TSP)[4]			
		LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]
Boston Intersections																	
Melnea Cass at Washington						*Existing timings optimal*								*Shared RT lane*			
Melnea Cass Blvd – EB	L	D	37.2	0.73	71					D	43.2	0.76	75	D	45.6	0.78	72
Melnea Cass Blvd – EB	TR	C	28.5	0.79	300					C	32.5	0.84	318	C	31.5	0.82	301
Melnea Cass Blvd – WB	*L*	*D*	*36.8*	*0.80*	*46*					C	25.6	0.69	50	*D*	*49.0*	*0.85*	*48*
Melnea Cass Blvd – WB	TR	B	14.9	0.53	191					B	14.5	0.53	191	B	16.6	0.55	191
Washington Street – NB	L	D	42.0	0.56	37					D	45.3	0.59	37	D	47.4	0.62	38
Washington Street – NB	T	C	31.6	0.64	204					C	32.4	0.65	204	C	27.0	0.61	204
Washington Street – NB	*R*	*C*	*21.6*	*0.11*	*11*					C	22.0	0.11	11	*C*	*22.9*	*0.11*	*12*
Washington Street – SB	L	C	25.0	0.26	27					C	25.7	0.27	27	C	26.3	0.24	27
Washington Street – SB	T	C	34.1	0.71	248					D	35.2	0.73	248	D	39.0	0.76	248
Washington Street – SB	R	C	21.3	0.10	3					C	21.7	0.10	3	C	23.5	0.11	5
Overall		**C**	**26.2**	**0.76**	**–**					**C**	**27.4**	**0.77**	**–**	**C**	**28.9**	**0.82**	**–**
Melnea Cass at Harrison														*Green extension*			
Melnea Cass Blvd – EB	L	F	400.6	1.74	251	F	92.0	1.01	153	F	210.4	1.32	209	F	222.5	1.40	167
Melnea Cass Blvd – EB	*TR*	*C*	*29.6*	*0.87*	*356*	*C*	*25.1*	*0.83*	*328*	*C*	*25.1*	*0.83*	*328*	*C*	*33.0*	*0.92*	*315*
Melnea Cass Blvd – WB	L	C	30.3	0.69	42	E	56.3	0.83	48	C	23.7	0.59	40	B	17.7	0.60	26
Melnea Cass Blvd – WB	*TR*	*C*	*25.8*	*0.81*	*317*	*D*	*53.2*	*0.99*	*366*	*C*	*25.2*	*0.80*	*305*	*C*	*27.2*	*0.85*	*281*
Harrison Ave – NB	LT	E	75.8	0.97	188	F	89.1	1.01	199	F	277.4	1.48	270	E	67.6	0.96	148
Harrison Ave – NB	R	C	24.5	0.20	3	C	25.6	0.29	24	C	27.5	0.19	0	C	22.1	0.22	7
Harrison Ave – SB	L	C	24.3	0.17	16	C	24.7	0.18	16	C	28.0	0.23	18	C	21.8	0.17	13
Harrison Ave – SB	TR	D	45.6	0.87	256	D	48.4	0.88	264	F	81.3	1.01	286	D	43.5	0.88	204
Overall		**E**	**63.5**	**1.37**	**–**	**D**	**47.9**	**1.00**	**–**	**E**	**67.5**	**1.32**	**–**	**D**	**49.3**	**1.23**	**–**
Melnea Cass at Albany														*Not recommended*			
Melnea Cass Blvd – EB	*LTR*	*C*	*22.0*	*0.88*	*251*	*C*	*20.6*	*0.87*	*251*	*C*	*21.8*	*0.88*	*251*				
Melnea Cass Blvd – WB	LTR	C	20.4	0.79	317	B	14.6	0.71	276	C	22.9	0.82	333				
Albany St – NB	LTR	D	38.2	0.57	70	D	42.3	0.63	75	D	38.0	0.57	69				
Albany St – SB	*LTR*	*D*	*47.8*	*0.76*	*121*	*E*	*59.7*	*0.85*	*140*	*D*	*47.8*	*0.76*	*121*				
Overall		**C**	**24.8**	**0.85**	**–**	**C**	**23.3**	**0.86**	**–**	**C**	**25.7**	**0.85**	**–**				

TABLE A-2 cont. PM-Peak-Hour* Level-of-Service Summary

Intersection/Approach[1]	Mvmt	Existing Conditions				Alt. 1 (Intersect. Timings)				Alt. 2 (Bus Timings)				Alt. 3 (TSP)[4]			
		LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]
Albany at Northampton														Not recommended			
Northampton St – EB	LT	D	41.3	0.54	82	D	41.3	0.54	82	D	41.9	0.55	82				
Northampton St – EB	R	D	36.1	0.12	0	D	36.1	0.12	0	D	36.4	0.12	0				
Northampton St – WB	LT	E	74.7	0.88	145	E	74.7	0.88	145	E	77.7	0.89	145				
Northampton St – WB	R	D	46.9	0.67	105	D	46.9	0.67	105	D	51.9	0.74	123				
Albany St – NB	*LTR*	*B*	*16.1*	*0.42*	*90*	*B*	*16.3*	*0.43*	*90*	*B*	*16.1*	*0.43*	*91*				
Albany St – SB	*LTR*	*C*	*20.6*	*0.39*	*138*	*B*	*18.0*	*0.36*	*129*	*B*	*17.8*	*0.36*	*130*				
Overall		**C**	**32.9**	**0.56**	**–**	**C**	**32.1**	**0.57**	**–**	**C**	**33.3**	**0.57**	**–**				
Massachusetts at Albany														Not recommended			
Massachusetts Ave – SE	L	D	54.0	0.47	41	E	65.7	0.63	43	D	52.9	0.43	41				
Massachusetts Ave – SE	*TR*	*C*	*24.3*	*0.71*	*333*	*C*	*23.5*	*0.70*	*315*	*C*	*23.9*	*0.70*	*333*				
Massachusetts Ave – NW	T	F	80.4	1.06	604	E	57.7	0.99	513	F	83.7	1.07	604				
Massachusetts Ave – NW	R	B	16.5	0.18	5	B	12.3	0.16	0	B	18.5	0.19	10				
Albany St – NE	*L*	*D*	*42.5*	*0.57*	*45*	*D*	*49.5*	*0.61*	*48*	*D*	*42.3*	*0.59*	*44*				
Albany St – NE	TR	D	46.5	0.79	191	E	73.1	0.90	212	D	41.9	0.67	183				
Albany St – SW	L	F	131.4	1.13	178	F	96.1	1.03	181	F	161.1	1.20	188				
Albany St – SW	TR	D	53.5	0.91	352	E	57.8	0.93	369	E	55.7	0.92	352				
Overall		**E**	**57.7**	**0.99**	**–**	**D**	**49.9**	**0.94**	**–**	**E**	**61.1**	**1.02**	**–**				
Massachusetts at Harrison						Existing timings optimal								Green extension			
Massachusetts Ave – SE	L	C	26.2	0.29	15					C	25.4	0.29	14	C	23.7	0.30	19
Massachusetts Ave – SE	*TR*	*C*	*21.7*	*0.77*	*145*					*C*	*20.3*	*0.74*	*146*	*C*	*28.4*	*0.80*	*277*
Massachusetts Ave – NW	L	C	25.8	0.36	32					C	23.5	0.35	30	C	30.1	0.39	32
Massachusetts Ave – NW	*TR*	*D*	*47.9*	*0.99*	*410*					*D*	*37.9*	*0.95*	*392*	*E*	*64.3*	*1.04*	*413*
Harrison Ave – NE	L	D	44.1	0.52	29					E	58.5	0.63	31	C	27.8	0.41	29
Harrison Ave – NE	TR	D	36.8	0.67	179					D	40.7	0.72	184	C	30.4	0.62	179
Harrison Ave – SW	L	D	35.2	0.44	37					D	40.4	0.50	39	C	26.8	0.38	37
Harrison Ave – SW	TR	D	49.1	0.86	252					E	58.9	0.91	260	D	37.9	0.79	252
Overall		**D**	**37.6**	**0.93**	**–**					**D**	**35.2**	**0.93**	**–**	**D**	**43.5**	**0.93**	**–**

TABLE A-2 cont.   PM-Peak-Hour* Level-of-Service Summary

Intersection/Approach[1]	Mvmt	Existing Conditions				Alt. 1 (Intersect. Timings)				Alt. 2 (Bus Timings)				Alt. 3 (TSP)[4]			
		LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]
Massachusetts at Shawmut						*Existing timings optimal*								*Green extension*			
Massachusetts Ave – SE	*TR*	*B*	*10.7*	*0.61*	*247*					*B*	*10.5*	*0.60*	*234*	*B*	*11.7*	*0.58*	*200*
Massachusetts Ave – NW	*L*	*A*	*4.2*	*0.09*	*3*					*A*	*3.3*	*0.09*	*2*	*A*	*4.8*	*0.09*	*4*
Massachusetts Ave –NW	T	A	2.8	0.40	50					A	2.2	0.40	41	A	4.0	0.39	77
Shawmut Ave – SW	LTR	D	39.8	0.58	94					D	39.8	0.58	94	D	45.3	0.64	94
Overall		**B**	**11.3**	**0.59**	**–**					**B**	**10.9**	**0.58**	**–**	**B**	**12.9**	**0.58**	**–**
Massachusetts at Tremont														*Green extension*			
Massachusetts Ave – SE	L	B	11.6	0.47	20	A	8.4	0.47	16	A	9.3	0.47	18	B	14.6	0.45	37
Massachusetts Ave – SE	*TR*	*B*	*15.1*	*0.88*	*277*	*B*	*11.1*	*0.85*	*259*	*B*	*12.9*	*0.85*	*204*	*C*	*29.7*	*0.83*	*324*
Massachusetts Ave – NW	L	B	18.0	0.60	26	B	19.6	0.60	27	B	17.5	0.60	24	B	18.3	0.57	36
Massachusetts Ave – NW	*TR*	*C*	*26.0*	*0.73*	*284*	*C*	*25.1*	*0.71*	*242*	*C*	*23.6*	*0.71*	*283*	*C*	*24.4*	*0.69*	*234*
Tremont St – NE	L	C	27.9	0.62	67	C	29.5	0.64	67	C	30.8	0.65	68	C	32.3	0.66	66
Tremont St – NE	TR	D	41.9	0.82	190	D	45.3	0.86	190	D	41.9	0.82	190	D	48.7	0.87	188
Tremont St – SW	L	C	32.5	0.69	64	D	35.2	0.72	65	D	38.1	0.74	66	D	40.3	0.75	64
Tremont St – SW	TR	C	34.4	0.65	147	D	35.7	0.68	147	C	34.4	0.65	147	D	37.5	0.69	146
Overall		**C**	**26.2**	**0.82**	**–**	**C**	**25.7**	**0.82**	**–**	**C**	**25.2**	**0.81**	**–**	**C**	**32.4**	**0.81**	**–**
Massachusetts at St. Botolph						*Existing timings optimal*								*Green extension*			
Massachusetts Ave – SE	*LTR*	*B*	*13.0*	*0.69*	*195*					*B*	*12.0*	*0.68*	*186*	*B*	*11.1*	*0.68*	*202*
Massachusetts Ave – NW	*LTR*	*B*	*14.0*	*0.88*	*91*					*B*	*14.1*	*0.88*	*98*	*B*	*17.0*	*0.87*	*145*
St. Botolph St – NE	LTR	D	46.7	0.66	65					D	47.9	0.68	65	D	53.1	0.70	65
St. Botolph St – SW	LTR	E	64.4	0.81	84					E	67.3	0.83	85	E	80.0	0.87	84
Overall		**B**	**17.8**	**0.87**	**–**					**B**	**17.6**	**0.87**	**–**	**B**	**19.5**	**0.87**	**–**
Massachusetts at Westland						*Permit NBLT during NBSB*								*Not recommended*			
Westland – EB	R	D	40.4	0.88	282	D	44.5	0.90	282	E	60.6	0.97	305				
Massachusetts Ave – NB	L	F	287.1	1.56	551	A	8.4	0.57	86	F	338.4	1.67	551				
Massachusetts Ave – NB	*T*	*A*	*4.8*	*0.37*	*79*	*A*	*4.8*	*0.37*	*79*	*A*	*4.8*	*0.37*	*79*				
Massachusetts Ave – SB	*TR*	*D*	*49.2*	*0.93*	*250*	*D*	*38.2*	*0.86*	*242*	*D*	*36.1*	*0.84*	*233*				
Overall		**E**	**77.6**	**1.31**	**–**	**C**	**23.7**	**0.86**	**–**	**F**	**87.0**	**1.29**	**–**				

TABLE A-2 cont.   PM-Peak-Hour* Level-of-Service Summary

Intersection/Approach[1]	Mvmt	Existing Conditions				Alt. 1 (Intersect. Timings)				Alt. 2 (Bus Timings)				Alt. 3 (TSP)[4]			
		LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]
Massachusetts at Belvidere								Green extension									
Belvidere St – EB	**LTR**	D	40.8	0.51	100	D	48.4	0.61	105	D	54.0	0.67	108	D	40.5	0.50	110
Massachusetts Ave – NB	*LT*	*C*	*23.3*	*0.67*	*252*	*B*	*19.8*	*0.62*	*233*	*B*	*18.2*	*0.60*	*224*	*C*	*21.3*	*0.66*	*252*
Massachusetts Ave – SB	*TR*	*C*	*20.6*	*0.56*	*215*	*B*	*17.6*	*0.52*	*200*	*B*	*16.2*	*0.51*	*192*	*C*	*19.0*	*0.55*	*215*
Overall		**C**	**23.8**	**0.62**	**–**	**C**	**21.5**	**0.62**	**–**	**C**	**20.6**	**0.62**	**–**	**C**	**22.0**	**0.61**	**–**
Massachusetts at Newbury						Permit NBLT during NBSB								IB/OB queue jump			
Newbury St – WB	LTR	D	42.3	0.43	36	D	42.3	0.42	36					D	42.3	0.43	36
Massachusetts Ave – NB	L	F	1034.4	3.15	633	D	64.3	1.03	259	No improvement over Alternative 1 without decreasing pedestrian time past minimum				F	130.2	1.22	245
Massachusetts Ave – NB	*T*	*A*	*3.6*	*0.16*	*40*	*A*	*3.6*	*0.16*	*40*					*A*	*5.3*	*0.31*	*88*
Massachusetts Ave – NB	*QJ*													*A*	*4.7*	*0.03*	*2*
Massachusetts Ave – SB	*TR*	*B*	*12.5*	*0.50*	*192*	*C*	*18.6*	*0.58*	*234*					*B*	*14.0*	*0.52*	*192*
Massachusetts Ave – SB	*QJ*													*A*	*8.8*	*0.05*	*1*
Overall		**F**	**256.4**	**0.81**	**–**	**C**	**31.4**	**0.92**	**–**					**D**	**44.9**	**1.05**	**–**
Massachusetts at Marlboro.						Existing timings optimal								Green extension			
Marlborough St – EB	LTR	D	42.4	0.47	65					No improvement without decreasing pedestrian time past minimum				D	43.5	0.49	72
Massachusetts Ave – NB	*TR*	*B*	*12.3*	*0.64*	*247*									*B*	*10.7*	*0.64*	*247*
Massachusetts Ave – SB	*LT*	*B*	*16.7*	*0.86*	*168*									*B*	*15.6*	*0.85*	*168*
Overall		**B**	**17.0**	**0.79**	**–**									**B**	**15.9**	**0.78**	**–**
Massachusetts at Beacon														Green extension			
Beacon St – WB	LT	D	42.9	0.73	166	D	53.3	0.85	173	No improvement over Alternative 1 without decreasing pedestrian time past minimum				D	47.4	0.76	181
Beacon St – WB	R	D	52.1	0.77	143	D	76.5	0.90	148					E	60.4	0.82	157
Massachusetts Ave – NB	*LT*	*C*	*28.1*	*0.92*	*182*	*C*	*22.2*	*0.89*	*163*					*C*	*27.7*	*0.92*	*195*
Massachusetts Ave – SB	*TR*	*F*	*106.9*	*1.16*	*667*	*E*	*75.0*	*1.08*	*635*					*F*	*87.7*	*1.11*	*703*
Overall		**E**	**68.2**	**1.01**	**–**	**D**	**54.6**	**1.01**	**–**					**E**	**60.4**	**1.00**	**–**

TABLE A-2 cont.   PM-Peak-Hour* Level-of-Service Summary

Intersection/Approach[1]	Mvmt	Existing Conditions				Alt. 1 (Intersect. Timings)				Alt. 2 (Bus Timings)				Alt. 3 (TSP)[4]			
		LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]
Cambridge Intersections																	
Massachusetts at Memorial														Green extension			
North Int. Memorial Dr – WB	R	D	49.1	0.63	81	D	36.0	0.45	74	D	49.1	0.63	81	E	55.0	0.67	81
Massachusetts Ave – NB	L	A	1.8	0.25	0	A	0.9	0.29	0	A	1.9	0.27	0	A	6.0	0.25	15
Massachusetts Ave – NB	*T*	*A*	*0.4*	*0.32*	*0*	*A*	*0.0*	*0.35*	*0*	*A*	*0.4*	*0.32*	*0*	*A*	*4.4*	*0.31*	*62*
Massachusetts Ave – SB	*T*	*B*	*15.0*	*0.56*	*170*	*B*	*18.2*	*0.61*	*188*	*B*	*12.3*	*0.52*	*151*	*B*	*13.2*	*0.54*	*170*
South Int. Memorial Dr – EB	R	F	559.9	2.12	370	F	83.0	1.02	238	F	559.9	2.12	370	F	371.2	1.69	359
Massachusetts Ave – NB	*T*	*B*	*12.0*	*0.78*	*218*	*E*	*58.7*	*1.04*	*446*	*B*	*12.0*	*0.78*	*218*	*B*	*15.5*	*0.83*	*298*
Massachusetts Ave – SB	*T*	*A*	*4.3*	*0.49*	*25*	*A*	*7.7*	*0.65*	*16*	*A*	*3.8*	*0.45*	*25*	*B*	*15.5*	*0.51*	*173*
Overall Note: acts as 2 ints.		–	–	–	–									–	–	–	–
Massachusetts at 77 Mass Av						Existing timings optimal								Green extension/QJ			
Massachusetts Ave – EB	*T*	*D*	*41.6*	*1.02*	*613*					No improvement without decreasing pedestrian time past minimum				*D*	*37.2*	*0.97*	*558*
Massachusetts Ave – EB	*QJ*													*F*	*8.6*	*0.01*	*2*
Massachusetts Ave – WB	T	A	7.4	0.57	78									A	8.6	0.55	178
Overall		**C**	**24.0**	**1.02**	**–**									**C**	**22.9**	**0.97**	**–**
Massachusetts at Vassar						Existing timings optimal				1 second to Mass Ave				Green extension			
Massachusetts Ave – EB	*LTR*	*B*	*13.4*	*0.72*	*119*					*A*	*8.1*	*0.67*	*96*	*B*	*16.9*	*0.70*	*211*
Massachusetts Ave – WB	*LTR*	*C*	*28.5*	*0.69*	*231*					*C*	*24.0*	*0.64*	*214*	*B*	*16.3*	*0.67*	*183*
Vassar St – NB	L	C	22.6	0.31	35					C	26.5	0.37	37	C	26.4	0.35	35
Vassar St – NB	TR	C	23.9	0.49	144					C	27.1	0.54	152	C	27.3	0.52	144
Vassar St – SB	L	C	31.8	0.60	77					D	42.1	0.71	83	D	39.6	0.68	78
Vassar St – SB	TR	C	23.9	0.49	137					C	27.1	0.54	146	C	27.4	0.52	139
Overall		**C**	**22.1**	**0.67**	**–**					**C**	**20.3**	**0.68**	**–**	**C**	**20.8**	**0.68**	**–**
Massachusetts at Albany						Add 8 second EB LT phase				Add phase and 1sec bias				Green extension			
Massachusetts Ave – EB	*LTR*	*A*	*9.6*	*0.55*	*177*	*A*	*7.3*	*0.38*	*28*	*A*	*6.8*	*0.56*	*27*	*B*	*14.3*	*0.53*	*144*
Massachusetts Ave – WB	*LTR*	*B*	*15.5*	*0.71*	*251*	*C*	*27.1*	*0.88*	*291*	*C*	*25.1*	*0.84*	*277*	*B*	*17.1*	*0.68*	*229*
Albany St – NB	L	B	17.7	0.08	10	B	17.7	0.08	10	B	18.4	0.08	10	C	20.2	0.08	10
Albany St – NB	TR	C	29.0	0.70	225	C	29.0	0.70	225	C	30.7	0.72	231	C	34.0	0.75	227
Albany St – SB	LTR	E	70.0	0.96	160	E	70.0	0.96	160	F	93.0	1.04	184	F	140.0	1.17	194
Overall		**C**	**22.5**	**0.82**	**–**	**C**	**26.5**	**0.90**	**–**	**C**	**28.4**	**0.92**	**–**	**C**	**33.2**	**0.87**	**–**

Intersection/Approach[1]	Mvmt	Existing Conditions				Alt. 1 (Intersect. Timings)				Alt. 2 (Bus Timings)				Alt. 3 (TSP)[4]			
		LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]	LOS	Delay[2]	V/C	Q[3]
Massachusetts at Brookline						Actuate signal				2 seconds to Mass Ave				Green extension			
Massachusetts Ave – EB	*LT*	*B*	*12.4*	*0.55*	*110*	*B*	*11.3*	*0.54*	*110*	*B*	*11.3*	*0.54*	*110*	*A*	*9.9*	*0.53*	*166*
Massachusetts Ave – WB	*TR*	*B*	*18.4*	*0.76*	*426*	*B*	*16.0*	*0.73*	*426*	*B*	*16.0*	*0.73*	*426*	*B*	*13.9*	*0.72*	*290*
Brookline St – NB	L	C	27.7	0.41	89	C	27.4	0.44	89	C	27.4	0.44	89	C	32.9	0.45	89
Brookline St – NB	TR	D	36.4	0.70	167	D	36.9	0.76	167	D	36.9	0.76	167	D	45.4	0.77	167
Overall		**C**	**20.9**	**0.74**	**–**	**B**	**19.6**	**0.74**	**–**	**B**	**19.6**	**0.74**	**–**	**C**	**20.4**	**0.73**	**–**
Massachusetts at Essex						Existing timings optimal				No improvement without decreasing pedestrian time past minimum				Green extension			
Massachusetts Ave – EB	L	A	5.2	0.10	1									A	9.6	0.10	2
Massachusetts Ave – EB	*T*	*A*	*6.7*	*0.58*	*95*									*B*	*10.3*	*0.57*	*186*
Massachusetts Ave – WB	*TR*	*C*	*21.1*	*0.92*	*386*									*C*	*24.0*	*0.89*	*436*
Overall		**B**	**15.4**	**0.92**	**–**									**B**	**18.6**	**0.89**	**–**
Massachusetts at Prospect						Existing timings optimal				2 seconds to Mass Ave				Queue jump/RT lane			
Massachusetts Ave – EB	*T*	*C*	*29.7*	*0.72*	*168*					C	25.8	0.67	153	*C*	*35.0*	*0.72*	*195*
Massachusetts Ave – EB	R	C	23.6	0.15	24					C	21.1	0.14	22	C	20.1	0.16	30
Massachusetts Ave – WB	*T*	*C*	*23.2*	*0.83*	*168*					B	19.1	0.78	145	*D*	*42.2*	*0.83*	*238*
Massachusetts Ave – WB	R	B	16.1	0.23	23					B	13.8	0.21	20	C	20.7	0.23	44
Western Ave – NB	T	C	27.2	0.87	373					C	32.5	0.90	395	C	29.9	0.90	373
Western Ave – NB	R	F	128.2	1.13	129					F	147.1	1.17	134	F	164.9	1.22	142
Prospect St – SB	TR	B	15.4	0.59	190					B	17.1	0.61	201	B	15.3	0.61	190
Overall		**C**	**31.3**	**1.01**	**–**					**C**	**33.2**	**1.01**	**–**	**D**	**39.0**	**1.00**	**–**
Massachusetts at Inman						Add permissive WB LT				Perm. WB LT + 1 sec to Mass				Green extension			
Massachusetts Ave – EB	*T*	*C*	*33.3*	*0.84*	*296*	*C*	*33.3*	*0.84*	*296*	*C*	*31.0*	*0.82*	*289*	*C*	*24.3*	*0.75*	*296*
Massachusetts Ave – WB	L	C	26.4	0.18	28	C	3.1	0.13	1	A	3.4	0.13	1	D	38.6	0.20	24
Massachusetts Ave – WB	*T*	*A*	*5.1*	*0.59*	*27*	*A*	*5.1*	*0.59*	*27*	*A*	*4.9*	*0.57*	*27*	*B*	*17.8*	*0.53*	*181*
Inman Street – SB	T	F	86.9	1.04	270	F	86.9	1.04	270	F	86.9	1.04	270	F	126.1	1.14	270
Inman Street – SB	R	D	53.7	0.85	169	D	53.7	0.85	169	D	53.7	0.85	169	E	69.6	0.93	169
Overall		**D**	**42.5**	**0.77**	**–**	**D**	**41.9**	**0.79**	**–**	**D**	**41.2**	**0.76**	**–**	**D**	**54.9**	**0.76**	**–**
Massachusetts at Hancock						Existing timings optimal				No improvement without decreasing pedestrian time past minimum				Green extension			
Massachusetts Ave – EB	*LTR*	*A*	*8.3*	*0.70*	*230*									*A*	*5.9*	*0.69*	*230*
Massachusetts Ave – WB	*LTR*	*A*	*5.5*	*0.56*	*179*									*A*	*3.9*	*0.55*	*179*
Overall		**A**	**6.9**	**0.70**	**–**									**A**	**4.9**	**0.69**	**–**

*For each intersection, that individual intersection's PM peak hour was used in the analysis.

1. Route 66 approaches are shown in bold.
2. Delay is measured in seconds.
3. 50th percentile queue, measured in feet.
4. TSP was modeled by changing the signal from an actuated, coordinated signal to a semi-actuated, uncoordinated signal.