MEMORANDUM

To: **Mike Lambert** **July 8, 2010**
Director of Transportation & Infrastructure, City of Somerville

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

Re: **Boston Region MPO Congested and High-Crash Intersections Study: Alewife Brook Parkway (Route 16) at Broadway in Somerville**

This memorandum summarizes safety and operations analyses and proposes improvement strategies for the intersection of Alewife Brook Parkway at Broadway in Somerville. It contains the following sections:

- Intersection Layout and Traffic Control
- Issues and Concerns
- Crash Data Analysis
- Intersection Capacity Analysis
- Review of Pedestrian Crossing Time
- Analyses of Improvement Alternatives
- Improvement Recommendations and Discussions

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

INTERSECTION LAYOUT AND TRAFFIC CONTROL

This is a signalized intersection where two major roadways meet. Alewife Brook Parkway, functioning as an urban principal arterial, is a part of State Route 16 that connects with Interstate 93 in Medford to the east and Alewife Station in Cambridge to the west. Broadway, functioning as an urban minor arterial, is a major crosstown connector that runs from Arlington Center to Sullivan Square in Boston.

As Figure 1 shows, Alewife Brook Parkway is a four-lane roadway running in the north-south direction. Broadway is, for the most part, a two-lane roadway but has two entry lanes approaching the intersection. However, it has only one lane in the eastbound direction leaving the intersection. Crosswalks are installed on all four approaches of the intersection. Sidewalks are in place on both sides of all approaches, except the west side of the northbound approach.

The traffic signal currently operates in three phases: eastbound only, westbound only, and northbound/southbound. Right turns on red are allowed on all four approaches. The signal

CTPS

FIGURE 1
Alewife Brook Parkway (Route 16) at Broadway, Somerville

Operational Improvements at Congested and High-Crash Intersections

control also includes an exclusive pedestrian phase that lasts about 17 seconds (when manually activated), which is somewhat tight for pedestrians crossing the intersection (detailed analysis in the section "Review of Pedestrian Crossing Time").

The area is residential mixed with commercial uses. At the intersection, there is a supermarket with a parking lot on the northeastern corner; a high-rise apartment on the southeastern corner; and a cemetery on the southwestern corner. West of the intersection, Alewife Brook runs along the parkway in close proximity.

ISSUES AND CONCERNS

The intersection is congested during peak periods on almost all the approaches, depending on the peak direction. Traffic on Alewife Brook Parkway is heavy in the northbound direction during the AM peak period and in both directions during the PM period. The left-turn traffic on the parkway frequently blocks its shared-lane through traffic due to the lack of an exclusive left-turn lane. It causes delays for the entire approach and increases potential conflicts between the left turns and the opposite through traffic. Traffic on Broadway is congested during peak periods, with a high proportion of left turns on both approaches.

With the Clarendon Hills residence, the Food Master supermarket, and the residential neighborhoods located nearby, the intersection carries a relatively high number of pedestrians (about 30 to 50 pedestrians per hour) during peak periods. Field observations indicate that the pedestrian signal time appears to be insufficient for pedestrian crossing, especially for seniors and people with young children.

Based on field observations and a quick review of the crash and traffic data, the issues and concerns for this intersection can be summarized as:

- High-crash location
- Traffic congestion during peak hours
- Short pedestrian crossing time
- Horizontal and vertical alignment
- Limited roadway pavement on the parkway
- Left-turning vehicles on the parkway blocking through traffic
- Excessive vegetation obstructing drivers' and pedestrians' views

CRASH DATA ANALYSIS

Based on the 2004–2006 Massachusetts Registry of Motor Vehicle (RMV) crash data, Table 1 shows that on average 20 crashes occurred at the intersection each year. About a quarter of the crashes resulted in personal injuries. The crash types include about 50% angle collisions and about 20% rear-end collisions.

TABLE 1
Summary of RMV Crash Data (2004–2006)

Statistics Period		2004	2005	2006	3-Year	Average
Total number of crashes		10	20	30	60	20
Severity	**Property damage only**	6	13	21	40	13
	Personal injury	3	6	6	15	5
	Fatality	0	0	0	0	0
	Not reported	1	1	3	5	2
Collision Type	**Angle**	7	10	13	30	10
	Rear-end	2	5	6	13	4
	Sideswipe	0	0	2	2	1
	Head-on	0	1	1	2	1
	Single vehicle	1	2	5	8	3
	Not reported	0	2	3	5	2
Crashes involved pedestrian(s)		0	0	0	0	0
Crashes involved cyclist(s)		0	0	0	0	0
Occurred during weekday peak periods*		1	6	6	13	4
Wet or icy pavement conditions		5	7	13	25	8
Dark/lighted conditions		4	4	8	16	5

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

Crash rate[1] is another effective tool to examine the relative safety of a particular location. Based on the above data and the recently collected traffic volume data, the crash rate for this intersection is calculated as 1.59 (see Appendix A for the calculation sheet). The rate is much higher than the average rate for the signalized locations in MassDOT Highway Division's District 4, which is estimated to be 0.78.[2]

INTERSECTION CAPACITY ANALYSIS

CTPS collected turning-movement counts at the intersection on May 27, 2009. The data were recorded in 15-minute intervals for the peak traffic periods in the morning from 7:00 to 9:00 and in the evening from 4:00 to 6:00. As Table 2 shows, the intersection carried about 2,750 vehicles in the morning peak hour from 7:15 to 8:15 and about 3,100 vehicles in the evening peak hour from 5:00 to 6:00. In addition, about 30 and 50 pedestrians crossed the intersection during the AM and PM peak hours, respectively. There were 12 and 8 bicycles crossing the intersection in the AM and PM peak hours, respectively (not shown in the table). All of them performed through movements, mostly on Broadway (80%) and some on the parkway (20%).

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

[2] The average crash rates estimated by the MassDOT Highway Division are based upon a database that contains intersection crash rates submitted to the Highway Division as a part of review processes for environmental impact reports and functional design reports. The most recent average crash rates, which are updated on a nearly yearly basis, are based on all entries in the database, not just those entries made within the past year.

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

Street name		**Alewife Brook Parkway (Route 16)**						**Broadway**						**Total**
Direction		**Northbound**			**Southbound**			**Eastbound**			**Westbound**			
Turning movement		LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT	
AM peak hour	Turning volume	24	937	168	35	452	99	183	277	8	154	351	45	2733
	Approach volume	1129			586			468			550			
	Ped. crossings	10			15			1			3			29
PM peak hour	Turning volume	38	835	226	13	758	123	222	329	54	132	341	29	3100
	Approach volume	1099			894			605			502			
	Ped. crossings	23			17			3			5			48

Based on the turning-movement counts and the signal timings measured on the site, the intersection capacity was analyzed by using a traffic signal analysis program: Synchro.[3] As Table 3 shows, the intersection is evaluated as operating at level of service (LOS) E in the morning peak hour and at LOS F in the evening peak hour. The level of service criteria are based on Highway Capacity Manual 2000.[4] The intersection was modeled as an actuated-uncoordinated signal with a maximum cycle length of 110 seconds for vehicular traffic and a pedestrian phase of 17 seconds. Detailed settings of the signal phases and timings for both the AM and PM peak hour analyses are included in Appendix B.

TABLE 3
Intersection Capacity Analysis of Existing Conditions

Street name		**Alewife Brook Parkway (Route 16)**						**Broadway**						**Overall**
Direction		**Northbound**			**Southbound**			**Eastbound**			**Westbound**			
Turning movement		LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT	
AM peak hour	LOS	**E**			**D**			**D**	**E**		**F**			**E**
	Delay (sec/veh)	59			36			54	78		132			70
PM peak hour	LOS	**F**			**D**			**E**	**F**		**F**			**F**
	Delay (sec/veh)	135			47			63	169		112			105

REVIEW OF PEDESTRIAN CROSSING TIME

Field observations indicate that the pedestrian crossing time at this intersection may need to be extended somewhat. Although most pedestrians were able to complete their crossing before the conflicting traffic was released, in a few instances pedestrians were close to but had not reached the other end of the crosswalk. The available signal time appeared to be insufficient for pedestrian crossing, especially for seniors and people with young children.

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[3] Synchro is a traffic signal coordination software developed and distributed by Trafficware, Ltd. It can perform capacity analysis and traffic simulation (when combined with SimTraffic) for an individual intersection or a series of intersections.

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

The Manual for Uniform Traffic Control Devices[5] (MUTCD) shows that the time required for pedestrians to cross an intersection equipped with pedestrian signal heads should consist of a WALK indication interval and a pedestrian clearance time. The WALK indication interval is the time during which pedestrians are permitted to leave the curb or shoulder (indicated by the steady symbol of a walking person) and should be at least 4 to 7 seconds depending on the intersection characteristics. The pedestrian clearance time should be sufficient to allow a pedestrian who left the curb or shoulder during the WALK indication interval to travel at a walking speed of 3.5 feet per second to at least the far side of the travel way.[6]

Using a distance measuring wheel, CTPS estimated that the crosswalk crossing the parkway is about 48 feet long and the crosswalk crossing Broadway is about 56 feet long. In this case, the longer distance (56 feet) should be used to calculate the pedestrian clearance time.

The current pedestrian phase time of 17 seconds is shorter than the new standard of MUTCD. Based on a walking speed of 3.5 feet per second, the required signal phase time is estimated below:

WALK Interval	=	4 seconds
Pedestrian Clearance Time	=	56 feet ÷ 3.5 feet per second
	=	16 seconds
All-Red Clearance Interval	=	1 second
Total Pedestrian Phase Time	=	21 seconds

It is suggested that the pedestrian phase be extended by 4 seconds to 21 seconds, considering pedestrians with slower walking speeds and the gradient crosswalk crossing the parkway.

ANALYSES OF IMPROVEMENT ALTERNATIVES

This section examines five different traffic/pedestrian signal and geometric design strategies to improve the safety and operation at this intersection. The analyses were performed progressively from simple to more involved modifications for the five alternatives. The intersection capacity was evaluated by using Synchro optimization and simulation software.

The improvement alternatives were developed with improving pedestrian safety as a major objective, among other objectives. They were also developed based on suggestions from the City (see Appendix C).[7] Alternatives 1, 2, and 5 include exclusive pedestrian signal phases. The operation is the same as the existing conditions, but the pedestrian signal time would be extended from 17 seconds to 21 seconds. Alternatives 3 and 4 would include pedestrian phases concurrent with prevailing traffic on the same approach. The operation is supposed to increase intersection capacity for both traffic and pedestrians. However, concurrent pedestrian phases usually require sufficient approaching lanes to separate turning traffic from through movements in order to allow

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[5] Federal Highway Administration, U.S. Department of Transportation, *Chapter 4E. Pedestrian Control Features*, 2003 edition with revision numbers 1 and 2 incorporated, December 2007.

[6] The pedestrian walking speed has changed from 4.0 to 3.5 feet per second in the latest MUTCD, effective January 15, 2010.

[7] These suggestions were the City's responses to a preliminary alternative (Alternative 1 in this report) developed in the early stages of this study.

only through traffic movements during the concurrent pedestrian phases and minimize conflicts of turning traffic with pedestrians.[8]

The five alternatives are:

1. Prohibit left turns on the parkway and retime traffic signal with existing phasing sequence
2. Change Broadway operation from split phasing to protected-permissive left-turn phasing
3. Prohibit left turns on the parkway, change Broadway to protected-only left-turn operation, and allocate pedestrian phases concurrent with through/right-turn traffic movements on both streets
4. Change the parkway to protected-only left-turn operation by reducing two through lanes to one, change Broadway to protected-only left-turn operation, and allocate pedestrian phases concurrent with through/right-turn traffic movements on both streets
5. Change the parkway to protected-only left-turn operation by adding an exclusive left-turn lane, change Broadway to protected-permissive left-turn operation, and operate pedestrian phases exclusively from traffic phases

The signal operations and geometry requirements of the five alternatives are summarized in Table 4. The intersection capacity analyses of the alternatives are summarized in Table 5. Major components and analyses of the alternatives are further described below.

1. Prohibit left turns on the parkway and retime traffic signal with existing signal sequence

As the conflict between left-turn and through traffic on the parkway is one of the major issues of the intersection, one improvement option would be to prohibit left turns on the parkway. The turning movement counts show that during peak hours the numbers of left turns on the parkway are relatively small (less than 40 vehicles per hour in each direction). In addition, the left-turning traffic (in both directions of the parkway) can be detoured through the rotary at Powder House Boulevard, which is less than 1,000 feet north of this intersection.

This alternative thus proposes to prohibit left turns on the parkway and retime the traffic signal with the existing signal sequence, including an exclusive pedestrian signal phase. To maintain a similar expectation for the intersection users, the existing total cycle length (127 seconds for both the traffic and pedestrians) was applied to the tested model.

In addition, this alternative would require the installation of "No Turn on Red" (NTOR) signs on all approaches. Currently, right turns on red are prohibited on the parkway southbound approach but not on the other approaches of the intersection. This allows potential conflicts between the right-turn traffic and pedestrians during the exclusive pedestrian signal phases. The installation of the NTOR signs would prevent these potential conflicts. The overall intersection traffic capacity would be reduced only slightly as the right-turn traffic is frequently blocked by the through traffic under the existing lane-sharing conditions.

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[8] A typical example of this operation is at the intersection of Massachusetts Avenue at Pleasant/Mystic Street in Arlington Center. It is preferable to allow only the through traffic movement to be concurrent with the pedestrian phase at suburban intersections where the traffic speed is high and the pedestrian volume is moderate or high. It is acceptable to allow turning movements concurrent with the pedestrian phase at intersections in the downtown area or central business districts where traffic speed is low and the pedestrian volume is high.

Intersection capacity analysis indicates that this alternative would maintain a similar overall level of service (LOS) as the existing conditions in both peak hours (see Table 5). Though not shown in the capacity analysis, pedestrian safety is expected to improve significantly with the increased crossing time and the installation of the NTOR traffic signs. Detailed analyses of this alternative for both the AM and PM peak hours are included in Appendix D.

TABLE 4
Summary of Improvement Alternatives

Alternatives	Alewife Brook Pkwy (NB/SB) Signal Operation	Broadway (EB/WB) Signal Operation	Pedestrian Signal	Operational/Geometry Modifications
Existing	Permissive	Split	Exclusive	N.A.
Alt. 1	Permissive, No LT	Split	Exclusive	NB/SB LT prohibited. Install NTOR signs.
Alt. 2	Permissive	Prot.-Perm. LT	Exclusive	Restripe EB/WB lanes. Install NTOR signs.
Alt. 3	Permissive, No LT	Protected-only LT	Concurrent	NB/SB LT prohibited. Restripe EB/WB lanes. Install R10-15 signs.
Alt. 4	Protected-only LT	Protected-only LT	Concurrent	Restripe NB/SB and EB/WB lanes. Install R10-15 signs.
Alt. 5	Protected-only LT	Prot.-Perm. LT	Exclusive	Add a NB/SB LT lane. Restripe EB/WB lanes. Install NTOR signs.

Note: Alternatives 1, 2, and 5 require traffic operation under the "No Turn on Red" (NTOR) regulation on all approaches. Alternatives 3 and 4 require the installation of "Turning Traffic Must Yield to Pedestrians" sign (MUTCD R10-15) on all approaches.

TABLE 5
Intersection Capacity Analyses of Improvement Alternatives

Street name		**Alewife Brook Pkwy (Rte. 16)**		**Broadway**		**Overall**
Approach		**Northbound**	**Southbound**	**Eastbound**	**Westbound**	
AM peak hour	Existing	E/59	D/36	E/69	F/132	E/70
	Alternative 1	E/70	C/32	E/75	F/86	E/66
	Alternative 2	D/55	C/34	E/64	E/70	D/55
	Alternative 3	D/41	C/20	D/49	E/57	D/41
	Alternative 4	F/204	C/34	F/120	F/180	F/148
	Alternative 5	D/44	C/26	D/38	D/46	D/40
PM peak hour	Existing	F/135	D/47	F/130	F/112	F/105
	Alternative 1	E/77	D/47	F/119	F/111	F/82
	Alternative 2	F/96	D/38	F/125	F/107	F/87
	Alternative 3	D/42	C/29	D/48	E/59	D/42
	Alternative 4	F/156	F/95	F/157	F/183	F/143
	Alternative 5	D/35	C/34	D/37	D/54	D/38

Note: Performance measures - Level of Service (A to F)/Average Delay (seconds per vehicle)

2. Change Broadway operation from split phasing to protected-permissive left-turn phasing

Currently, traffic on Broadway is processed under a split signal phase, which usually consumes a greater share of signal green time than the permissive or protected left-turn design. This alternative proposes to change the Broadway operation from the split phase design to a protected-permissive left-turn phase design. Traffic operation on the parkway would remain the same as under existing conditions. The alternative was tested with the same total cycle length (127 seconds), pedestrian signal time (21 seconds), and installation of an NTOR sign on all the approaches as in Alternative 1.

Intersection capacity analysis indicates that this alternative would improve the overall traffic operation from LOS E to LOS D in the AM peak hour. It would remain at a similar overall level of service but with significant delay reductions (especially on the northbound approach) in the PM peak hour (see Table 5). Meanwhile, pedestrian safety is expected to improve significantly with the increased crossing time and the installation of the NTOR signs. Detailed analyses of this alternative in both the AM and PM peak hours are included in Appendix E.

3. Prohibit left turns on the parkway, change Broadway to protected-only left-turn operation, and allocate pedestrian phases concurrent with through/right-turn traffic movements on both streets

This alternative would provide pedestrian signal phases concurrent with through/right-turn traffic movements on both streets. The major issue of concurrent pedestrian/traffic phasing is how to prevent or reduce the conflicts between turning vehicles and pedestrians. At this intersection, it is especially essential to prevent conflicts between left-turning traffic and pedestrians, as the left turns on the parkway are frequently performed under pressure. Also, left-turn volumes on Broadway are high in both directions. This alternative, therefore, prohibits left turns on the parkway and allows only protected left turns on Broadway.

It would be ideal if a separate right-turn lane and signal phase were provided for all the approaches so as to prevent conflicts between the right-turn traffic and pedestrians. However, the intersection has limited space available for expansion, as its vicinity is well developed and Alewife Brook is located very close along its west side. To reduce conflicts between the right-turn traffic and pedestrians, this alternative would require the installation of a “Turning Traffic Must Yield to Pedestrians” sign (the regulation sign R10-15 in MUTCD) on all approaches near the intersection.

Intersection capacity analysis indicates that this alternative would improve the overall traffic operation from LOS E to LOS D in the AM peak hour and from LOS F to LOS D in the PM peak hour (see Table 5). Pedestrian safety would be expected to improve with sufficient crossing times (about 30 seconds for crossing the parkway and about 40 seconds for crossing Broadway). However, potential conflicts between the right-turn traffic and pedestrians would remain under the lane-sharing condition for the right turns and through movements on all the approaches. Detailed analyses of this alternative in both the AM and PM peak hours are included in Appendix F.

4. Change the parkway operation to protected-only left-turn design by reducing two through lanes to one, change Broadway to protected-only left-turn operation, and allocate pedestrian phases concurrent with through/right-turn traffic movements on both streets

This alternative was developed based on the idea of narrowing the parkway to a two-lane roadway with the potential of adding bike lanes on both sides and adding a protected left-turn lane approaching the intersection. However, under this lane configuration, it is difficult to process a daily traffic volume of over 30,000 vehicles along the parkway.

Intersection capacity analysis indicates that the overall level of service and average delay under this alternative would deteriorate significantly in the AM and PM peak hours (see Table 5). Even with an extended total cycle length of 150 seconds, analysis estimates extensive traffic queues on almost all approaches, especially for the northbound and the westbound queues, which would potentially extend to their upstream signalized intersections. Detailed analyses of this alternative in both the AM and PM peak hours are included in Appendix G.

This alternative was also tested with 10% reduction of traffic on all approaches to represent potential traffic diversion caused by the narrowing of the parkway. Capacity analysis indicates that the overall traffic operation would still be worse than the existing conditions, with extensive delays on almost all the approaches.

5. Change the parkway to protected-only left-turn operation by adding an exclusive left-turn lane, change Broadway to protected-permissive left-turn operation, and operate pedestrian phases exclusively from traffic phases

This alternative represents the case of a minimal expansion of the intersection under the assumption that right-of-way can be obtained from the east side of the parkway. As the City prefers to maintain left turns on the parkway, adding a protected left-turn lane on the busy and speedy parkway would be quite beneficial to the traffic and, consequently, to pedestrians. Review of the intersection aerial photography indicates that there may be space available on the east side of the parkway.

Intersection capacity analysis indicates that this alternative would improve the overall traffic operation from LOS E to LOS D in the AM peak hour and from LOS F to LOS D in the PM peak hour. It would significantly reduce delays on almost all the approaches in both peak hours (see Table 5). Meanwhile, pedestrian safety would be expected to improve significantly with the increased crossing time and the installation of the NTOR signs. Detailed analyses of this alternative in both the AM and PM peak hours are included in Appendix H.

IMPROVEMENT RECOMMENDATIONS AND DISCUSSIONS

The intersection carries heavy traffic and a relatively high number of pedestrians. As indicated by the City, pedestrians include seniors and people with young children. Thus, this study considers improving pedestrian safety the most important objective among the issues and concerns. The existing pedestrian crossing time was reviewed. Several alternatives containing exclusive or concurrent pedestrian signal phases integrated with feasible traffic operations were developed and analyzed. Among them, five were selected for further analysis.

The five alternatives are:

1. Prohibit left turns on the parkway and retime traffic signal with existing phasing sequence (exclusive pedestrian signal phasing)
2. Change Broadway operation from split phasing to protected-permissive left-turn phasing (exclusive pedestrian signal phasing)
3. Prohibit left turns on the parkway and change Broadway to protected-only left-turn operation (concurrent pedestrian signal phasing)
4. Change the parkway to protected-only left-turn operation by reducing two through lanes to one and change Broadway to protected-only left-turn operation (concurrent pedestrian signal phasing)
5. Change the parkway to protected-only left-turn operation by adding an exclusive left-turn lane and change Broadway to protected-permissive left-turn operation (exclusive pedestrian signal phasing)

The analyses in the previous section (see Table 5) indicate that Alternative 1 would improve the existing traffic conditions slightly; Alternative 2 would improve the traffic conditions noticeably; Alternatives 3 and 5 would improve the traffic conditions significantly; and Alternative 4 would degrade the existing traffic conditions significantly.

Alternatives 1, 2, and 5, which include an exclusive pedestrian phase, would be expected to improve pedestrian safety significantly with the increased pedestrian crossing time (from 17 seconds to 21 seconds) and the installation of a "No Turn on Red" traffic regulation sign on all approaches.

Alternatives 3 and 4, which have a concurrent pedestrian phase, provide sufficient crossing times (more than the needed 21 seconds) on both streets. However, potential conflicts between the right-turn traffic and pedestrians can only be lowered by the installation of the "Turning Traffic Must Yield to Pedestrians" sign. The conflicts can be potentially hazardous as the prevailing traffic speed on Alewife Brook Parkway is high and drivers' sight distance is limited due to the curvature of the parkway. Therefore, we do not recommend the concurrent pedestrian phase design for this intersection unless turning traffic can be completely removed for the concurrent pedestrian phases.

Based on the analyses, we propose Alternative 5 for improving the intersection operation and safety for both the traffic and pedestrians. Alternative 5 presents the case of a minimal intersection expansion with a minor land acquisition on the east side of the parkway near the intersection. If the expansion is not feasible or is not supported by the community, Alternative 2 should be considered instead.

In addition, we propose the following improvements for this intersection that should be considered together with Alternative 2 or 5:

- Add bike lanes in both directions of Broadway
- Consider adding bike lanes on the parkway

  As a crosstown minor arterial with moderate daily traffic, Broadway is suitable for installing bike lanes. According to the State Roadway Inventory file, the Broadway

section on both sides of the intersection has 70 feet of right-of-way (ROW) and a surface width of 46 feet. The surface width should be sufficient for three 12-foot traffic lanes (two approaching lanes and one departing lane) and two 5-foot bike lanes (one approaching and one departing). The ROW covers the roadway surface and two 12-foot sidewalks on both sides.

The parkway near the intersection has a narrower ROW (60 feet) and a narrower surface width (40 feet). However, the potential of adding bike lanes should be explored in a future corridor or bike study for the entire Route 16 corridor. The roadway ROW width may not be constant along the entire roadway but at the segment near the subject intersection one potential cross-section could be two 12-foot inside lanes, two 11-foot outside lanes, two 5-foot bike lanes, and two 2-foot shoulders. Another cross-section could be two 10-foot inside lanes, two 11-foot outside lanes, one 5-foot bike lane, one 9-foot sidewalk, and two 2-foot shoulders. This would be determined by the needs of the area's bike and pedestrian networks.

- Upgrade the signal and controller equipment
- Install mast-arm-mounted traffic signals on Broadway
- Install appropriate signal heads for left-turn indications
- Install "countdown" pedestrian signals

Currently traffic signals on Broadway are mounted on posts. They are low and hard to observe from the elevated westbound Broadway. They also are confused with the nearby flashing yellow light at the crosswalk of the supermarket from eastbound Broadway. Signals should be overhung from mast arms, like the traffic signals on the parkway. In addition, appropriate signal heads should be installed for the "protected-only" left-turn and "protected-permissive" left-turn phases.[9] The "countdown" pedestrian signal head would assist pedestrians in making their judgments and adjusting movements.

- Clearly mark the exclusive left-turn lane(s) on Broadway

Currently Broadway operates under a split phase with no clear lane markings for the left-turn lanes. This is acceptable for the westbound direction, as its receiving side is wide enough to accept two-lane through traffic. However, the eastbound inside lane should be clearly marked (on the pavement with left-turn arrows) as an exclusive left-turn lane, as the eastbound receiving side is narrow and can accept only one-lane traffic. If Alternative 2 or 5 is to be implemented, the westbound inside lane should also be clearly marked as an exclusive left-turn lane.

- Consider bulb-outs on Broadway for pedestrians
- Clear excessive vegetation near the intersection

[9] The desirable "protected-only" left-turn indication consists of a three-section signal head with red ball, yellow arrow, and green arrow and an accompanying sign, "Left Turn Signal." The "protected-permissive" left-turn indication should consist of a five-section signal head with red ball, yellow arrow, yellow ball, green arrow, and green ball and an accompanying sign, "Left Turn Yield on Green Ball."

> As Broadway is wider than the parkway at this intersection, bulb-outs or curb extensions can shorten the crossing distance for pedestrians. However, there may not be enough space for bulb-outs with the installation of bike lanes. Smaller-scale curb extensions can be considered near the departing bike lane of Broadway. Meanwhile, the excessive vegetation should be cleared regularly so that drivers and pedestrians can have a clear view at the intersection.

This study proposes potential improvements at this intersection in the near future. In the long term, a comprehensive study of the Alewife Brook Parkway corridor that includes this intersection and other major intersections in the corridor should be considered. In the immediate term, the intersection's pedestrian signal time should be extended from 17 seconds to 21 seconds. The additional 4 seconds of pedestrian time can be obtained evenly from both streets of the intersection.

Appendix A

Intersection Crash Rate Calculation
Alewife Brook Parkway at Broadway, Somerville

MassHighway

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Somerville COUNT DATE : 5/27/09

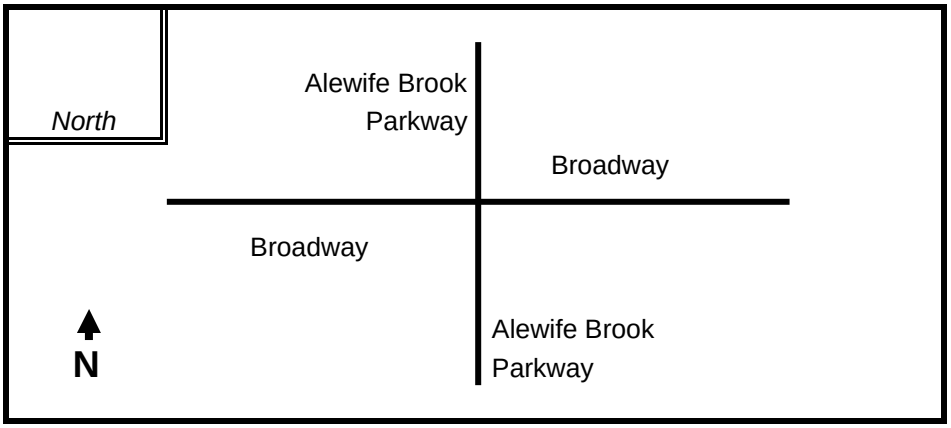
DISTRICT : 4 UNSIGNALIZED : SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : Alewife Brook Parkway (Rt. 16)

MINOR STREET(S) : Broadway

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :	NB	SB	EB	WB		
PEAK HOURLY VOLUMES (AM/PM) :	1099	894	605	502		**3,100**

" K " FACTOR : **0.090** INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **34,444**

TOTAL # OF CRASHES : 60 # OF YEARS : 3 AVERAGE # OF CRASHES PER YEAR (**A**) : **20.00**

CRASH RATE CALCULATION : **1.59** RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments :

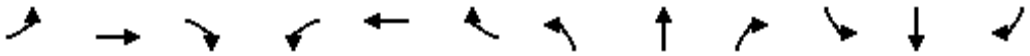
Project Title & Date: Boston MPO Congested and High-Crash Intersections Study

Appendix B

AM/PM Peak Hour Intersection Capacity Analysis

Existing Conditions

Alewife Brook Parkway at Broadway, Somerville



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	183	277	8	154	351	45	24	937	168	35	452	99
Confl. Peds. (#/hr)	15		10	10		15	1		3	3		1
Confl. Bikes (#/hr)			6			4			2			
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	3%	3%	3%	0%	0%	0%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	193	300	0	0	578	0	0	1188	0	0	617	0
Turn Type	Split			Split			Perm			Perm		
Protected Phases	2	2		6	6			8			4	
Permitted Phases							8			4		
Detector Phase	2	2		6	6		8	8		4	4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	21.0	21.0		21.0	21.0		21.0	21.0		21.0	21.0	
Total Split (s)	30.0	30.0	0.0	25.0	25.0	0.0	55.0	55.0	0.0	55.0	55.0	0.0
Total Split (%)	23.6%	23.6%	0.0%	19.7%	19.7%	0.0%	43.3%	43.3%	0.0%	43.3%	43.3%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		3.0	3.0	
All-Red Time (s)	2.0	2.0		2.0	2.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	None	None		None	None		Min	Min		Min	Min	
Act Effct Green (s)	24.2	24.2			20.1			50.3			50.3	
Actuated g/C Ratio	0.20	0.20			0.17			0.42			0.42	
v/c Ratio	0.61	0.91			1.15			0.99			0.72	
Control Delay	54.1	78.3			131.5			59.2			36.1	
Queue Delay	0.0	0.0			0.0			0.0			0.0	
Total Delay	54.1	78.3			131.5			59.2			36.1	
LOS	D	E			F			E			D	
Approach Delay		68.8			131.5			59.2			36.1	
Approach LOS		E			F			E			D	
Queue Length 50th (ft)	147	244			~307			~561			229	
Queue Length 95th (ft)	232	#423			#427			#700			308	
Internal Link Dist (ft)		589			135			414			470	
Turn Bay Length (ft)												
Base Capacity (vph)	328	344			504			1198			860	
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	0.59	0.87			1.15			0.99			0.72	

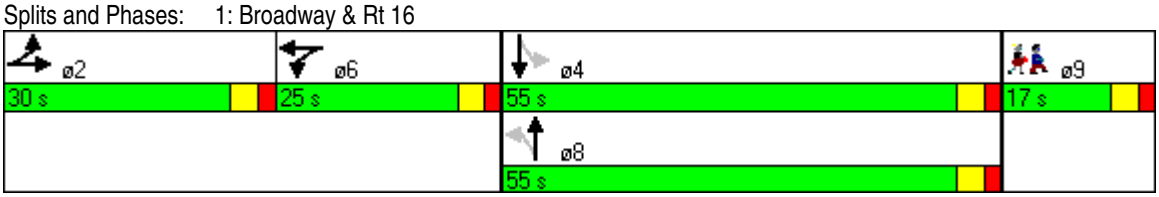
Intersection Summary
Cycle Length: 127

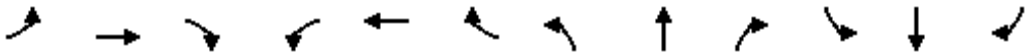
Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	17.0
Total Split (s)	17.0
Total Split (%)	13%
Yellow Time (s)	3.0
All-Red Time (s)	2.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Actuated Cycle Length: 119.4
Natural Cycle: 150
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 1.15
Intersection Signal Delay: 70.4 Intersection LOS: E
Intersection Capacity Utilization 101.0% ICU Level of Service G
Analysis Period (min) 15
~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 1: Broadway & Rt 16





Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	222	329	54	132	341	29	38	835	226	13	758	123
Confl. Peds. (#/hr)	17		23	23		17	3		5	5		3
Confl. Bikes (#/hr)			2			6						
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	234	403	0	0	529	0	0	1157	0	0	941	0
Turn Type	Split			Split			Perm			Perm		
Protected Phases	2	2		6	6			8			4	
Permitted Phases							8			4		
Detector Phase	2	2		6	6		8	8		4	4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	21.0	21.0		21.0	21.0		21.0	21.0		21.0	21.0	
Total Split (s)	30.0	30.0	0.0	25.0	25.0	0.0	55.0	55.0	0.0	55.0	55.0	0.0
Total Split (%)	23.6%	23.6%	0.0%	19.7%	19.7%	0.0%	43.3%	43.3%	0.0%	43.3%	43.3%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		3.0	3.0	
All-Red Time (s)	2.0	2.0		2.0	2.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	None	None		None	None		Min	Min		Min	Min	
Act Effct Green (s)	25.1	25.1			20.1			50.2			50.2	
Actuated g/C Ratio	0.20	0.20			0.16			0.41			0.41	
v/c Ratio	0.74	1.23			1.08			1.20			0.90	
Control Delay	62.6	168.8			111.9			134.5			47.6	
Queue Delay	0.0	0.0			0.0			0.0			0.0	
Total Delay	62.6	168.8			111.9			134.5			47.6	
LOS	E	F			F			F			D	
Approach Delay		129.8			111.9			134.5			47.6	
Approach LOS		F			F			F			D	
Queue Length 50th (ft)	184	~415			~261			~615			384	
Queue Length 95th (ft)	#304	#620			#377			#755			#522	
Internal Link Dist (ft)		589			152			414			470	
Turn Bay Length (ft)												
Base Capacity (vph)	315	328			491			962			1049	
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	0.74	1.23			1.08			1.20			0.90	

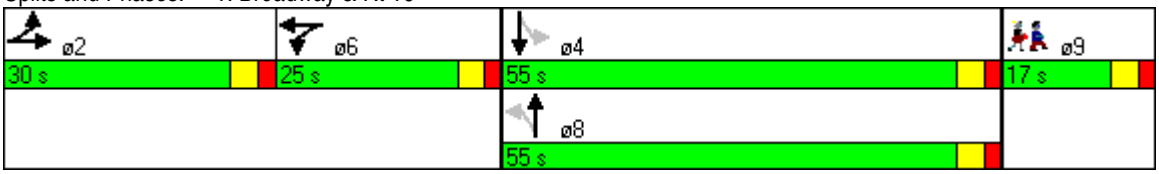
Intersection Summary
Cycle Length: 127

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	17.0
Total Split (s)	17.0
Total Split (%)	13%
Yellow Time (s)	3.0
All-Red Time (s)	2.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Actuated Cycle Length: 123.6
Natural Cycle: 150
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 1.23
Intersection Signal Delay: 104.8 Intersection LOS: F
Intersection Capacity Utilization 117.0% ICU Level of Service H
Analysis Period (min) 15
~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 1: Broadway & Rt 16



Appendix C

Letter from Somerville
Responding to a Preliminary Alternative Developed in the Early Study Stage

CITY OF SOMERVILLE, MASSACHUSETTS
OFFICE OF STRATEGIC PLANNING & COMMUNITY DEVELOPMENT
JOSEPH A. CURTATONE
MAYOR

TRANSPORTATION AND INFRASTRUCTURE DIVISION

October 12, 2009

Chen-Yuan Wang
Central Transportation Planning Staff
10 Park Plaza, Suite 2150
Boston, MA 02116

Dear Chen-Yuan Wang,

Thank you for soliciting the City of Somerville's response to CTPS' review of the intersection at Alewife Brook Parkway and Broadway. We appreciate the efforts to look at the intersection in more detail, which is home to several key issues concerning multi-modal access, mobility, safety issues.

Taking a step back from the details presented in your review, we think it critical to consider expanding the scope of your study to include a greater length of Alewife Brook Parkway. It was our interpretation from the MPO meeting that this study was to include the area surrounding the future Green Line Station, which would include the rotary at the intersection with Powder House Boulevard. Conceptually, the whole of Alewife Brook Parkway needs to function less like a highway and more like a parkway, with reduced speeds, to provide the ability to connect from Somerville across to the recreational and natural resources along the Alewife Brook greenway and park area.

The following is a list of suggestions to help focus the vision of for the area, as well as respond to some of the more technical aspects of your report:

- Pedestrian timing for lights is critical, especially given the senior population at Clarendon Hills. As opposed to pedestrian exclusive lighting, which highly affects LOS, change to lead-concurrent for pedestrian timing (p.5, 7).
- Traffic light signals are installed at the corner, as opposed to the over-hang, over-head variety. Coming eastbound from Arlington, this is confusing at night as you see up ahead a flashing yellow light for the crosswalk between Clarendon Hills and the Food Master. Vegetation obscures the lights and vehicles on Route 16, so it does not seem that there is

a major intersection before the crosswalk (especially if a driver is unfamiliar with the intersection). This problem needs to be addressed.

- Two of the three signal periods (the eastbound and westbound) are protected left-hand turns, but there is no indication of this. This contributes to confusion at the intersection and delays traffic due to uncertainty of who has the right of way. Green arrows should be installed.
- Do not prohibit left-turns from Route 16 onto Broadway. Consider providing each approach with protective greens.
- The Rotary at Powder House Boulevard is an area of concern; and bringing more traffic into the area by prohibiting left-hand turns from Alewife Brook at Broadway would bring more traffic past the West Somerville Neighborhood School (p.6). The City does not support this idea.
- The potential for bike lanes on the parkway should be addressed.
- The solutions presented in this report make improvements to the delay waiting time, but in the end westbound traffic on Broadway still has level of service F and eastbound has levels D, E, and F. More effective solutions need to be evaluated.

Somerville is also considering various options for improving safety and access at the intersection, including the following:

- Adding bike lanes on Broadway.
- Striped left-hand turns from Broadway onto Alewife Brook southbound to eliminate uncertainty for turning movements, with a green left arrow.
- Bump-outs at the southeastern corner of the intersection (as opposed to the striping which exist currently), bringing traffic into one-lane and eliminating confusion at the intersection.

A major option not identified in this study that deserves more consideration is narrowing Alewife Brook Parkway to two-lanes, adding bike lanes, and having protective left-hand turns. We look forward to working with you to develop solutions to make this intersection safer by reducing speed and congestion along all of Alewife Brook Parkway, and thus making this area more livable and a greater asset for the area.

We would like to meet with you to discuss future improvements, at your convenience.

Sincerely,

Michael Lambert

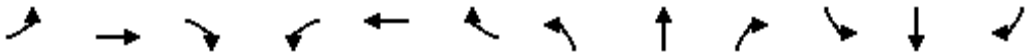
Michael Lambert
Director of Transportation & Infrastructure

Appendix D

AM/PM Peak Hour Intersection Capacity Analysis

Alternative 1: Prohibit left turns on the parkway and retime traffic signal with existing phasing sequence (exclusive pedestrian signal phasing)

Alewife Brook Parkway at Broadway, Somerville



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	183	277	8	154	351	45	0	957	168	0	470	119
Confl. Peds. (#/hr)	15		10	10		15	1		3	3		1
Confl. Bikes (#/hr)			6			4			2			
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	3%	3%	3%	0%	0%	0%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	193	300	0	0	578	0	0	1184	0	0	620	0
Turn Type	Split			Split								
Protected Phases	2	2		6	6			8			4	
Permitted Phases												
Detector Phase	2	2		6	6			8			4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0			4.0			4.0	
Minimum Split (s)	21.0	21.0		21.0	21.0			21.0			21.0	
Total Split (s)	28.0	28.0	0.0	28.0	28.0	0.0	0.0	50.0	0.0	0.0	50.0	0.0
Total Split (%)	22.0%	22.0%	0.0%	22.0%	22.0%	0.0%	0.0%	39.4%	0.0%	0.0%	39.4%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0			3.0			3.0	
All-Red Time (s)	2.0	2.0		2.0	2.0			2.0			2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	5.0	4.0	5.0	5.0	4.0	4.0	5.0	4.0	4.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	None	None		None	None			Min			Min	
Act Effct Green (s)	23.2	23.2			23.2			45.4			45.4	
Actuated g/C Ratio	0.20	0.20			0.20			0.38			0.38	
v/c Ratio	0.63	0.94			1.00			1.02			0.54	
Control Delay	56.4	86.6			86.0			69.5			32.3	
Queue Delay	0.0	0.0			0.0			0.0			0.0	
Total Delay	56.4	86.6			86.0			69.5			32.3	
LOS	E	F			F			E			C	
Approach Delay		74.8			86.0			69.5			32.3	
Approach LOS		E			F			E			C	
Queue Length 50th (ft)	150	~256			~278			~582			217	
Queue Length 95th (ft)	#239	#444			#397			#720			280	
Internal Link Dist (ft)		589			169			414			470	
Turn Bay Length (ft)												
Base Capacity (vph)	304	318			578			1158			1139	
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	0.63	0.94			1.00			1.02			0.54	

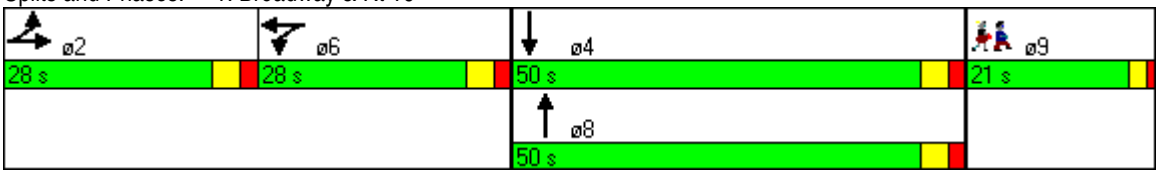
Intersection Summary
Cycle Length: 127

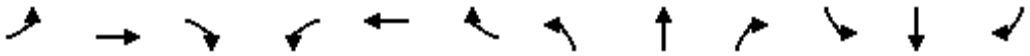
Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	21.0
Total Split (s)	21.0
Total Split (%)	17%
Yellow Time (s)	2.0
All-Red Time (s)	1.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Actuated Cycle Length: 118.6
Natural Cycle: 145
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 1.02
Intersection Signal Delay: 65.7 Intersection LOS: E
Intersection Capacity Utilization 82.1% ICU Level of Service E
Analysis Period (min) 15
~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 1: Broadway & Rt 16





Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	222	329	54	132	341	29	0	865	226	0	771	153
Confl. Peds. (#/hr)	17		23	23		17	3		5	5		3
Confl. Bikes (#/hr)			2			6						
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	234	403	0	0	529	0	0	1149	0	0	973	0
Turn Type	Split			Split								
Protected Phases	2	2		6	6			8			4	
Permitted Phases												
Detector Phase	2	2		6	6			8			4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0			4.0			4.0	
Minimum Split (s)	21.0	21.0		21.0	21.0			21.0			21.0	
Total Split (s)	31.0	31.0	0.0	25.0	25.0	0.0	0.0	50.0	0.0	0.0	50.0	0.0
Total Split (%)	24.4%	24.4%	0.0%	19.7%	19.7%	0.0%	0.0%	39.4%	0.0%	0.0%	39.4%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0			3.0			3.0	
All-Red Time (s)	2.0	2.0		2.0	2.0			2.0			2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	5.0	4.0	5.0	5.0	4.0	4.0	5.0	4.0	4.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	None	None		None	None			Min			Min	
Act Effct Green (s)	26.1	26.1			20.1			45.2			45.2	
Actuated g/C Ratio	0.21	0.21			0.16			0.37			0.37	
v/c Ratio	0.71	1.19			1.08			1.04			0.87	
Control Delay	59.1	153.6			111.3			77.1			47.2	
Queue Delay	0.0	0.0			0.0			0.0			0.0	
Total Delay	59.1	153.6			111.3			77.1			47.2	
LOS	E	F			F			E			D	
Approach Delay		118.9			111.3			77.1			47.2	
Approach LOS		F			F			E			D	
Queue Length 50th (ft)	182	~410			~263			~556			398	
Queue Length 95th (ft)	#294	#612			#378			#692			#526	
Internal Link Dist (ft)		589			171			414			470	
Turn Bay Length (ft)												
Base Capacity (vph)	331	339			492			1104			1114	
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	0.71	1.19			1.08			1.04			0.87	

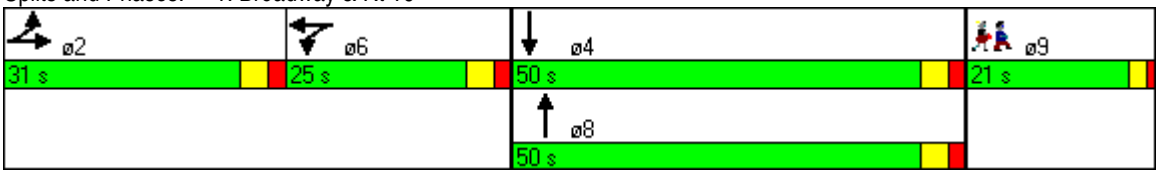
Intersection Summary
Cycle Length: 127

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	21.0
Total Split (s)	21.0
Total Split (%)	17%
Yellow Time (s)	2.0
All-Red Time (s)	1.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Actuated Cycle Length: 122.8
Natural Cycle: 145
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 1.19
Intersection Signal Delay: 81.8 Intersection LOS: F
Intersection Capacity Utilization 86.2% ICU Level of Service E
Analysis Period (min) 15
~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 1: Broadway & Rt 16

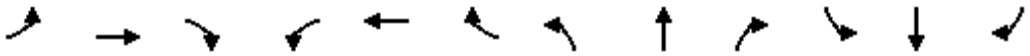


Appendix E

AM/PM Peak Hour Intersection Capacity Analysis

Alternative 2: Change Broadway operation from split phasing to protected-permissive left-turn phasing (exclusive pedestrian signal phasing)

Alewife Brook Parkway at Broadway, Somerville



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	183	277	8	154	351	45	24	937	168	35	452	99
Confl. Peds. (#/hr)	15		10	10		15	1		3	3		1
Confl. Bikes (#/hr)			6			4			2			
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	3%	3%	3%	0%	0%	0%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	193	300	0	162	416	0	0	1188	0	0	617	0
Turn Type	pm+pt			pm+pt			Perm			Perm		
Protected Phases	5	2		1	6			8			4	
Permitted Phases	2			6			8			4		
Detector Phase	5	2		1	6		8	8		4	4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	9.0	21.0		9.0	21.0		21.0	21.0		21.0	21.0	
Total Split (s)	13.0	38.0	0.0	12.0	37.0	0.0	56.0	56.0	0.0	56.0	56.0	0.0
Total Split (%)	10.2%	29.9%	0.0%	9.4%	29.1%	0.0%	44.1%	44.1%	0.0%	44.1%	44.1%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		3.0	3.0	
All-Red Time (s)	1.0	2.0		1.0	2.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	5.0	4.0	4.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag	Lead	Lag		Lead	Lag							
Lead-Lag Optimize?	Yes	Yes		Yes	Yes							
Recall Mode	None	None		None	None		Max	Max		Max	Max	
Act Effct Green (s)	43.3	33.3		41.3	32.3			51.4			51.4	
Actuated g/C Ratio	0.37	0.28		0.35	0.27			0.43			0.43	
v/c Ratio	0.97	0.66		0.60	0.97			0.97			0.68	
Control Delay	89.1	47.5		39.3	81.7			54.6			33.6	
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	
Total Delay	89.1	47.5		39.3	81.7			54.6			33.6	
LOS	F	D		D	F			D			C	
Approach Delay		63.8			69.8			54.6			33.6	
Approach LOS		E			E			D			C	
Queue Length 50th (ft)	~123	225		94	~372			~560			224	
Queue Length 95th (ft)	#265	332		153	#578			#697			301	
Internal Link Dist (ft)		589			169			414			470	
Turn Bay Length (ft)												
Base Capacity (vph)	199	457		272	428			1221			903	
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	0.97	0.66		0.60	0.97			0.97			0.68	

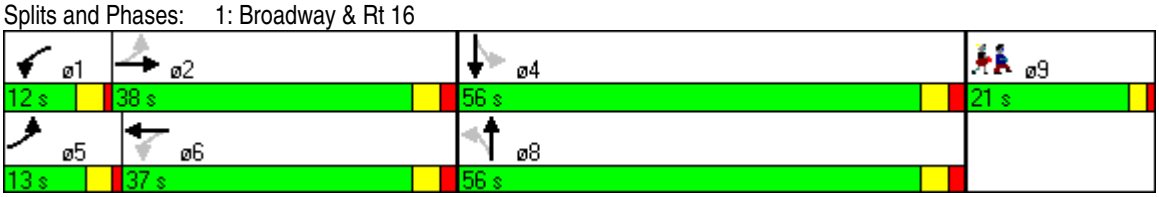
Intersection Summary
Cycle Length: 127

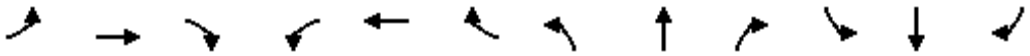
Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	21.0
Total Split (s)	21.0
Total Split (%)	17%
Yellow Time (s)	2.0
All-Red Time (s)	1.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Actuated Cycle Length: 118.6
Natural Cycle: 150
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 0.97
Intersection Signal Delay: 54.7 Intersection LOS: D
Intersection Capacity Utilization 100.9% ICU Level of Service G
Analysis Period (min) 15
~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 1: Broadway & Rt 16





Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	222	329	54	132	341	29	38	835	226	13	758	123
Confl. Peds. (#/hr)	17		23	23		17	3		5	5		3
Confl. Bikes (#/hr)			2			6						
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	234	403	0	139	390	0	0	1157	0	0	941	0
Turn Type	pm+pt			pm+pt			Perm			Perm		
Protected Phases	5	2		1	6			8			4	
Permitted Phases	2			6			8			4		
Detector Phase	5	2		1	6		8	8		4	4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	9.0	21.0		9.0	21.0		21.0	21.0		21.0	21.0	
Total Split (s)	15.0	37.0	0.0	11.0	33.0	0.0	58.0	58.0	0.0	58.0	58.0	0.0
Total Split (%)	11.8%	29.1%	0.0%	8.7%	26.0%	0.0%	45.7%	45.7%	0.0%	45.7%	45.7%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		3.0	3.0	
All-Red Time (s)	2.0	2.0		2.0	2.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag	Lead	Lag		Lead	Lag							
Lead-Lag Optimize?	Yes	Yes		Yes	Yes							
Recall Mode	None	None		None	None		Min	Min		Min	Min	
Act Effct Green (s)	42.2	32.2		34.2	28.1			53.3			53.3	
Actuated g/C Ratio	0.34	0.26		0.28	0.23			0.43			0.43	
v/c Ratio	1.30	0.97		0.93	1.07			1.11			0.80	
Control Delay	199.6	82.7		94.0	111.6			96.2			37.8	
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	
Total Delay	199.6	82.7		94.0	111.6			96.2			37.8	
LOS	F	F		F	F			F			D	
Approach Delay		125.6			107.0			96.2			37.8	
Approach LOS		F			F			F			D	
Queue Length 50th (ft)	~209	~335		83	~366			~588			358	
Queue Length 95th (ft)	#377	#547		#186	#566			#726			453	
Internal Link Dist (ft)		589			171			414			470	
Turn Bay Length (ft)												
Base Capacity (vph)	180	417		150	366			1045			1173	
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	1.30	0.97		0.93	1.07			1.11			0.80	

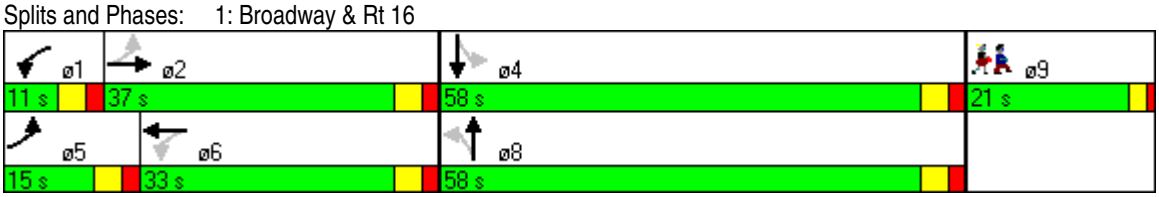
Intersection Summary
Cycle Length: 127

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	21.0
Total Split (s)	21.0
Total Split (%)	17%
Yellow Time (s)	2.0
All-Red Time (s)	1.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Actuated Cycle Length: 122.8
Natural Cycle: 150
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 1.30
Intersection Signal Delay: 86.9 Intersection LOS: F
Intersection Capacity Utilization 113.6% ICU Level of Service H
Analysis Period (min) 15
~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 1: Broadway & Rt 16

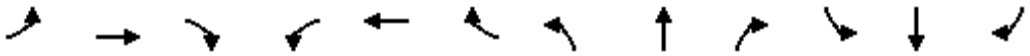


Appendix F

AM/PM Peak Hour Intersection Capacity Analysis

Alternative 3: Prohibit left turns on the parkway and change Broadway to protected-only left-turn operation (concurrent pedestrian signal phasing)

Alewife Brook Parkway at Broadway, Somerville



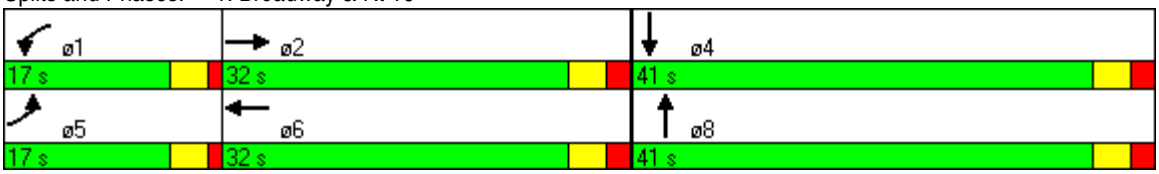
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	183	277	8	154	351	45	0	957	168	0	470	119
Confl. Peds. (#/hr)	15		10	10		15	1		3	3		1
Confl. Bikes (#/hr)			6			4			2			
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	3%	3%	3%	0%	0%	0%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	193	300	0	162	416	0	0	1184	0	0	620	0
Turn Type	Prot			Prot								
Protected Phases	5	2		1	6			8			4	
Permitted Phases												
Detector Phase	5	2		1	6			8			4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0			4.0			4.0	
Minimum Split (s)	9.0	21.0		9.0	21.0			21.0			21.0	
Total Split (s)	17.0	32.0	0.0	17.0	32.0	0.0	0.0	41.0	0.0	0.0	41.0	0.0
Total Split (%)	18.9%	35.6%	0.0%	18.9%	35.6%	0.0%	0.0%	45.6%	0.0%	0.0%	45.6%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0			3.0			3.0	
All-Red Time (s)	1.0	2.0		1.0	2.0			2.0			2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	5.0	4.0	4.0	5.0	4.0	4.0	5.0	4.0	4.0	5.0	4.0
Lead/Lag	Lead	Lag		Lead	Lag							
Lead-Lag Optimize?	Yes	Yes		Yes	Yes							
Recall Mode	None	None		None	None			Max			Max	
Act Effct Green (s)	12.6	25.9		12.2	25.4			36.0			36.0	
Actuated g/C Ratio	0.14	0.29		0.14	0.29			0.41			0.41	
v/c Ratio	0.87	0.62		0.77	0.91			0.94			0.50	
Control Delay	72.7	33.6		61.7	55.7			41.4			20.1	
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	
Total Delay	72.7	33.6		61.7	55.7			41.4			20.1	
LOS	E	C		E	E			D			C	
Approach Delay		48.9			57.4			41.4			20.1	
Approach LOS		D			E			D			C	
Queue Length 50th (ft)	109	145		89	220			333			126	
Queue Length 95th (ft)	#229	232		#185	#390			#484			178	
Internal Link Dist (ft)		589			169			414			470	
Turn Bay Length (ft)												
Base Capacity (vph)	230	501		225	487			1253			1240	
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	0.84	0.60		0.72	0.85			0.94			0.50	

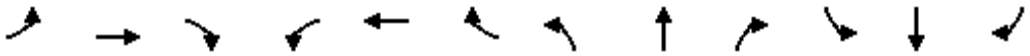
Intersection Summary
Cycle Length: 90

Actuated Cycle Length: 88.1	
Natural Cycle: 90	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.94	
Intersection Signal Delay: 41.3	Intersection LOS: D
Intersection Capacity Utilization 82.1%	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: Broadway & Rt 16





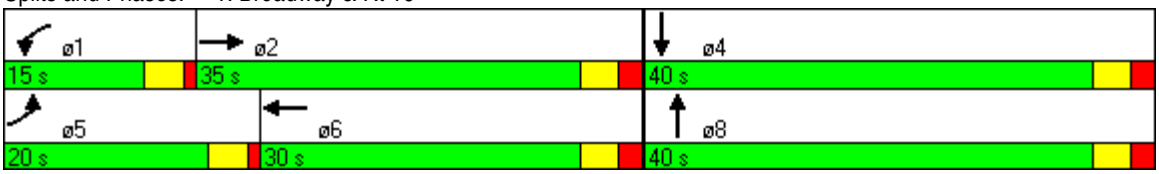
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	222	329	54	132	341	29	0	865	226	0	771	153
Confl. Peds. (#/hr)	17		23	23		17	3		5	5		3
Confl. Bikes (#/hr)			2			6						
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	234	403	0	139	390	0	0	1149	0	0	973	0
Turn Type	Prot			Prot								
Protected Phases	5	2		1	6			8			4	
Permitted Phases												
Detector Phase	5	2		1	6			8			4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0			4.0			4.0	
Minimum Split (s)	20.0	21.0		9.0	21.0			21.0			21.0	
Total Split (s)	20.0	35.0	0.0	15.0	30.0	0.0	0.0	40.0	0.0	0.0	40.0	0.0
Total Split (%)	22.2%	38.9%	0.0%	16.7%	33.3%	0.0%	0.0%	44.4%	0.0%	0.0%	44.4%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0			3.0			3.0	
All-Red Time (s)	1.0	2.0		1.0	2.0			2.0			2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	5.0	4.0	4.0	5.0	4.0	4.0	5.0	4.0	4.0	5.0	4.0
Lead/Lag	Lead	Lag		Lead	Lag							
Lead-Lag Optimize?	Yes	Yes		Yes	Yes							
Recall Mode	None	None		None	None			Max			Max	
Act Effct Green (s)	15.3	28.5		10.5	23.7			35.1			35.1	
Actuated g/C Ratio	0.17	0.32		0.12	0.27			0.40			0.40	
v/c Ratio	0.87	0.77		0.76	0.90			0.94			0.80	
Control Delay	66.7	37.7		65.2	56.9			41.8			29.2	
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	
Total Delay	66.7	37.7		65.2	56.9			41.8			29.2	
LOS	E	D		E	E			D			C	
Approach Delay		48.4			59.1			41.8			29.2	
Approach LOS		D			E			D			C	
Queue Length 50th (ft)	130	197		77	209			320			248	
Queue Length 95th (ft)	#258	#334		#170	#374			#470			332	
Internal Link Dist (ft)		589			171			414			470	
Turn Bay Length (ft)												
Base Capacity (vph)	283	550		193	458			1217			1220	
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	0.83	0.73		0.72	0.85			0.94			0.80	

Intersection Summary
Cycle Length: 90

Actuated Cycle Length: 88.1	
Natural Cycle: 90	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.94	
Intersection Signal Delay: 42.1	Intersection LOS: D
Intersection Capacity Utilization 82.1%	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: Broadway & Rt 16

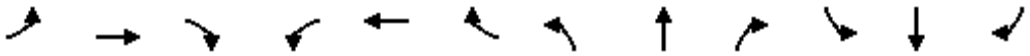


Appendix G

AM/PM Peak Hour Intersection Capacity Analysis

Alternative 4: Change the parkway to protected-only left-turn operation by reducing two through lanes to one and change Broadway to protected-only left-turn operation (concurrent pedestrian signal phasing)

Alewife Brook Parkway at Broadway, Somerville

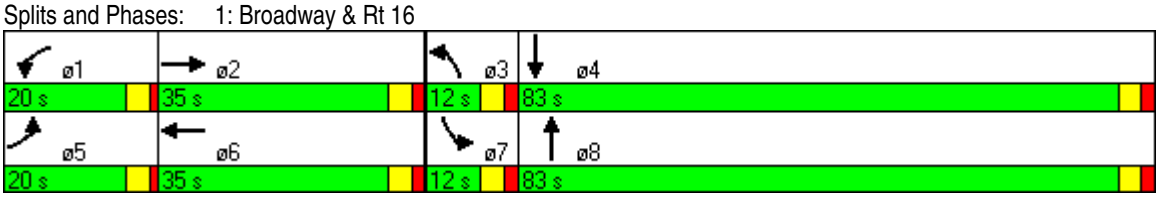


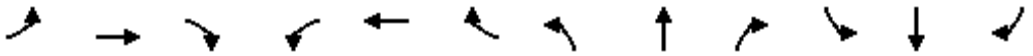
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	183	277	8	154	351	45	24	937	168	35	452	99
Confl. Peds. (#/hr)	15		10	10		15	1		3	3		1
Confl. Bikes (#/hr)			6			4			2			
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	3%	3%	3%	0%	0%	0%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	193	300	0	162	416	0	25	1163	0	37	580	0
Turn Type	Prot			Prot			Prot			Prot		
Protected Phases	5	2		1	6		3	8		7	4	
Permitted Phases												
Detector Phase	5	2		1	6		3	8		7	4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	9.0	21.0		9.0	21.0		9.0	21.0		9.0	21.0	
Total Split (s)	20.0	35.0	0.0	20.0	35.0	0.0	12.0	83.0	0.0	12.0	83.0	0.0
Total Split (%)	13.3%	23.3%	0.0%	13.3%	23.3%	0.0%	8.0%	55.3%	0.0%	8.0%	55.3%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		3.0	3.0	
All-Red Time (s)	1.0	2.0		1.0	2.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	5.0	4.0	4.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag	Lead	Lag		Lead	Lag		Lead	Lag		Lead	Lag	
Lead-Lag Optimize?	Yes	Yes		Yes	Yes		Yes	Yes		Yes	Yes	
Recall Mode	None	None		None	None		None	Max		None	Max	
Act Effct Green (s)	16.0	30.0		16.0	30.0		6.6	78.1		6.7	80.4	
Actuated g/C Ratio	0.11	0.20		0.11	0.20		0.04	0.53		0.05	0.54	
v/c Ratio	1.14	0.90		0.98	1.30		0.36	1.38		0.53	0.67	
Control Delay	169.4	87.7		128.9	200.3		83.8	206.6		96.4	29.5	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	169.4	87.7		128.9	200.3		83.8	206.6		96.4	29.5	
LOS	F	F		F	F		F	F		F	C	
Approach Delay		119.7			180.3			204.0			33.5	
Approach LOS		F			F			F			C	
Queue Length 50th (ft)	~223	290		161	~524		24	~1521		36	413	
Queue Length 95th (ft)	#390	#474		#320	#742		58	#1790		#83	565	
Internal Link Dist (ft)		589			169			414			470	
Turn Bay Length (ft)												
Base Capacity (vph)	169	332		166	320		74	845		73	861	
Starvation Cap Reductn	0	0		0	0		0	0		0	0	
Spillback Cap Reductn	0	0		0	0		0	0		0	0	
Storage Cap Reductn	0	0		0	0		0	0		0	0	
Reduced v/c Ratio	1.14	0.90		0.98	1.30		0.34	1.38		0.51	0.67	

Intersection Summary
Cycle Length: 150

Actuated Cycle Length: 147.6
Natural Cycle: 150
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 1.38
Intersection Signal Delay: 148.2 Intersection LOS: F
Intersection Capacity Utilization 112.8% ICU Level of Service H
Analysis Period (min) 15
~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 1: Broadway & Rt 16



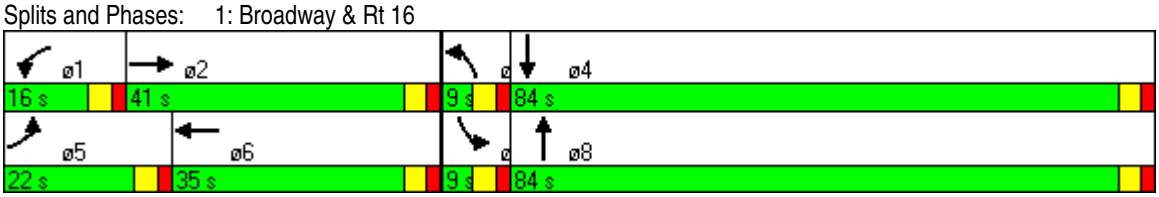


Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	222	329	54	132	341	29	38	835	226	13	758	123
Confl. Peds. (#/hr)	17		23	23		17	3		5	5		3
Confl. Bikes (#/hr)			2			6						
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	234	403	0	139	390	0	40	1117	0	14	927	0
Turn Type	Prot			Prot			Prot			Prot		
Protected Phases	5	2		1	6		3	8		7	4	
Permitted Phases												
Detector Phase	5	2		1	6		3	8		7	4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	9.0	21.0		9.0	21.0		9.0	21.0		9.0	21.0	
Total Split (s)	22.0	41.0	0.0	16.0	35.0	0.0	9.0	84.0	0.0	9.0	84.0	0.0
Total Split (%)	14.7%	27.3%	0.0%	10.7%	23.3%	0.0%	6.0%	56.0%	0.0%	6.0%	56.0%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		3.0	3.0	
All-Red Time (s)	2.0	2.0		2.0	2.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag	Lead	Lag		Lead	Lag		Lead	Lag		Lead	Lag	
Lead-Lag Optimize?	Yes	Yes		Yes	Yes		Yes	Yes		Yes	Yes	
Recall Mode	None	None		None	None		None	Min		None	Min	
Act Effct Green (s)	17.0	36.0		11.0	30.0		4.0	84.4		4.0	79.0	
Actuated g/C Ratio	0.11	0.24		0.07	0.20		0.03	0.56		0.03	0.53	
v/c Ratio	1.33	1.06		1.23	1.22		0.98	1.26		0.34	1.10	
Control Delay	230.4	114.9		213.3	172.0		202.8	154.4		93.5	95.3	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	230.4	114.9		213.3	172.0		202.8	154.4		93.5	95.3	
LOS	F	F		F	F		F	F		F	F	
Approach Delay		157.3			182.9			156.1			95.3	
Approach LOS		F			F			F			F	
Queue Length 50th (ft)	~296	~427		~167	~466		40	~1325		14	~1023	
Queue Length 95th (ft)	#472	#645		#313	#680		#124	#1689		40	#1286	
Internal Link Dist (ft)		589			171			414			470	
Turn Bay Length (ft)												
Base Capacity (vph)	176	381		113	320		41	889		41	844	
Starvation Cap Reductn	0	0		0	0		0	0		0	0	
Spillback Cap Reductn	0	0		0	0		0	0		0	0	
Storage Cap Reductn	0	0		0	0		0	0		0	0	
Reduced v/c Ratio	1.33	1.06		1.23	1.22		0.98	1.26		0.34	1.10	

Intersection Summary
Cycle Length: 150

Actuated Cycle Length: 150
Natural Cycle: 150
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 1.33
Intersection Signal Delay: 143.2 Intersection LOS: F
Intersection Capacity Utilization 112.4% ICU Level of Service H
Analysis Period (min) 15
~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 1: Broadway & Rt 16

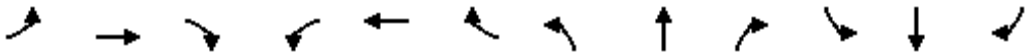


Appendix H

AM/PM Peak Hour Intersection Capacity Analysis

Alternative 5: Change the parkway to protected-only left-turn operation by adding an exclusive left-turn lane and change Broadway to protected-permissive left-turn operation (exclusive pedestrian signal phasing)

Alewife Brook Parkway at Broadway, Somerville



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	183	277	8	154	351	45	24	937	168	35	452	99
Confl. Peds. (#/hr)	15		10	10		15	1		3	3		1
Confl. Bikes (#/hr)			6			4			2			
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	3%	3%	3%	0%	0%	0%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	193	300	0	162	416	0	25	1163	0	37	580	0
Turn Type	pm+pt			pm+pt			Prot			Prot		
Protected Phases	5	2		1	6		3	8		7	4	
Permitted Phases	2			6								
Detector Phase	5	2		1	6		3	8		7	4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0		3.0	4.0		3.0	4.0	
Minimum Split (s)	9.0	21.0		9.0	21.0		7.0	21.0		7.0	21.0	
Total Split (s)	13.0	36.0	0.0	13.0	36.0	0.0	10.0	47.0	0.0	10.0	47.0	0.0
Total Split (%)	10.2%	28.3%	0.0%	10.2%	28.3%	0.0%	7.9%	37.0%	0.0%	7.9%	37.0%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		3.0	3.0	
All-Red Time (s)	1.0	2.0		1.0	2.0		1.0	2.0		1.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	5.0	4.0	4.0	5.0	4.0	4.0	5.0	4.0	4.0	5.0	4.0
Lead/Lag	Lead	Lag		Lead	Lag		Lead	Lag		Lead	Lag	
Lead-Lag Optimize?	Yes	Yes		Yes	Yes		Yes	Yes		Yes	Yes	
Recall Mode	None	None		None	None		None	Max		None	Max	
Act Effct Green (s)	41.2	31.2		41.0	31.1		5.9	42.1		5.9	42.1	
Actuated g/C Ratio	0.40	0.31		0.40	0.30		0.06	0.41		0.06	0.41	
v/c Ratio	0.74	0.60		0.48	0.87		0.28	0.93		0.42	0.47	
Control Delay	40.0	37.1		24.6	54.4		55.8	43.7		62.1	24.1	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	40.0	37.1		24.6	54.4		55.8	43.7		62.1	24.1	
LOS	D	D		C	D		E	D		E	C	
Approach Delay		38.2			46.1			43.9			26.4	
Approach LOS		D			D			D			C	
Queue Length 50th (ft)	84	176		69	271		17	400		25	152	
Queue Length 95th (ft)	#153	270		118	#455		45	#553		60	205	
Internal Link Dist (ft)		589			169			414			470	
Turn Bay Length (ft)												
Base Capacity (vph)	260	498		337	479		92	1249		91	1232	
Starvation Cap Reductn	0	0		0	0		0	0		0	0	
Spillback Cap Reductn	0	0		0	0		0	0		0	0	
Storage Cap Reductn	0	0		0	0		0	0		0	0	
Reduced v/c Ratio	0.74	0.60		0.48	0.87		0.27	0.93		0.41	0.47	

Intersection Summary
Cycle Length: 127

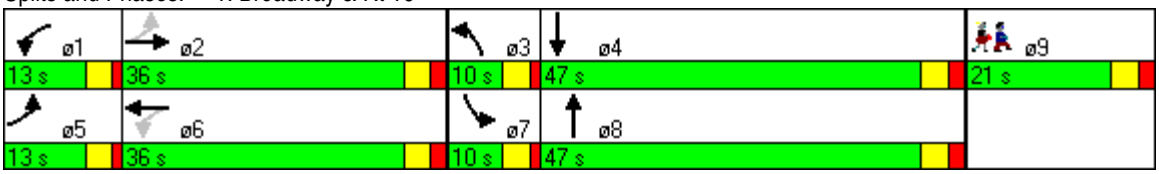
Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	21.0
Total Split (s)	21.0
Total Split (%)	17%
Yellow Time (s)	3.0
All-Red Time (s)	2.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

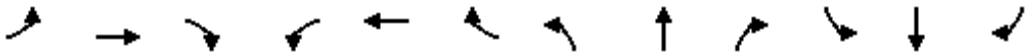
Intersection Summary

Actuated Cycle Length: 102	
Natural Cycle: 150	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.93	
Intersection Signal Delay: 39.6	Intersection LOS: D
Intersection Capacity Utilization 81.4%	ICU Level of Service D
Analysis Period (min) 15	

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

Splits and Phases: 1: Broadway & Rt 16





Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	222	329	54	132	341	29	38	835	226	13	758	123
Confl. Peds. (#/hr)	17		23	23		17	3		5	5		3
Confl. Bikes (#/hr)			2			6						
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	234	403	0	139	390	0	40	1117	0	14	927	0
Turn Type	pm+pt			pm+pt			Prot			Prot		
Protected Phases	5	2		1	6		3	8		7	4	
Permitted Phases	2			6								
Detector Phase	5	2		1	6		3	8		7	4	
Switch Phase												
Minimum Initial (s)	3.0	4.0		3.0	4.0		3.0	4.0		3.0	4.0	
Minimum Split (s)	7.0	21.0		7.0	21.0		7.0	21.0		7.0	21.0	
Total Split (s)	18.0	42.0	0.0	9.0	33.0	0.0	9.0	46.0	0.0	9.0	46.0	0.0
Total Split (%)	14.2%	33.1%	0.0%	7.1%	26.0%	0.0%	7.1%	36.2%	0.0%	7.1%	36.2%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		3.0	3.0	
All-Red Time (s)	1.0	2.0		1.0	2.0		1.0	2.0		1.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	5.0	4.0	4.0	5.0	4.0	4.0	5.0	4.0	4.0	5.0	4.0
Lead/Lag	Lead	Lag		Lead	Lag		Lead	Lag		Lead	Lag	
Lead-Lag Optimize?	Yes	Yes		Yes	Yes		Yes	Yes		Yes	Yes	
Recall Mode	None	None		None	None		None	Min		None	Min	
Act Effct Green (s)	47.1	37.1		34.1	28.0		5.0	45.9		5.0	40.5	
Actuated g/C Ratio	0.45	0.36		0.33	0.27		0.05	0.44		0.05	0.39	
v/c Ratio	0.76	0.71		0.54	0.90		0.53	0.84		0.19	0.78	
Control Delay	36.9	37.4		30.5	63.1		75.2	33.6		54.5	33.8	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	36.9	37.4		30.5	63.1		75.2	33.6		54.5	33.8	
LOS	D	D		C	E		E	C		D	C	
Approach Delay		37.2			54.5			35.0			34.1	
Approach LOS		D			D			D			C	
Queue Length 50th (ft)	102	236		56	258		27	325		9	287	
Queue Length 95th (ft)	#206	353		98	#440		#77	#533		31	370	
Internal Link Dist (ft)		589			171			414			470	
Turn Bay Length (ft)												
Base Capacity (vph)	307	569		258	432		75	1323		75	1202	
Starvation Cap Reductn	0	0		0	0		0	0		0	0	
Spillback Cap Reductn	0	0		0	0		0	0		0	0	
Storage Cap Reductn	0	0		0	0		0	0		0	0	
Reduced v/c Ratio	0.76	0.71		0.54	0.90		0.53	0.84		0.19	0.77	

Intersection Summary
Cycle Length: 127

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	21.0
Total Split (s)	21.0
Total Split (%)	17%
Yellow Time (s)	3.0
All-Red Time (s)	2.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Actuated Cycle Length: 103.7	
Natural Cycle: 140	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.90	
Intersection Signal Delay: 38.3	Intersection LOS: D
Intersection Capacity Utilization 82.4%	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: Broadway & Rt 16